Networks for LIFE

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An Ecological Network Analysis for the Brown bear (*Ursus arctos*) - and indicator species in Regione Abruzzo

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ABSTRACT

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Pictures on front page by Bas Pedroli & Theo van der Sluis

This report gives the result of an analysis of the ecological network of Regione Abruzzo. Seven species were analysed, which can be related to 4 ecosystem types: woodland, wetland, grassland and steppe, and shrubland. The model LARCH was used to assess whether these ecosystems still function as an ecological network.
The study shows that the Region has no serious fragmentation problem at the moment, considering the viability of the networks. However, corridors are essential to maintain the high quality of nature as we find it in Abruzzo. With little investments a well functioning sustainable ecological network can be realised. Through the development and consolidation of an optimised ecological network good opportunities are created for the long-term future development.
This study presents ideas and forms a good basis for further development of an improved ecological network. Based on the spatial cohesion for the ecoprofiles used in this analysis, a lay-out for a possible ecological network has been prepared. This is a lay-out for terrestrial corridors, i.e. for the forest, shrubland and grassland ecosystems

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

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Contents

Preface

Regione Abruzzo has commissioned a research project to ALTERRA to analyse the ecological network for Regione Abruzzo. The set-up of this research project follows the outline as given in the project proposal, which was discussed with the Steering Committee from Regione Abruzzo.

The Steering Committee consists of:

Antonio Perrotti	Project leader, Regione Abruzzo
Annabella Pace	Regione Abruzzo
Maurizio Calabrese	“ “
Daniela Spoltore	“ “
Claudia D'Aurizio	“ “
Bernardino Romano	Università L'Aquila
Maurizio Biondi	“ “
Mauro Bernoni	Consultant Ornithology

We would like to thank the Steering Committee, which has helped us to finish this study. Especially thanks to the project leader Antonio Perrotti that brought us, with much enthusiasm, in contact with much valued aspects of Abruzzo, its natural values and diversity, its culture and in particular its local cuisine. Thanks also to Maurizio Calabrese, who was helpful at different stages in the project, to Maurizio Bernoni and Maurizio Biondi, who added useful data on the ecology of species. Furthermore, we wish to thank all other experts and the LIFE-Econet team that contributed to the meetings and the field visit.
Finally we want to thank Giovanna Corridore for preparing the Italian summary of the report, and Bernardino Romano who realised the first contacts, already in 1999, between the Regione and at that time IBN, now ALTERRA.

We are grateful to Robbert Kwak, who assisted in the preparation of the ecological profiles for three bird species for this study, Wim Nieuwenhuizen (modelling of the Hedgehog) and Rogier Pouwels, who commented on parts of the report.

In Italy, we received useful information from experts and biologists from Gran-Sasso, Sirente-Velino and the Corpo Forestale from Abruzzo, in particular M. Possilico.

Picture lynx: Courtesy of P. Kaczansky

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 nature reserves by means of corridors and small habitat patches.
Development of ecological networks is part of European policy (Bern Convention, Habitat Directive, Natura 2000) and 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 Abruzzo. Abruzzo is a region with large natural areas, mainly located in the highest part of the Apennine mountain range, with 5 large national parks, mountain areas and forests. These areas are of outstanding beauty, and in particular the wilderness aspect makes them both of importance as refuge for e.g. a number of large carnivores are the Brown bear, Wolf and lynx, and very important for tourism and regional development.

In this study the ecological network was analysed at two levels: the potential for ecosystem functioning was assessed for Abruzzo Region, and the situation for the Brown bear, which mainly lives in Abruzzo and other surrounding national park, was assessed at a supra-regional level. These both studies were done with different tools and methods.

Aim of the analysis is (1) to identify the functional ecological network at present, (2) to identify opportunities to optimise the ecological network and (3) to identify the (potential) ecological network for the Brown Bear, the population viability for the present situation and to evaluate whether the planned corridors between Abruzzo National park and other surrounding parks would improve the current viability of the Brown bear population.
The landscape ecological model LARCH was used for the Regional analysis. Four ecosystem types were selected, which cover most important natural habitat types in the study area: woodland, grassland and steppe, wetland, and shrubland. Seven species were selected as indicators for different ecosystems, to be able to assess in more detail the functioning of ecosystems and ecological networks. These species are the Wolf, Chiffchaff, Common toad, Hedgehog, Green lizard, Stonechat and Crested newt .
Priority ecosystems, and very particular for Abruzzo, are the forests, and the Alpine meadows, grasslands and steppe of the higher Apennines. In addition, also the aquatic ecosystem is probably very important since most species are to some extent dependent on water, and many species tend to migrate along water courses.

For the Brown bear metapopulation analysis two models, SmallSteps and METAPHOR are used. SmallSteps, a movement model, provides an estimate of the connectivity of habitat patches for the Brown Bear over a large part of the Appenine

mountain region. Connectivity is defined as the probability of reaching another habitat patch when dispersing from the natal patch. The model takes into account the properties (resistance) of the landscape in-between the patches (landscape matrix). Calculated connectivity is used in METAPHOR, a population dynamic simulation model, to estimate metapopulation viability. Both models require identification of habitat patches, as starting and endpoints for dispersal movements, and as reproduction sites. A species-specific habitat suitability model was used to identify patches (Posillico 1999).
To estimate corridor effectiveness, SmallSteps was also used, on a more detailed (sub-regional) scale, based on the land use map for the Regione Abruzzo (Giunta Regione Abruzzo 1999).

Most ecosystems seem in potential large enough to sustain potential wildlife populations in Regione Abruzzo. In the coastal plain and intensively farmed areas, e.g. the main valleys and Lago Fucino, some species populations are small and fragmented. Species affected are Wolf, Hedgehog, Green lizard, Stonechat and Crested newt.
Observing network viability it is obvious that all species are viable on its own, except for the Wolf. The Wolf is dependent on neighbouring regions in Italy. The Hedgehog has local networks, presently not sustainable, due to fragmentation, but overall even for this species the network is sustainable.

With respect to Brown bear population viability, results indicate that the current Abruzzo population is viable. However, we have as yet to establish to what extent variation in demographic rates, an increased amount of environmental stochasticity acting on these rates, or uncertainty in the carrying capacity estimates affect this outcome. A sensitivity analysis is therefore required. In any case, an increase in the size of the network due to re-colonization of habitat within the historical range, will benefit the population. Metapopulation simulations show that from the Abruzzo park within decennia a considerable part of the Appenine mountains range can become re-colonized.

The study shows that the Region has no serious fragmentation problem at the moment, considering the viability of the networks. Obviously, the 50% of natural habitat (par. 2.2) is sufficient for most species at present. This means that with little investments a well functioning sustainable ecological network can be realised, so now it is the time to propose an optimised ecological network. Through the development and consolidation of an optimised ecological network good opportunities are created for the long-term future development.

As mentioned, the habitat is sufficient for viable networks of the considered species. However, corridors are essential to maintain the high quality of nature as we find it in Abruzzo. This study presents ideas and forms a good basis for further development of an improved ecological network. Based on the spatial cohesion for the ecoprofiles used in this analysis, a lay-out for a possible ecological network has been prepared. This is a lay-out for terrestrial corridors, i.e. for the forest, shrubland and grassland ecosystems.

The network is based on areas with the best potential for realisation of corridors (based on habitat present), and taking the present national parks as the ‘core-areas’ for the ecological network.

The coastal plain and intensively used agricultural areas in Abruzzo show effects of fragmentation. Here measures should be considered to decrease fragmentation. Also particular points along the Autostrada and railway line in potential conflict with the proposed ecological network. Here measures should be considered to decrease the negative impact of infrastructure.

The metapopulation simulations for the Brown bear are based on an optimistic view of population growth rate, potential population size (carrying capacity) and mortality risk while dispersing. The patch connectivity data itself, obtained from movement simulations on the large spatial scale, indicate that habitat patches for the bear are not well-connected, even for an optimistic estimate of an individual’s inclination to venture out into low quality or hostile habitat. Corridors may thus improve connectivity a lot, but (according to scenario studies) only when these corridor zones are connected to relatively high quality habitat. Zooming in on the corridor zones between protected areas in the Abruzzo region, results from the movement model indicate that corridors indeed may improve connectivity locally, and more closely link the Sirente-Velino area to the Gran Sasso park. Further investigations based on (1) more detailed design of the corridor zones and (2) a thorough analysis of empirical data with respect to bear movement, are required to evaluate the effectiveness of the planned corridors.

A challenge will be to extend the ecological network nationwide, since a network for large carnivores requires intensive cooperation across regional boundaries. Similar projects done elsewhere (Regione Emilia-Romagna, Umbria, Sicily) call now for an analysis and design of an ecological network for all of Italy. The Apennines should form the backbone for this network, as is also shown by this study. This network should be consolidated as soon as possible, with all required legal actions and protection.
Abruzzo can be one of the leading regions in Italy for development of such a national ecological network, targetting at e.g. Lynx, Wolf, Brown bear as indicator species for sustainable ecological development.

Based on the present results a design is prepared for corridors in Navelli area, Abruzzo, detailing specific site locations where corridors should be developed, as well as some corridor designs based on the specific requirements of species. This entails more detailed the solutions for the planning context of Abruzzo.

Courtesy of M. Huyser

Courtesy of P. Kaczansky

Riassunto

La diversità biologica è strettamente dipendente dalla qualità, dalla quantità e dalla coesione spaziale delle aree naturali. La frammentazione degli habitat naturali influisce negativamente sull'abbondanza delle specie. Una risposta a questo problema è la realizzazione di reti ecologiche che colleghino le riserve naturali con corridoi ecologici e piccole "chiazze" (patches) di habitat.
La realizzazione di tali reti ecologiche fa parte della politica dell'Unione Europea (Convenzione di Berna, Direttiva Habitat, rete Natura 2000) che è culminata nella formazione della Rete Ecologica PanEuropea (Pan European Ecological Network PEEN).

In questa relazione sono riportati i risultati di uno studio per il progetto della rete ecologica della Regione Abruzzo. L'Abruzzo è una regione con aree naturali estese, prevalentemente collocate nella parte più alta dell'Appennino: tra esse tre parchi nazionali (Majella, d'Abruzzo, Gran Sasso-Monti della Laga), uno regionale (Sirente-Velino) e varie altre aree protette, montagnose e forestali. Queste aree sono di estrema bellezza e sono molto importanti ai fini dello sviluppo turistico regionale; gli aspetti di naturalità incontaminata ivi presente ne fanno aree di rifugio per un gran numero di carnivori, per l'orso bruno, il lupo e la lince.

Gli obiettivi delle analisi sono: (1) individuare la rete ecologica funzionale attuale, e (2) individuare le possibilità di ottimizzazione della rete.
Le finalità dello studio alla specie dell'Orso bruno si riassumono in tre punti:

1. individuare la potenzialità della rete ecologica,
2. valutare la sostenibilità della specie nelle situazione attuale,
3. valutare l'effetto della presenza dei corridoi ecologici sulla connettività degli habitat e sulla vitalità della popolazione.

I modelli utilizzati a tali scopi sono due: SmallSteps e Metaphor.

Per analizzare la rete ecologica in Abruzzo è stato utilizzato il LARCH, che è un modello spaziale di analisi ecopaesistica. Il modello LARCH fornisce informazioni sulla relazione tra distribuzione dell'habitat e popolazioni delle specie selvatiche e sulla loro sostenibilità.
Come materiale di base è stata utilizzata la mappa dell'uso del suolo elaborata dalla regione Abruzzo (Giunta Regione Abruzzo 1999) che è sembrata essere adatta.

Sono stati scelti 4 tipi di ecosistema che ricoprono i più importanti tipi di habitat naturali nell'area di studio: le aree boscate, le aree umide, pascoli e cespuglieti. Al fine di valutare la funzionalità dei suddetti ecosistemi sono state selezionate sette specie selvatiche, ritenute per questi le più rappresentative e, più precisamente la scelta ha interessato il Lupo, il Luì piccolo, il Rospo comune, il Riccio, la Lucertola verde, Saltimpalo ed il Tritone crestato. Si è poi valutato per ognuna di esse se l'ecosistema svolgesse ancora un ruolo funzionale come rete ecologica.

Gli ecosistemi principali, particolarmente per l'Abruzzo, sono le aree boscate, le praterie Alpine, steppe e praterie dell'alto Appennino. Ma anche gli ecosistemi acquatici sono importanti dato che molte specie dipendono in certa misura dall'acqua e molte altre usano i corsi d'acqua per gli spostamenti.

Il modello SmallSteps è basato sui movimenti della specie ed è stato utilizzato per stimare la connettività dei patches potenzialmente idonei su gran parte della regione montuosa dell'Appennino centro-settentrionale. Per connettività si intende la probabilità di raggiungere un patch diverso da quello natale, a seguito di fenomeni di dispersione della specie. Il modello tiene in considerazione le caratteristiche del paesaggio (in particolare la presenza di elementi che si oppongono alla dispersione) dentro e tra i vari patches (la matrice del paesaggio). La connettività calcolata è stata utilizzato in Metaphor, un modello che simula le dinamiche evolutive delle specie, al fine di stimarne la vitalità della metapopolazione. Entrambi i modelli richiedono l'individuazione degli patches idonei, gli habitat, punto di partenza e di arrivo a seguito della dispersione e al tempo stesso siti riproduttivi. Per identificare l'idoneità degli habitat, specie-specifici, si è utilizzato l'elaborazione messa a punto nell'ambito del progetto Life Orso elaborato dal Corpo Forestale di Castel di Sangro (Posillico 1999). Il modello SmallSteps è stato poi utilizzato per stimare l'effettivo funzionamento del corridoio, ad una scala più dettagliata basata sulla mappa dell'uso del suolo fornita dalla Regione Abruzzo.

In Abruzzo la maggior parte degli ecosistemi sembrano essere sufficientemente grandi da sostenere popolazioni potenziali. Nelle zone costiere e nelle aree industriali o ad agricoltura intensiva come ad esempio le principali valli ed il lago del Fucino, alcune specie hanno popolazioni piccole e frammentate. Tali specie sono il lupo, il riccio, la lucertola verde, Saltimpalo ed il Tritone crestato.
Tutte le specie analizzate in Abruzzo sono di per se stesse vitali, escluso il lupo che, al contrario, dipende dalle regioni circostanti dell'Italia Centrale. Il riccio, che apparentemente non ha non ha una popolazione sostenibile nella situazione attuale, ha in realtà una rete locale.

Attualmente la situazione in Abruzzo sembra essere "sostenibile" per la sopravvivenza dell' Orso bruno. Vale la pena di fare un analisis di incertezza relativo ai parametri demografici, e delle stime della carrying capacity. In ogni caso, un incremento nella dimensione della rete favorisce indubbiamente la ricolonizzazione degli habitat con benefici per la popolazione.

Lo studio effettuato mostra che la regione Abruzzo, per quanto concerne la rete ecologica, non ha al momento seri problemi di frammentazione. Ovviamente il 50% degli habitat naturali è sufficiente per molte specie. Ciò vuol dire che la rete ecologica può realizzarsi con piccoli investimenti: è giunto il momento di ottimizzare la rete ecologica così da creare buone opportunità per sviluppi futuri a lungo termine.

Come già detto gli habitat sono sufficienti per la vitalità delle specie considerate per la rete. In ogni caso per il mantenimento dell'alta qualità della naturalità esistente

sono necessari dei corridoi ecologici. Il lavoro effettuato mostra idee e forme da utilizzarsi come basi per gli sviluppi futuri e per il miglioramento della rete ecologica. È stato preparato un lay-out per la realizzazione di una possibile rete ecologica, basato sulla coesione spaziale per gli ecoprofili usati nelle analisi iniziali. Questo lay-out riguarda corridoi terrestri, come per esempio le aree boscate, ed ecosistemi quali praterie e cespuglieti.
La rete è basata sulle aree con le maggiori potenzialità per la realizzazione dei corridoi (basati sugli habitat già presenti) e considera i parchi nazionali esistenti come elementi base per la rete ecologica, le cosiddette "core areas".

Per quanto riguarda le zone costiere e le aree agricole ad uso intensivo, gli effetti della frammentazione sono maggiori e quindi sono necessarie azioni volte a ridurli. Ad esempio alcune aree situate lungo l'autostrada o la linea ferroviaria, in conflitto potenziale con la realizzazione della rete ecologica, sono state considerate proprio al fine di ridurre l'impatto negativo prodotto da tali infrastrutture.

Ad una scale spaziale maggiore le simulazioni dei movimenti dell'Orso indicano che i vari patches sono non ben connessi, anche con le stime più ottimistiche. I corridoi possono migliorare molto la connettività, ma solo quando queste zone sono connesse con habitat di relativamente alta qualità. Alla scale locale, la situazione sembra più favorevole per l'area del Sirente-Velino / Gran Sasso-Monti della Laga. Per valutare l'effettivo funzionamento dei corridoi progettati c'è bisogno di analisi più dettagliate dell'area e di dati empirici.

La sfida sarà di estendere la rete ecologica su scala nazionale: per creare una rete per i grandi carnivori si richiede una forte cooperazione regionale.
Progetti simili fatti altrove (Regione Emilia-Romagna , Sicilia) suggeriscono le analisi ed il disegno di tale rete e, prevedono l'applicazione di azioni protettive e legislative. L'Abruzzo può essere una delle regioni leader per lo sviluppo di una rete ecologica tarata su alcune specie target come la Lince, il Lupo e l'Orso bruno, specie indicatrici per uno sviluppo eco-sostenibile.

Utilizzando i presenti risultati si possono disegnare i corridoi ecologici specificandone la localizzazione e basando la progettazione degli stessi sulle specifiche necessità delle specie considerate.


Courtesy of P. Kaczansky

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 repopulation or restocking of small areas and habitats, the areas need to be connected to the remaining core areas in the vicinity (Hanski & Gilpin 1997, Vos *et al.* 2002, 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 not-flying animals it might mean that often a physical connection is required, e.g. forests, streams, rivers, and natural grasslands.

An answer to this problem is the development of an ecological network, linking nature areas by means of corridors and small habitat patches. 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 (Foppen *et al.* 2000). However, in the first instance many small organisms will benefit from improvement in spatial cohesion and expansion of natural habitat.

Many European countries are attempting to realise ecological networks (‘*reti ecologiche*’ in Italian) at a national or regional scale (Van Opstal 1999). 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 development of ecological networks. 0The project is the joint initiative of local authorities, private industry and research centres from the UK, Italy and the Netherlands. Regione Abruzzo is partner in the Life-Econet project and intends to improve the ecological network in this region.

1.2 Study area: Regione Abruzzo

Abruzzo is a region with large natural areas, mainly located in the highest part of the Apennine mountain range, with 5 large national parks, mountain areas and forests: Abruzzo, Gran Sasso, Maiella, Monte della Laga, Monti Sibillini (fig. 1, based on: http://www.regione.abruzzo.it/turismo/parchi/mappa.htm). These areas are of outstanding beauty, and in particular the wilderness aspect makes them both of

importance as refuge for e.g. a number of large carnivores like the Brown bear, Wolf and lynx, and very important for tourism and regional development.
Focal species for the National park Abruzzo is the Brown bear, which is important for attracting tourism in this Region, but also of importance on a European scale (http://www.nature.coe.int/english/main/Bern/texts/rec8810%20.htm). The tourism generates income and development for the area, which faces problems of land abandonment and land degradation.
Most developed areas and industrialised zones are in the coastal zone, a densely populated coastal plain on the Adriatic coast (see Text box 1). This has resulted here in a highly fragmented landscape, with few remaining natural areas. This has resulted in the fragmentation of areas and decrease of ecological value and bears its effect on the wildlife populations. Also the mountain areas, though partly well protected due to their isolation, bear effects of fragmentation, mainly due to infrastructure and urban sprawl in the valleys.

Box 1: Abruzzo (LIFE internet site, http://www.lifeeconet.com/study_areas2.htm)

Topographically, the region includes two distinct areas. The western portion, almost contiguous with the province of L'Aquila, consists of three ranges of the Apennines, including their valleys and basins. Extending in a north-west to south-east direction, the highest range culminates at 2,941 m above sea level in Corno Grande, a peak of the Gran Sasso d'Italia.
In the east, sand and clay hills slope gradually down to a broad coastal plain on the Adriatic Sea encompassing the provinces of Chieti, Pescara, and Teramo. The coastline lacks good natural harbours. The Pescara River, an important source of hydroelectric power, and the Sangro, Trigno, and Biferno rivers irrigate the lower valleys: all drain into the Adriatic. The primary economic activities of the region are sheep and cattle grazing and raising potatoes and wheat in the highlands; growing corn, olives, grapes, and citrus fruit in the coastal valleys; and sugar beet in the drained basin of Lake Fucino. Bauxite mining is extensive in L'Aquila Province. Abruzzo Region covers 10,794 sq. km and has a population of 1,249,388.

The University of L'Aquila has done much work on promotion of the ecological network. The areas of Navelli and Cucolli are selected locations where efforts are concentrated to establish corridors (Romano 2000, Romano & Tamburini 2002). The areas were visited by ALTERRA in October 2000 and November 2001 in the framework of the Life Econet project.

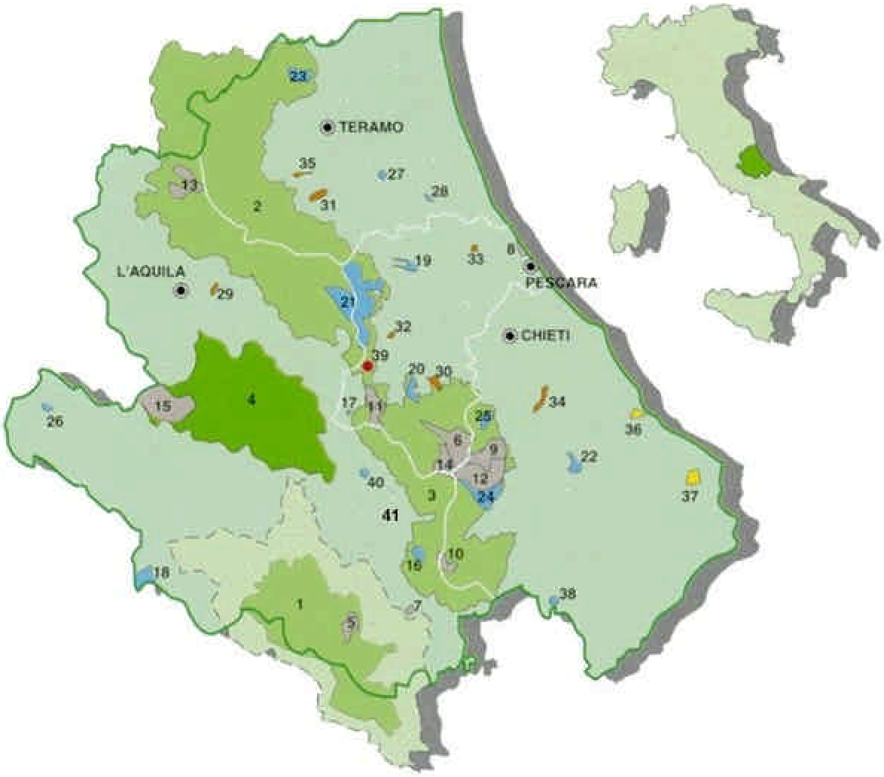

Figure 1: Region Abruzzo, location and national parks (based on http://www.regione.abruzzo.it/turismo/parchi/mappa.htm)

1.3 Problem definition

The two main problems for Region Abruzzo in regard of nature protection are:
Fragmentation within and between the parks. The parks are large on their own account, but for mammals like the Brown bear and Wolf the area is still limited in size. Connecting the parks by wildlife corridors might improve this situation. A number of possible locations for corridors were identified (Romano & Tamburini 2002) and two were studied in detail (Bernoni 2002, Biondi & Tete 2002), but it should be assessed if the corridors would result in an improved situation for the target species, the Brown bear.
Fragmentation of the landscape. Due to the geomorphology all infrastructure is concentrated, in the valleys, which bundle the Autostrada, roads and railway lines, forming real barriers. The settlement pattern changes, from small hillside villages down to the valleys. Uncontrolled urban spread will result in fragmentation of natural areas, decreasing wildlife populations and finally decreasing income from tourism.
The coastal plain is very important for economical development and infrastructure development and urban pressure is much stronger here. Here even more fragmentation occurs.
The creation of an ecological network might balance economical requirements with environmental protection.

Aim of this project is therefore to identify:

1. what is the ecological network for different ecosystems and wildlife populations, and
2. where should the cohesion of the natural areas be improved, and
3. is the Brown bear population at present viable, and does connecting existing national parks with the two identified corridors result in a more sustainable Brown bear population.

Ad 1) The ecological network is assessed to see whether available (fragments of) habitat is large enough for species to survive. This is done through an assessment of the habitat requirements of specific species and the connectivity of the area with LARCH. Selected ecosystems are the forests, the rivers and streams, and natural grasslands. The situation will be assessed for relevant selected species: some short-range species, i.e. reptiles, amphibian species, mammals, species which are all vulnerable for fragmentation. In addition, some bird species are analysed.
The assessment is done for the entire Regione Abruzzo, based on the Land Use map, which is since recently available.

Ad 2) 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, so that recommendations can be made where road passages or other measures might be considered.
LARCH is used with ecological profiles, developed for this purpose at ALTERRA.

Ad 3) A metapopulation analysis for the Brown bear is done.

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 models LARCH, SmallSteps and METAPHOR, the species selected, and the used base maps. The results of the LARCH analysis are presented in chapter 3, the metapopulation analysis of the Brown bear in chapter 4. This is followed by chapter 5 with discussion of results, and conclusions and recommendations (chapter 6).
An explanation of terms frequently used in this report is found in paragraph 1.5.

1.4 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 *et al.* 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.

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. a fire, pollution, or climatic events. Occasionally breeding results might fail, with disastrous consequences for 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 demand of e.g. insects are smaller.

1.5 Definitions of terms

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

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 with a local population usually is meant 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 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 (fig. 2), with a set of ecological parameters.

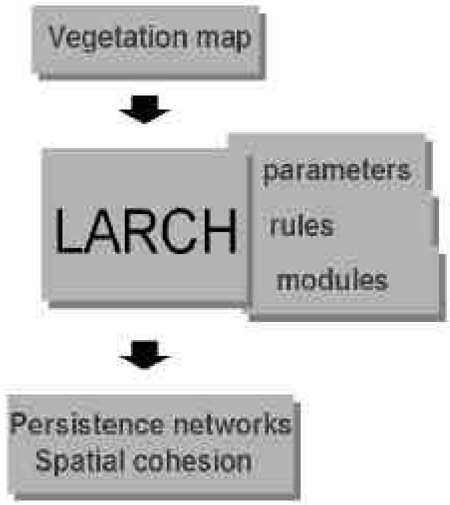

Figure 2: set-up of LARCH model

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. In the following paragraphs the functioning of LARCH is explained in more detail.

2.1.1 LARCH

LARCH is designed as an expert system, used for scenario analysis and policy evaluation. The model has been fully described elsewhere (Foppen *et al.* 1999a, 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) 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.

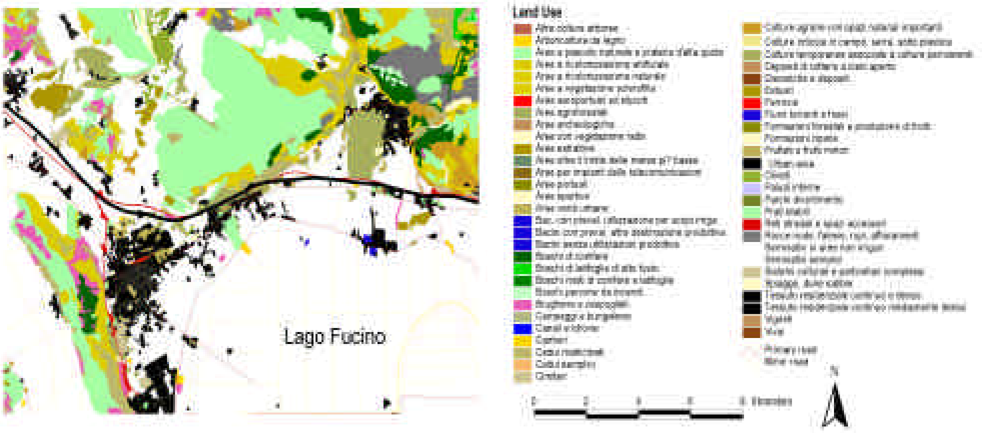

fig. 3A: Input for LARCH is Land Use map from Abruzzo

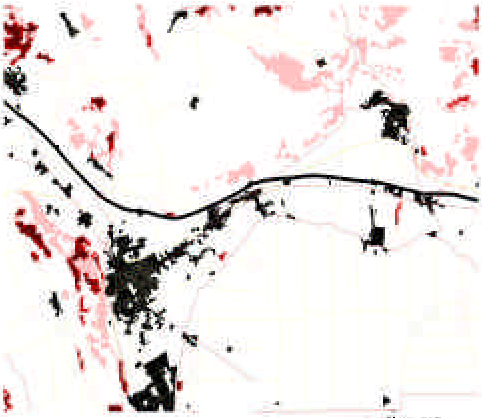

fig. 3B: Assessment carrying capacity

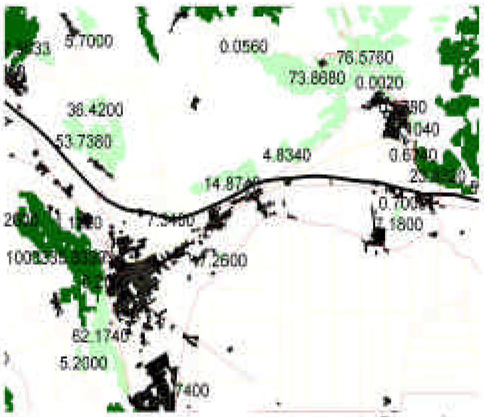

fig. 3C: Identification of local populations and key-patches based on

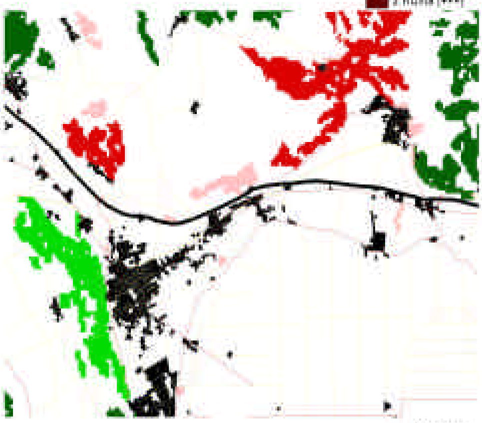

fig. 3D: Identification of network populations and sustaiability of network

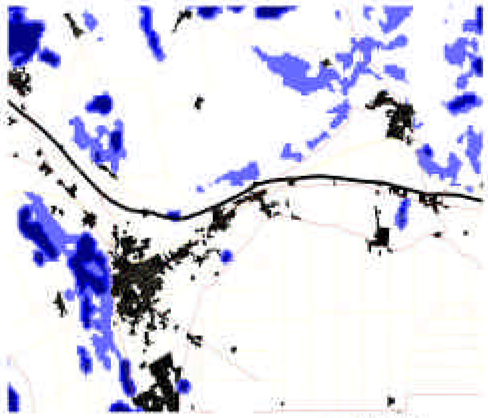

fig. 3E: LARCH-SCAN, analysis of spatial cohesion

Figure 3: LARCH analysis procedure; fig. 3A to 3E show the steps taken in LARCH to come to a viability assessment on the basis of the habitat map. Fig. 3E illustrates spatial cohesion. See text for further explanation

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.* 1999b, Verboom *et al.* 1993, 2001, Vos *et al.* 2001, 2002, Opdam *et al.* 2002). Actual species distribution or abundance data are not required 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:

- **Habitat modelling**

The land use map (fig. 3a) is used as the basis to define the relevant habitat 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. 3b), based on population densities 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. 3c). In the event that species are vulnerable for barriers, roads or other features are taken into account. 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. 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. 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 the total number of animals present, but also the rate of fragmentation: is it a 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.

- **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 in search for new habitat (dispersal). So in most cases, a set of local populations will form a population network, which may render it viable or sustainable (fig. 3D). 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. 3D). The criterion used is the chance that a (network) population still exists after 100 years is larger 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.

2.1.2 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 Green lizard is much smaller than that of a large mammal, such as the Wolf. In effect, this dispersal distance defines whether or not habitat patches will form part of a network for a species. A Wolf can utilise forest areas are within a radius of 200 km,

whereas an *Italian crested newt* may exploit habitat within a radius of 1000 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, Van der 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 3), 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. 3E) 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 also have been taken into account for some species.

Box 3: defining spatial cohesion in LARCH

The probability that a dispersing individual will cover a certain distance d_{ij} is estimated as:

$$p(d_{ij}) = a \cdot e^{-a \cdot d_{ij}}$$

LARCH determines the connectivity SC_i of a habitat grid cell 'i' by weighting the carrying capacity of all grid cells within the potential dispersal distance:

$$SC_i = \sum RU_j \cdot e^{-a \cdot d_{ij}}$$

where:

SC_i	is a measure for connectivity of grid cell i
RU_j	is the maximum number of reproductive units RU in gridcell j (taking account of differences in carrying capacity between habitat types, and the effect of roads)
d_{ij}	is the distance between the contributing grid cell j and cell i, measured as the shortest distance between j and i, avoiding built-up areas.

2.2 Base maps

The basis for the analysis with LARCH forms the Regional Land Use map (Carta dell'uso del suolo, Giunta Regione Abruzzo 1999). The land use map has a classification that resembles very well vegetation types, and is therefore very suitable for habitat modelling of species.
In Table 1 the distribution and quantity of land use types occurring is presented. It is clear that the area has a lot of natural areas, amounting to almost 50 % of forests, shrubland and natural (partly alpine) grasslands. Cultivated areas (mainly sowed

fields) form only some 46 %, part of which is extensively used, or tree plantations orchards or oliveyards. Urban or similar habitats form some 4 % of the total area.
Virtually absent are aquatic habitats, waters and lakes. This is partly due to the method used to compile the land use map, based on aerial photographs and satellite images (TM5), which results in a large underestimation of rivers and streams (but also roads, for that matter).
The natural habitat (50%) forms a large contrast with other Life-Econet areas like Emilia-Romagna with only 5 % (Van der Sluis *et al.* 2001a) or Cheshire with 15 % (Van der Sluis *et al.* 2003) natural areas observed.

Table 1: Natural habitats in Regione Abruzzo (based on Land Use map)

Typology carta dell'uso del suolo	Land Use type	# POLY-GONS	CODE	AREA (HA)	%
Superfici artificiale (ambiente urbanizzato)	Urban area and infrastructure	8858	1	42599.2	3.8
Seminativi e orticoltura	Arable land and horticulture	16800	2.1	264306.4	24.5
Oliveti	Oliveyard	6811	2.2.3	62501.4	5.8
Altre colture permanenti	Permanent crops (trees)	159	2.2.4	708.0	0.1
Prati stabili	Permanent grassland	4148	2.3	45888.8	4.3
Zone agricole eterogenee	Heterogenous agricultural areas	9865	2.4	71828	7
Boschi di latifoglie	Broadleaved forest	7158	3.1.1	249292.7	23.1
Boschi di conifere	Conifer forest	938	3.1.2	16194.7	1.5
Boschi misti di conifere e latifoglie	Mixed & broadleved	656	3.1.3	22561.7	2.1
Aree a pascolo naturale e praterie d'alta quota	Natural grassland, alpine meadows	2422	3.2.1	127056.2	11.8
Brughiere e cespuglieti	Heather and shrubs	4441	3.2.2	62162.5	5.8
Vegetazione arborea e arbustiva in evoluzione	Shrublands, recolonised	6150	3.2.4	62249	6
Formazioni riparie	Riverine area	1811	3.2.5	15558.1	1.4
Spiagge, dune sabbie	Beach, dunes	218	3.3.1	1439.6	0.1
Rocce nude, falesie, rupi, affioramenti	Bare rock, dwarf shrubs	648	3.3.2	18189.1	1.7
Aree con vegetazione rada	Open vegetation	874	3.3.3	13379.8	1.2
Boschi percorsi da incendi	Forest after fires	4	3.3.4	100.9	0.0
Paludi interne	Marshland	5	4.1.1	17.9	0.0
Corsi d'acqua, canali e idrovie, bacini	Rivers, brooks, streams	219	5.1	2760	0.0
Zone umide marittime	Tidal areas, wet	20	5.2	61.4	0.0
		SUM AREA		1078855.4	100

In addition to the Land Use map, use was made of a roads and infrastructure map, the map with contour lines, and a map with rivers and streams. All these maps were provided by the University of L'Aquila.

2.3 Brown bear habitat connectivity

The brown bear habitat in the Abruzzo region is divided over several more or less isolated areas, in the following referred to as (habitat) patches. It is also part of a much bigger configuration of habitat patches covering the whole Appenine Mountains region (fig. 4).

Metapopulation viability has to be assessed over the whole metapopulation, including all the potentially occupied sites. We thus have to take into account an area larger than the Abruzzo region. Viability is defined as a survival probability for the metapopulation, exceeding 0.95 over a period of hundred years. In general, survival probability (or its complement extinction probability) of a metapopulation depends on the balance between extinctions and colonizations taking place in all the local populations.

For a local habitat patch, colonization probability depends on the number of dispersing individuals leaving potential (source) habitat patches, on the per-disperser probability of arriving into this particular habitat patch, and on the number of immigrants required to establish a new population. In this section we focus on the per-disperser probability of arriving into a target patch: the arrival probabilities. These *arrival probabilities* are required in the metapopulation viability analysis (2.4). However, the matrix of arrival probabilities can be considered an independent measure of patch connectivity; as we will do in the following, this matrix is often called the *connectivity matrix*. It defines the functional connectivity of the landscape: "*functional* or *behavioral connectivity* refers to how connected an area is for a process, such as an animal moving through different types of landscape elements " (R. T. T. Forman 1997). We calculate the connectivity matrix for all the patches shown in figure 4.

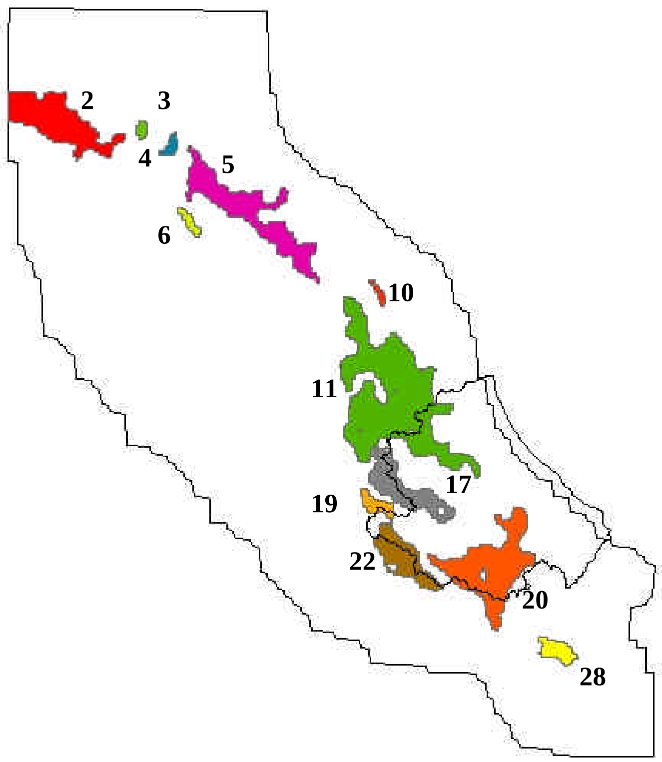

Figure 4: Patches of potential Brown bear habitat in the Appenine mountains region (after Posillico 1999), including the Abruzzo region

Arrival probabilities are estimated using a movement model (SmallSteps, see appendix 1 for a description of the model). This allows us to take into account characteristics of the landscape between the patches. We compare the outcome of movement simulations for two different scenarios: one with the current landscape, and another one with planned corridors in the Navelli and Cocullo area. Both scenarios are run for two different parameter sets, with respect to the boundary transition probabilities. One of the sets ("moderate") assumes a linear relationship between the perceived difference in habitat quality on both sides of a boundary and the probability of crossing this boundary; this implies that individuals with a small but substantial probability will move into low-quality habitat. The other ("extreme") set assumes an exponential relationship, implying that individuals will hardly ever move into low-quality habitat. These transition probabilities are parameters with undoubtedly the highest uncertainty, as they are hard to measure in the field (see Appendix 1).
The landscape in which we simulate movement is derived from a probability-of-occurrence map in grid-format, generated by applying a statistical habitat suitability model on the CORINE landuse map (Posillico 1999). The continuous units on the map are mapped into 10 discrete classes of habitat "quality", where class 1 refers to a probability of occurrence between 0.01 and 0.1, class 2 between 0.1 to 0.2, etc. (fig. 5). The 3 classes with the highest quality are assumed to represent core (reproduction) habitat.

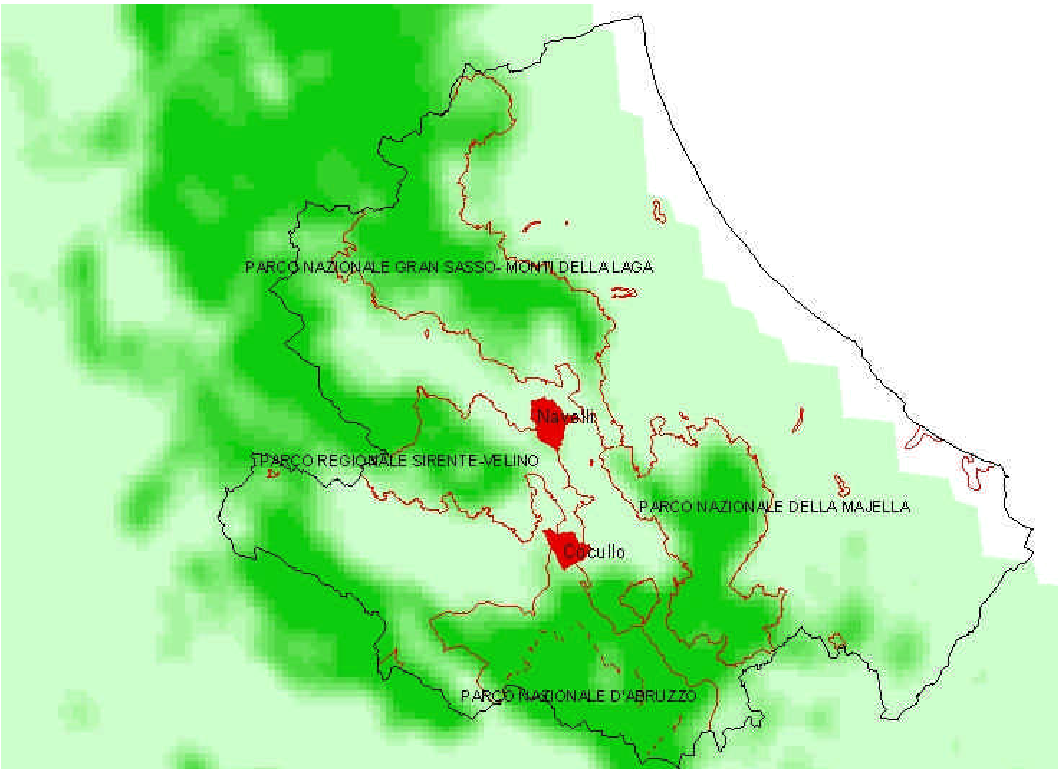

Figure 5: The Abruzzo region with protected zones and planned corridors. The green-shades refer to habitat quality (10 classes). In the corridor scenario the landscape within both corridor zones is increased in quality. Patches: Gran Sasso-Monti della Laga (11), Sirente-Velino (17) and Parco Nazionale D'Abruzzo & Majella (20)

2.4 Estimation of Brown bear population viability

The viability of the bear population, in both the current situation and in a situation taking into account possible recolonizations, is estimated using the population dynamic model METAPHOR (see Appendix 2). Local birth- and death-processes and dispersal are simulated. For the dispersal part the matrix of arrival probabilities estimated by modeling movement (see first chapter) is used, selecting the results obtained with the “moderate” parameter sets. Population viability is defined as a less than 5% probability of extinction over a period of 100 years (a commonly applied measure).
The population parameters are obtained from Knauer (2000) and Wiegand *et al.* (1999, in press), see Appendix 2 for an overview of the parameters in the model. We estimate population viability in the current situation (with only the patch with the National Parks d’Abruzzo & Majella inhabited) by assuming that no successful dispersal can take place outside the National Park area (scenario “current”). Population extinction risk in this situation relates to the pessimistic case, where the current national park population does not benefit from colonizations from other local populations. In addition, extinction risk is estimated in case dispersal to and thus re-colonization of other habitat patches is possible (the “potential” scenario). For this scenario the arrival probability matrix (assuming the “moderate” parameter set) determined by the movement simulations (see paragraph 2.3) is used. Both scenarios are investigated for two values (0.5 and 0.75) of an important dispersal parameter: the probability (male individuals only) of settling into a vacant territory while dispersing.

2.5 Estimation of Brown bear corridor effectiveness using a movement model

In this section we focus on the relationship between the landscape configuration in the two corridor zones and the potential effectiveness of these zones in facilitating movement of bears from the Abruzzo National Park into nearby suitable habitat. The habitat suitability map underlying the previous analysis is too coarse-grained to be used for this purpose (no effect will be observed); as its basic cell size measures 1.25 by 1.25 km^2 details in the landscape configuration that are likely to affect bear movement will be averaged out.
Therefore, we apply the vector-based land-use map (Carta dell uso dell suolo, Giunta Regione Abruzzo 1999) from which we extract the part containing both corridor zones and nearby patches with suitable habitat in the currently protected areas. The land-use map has a much higher resolution than the habitat suitability map. The movement model has to be adapted, scaling back the step-size to become on average smaller than the average polygon diameter. By using timesteps of five minutes, instead of one hour, mean movement step size of 722 m was scaled back to 208 m (see Appendix 1). The numerous categories of the land-use map (based on the CORINE landuse classification), are translated into a limited number of classes representing the quality of the land-use in relation to bear movement. The new classification is based on the amount of human influence on the landscape, roughly

represented by the 6 main categories of the CORINE classification; for the (semi)natural landscape classes (CORINE category 3) we further distinguish between open, half-open and closed (forest) landscapes (using the second level of the CORINE classification). Figure 6 depicts the map resulting from a classification based solely on human impact; the map in figure 7 differentiates further according to openness of the landscape.

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Figure 6: Map of the area, classified according to CORINE, using the highest level of the classification

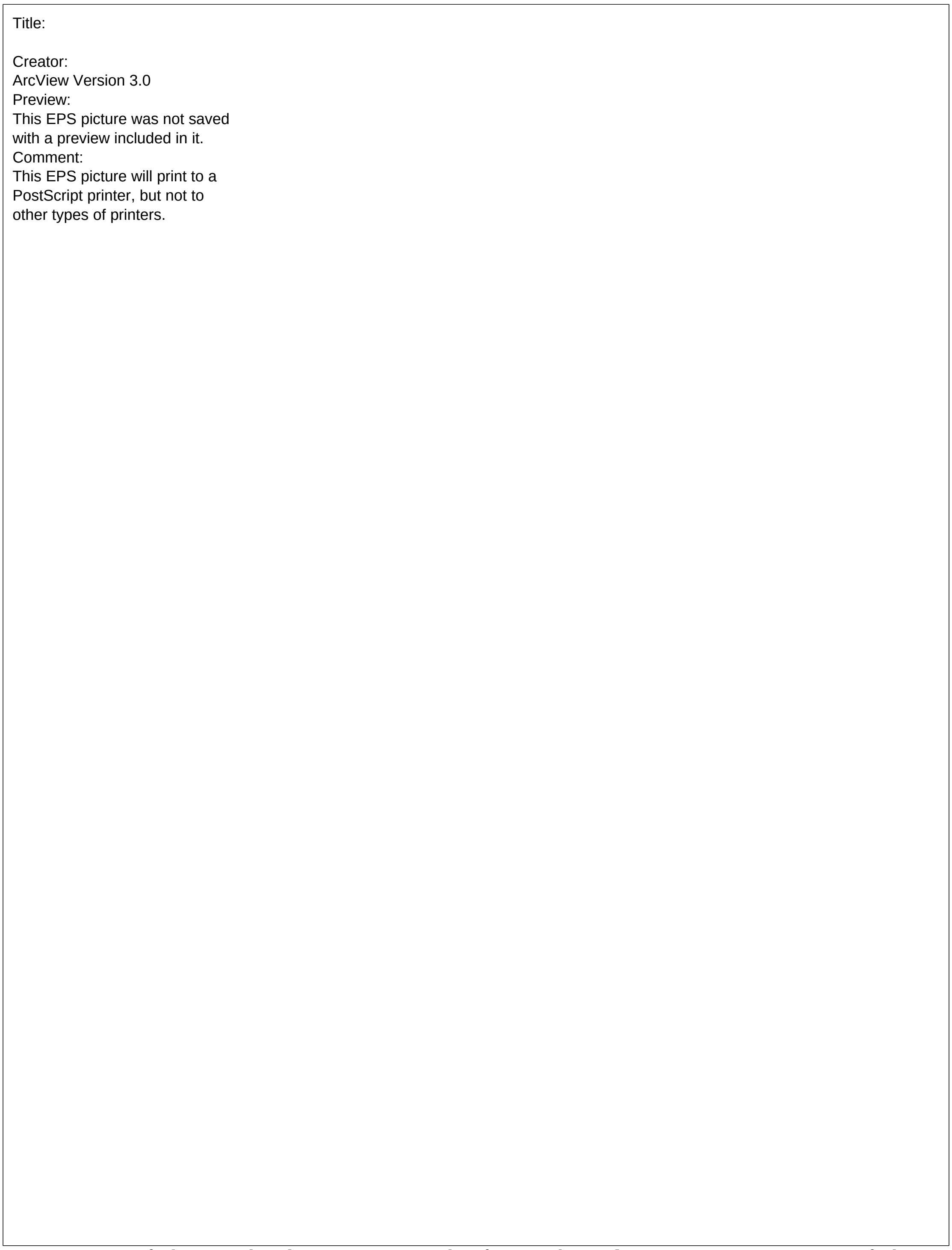

Figure 7: Map of the area based on CORINE classification, but taking into account openness of the (semi)natural areas.

With respect to the parameterization of movement, we assume that in all elements belonging to all the different landscape classes, movement is of the same type (random walk). Furthermore, we assume that velocity is equal. The impact of the landscape on movement is thus exerted through the values of the boundary

transition probabilities, see appendix SmallSteps.
With the model, we calculate the probabilities of reaching other protected zones, for dispersers starting from 4 different locations in the core areas (Table 2). Probabilities are based on 10000 simulated paths, for each starting location.
To compare the present situation with the situation after corridors have been established, we changed the landscape definition within the corridor zones according to the following, simple rule: all landuse in CORINE class 2 (“superfici agricole utilizzate”) is changed into landuse class 3.2 (“Ambienti seminaturali caraterizzati da vegetazione arbustiva e/o erbacea”), the “half-open” natural landscape.

Table 2: Starting locations in the simulations

x	y	Protected area	Area ID
402500	4681000	Gran Sasso-Monti della Laga	3
383700	4672400	Sirente-Velino (west)	6
397000	4667500	Sirente-Velino (east)	6
397300	4646000	National Park d'Abruzzo	8

2.6 LARCH Species selection and habitat modelling

A table was prepared of relevant species for Regione Abruzzo, to be analysed with LARCH (Appendix 3).
Based on a number of criteria a further selection of species for analysis was made by the Steering Committee from Abruzzo and specialists from the University of L’ Aquila:

- Species should be not 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
- Covered in the study from the consultants from L’ Aquila
- if possible, species should already have been analysed in one of the other Life-Econet studies, for comparative purposes

Based on these criteria 10 species were selected for analysis with LARCH in the first stage (Table 3). Based on the analysis results, a further selection of seven species was made (Table 4). Species which were considered to show overlap with other species or give less meaningful results were further disregarded in this study: Blackcap, Whitethroat and Red-backed shrike.

Table 3: Species selection and ecosystems and their presence in 2 the corridor areas; x and X indicate respectively minor and major importance of this ecosystem

Nome italiano	English name	Scientific name	Cocullo corridor	Barisciano corridor	Forest	Pastures & Steppe	Wetland	Shrubland, macchia
Rospo comune	Common toad	*Bufo bufo*			x	X	x	
Riccio	Hedgehog	*Erinaceus europaeus*				X		
Ramarro occidentale	Green lizard	*Lacerta bilineata*				X		x
Lupo	Wolf	*Lupus canis*			X	x		
Tritone crestato meridionale	Italian crested newt	*Triturus carnifex*				x	X	
Averla piccola	Red-backed shrike	*Lanius collurio*	X	X		x		X
Luì piccolo	Chiffchaff	*Phylloscopus collybita*	X	X	X			
Saltimpalo	Stonechat	*Saxicola torquata*	X	X		x		X
Capinera	Blackcap	*Sylvia atricapilla*	X	X	X			
Sterpazzola	Whitethroat	*Sylvia communis*		X		x		X

Main ecosystems found in Abruzzo are Forests, Grassland and steppe, Macchia and shrublands, and Wetlands. The steppe ecosystem here is regarded as a sub-type of the grassland ecosystem, which is bound to more arid environments (pers. comm. B. Bunce).

The species are organised according to dispersal capacity and habitat requirements (Table 4). These parameters define very much the landscape ecological requirements for the species, and define in fact also the functioning of the ecological network.

Table 4: Spatial profiles of species selected for the final analysis

Ka \ Nd	<1	1-3	3-7	7-15	15-35	>35
0-1	Green lizard		Common toad			
1-5			Chiffchaff Stonechat			
5-10		Italian crested newt	Hedgehog			
10-50						
50-150						
>150						Brown bear Wolf

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

We see that species differ in habitat requirements for viable populations and dispersal range. A species like the Green lizard has a limited range of a few hundred meters and needs only some 1 km^2 for a viable key population, whereas a Wolf can move as far as 200 km and might require 4000 ha for a viable population (Table 4).

In the following paragraphs the different ecosystems and selected species as well as their modelling parameters are discussed.

2.6.1 Forest ecosystems

2.6.1.1 Wolf (Lupo)

The **Wolf** (*Canis lupus*) is a predator species, which feeds mainly on wild and domestic ungulates, hares, small rodents, and occasionally on ground-dwelling birds, frogs, insects and berries. They are territorial for most part of the year and form small packs of appr. 2-6 animals, the size of the pack depends on the availability of prey (Knauer, pers. comm.). The young are raised in a rocky cavern, beneath the roots of fallen tree or in burrows. In Abruzzo Wolf were observed between 800 - 2000 m altitude (Zimen & Boitani 1979). In Switzerland this was shown to be the result of presence of prey, geomorphological conditions and presence of man (Glenz *et al.* 2001).

The Wolf occurs in the remote and least disturbed areas of the Apennines. Its prime habitat forms densely forested areas, with human habitation virtually absent. The Wolf could recover from the hunting and persecution in the past and has shown an expansion of habitat over the past decades. In the early seventies some 100 wolves occurred in Italy, in Abruzzo and the Maiella mountains no more than 16-21 were counted, but ten years later the population increased upto 500 (Smit & Wijngaarden 1981). Nowadays there might be as many as 400-500 in the Apennines (Corsi *et al.* 1999). This is also a result of increased prey, due to (local) re-introduction of species. The dispersal range might be as much as 200 km but occasionally more (Boitani pers. comm.) Recently the first dispersing Wolf has been shot in the Alps, Switzerland, which is indicative for the territorial expansion of the species.
The territory is appr. 70-200 km^2 (Zimen & Boitani 1979), or 106 km^2 (Corsi *et al.* 1999). For modelling a density of 0.01 RU / 100 ha is used.
For habitat modelling only habitat patches exceeding 100 ha are selected, between 800-2000 m altitude (Possillico 1999).
The selected habitat of the Wolf consists of (Table 5):

Table 5: Relevant habitat types in the land use map for the Wolf; + = marginal habitat, ++ = intermediate habitat, +++ = optimal habitat

Habitat type	Description	Importance
Broad-leaved forest	3111,3112,3113	+++
Natural and alpine grassland	3210	++
Brughiere e cespuglieti	3220	++
Transitional woodland-scrub	3241,3242	++
Sparsely vegetated areas	3330	++

2.6.1.2 Chiffchaff (Luì piccolo)

The **Chiffchaff** *(Phylloscopus collybita)* is a variable species with several subspecies, wich are sometimes regarded as separate species e.g. the “Spanish Chiffchaf” *Phylloscopus collybita brehmii)*. The nominate race breeds over the largest part of Europe, including Italy. The distribution range is far into Asia, reaching as far as the Kolyma river in

eastern Siberia. The species is wintering with large numbers in the Mediterranean area. In the Chiffchaff there is no evidence of a clear trend in the population.
The breeding habitat can be pinpointed as “trees”. As soon as some large threes occur the Chiffchaff may be found. The type of woodland is less important, also the scrub layer is of less importance.
Densities in southern Italy are mostly lest than 5000 bp / 50 km square (Hagemeijer & Blair 1997). In Abruzzo the density is up to 45 bp / 100 ha (Bernoni 2002). The estimates for the Cocullo area and the Barisciano area are 2617 and 504 bp respectively. In Central Europe the territories can be small in optimal habitat (less than 0,5 ha) but are normally 1-2 ha This would implicate a home range of at least 100-150 m (Cramp & Brooks 1992, Hagemeijer & Blair 1997). The dispersal distance is 7000 m. The Chiffchaff breeds up to 2200 m in the mountains (Schmid *et al.* 1998).
The selected habitat of the Chiffchaff consists of (Table 6):

Table 6: Relevant habitat types in the land use map for the Chiffchaff; + = marginal habitat, ++ = intermediate habitat, +++ = optimal habitat

Habitat type	Description	Importance
Sport and leisure facilities	1421,1422,1423,1424	+
Cemetery	1430	+
Fruit trees and berry plantations	2220	+
Olive groves	2230	++
Other permanent plantations	2241,2242,2243	+
Agro-forestry areas	2440	++
Broad-leaved forest	3111,3112,3113	+++
Coniferous forest	3120	+
Mixed forest	3130	++
Sclerophyllous vegetation	3230	++

2.6.2 Grassland & steppe ecosystems

2.6.2.1 Common toad (Rospo commune)

The **Common toad** (*Bufo bufo*) is a fairly common and widespread species, in most of Europe. In Abruzzo it is also common, well distributed, with main threat coming from traffic in the reproductive season (Ferri *et al.* 2000).
The Common toad occurs in the Apennines up to an altitude 2000 m. (Biondi & Tete 2002).
For most of the year the species is terrestrial, only during the reproductive period (early spring) the toad is in its aquatic habitat. Reproduction sites utilised are variable, from lakes, springs, ponds, marshlands to concrete basins, canals and not fast running waters.
The Common toad prefers for its terrestrial habitat various kinds of forests, but also open and cultural landscapes such as meadows, parks, fields, gardens and human settlement (Gasc *et al.* 1997) and even in dry, xeric or urban habitats (Mazzotti *et al.* 1999). In winter the Common toad will seek an appropriate place to hibernate: walls, foundations, stems, wood piles, crevices in the soil and mammal burrows are used.

Common toad may migrate up to 4 km away from the reproduction sites (Biondi & Tete 2002). The home-range is not known. For habitat modelling all suitable terrestrial habitat within 4000 m. around the reproduction sites below 2000 m altitude is selected. In optimal habitat the density might be 400 RU/100 ha.
All roads are considered as barriers at local population level. At network level only autostrada are considered absolute barriers. For a key population #125 RU are required.
The selected habitat of the Common toad consists of (Table 7):

Table 7: Relevant habitat types in the land use map for Common toad; + = marginal habitat, ++ = intermediate habitat, +++ = optimal habitat, A = Aquatic habitat

Habitat type	Description	Importance
Streams	Fiume	A
Mineral extraction sites	1310	+++
Green urban areas	1410	+
Cemetery	1430	+
Fruit trees and berry plantations	2220	+
Olive groves	2230	++
Other permanent plantation	2241,2242,2243	++
Permanent grassland	2300	++
Complex cultivation patterns	2420	+
Agro-forestry areas	2440	++
Broad-leaved forest	3111,3112,3113	+++
Brughiere e cespuglieti	3220	+
Transitional woodland-scrub	3241,3242	+++
River banks	3250	+++
Sparsely vegetated areas	3330	+
Inland marshes	4110	+++

2.6.2.2 Hedgehog (Riccio)

The **Hedgehog** (*Erinaceus europaeus*) is a fairly common and widespread species. The species occupies many different habitats, including antropogenous habitats (http://www.regione.Abruzzo.it/parchi/fauna/mammi.htm).
The Hedgehog prefers in particular open and cultural landscapes such as meadows, parkland, fields, gardens and areas near human settlement. In winter it will seek an appropriate place to hibernate. Leaves, branches and wood piles are used. The species frequents in particular edge-habitats, i.e. grassland near hedges, lanes, stone walls etc. They use linear features and trees for cover, protection, for food, but probably also for orientation.
The presence of badgers causes lower densities of hedehogs, since badgers are effective predators (Bergers & Nieuwenhuizen). Hedgehogs tend to avoid badgers, or even wildlife tunnels used by badgers, constructed to mitigate road barriers (Doncaster 1994).

Traffic mortality in Hedgehog can be high, due to their high density in semi-urban areas. In the Netherlands traffic motality is estimated 6.1-9.0 % (Huijser 1999). In a 200 m. wide zone directly adjacent to the road, Hedgehog densities were estimated to

be 30 % lower than in the remaining habitat (Huijser 1999). However, Hedgehogs were frequently observed crossing busy secondary roads. Roads are therefore not absolute population boundaries, some exchange is always likely to occur. There are anecdotical observations of swimming Hedgehogs, so also canals or rivers are not likely to form absolute barriers for this species.
There are some indications that local populations might get close to extinction, or have indeed gone extinct, probably as a result of traffic mortality (Reicholf 1983, in Bergers and Nieuwenhuizen 1999).

The Hedgehog may migrate distances of up to 5 km. The home-range is some 2 km, network distance 5000 m. The density is maximally 70/100 ha in small scale agricultural landscapes with hedgerows and woodland fragments (Doncaster 1994). However, more common figure based on different sources is appr. 30 /100 ha Primary roads and autostrada are considered barriers at local population level and network level.

The Hedgehog occurs in the Apennines up to 2000 m altitude (Biondi & Tete 2002). The home-range is 2 km, network distance 5 km The optimal density might be 15 pairs/100 ha.
The selected habitat of the *Hedgehog* consists of (Table 8):

Table 8: Relevant habitat types in the land use map for the Hedgehog; + = marginal habitat, ++ = intermediate habitat, +++ = optimal habitat

Habitat type	Description	Importance
Mineral extraction sites	1310	++
Green urban areas	1410	+++
Cemetery	1430	++
Fruit trees and berry plantations	2220	+++
Olive groves	2230	+
Other permanent plantation	2241,2242,2243	++
Permanent grassland	2300	+++
Complex cultivation patterns	2420	++
Agro-forestry areas	2440	++
Broad-leaved forest	3111,3112,3113	+
Natural grassland	3210	+++
Brughiere e cespuglieti	3220	+
Transitional woodland-scrub	3241,3242	++
River banks	3250	+
Sparsely vegetated areas	3330	+

2.6.2.3 Green lizard (Ramarro)

The **Green lizard**, *Lacerta bilineata* has only recently been identified as a distinct species from *Lacerta viridis*, through genetical research (Joger *et al.* 2001). The Green lizard is vulnerable in most of its habitat. The species has shown a decline as a result of habitat destruction. Also the weather conditions are of importance for this species (Gasc *et al.* 1997).

The Green lizard (*Lacerta bilineata*) occupies well vegetated habitats, especially where there is some dense cover adjacent to open areas (http://www.regione.Abruzzo.it/parchi/fauna/retanfi.htm). Good structurally varied vegetation with open patches but at the same time providing physical cover from predators, is essential. Green lizards often use woodpiles, dead branches and similar structures, or stone walls and rocks for basking in the sun (Biondi & Tete 2002; Cabela *et al.* 2001)
The Green lizard occurs up to 2130 m in the Central Apennines (Bressi 1992, in Gasc. *et al.* 1997).

Little research was done on spatial requirements of the Green lizards. Two animals, one male and one female, were followed during one year with radiotelemetry in the middle-Rhine area in Germany (Sound & Veith 2001). This gives an indication of habitat use, however, since this research was done at its northern boundary of the distribution area, the results might not be representative.
In Germany it has been observed that the species is very little mobile: it lives almost its entire life in an area of 30 or at most 50 m. in diameter (Peters, in Street 1979). Average home-range for the female is 77 m^2, for the male 125 m^2. The home-range of both sexes do overlap. We assume therefore that the home-range is some 100 m^2 on average, which gives a density of 10,000 RU per 100 ha
It was found that the female lizard had a radius of 33 m within a day, the male might move up to 50 m. though. Over the year, the observed radius was some 85 m (Sound & Veith 2001).

The home range for *Lacerta viridis* may be up to 100 m, network distance up to 500 m. for Italian conditions. The maximal density is 1000 RU /100 ha
All roads are considered barriers at local population level. However, at network level only the autostrada are considered absolute barriers.
The selected habitat of the *Green lizard* consists of (Table 9):

Table 9: Relevant habitat types in the land use map for Green lizard; + = marginal habitat, ++ = intermediate habitat, +++ = optimal habitat

Habitat type	Description	Importance
Permanent grassland	2300	++
Natural grassland, alpine grassland	3210	++
Brughiere e cespuglieti	3220	+++
Sclerophyllous vegetation	3230	+++
Transitional woodland scrub	3241,3242	+
Sparsely vegetated area	3330	++
Burnt areas	3341	+

2.6.3 Wetland ecosystems

2.6.3.1 Italian crested newt (Tritone crestato italiano)

The **Italian crested newt** (*Triturus carnifex*) occurs most in the Southern Alps and Italy (Nöllert & Nöllert 1992, Günther 1996). It is mostly found in aquatic habitat (Umidi, 90%), of which respectively 18% and 15% is defined as 'lakes' and 'canals and streams' (Mazzotti *et al.* 1999). They occur in ponds, small lakes, sources, preferably with a rich submerse aquatic vegetation. Its terrestrial habitat consists of meadows and forested areas, located near their reproduction areas (Giacoma 1988a, 1988b).
The Crested newt is found in Abruzzo up to an altitude of 1800 m. (Gasc *et al.* 1997), however, it generally occurs between 400 and 1400 m, but that is also partly a result of the scarce availability of suitable habitats in lower altitudes (Biondi, pers. comm.).

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). Main threats observed in Abruzzo are aquatic predation of larvae, quick desiccation of streams, late occurrence of frost, and water use for irrigation purposes (Ferri *et al.* 2000).

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). Altitudinal boundary is 1400 m.
There are indications that fragmentation by roads forms a problem (Van der Sluis & Vos 1996, Vos & Chardon 1994). Therefore all roads are considered as barriers at local population level. However, at network level only autostrada are considered absolute barriers.

Since not all suitable streams and individual ponds can be identified on the basis of the Land use map, an additional map is used (Fiume.shp) as basis for the habitat modelling. All suitable terrestrial habitat within 1000 m. from streams is selected. The optimal density is estimated to be 400 RU/100 ha.
The selected habitat for the *Italian crested newt* consists of (Table 10):

Table 10: Relevant habitat types in the land use map for Italian crested newt; + = marginal habitat, ++ = intermediate habitat, +++ = optimal habitat, A = aquatic habitat

Habitat type	Description	Importance
Streams	Fiume	A
Mineral extraction sites	1310	++
Inland marshes	4110	++
Permanently irrigated land	2121,2122,2123	+
Fruit trees and berry plantations	2220	+
Other permanent plantation	2241,2242,2243	+
Agro forestry areas	2440	+
Broad-leaved forest	3111,3112,3113	++
Mixed forest	3130	++
River banks	3250	+++

2.6.4 Shrubland ecosystems

2.6.4.1 Stonechat (Saltimpalo)

The **Stonechat** (*Saxicola torquata*) occurs in most of Central and South-eastern Europe (Hagemeijer & Blair 1997). Its habitat consists of extensively cultivated agricultural areas with varied grass cover, and especially the shrub-like habitats in between. Open macchia with esp. Cistus species is preferred. Grassland with tall herbs and shrubs forms its prime habitat. There has been a marked decline of the Stonechat in Europe, due to agricultural intensification and a decline in cereals, which are being replaced by maize. In prime areas in the Mediterranean it achieves breeding densities of 15-25 bp/10 ha (Hagemeijer & Blair 1997).
The total population of Stonechat in Italy is estimated at some 2,500,000 birds. In Barisciano corridor some 500 pairs are estimated, in Cocullo corridor some 650 pairs. In the latter, almost all habitat types except for forested areas are utilised (Bernoni 2002).
There has been a marked decline of the Stonechat, due to agricultural intensification, but also the climate has marked effects on the population size and its distribution.

The home-range of the Stonechat is 200 m., the network distance 5000 m. Densities are estimated at some 50 RU/100 ha in optimal habitat.
The selected habitat of the *Stonechat* consists of (Table 11):

Table 11: Relevant habitat types in the land use map for Stonechat; + = marginal habitat, ++ = intermediate habitat, +++ = optimal habitat

Habitat type	Description	Importance
Natural grassland	3210	++
Brughiere e cespuglieti	3220	+++
Transitional woodland scrub	3241, 3242	+
Sparsely vegetated area	3330	+
Burnt areas	3341	+

3 Results spatial analysis Regione Abruzzo

3.1 Introduction

In this chapter general results are presented for the spatial analysis with LARCH.
Two points should be kept in mind, when interpreting these results: 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 species in that area. In reality, the situation might be much more complex as can be predicted with models.
Second, to be able to give useful advice on the quality of the proposed network, we look at more species at a time, and try to extract a ‘general’ result for the modelled species for this specific ecosystem. The species are therefore to be seen as ‘indicator’ for a number of species, a species group with similar characteristics. This result is of much more importance than the result for one single species.

In the following paragraphs resp. the population viability (see fig. 3C), the network viability (fig. 3D) and spatial cohesion (fig. 3E) are discussed. This is followed by a more detailed account for the areas identified as potential corridors Navelli and Cocullo area. The figures with results are included at the end of chapter 3.

3.2 Forest ecosystems

The selected species for forest ecosystems (Table 4: **Wolf** and **Chiffchaff**) are both versatile species, using a wide range of habitats. The **Wolf**, however, has large habitat requirements and occurs in low densities in comparison with the **Chiffchaff**. In addition, the species is much more restricted to the relatively low-populated, abandoned areas in Abruzzo Region.

The total suitable forested habitat is some 410,000 ha that might support in potential almost 30 pairs of wolves, sufficient for a key-population. The **Wolf** population forms one metapopulation because of the large home-range and network distance, which makes all habitat very well connected.
Under current conditions (only Abruzzo region) the population is nearly sustainable (fig. 9). If the surrounding regions are taken into account the population is sustainable for sure. In reality the number might be sligtly lower, since the species is territorial and lives in packs. Some areas might therefore not be occupied, in particular those areas near human settlements.

The **Chiffchaff** forms a large, viable population (fig. 10). Locally some smaller populations exist, which form not part of a network population (in particular in Lago Fucino and further north, Valle d’Aterna, near Sulmona, and coastal areas around Atessa and Teramo). The latter areas show more signs of fragmentation, which is a

result of intensive agriculture as well as urban development. For the **Chiffchaff** there is in potential one very viable network with some 150.000 pairs.
Except for the earlier mentioned areas all habitat is well connected.

The foreseen Navelli corridor is presently not well suited for the **Wolf**, due to absence of required habitat (fig. 9). Only south of Barisciano habitat is found. However, distances towards more suitable areas are not large, and for the **Wolf** therefore easy to cover. The Carrito corridor however, is suitable and in fact embedded in its natural environment.
For the **Chiffchaff** a more fragmented pattern is visible (fig. 10). In the Western part of Navelli corridor is in potential a local population. The southern part of Carrito corridor has limited habitat. Some local populations might occur though, and all form part of a viable network population.

3.3 Grassland & steppe ecosystems

The three species analysed for grassland and steppe ecosystems are **Common toad**, **Hedgehog**, and the **Green lizard:** all medium sized animals with a limited mobility.
The **Common toad** and **Hedgehog** have similar network distances, although the latter requires more habitat for a key population. All species use a wide range of habitats, and the term grassland & steppe ecosystems is therefore slightly deceiving.

The **Common toad** occurs in the entire Abruzzo territory, except for the upper parts of Majella Gran Sasso and Abruzzo National Park (fig. 11). Almost everywhere habitat is sufficient for a viable population, except for fragmented urbanised environments. In particular in the coastal plain, valleys and agricultural areas small populations or key populations are found.
This pattern is also found in the spatial cohesion maps: all areas are well connected, except for the high altitude areas and smaller, fragmented parts of the coastal plain.
The real distribution map shows a less positive picture (Bressi 1992). This migth partly be a result of the limited observations in the area, the presence is probably much wider. However, it might also be a result of the map with streams which forms the basis for the analysis. Terrestrial habitat choice is very wide for the species (Table 7) so in principle plenty of habitat is available, as long as reproduction sites are found. Here is possibly a bottleneck, and the modelling has some limitations in this respect.

The **Hedgehog** is more fragmented due to the larger area requirements for viable populations. However, the species still might occur in most of the areas, often forming MVPs in the higher parts of Abruzzo, and key populations or small populations in the coastal plain, and agricultural areas like Aterno valley and west of Lago Fucino (fig. 12). In the higher part the populations are highly sustainable, in the more fragmented areas still sustainable or nearly sustainable.
Some agricultural areas in the Coastal plain and Lago Fucino are showing little spatial cohesion. Here total available habitat is too small and fragmented.

The population analysis of the **Green lizard** shows a fragmented pattern with a large number of viable populations, but also smaller local populations (fig. 13). This result resembles actual distribution data (Ferri *et al.* 2000).
In the northern coastal areas many smaller patches occur which are too small to hold populations on their own. Overall the population is very viable, but smaller isolated pockets occur which are not viable, in particular in the coastal plain. This is due to the fragmentating effects of the dense road network and limited available habitat.

Both the identified Navelli and Carrito corridor are presently well suited for the **Common toad**, based on the presence of permanent grasslands and some cover of shrubs (fig. 11). The populations are viable. The higher ridge at Carrito corridor is not suitable though.
For the **Hedgehog** the major part of the corridors is suitable habitat. The populations are viable populations, which are now divided by roads. It is likely that in particular in Navelli area many traffic victims are found.
For both species counts that the two parks are well connected, and improved corridors are in fact not required here.

In the Western part of Navelli corridor a patchy pattern of mainly viable populations is visible for the **Green lizard**. Carrito corridor is well suited and embedded in the natural habitat. The spatial cohesion in these foreseen corridor areas is reasonable, and development of corridors would facilitate dispersal here.

3.4 Wetland ecosystems

The **Italian crested newt**, selected for marshland ecosystems, is a species which is dependent on wetlands for its reproduction. It can be considered representative for this ecosystem type.

The network of the **Italian crested newt** consists of a viable population and a number of local populations which are on their own not viable (fig. 14). However, the network as a whole is very viable. The coastal plain is fragmented, only small or key-populations are found here. In the intermediate parts of Regione Abruzzo we find mainly viable populations. Absence of species is usually a result of absence of streams, or an effect of altitude (exceeding 1400 m).
The coastal plain and valleys with intensive agriculture are not sustainable isolated areas, not part of a larger network. Most of the region is part of a larger network though.

Connectivity is for most of the area reasonable or good. The fragmentation in particular occurs in the coastal plain. Here main corridors for wetland ecosystems are of course the streams and rivers which run down from the Apennines to the Adriatic Sea.

The identified Navelli corridor is presently not suited for the **Crested newt**, probably due to absence of water, but some small populations might occur in the eastern part, which are not part of a sustainable network. Only the northern part of the Carrito corridor is suitable for the **Crested newt**. Also here only local populations are found, but also at some distance larger networks are found which might be suitable for viable populations, but the area is not well connected, and more extended corridors would be required for this species.

3.5 Shrubland ecosystems

The **Stonechat** was selected for shrubland ecosystems; however, also **Chiffchaff** and **Green lizard** will use to some extent shrubland.

The higher parts of Abruzzo are holding large viable populations of **Stonechat**, whereas the coastal areas and agricultural plains hold key populations or small populations. The total population might be some 60,000 pairs. In the coastal area many fragments are just too small to hold populations (fig. 15).
All habitat together forms one network and is very viable due to the network distance of 5 km The spatial cohesion is reasonable in the coastal plain. The medium ranges of the Appennines are all a well connected area, with no indication of fragmentation.

The foreseen Navelli corridor is presently not well suited for the **Stonechat** due to absence of required habitat. The Carrito corridor, however, is well suited, and in fact embedded in its natural environment. Both corridors lie in well connected areas, and for this species no corridor would be required in this location.

3.6 Summary LARCH-analysis

Most ecosystems seem in potential large enough to maintain potential wildlife populations in Regione Abruzzo. A summary of the results is presented below (Table 12).

Table 12: Summary of the results for the LARCH spatial analysis at regional level

Species	population assessment	network assessment	Spatial cohesion
Woodlands:			
Wolf	key population, limited	not sustainable	very well connected
Chiffchaff	MVP, key and local pop	highly sustainable	most well connected
Grasslands & steppe:			
Common toad	mainly viable pop.	sustainable	well connected
Hedgehog	MVP, key and local pop	partly sustainable	partly fragmented
Green lizard	MVP, key and local pop	highly sustainable	highly fragmented
Wetlands:			
Italian crested newt	small, mostly sustainable	sustainable	highly fragmented
Shrublands:			
Stonechat	MVP, key and local pop	highly sustainable	reasonably well connected

In the coastal plain and intensively farmed areas, e.g. the main valleys and Lago Fucino most populations are small and fragmented. Species affected are **Wolf, Chiffchaff, Hedgehog, Green lizard, Stonechat** and **Crested newt**.
The Apennines might be a classical example of a '*source and sink area*', the Appenines are the source that maintains biodiversity in its surrounding, less suitable habitat, the '*sinks*'.

The population assessment shows that the viability of in particular the amhibian species is limited, which is related to thce lack of suitable aquatic habitat (although quality of the present habitat hasn't even been taken into account) and the limited dispersal distance. Also species vulnerable for fragmentation have local limitations as a result of the locally dense road network and intensive agriculture. In particular the **Green lizard**, which has the most limited dispersal distance.

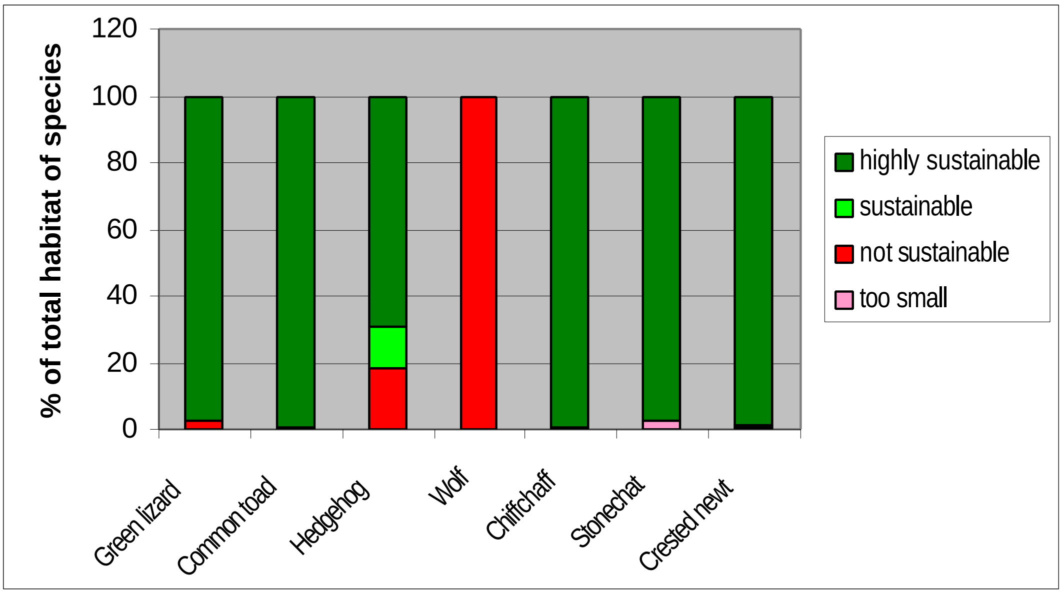

Figure 8: Network viability for the species analysed with LARCH

However, observing network viability (fig. 8) it is obvious that all species are viable on its own, except for the **Wolf**. The **Wolf** is dependent on neighbouring regions in Italy. The **Hedgehog** has local networks, presently not sustainable, due to fragmentation, but overall even for this species 80 % of the population is sustainable.

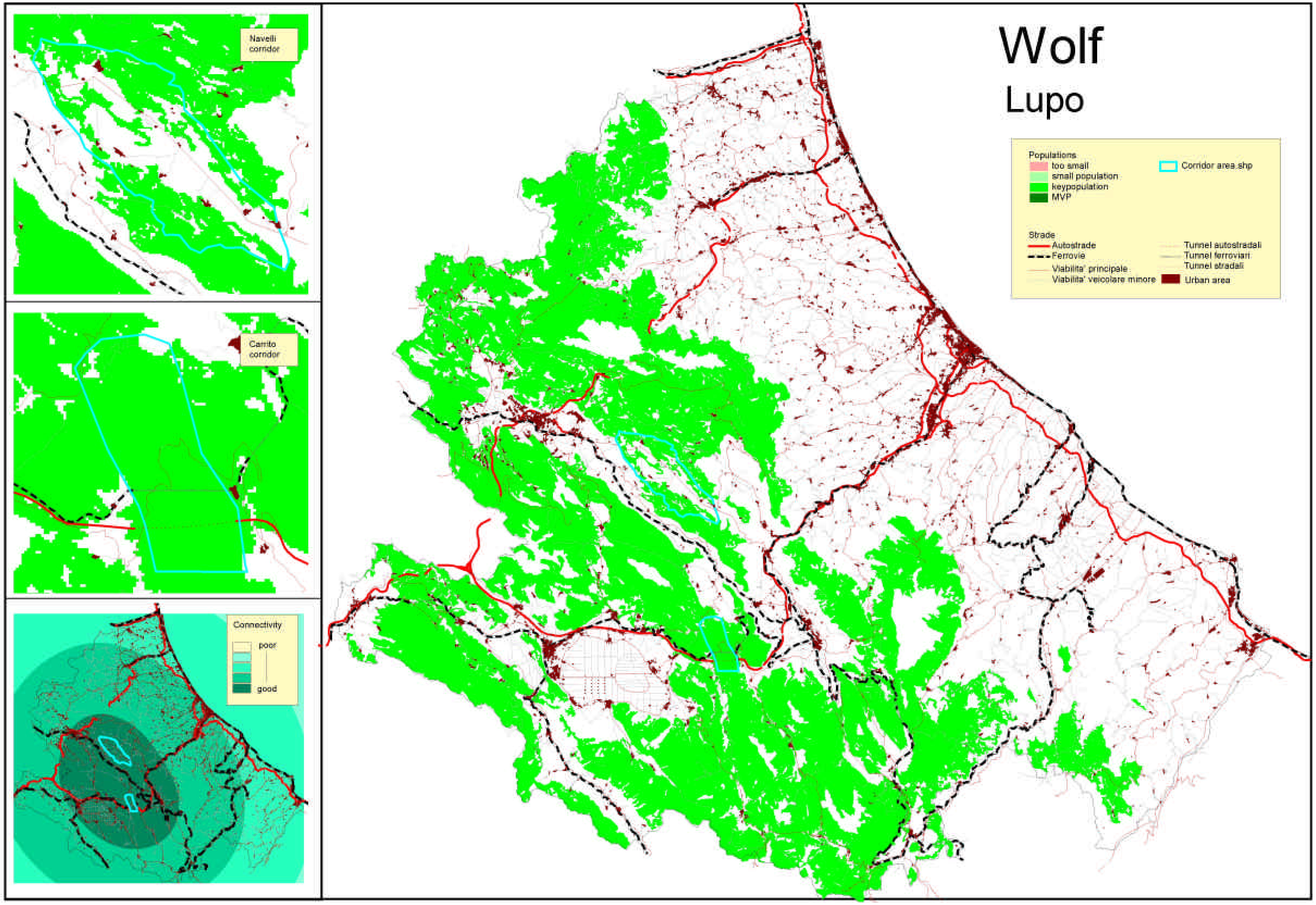

Figure 9: population assessment with LARCH of the forest species Wolf

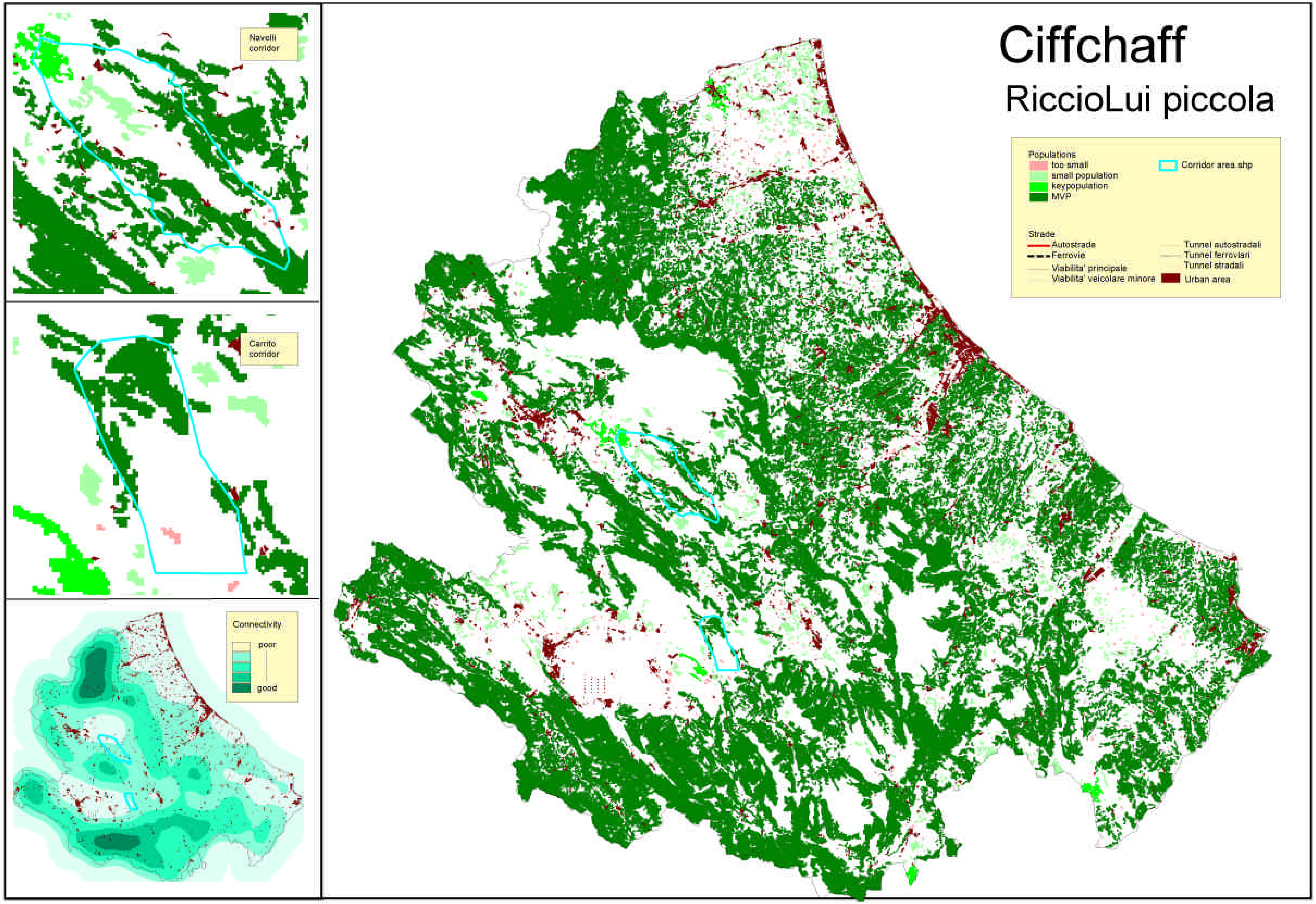

Figure 10: population assessment with LARCH of the forest species Chiffchaff

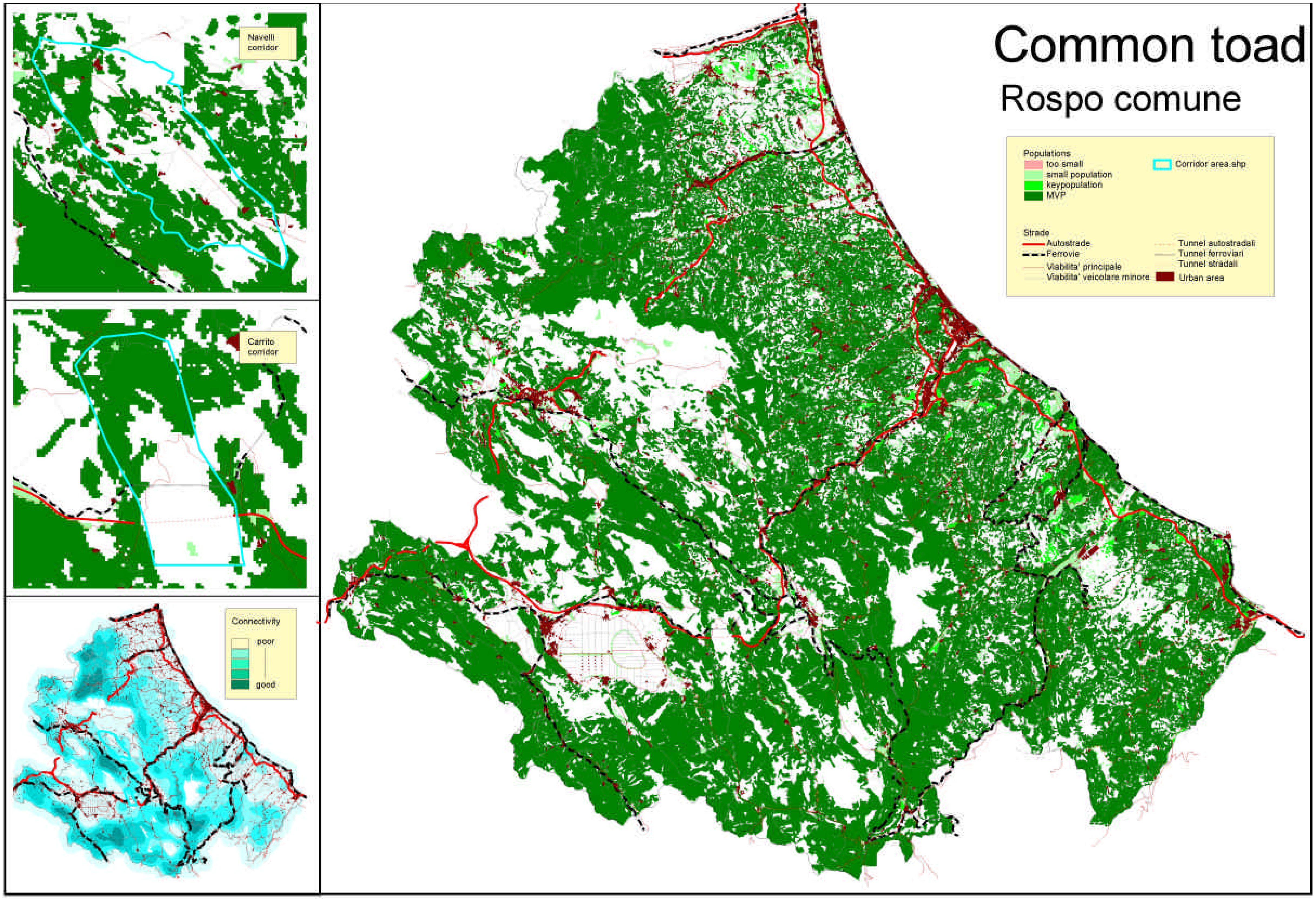

Figure 11: population assessment with LARCH of the grassland species Common toad

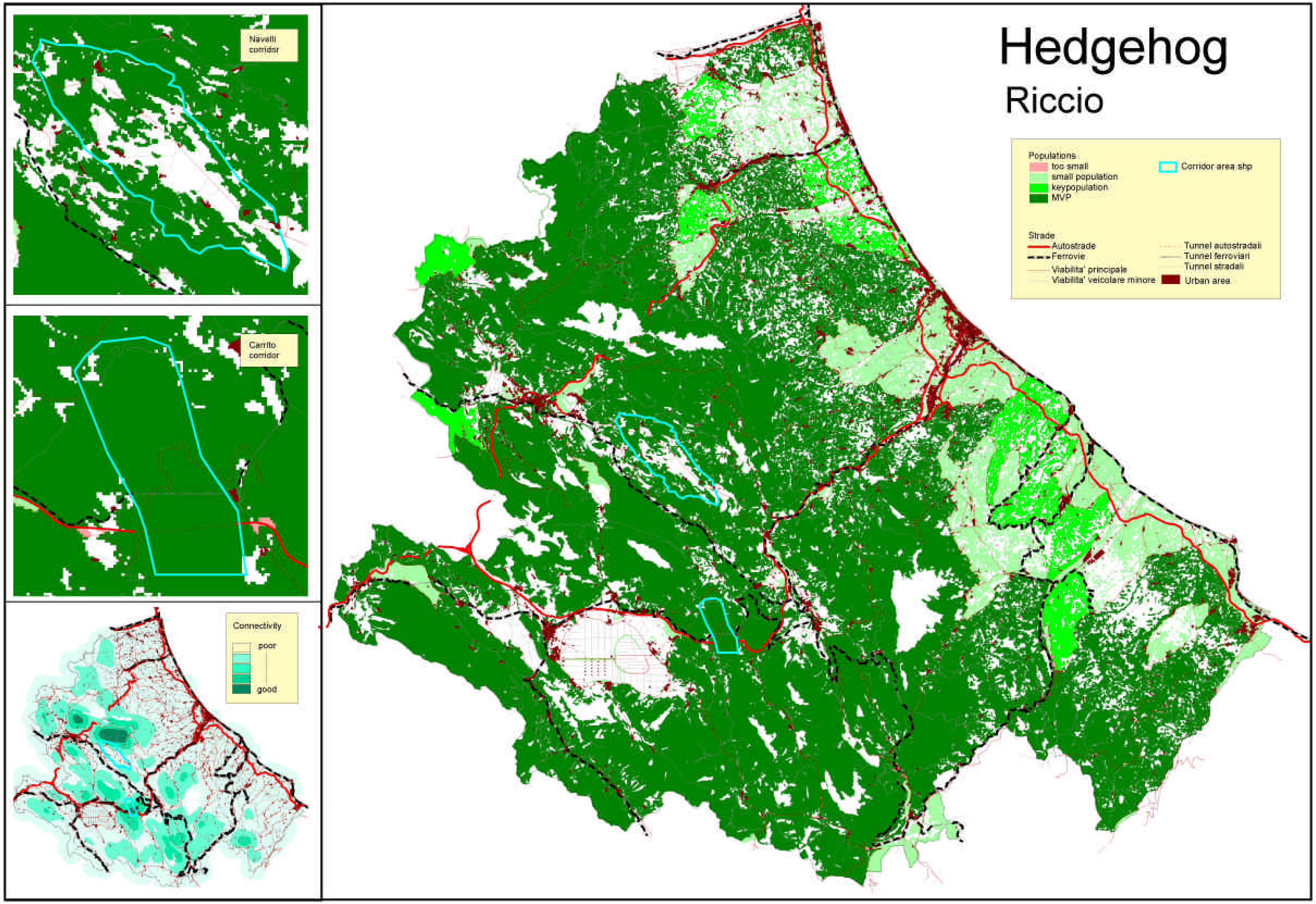

Figure 12: population assessment with LARCH of the grassland species Hedgehog

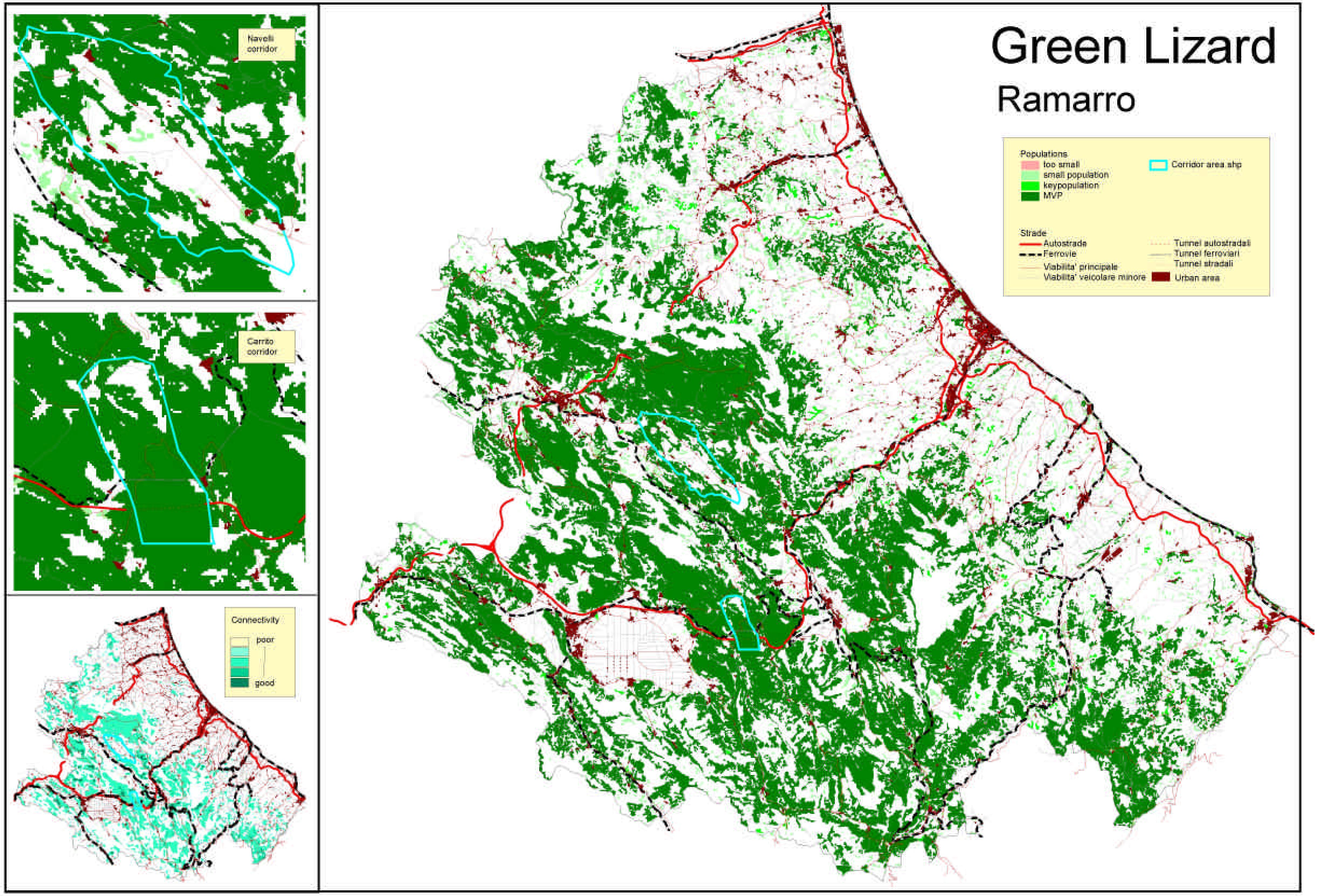

Figure 13: population assessment with LARCH of the grassland & steppe species Green lizard

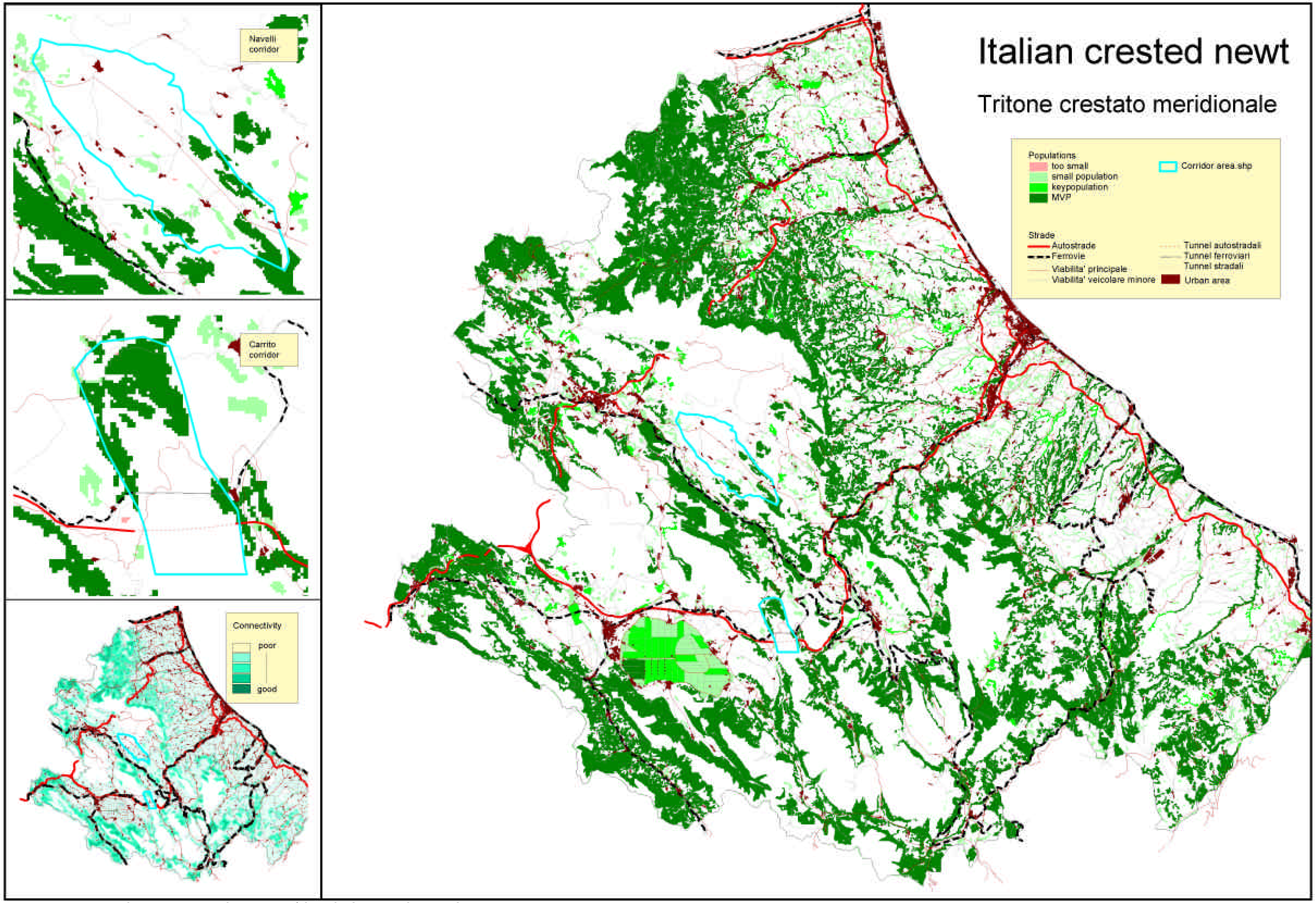

Figure 14: population assessment with LARCH of the wetland species Italian crested newt

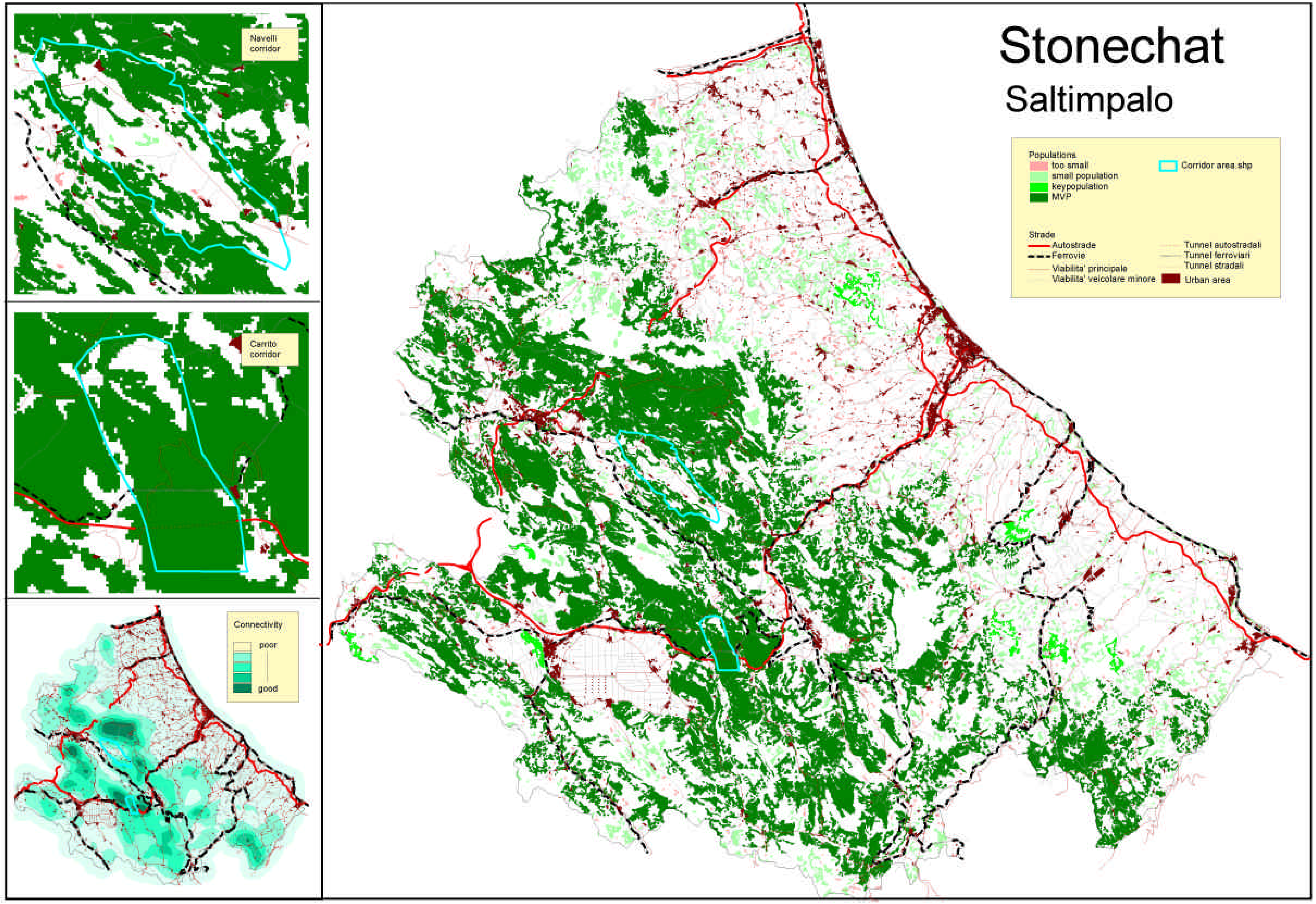

Figure 15: population assessment with LARCH of the shrubland species Stonechat

4 Results Brown bear metapopulation analysis

4.1 Habitat connectivity

4.1.1 Moderate set

For the moderate parameter set, the connectivity matrix is shown in table 13. For the regions these patches refer to, see the maps in figure 4 and 5 (11 - Gran Sasso-Monti della Laga, 17 - Sirente-Velino, 20 - Parco Nazionale D'Abruzzo & Majella). The arrival probabilities larger than 0.05 (rounded) are highlighted. Note that these results are based on simulations of 10000 movement paths. Thus a probability of 0.0001 means a single individual arrived, implying that table entries of say smaller than 0.001 are bound to be affected by chance and thus not really reliable estimates of the real arrival probabilities.
The table illustrates several general rules: 1) arrival probabilities increase with the size of the receiving patch. Relatively large patches (2, 5, 11, 17, 20 and 22) have higher arrival probabilities, 2) arrival probabilities decrease with distance between the patches, 3) the spatial configuration determines the total probability of reaching another patch after leaving the natal patch. The sum (last column) is lowest for the larger patches that have mainly small patches around them (2, 5, 11, 20). In general these sums are relatively high; for most of the largest patches the sum exceeds 0.2. The movement pattern and the length of the dispersal period (3000 steps), apparently lead to an overall high probability of reaching another patch.
Focussing on the Abruzzo/Majella patch (20) the model predicts about 25% of the dispersers to succeed in reaching another habitat patch, mainly the Abruzzo border region (22) and to a far lesser extent to Sirente-Velino (17), Gran Sasso – Monti della Laga (11) and (28).
A spatial overview is given in the figure 16. NB, note that probabilities are shown, not the expected flow of individuals from one patch to another.

Table 13: Arrival probabilities between habitat patches, moderate transition probabilities parameter set.

from\to	**2**	**3**	**4**	**5**	**6**	**10**	**11**	**17**	**19**	**20**	**22**	**28**	**sum**
2	0.0000	0.0453	0.0057	0.0016	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0539**
3	0.5555	0.0000	0.2629	0.0206	0.0052	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.8442**
4	0.0543	0.2184	0.0000	0.5955	0.0129	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.8811**
5	0.0023	0.0016	0.0615	0.0000	0.1119	0.0091	0.0286	0.0000	0.0000	0.0000	0.0000	0.0000	**0.215**
6	0.0150	0.0048	0.0169	0.6552	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	**0.6921**
10	0.0000	0.0000	0.0000	0.0580	0.0000	0.0000	0.6088	0.0000	0.0000	0.0000	0.0000	0.0000	**0.6668**
11	0.0000	0.0000	0.0000	0.0241	0.0001	0.0677	0.0000	0.1899	0.0026	0.0011	0.0000	0.0000	**0.2855**
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4041	0.0000	0.4143	0.0537	0.0428	0.0000	**0.9149**
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0324	0.6378	0.0000	0.0006	0.2666	0.0000	**0.9374**
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0118	0.0455	0.0000	0.0000	0.1595	0.0276	**0.2444**
22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0478	0.3661	0.3319	0.0000	0.0002	**0.7476**
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1509	0.0006	0.0000	**0.1515**
AREA	1250	58	80	1406	92	55	3433	778	184	1603	642	219	

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other types of printers.

Figure 16: Arrival probabilities visualized as arrows between patches, for the "moderate" parameter set. The size of the arrow-head relates to the probability of arrival

4.1.2 Extreme set

For the extreme set of transition probabilities, the matrix is shown in Table 14. Also a spatial overview of the arrival probabilities is provided (fig. 17). The general picture is the same as with the moderate parameter set; however on average probabilities are lower (individuals will be 'reluctant' to leave the better habitat). For the largest patches, the summed arrival probabilities are mostly smaller than 0.1. Focussing on the Abruzzo/Majella patch (20) the model predicts only 8% successful dispersal, about 4 times smaller than with the "moderate" parameter set. As with the moderate set, approximately half of successful dispersers end up in the Abruzzo border region (22).

Table 14: Arrival probabilities between habitat patches, extreme transition probabilities parameter set

from\to	**2**	**3**	**4**	**5**	**6**	**10**	**11**	**17**	**19**	**20**	**22**	**28**	**sum**
2	0.0000	0.0202	0.0007	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0211**
3	0.7577	0.0000	0.1424	0.0022	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.9026**
4	0.0143	0.1159	0.0000	0.7524	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.8843**
5	0.0002	0.0002	0.0373	0.0000	0.0320	0.0011	0.0070	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0778**
6	0.0016	0.0003	0.0029	0.5302	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.535**
10	0.0000	0.0000	0.0000	0.0302	0.0000	0.0000	0.3003	0.0000	0.0000	0.0000	0.0000	0.0000	**0.3305**
11	0.0000	0.0000	0.0000	0.0056	0.0000	0.0073	0.0000	0.1587	0.0005	0.0001	0.0000	0.0000	**0.1722**
17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2979	0.0000	0.3406	0.0039	0.0027	0.0000	**0.6451**
19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0059	0.7007	0.0000	0.0001	0.2603	0.0000	**0.967**
20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0014	0.0000	0.0400	0.0401	0.0013	**0.0834**
22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.4459	0.1101	0.0000	0.0000	**0.5582**
28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0133	0.0000	0.0000	**0.0133**

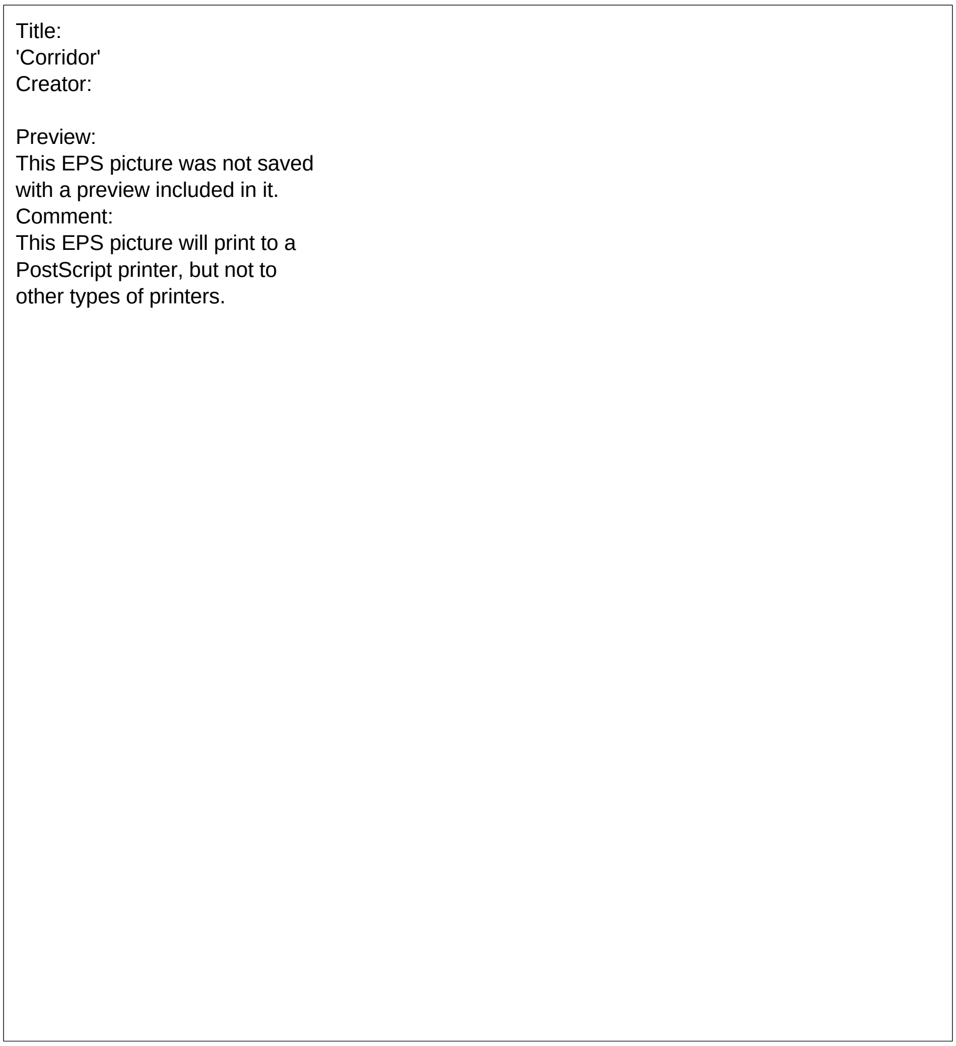

Figure 17: Arrival probabilities visualized as arrows between patches, for the"extreme" parameter set

4.1.3 Corridor effect

For the “moderate” set of transition probabilities, in combination with the corridor scenario, the difference (absolute and relative) in arrival probabilities is shown in Table 15. It shows that in terms of arrival probabilities, the impact of the corridor is negligible: there are few combinations of patches for which the relative increase exceeds say 10% and at the same time this increase exceeds 0.001 in absolute value (making a difference of more than 10 individuals out of 10000). Exceptions are a considerable decrease in 22→11 and increase in 11→19 and 20→28. Focussing on probabilities of arrival from the currently populated area (20) the corridor effect is limited to an increased probability of reaching the small 28 patch, and a slightly increased probability of reaching the Gran Sasso – Monti della Laga patch (11).
For the extreme parameter set, the results are comparable in overall effect. However, there is a notable increase in probabilities of arrival among patches 17 and 20, in both directions. Thus, the Sirente Velino area (17) appears to become better connected to the National Park d'Abruzzo, due to the corridors.

Table 15: Change in arrival probabilities for the corridor scenario, compared to the current situation. Only the habitat patches relevant to the Abruzzo region are shown

MODERATE	absolute					
	11	17	19	20	22	28
11	0	0.0069	0.001	0.0005	0	0
17	-0.0024	0	-0.0022	0.0011	0.0022	0
19	-0.0012	-0.0015	0	0.0002	0.0012	0
20	0.0008	-0.0003	0.0004	0	-0.0022	0.0054
22	-0.0015	0.0023	-0.0003	0.0066	0	0.0001
28	0	0	0	0.0014	-1E-04	0
	relative (%)					
	11	17	19	20	22	28
11	0	4	38	45	0	0
17	-1	0	-1	2	5	0
19	-4	0	0	33	0	0
20	7	-1	0	0	-1	20
22	-94	5	0	2	0	50
28	0	0	0	1	-17	0

EXTREEM	absolute					
	11	17	19	20	22	28
11	0	0.0054	-0.0003	-0.0001	0	0
17	0.0059	0	-0.0002	0.001	-0.0004	0
19	-0.0001	-0.0027	0	-0.0001	0.0067	0
20	0	0.001	0	0	-0.001	0.0001
22	0	0.0003	-0.0051	-0.0059	0	0
28	0	0	0	-0.0008	0	0
	relative (%)					
	11	17	19	20	22	28
11	0	3	-60	-100	0	0
17	2	0	0	26	-15	0
19	-2	0	0	-100	3	0
20	0	71	0	0	-2	8
22	0	14	-1	-5	0	0
28	0	0	0	-6	0	0

4.2 Metapopulation viability

The results indicate that even the isolated National Parks population is viable ("current" scenario). No extinctions occurred in the 200 replicate runs, for neither of the male settling probabilities.
For the "potential" scenario we observed the pattern of colonization emerging from the simulations. Figure 18 shows the distribution in time of the first reproduction event taking place in each patch, for a male settling probability of 0.5 (the pessimistic estimate). From the current population (patch 20), the nearby areas appear to become colonized relatively quickly, with a median time to the first reproductive event amounting to approximately 11 years for patch 22, 21 years for patch 17, 31 years for patch 19, 34 years for patch 28, and 44 years for patch 11. Median times to first reproduction event are plotted on the map, in figure 19. Clearly, there is a first wave of colonizations directly from patch 20 (into 22 and 17); the next colonization wave is driven by dispersers (mostly) originating from these newly buildup populations, while the colonization of patch 5 commences only after a population build-up in the relatively large patch 11.

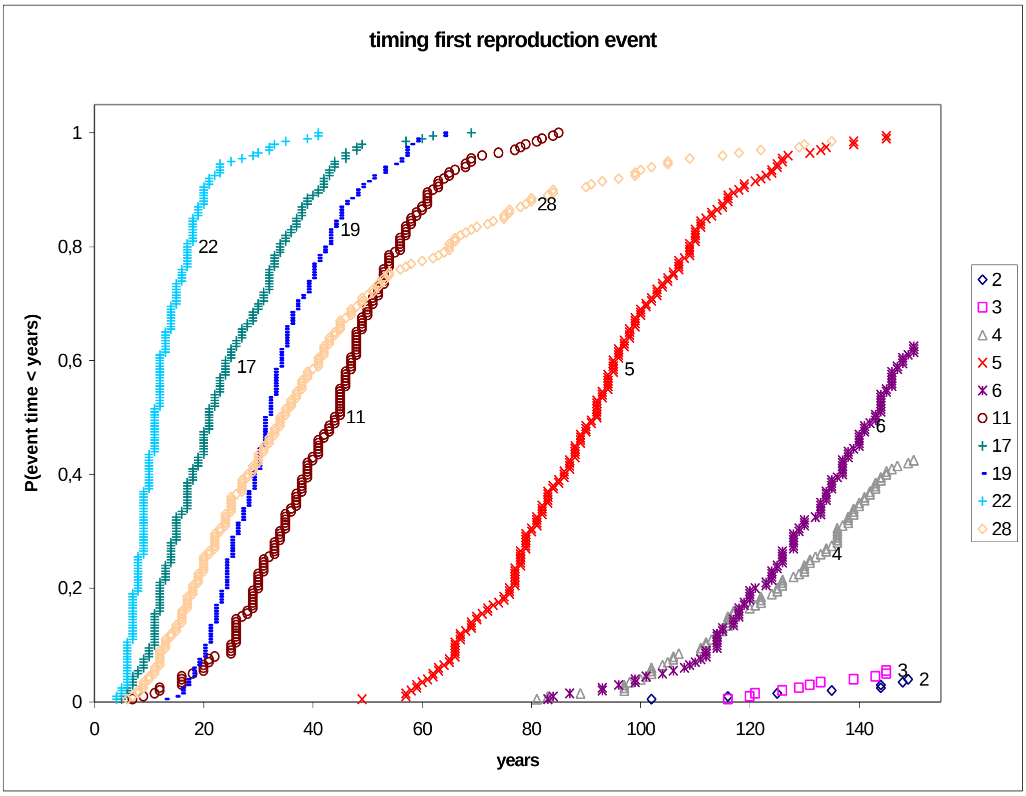

Figure 18: Curves show the distribution of the time to first reproduction event, for the different patches

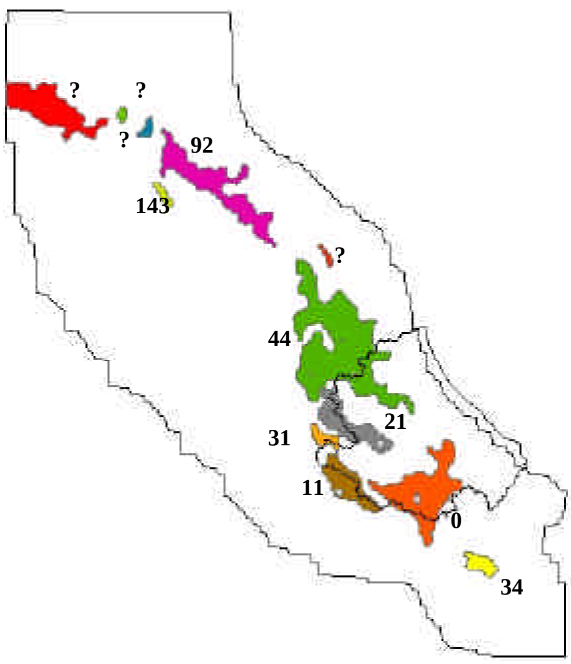

Figure 19: Spatial distribution of median times to first reproduction event. Question-marks indicate that median time is outside the simulation time window (150 years)

4.3 Analysis of corridor effectiveness

The calculated arrival probabilities for the current situation are shown in Table 16.

Table 16: Per-disperser probability of moving from the core area of one protected zone to another protected area, under the present situation

	Gran Sasso-Monti della Laga	Majella	Monte Genzana-Alto Gizio	Sirente-Velino & Gole di San Venanzio	Sorgenti del Pescara	PN d'Abruzzo & Gole del Sagittario	
from\to	3	4	5	6	7	8	all
3	0.0007	0.1827	0.0000	0.1462	0.0272	0.0000	0.3568
6	0.2902	0.1253	0.0078	0.0026	0.1596	0.2729	0.8584
8	0.0000	0.0008	0.0874	0.1960	0.0000	0.0003	0.2845

For the situation with corridors being implemented, the results are shown in Table 17.

Table 17: Per-disperser probability of moving from the core area of one protected zone to another protected area, under the corridor scenario

	Gran Sasso-Monti della Laga	Majella	Monte Genzana-Alto Gizio	Sirente-Velino & Gole di San Venanzio	Sorgenti del Pescara	PN d'Abruzzo & Gole del Sagittario	
from\to	3	4	5	6	7	8	all
3	0.0005	0.1570	0.0000	0.2050	0.0229	0.0000	0.3853
6	0.3545	0.1194	0.0056	0.0019	0.1412	0.2780	0.9006
8	0.0000	0.0013	0.0934	0.2030	0.0000	0.0007	0.2984

Comparing Table 16 and Table 17, it shows that the corridors lead to an increase in the probability of arriving at Sirente-Velino, when starting from Gran Sasso (increase from 15 to 21%) and going the opposite way (increase from 29 to 35%). Dispersal "routes" appear slightly changed, but also the total probability of reaching another protected area increases (the "all" column).

5 Discussion

5.1 General discussion method

Crucial for the results of the analysis is the base map used. In this study the land use map for the Regione Abruzzo has been used (Giunta Regione Abruzzo 1999), which proved to be quite suitable. Some limitations occur for the aquatic habitats: not all smaller waters, ponds etcetera were mapped; nor the rivers, probably linear features were partly missed.

No accurate digital vegetation maps just outside this Region were available. This might result in some underestimation since also in adjoining Regions natural areas will contribute to the network of Abruzzo. This concerns especially the **Wolf**, the species with the largest dispersal distance. Under present conditions the **Wolf** is not viable but, as explained in par. 5.2 in reality it is viable, due to the still extended habitat available in adjoining parts of the Apennines. For other species it is not considered to be a serious problem that the area assessed is limited since Abruzzo has extensive natural areas, large enough for viable populations.

5.2 Discussion of selected ecosystems

Seven species were selected as indicators for different ecosystems, to be able to assess in more detail the functioning of ecosystems and ecological networks.
Priority ecosystems, and very particular for Abruzzo, are the forests, and the Alpine meadows, grasslands and steppe of the higher Apennines. In addition, also the aquatic ecosystem is probably very important since most species are to some extent dependent on water, and many species tend to migrate along water courses.

Region Abruzzo has important **forest** areas. Woodlands are very diverse, from broadleaved and conifer forest to shrubland, parks and abandoned agricultural areas with initial stages of forests, etc. The total area of forest is app. 285000 ha (27 %), mainly broad-leaved forest (Table 1).
Most important core areas for forests are protected as nature reserves, e.g. in Majella pristine Beech forest is found, with many rare, partly endemic plant species.

The **Wolf** and **Chiffchaff** are mainly dependent on woodlands. Even for the **Wolf** and therefore also other species with large habitat requirements it is nearly a sustainable situation (based on the natural habitat and natural prey available in Abruzzo alone). To assess properly the ecological network for the **Wolf** one should take into account the larger network, in particular the Appenine range. Projects like APE and a national ecological network for Italy should take this aspect into account.
The **Chiffchaff** is viable, but some smaller parts of the coastal area as well as areas around lago Fucino are fragmented and hold only smaller populations. Here the connections with the hinterland, the Apennines should be strengthened, so that the

Apennines serve as source area, to maintain a base level of biodiversity also in this intensively used and partly densely populated area.

Grassland and steppe ecosystems consist in particular of alpine grasslands.
The **Common toad** and **Hedgehog** are using a wide range of habitat types, and are therefore not true grassland species. They need grassland, but also vegetation like hedges, with woodlogs, leaves, for feeding, protection, but also for hibernating. Therefore increasing hedges as corridors might prove to be very beneficial for these species, but also for many of the bird and insect species.
Management of the land and intensity of land use is crucial for a species like the toad.
Not much ecological information is available for the **green lizard**, some of the parameters could only be estimated. Landscape ecological data is urgently required to improve the knowledge of this species.

The **Italian crested newt** is the only selected species for **wetland ecosystems**. Also the **Common toad** utilises ponds for its reproduction, but only for a brief period in springtime and it is terrestrial for the remainder of the year.
The **Italian crested newt** is viable for the more elevated part of the region. Some smaller areas do not form part of the ecological network. The basis for the analysis has some limitations, since only part of the important aquatic habitat (ponds) is mapped. The streams are used for the analysis which are partly not suitable for reasons like water quality and velocity.
For the **Italian crested newt** water quality is very important. E.g. intensive-farming practices can be very detrimental. This might effectively reduce available habitat.
For improvement of the network one might consider creation of small aquatic habitats, restoration of filled in ponds, improvement and maintenance of wells etcetera. Also in farm plans initiatives can be taken to increase the number of ponds, since this directly affects abundance of wildlife.

It should be realised that we discuss only one species here. Additional analysis of species like Banded demoiselle, Water vole, Great reed warbler, Fan-tailed reed warbler or Reed bunting could result in more information for aquatic habitats.

For **shrubland** ecosystems the **Stonechat** is selected. It is an important indicator for extensive agricultural farming system, since it is dependent on a rich insect fauna. An increase in habitat is in particular required in the fragmented coastal plain, where at the moment only small remaining populations exist.
Increasing corridors will be beneficial for this species. Corridors from the Apennines into the coastal plain, along the rivers, might facilitate dispersal to the more fragmented areas. Here the focus should be on isolated key populations.
Management of land and intensity of land use is critical for the **Stonechat**. Environmental sensitive agricultural practices, with none or limited fertiliser and pesticides used will effectively increase available habitat. These farming practices can be related with environmental sensitive, high quality food production form Abruzzo region.

5.3 Habitat connectivity

Main factors determining the reliability of our results:

1. How reliable is the landscape map produced by Posillico (1999)? It seems currently the best available estimate as this map is based on application of a statistical model build on empirical data of bear observations. In theory it is possible that the area where empirical data were collected, is not sufficiently representative of the larger landscape the final statistical model is applied to. However, we have no indication that this might be the case.
2. Does habitat suitability (probability of occurrence) correlate with landscape permeability? It is likely there is a relationship between both, however, there is no empirical indication that it is simply linear – it is just the simplest assumption.
3. How reliable is the movement model? It is clear that islands of suitable habitat will not augment dispersal success. Is this realistic? Should we assume gap-crossing behavior? Only by a more thorough analysis of bear movement can we answer this question.

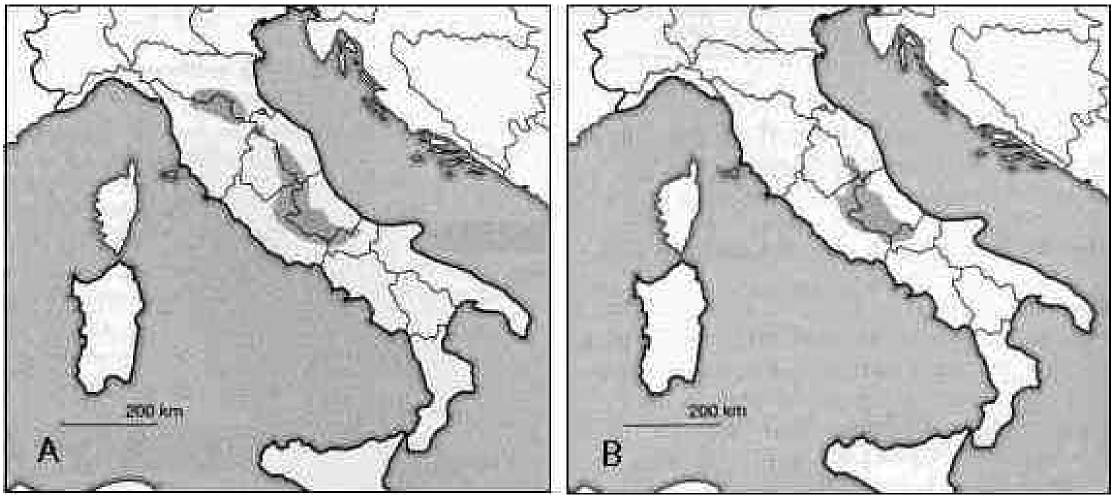

Figure 20: Distribuzione dell'orso bruno nell'Appennino. A: secoli XVIII - XIX; B: attuale (adattato da Boscagli 1999). Obtained from: http://www.corpoforestale.it/weborsolife/attivita/progettocattura.htm. The distribution depicted in the map at the right coincides well with the Posillico (1999) map

5.4 Metapopulation viability

The single population case ("current" scenario) may overestimate viability due to 1) a too optimistic assessment of the total amount of suitable habitat in the Nation Parks d'Abruzzo and Majella leading to an overestimate of the carrying capacity (80 bears) of this area. Even though we correct for the presumed habitat quality of each patch, there may be additional factors, e.g. edge effects, poaching, hiking routes, etc., that make parts of the patches unsuitable. 2) absence in the model of environmental stochasticity and catastrophes (the model takes into account demographic stochasticity in birth- and death-rates and sex-ratio).

The “potential” scenario, in which patches over the whole Appenine mountain region become gradually recolonized, may be too optimistic due to (1) its use of the movement simulation results based on the “moderate” boundary transition probabilities set. This parameter set results in considerably larger arrival probabilities than when applying the “extreme” boundary transition probabilities set. In addition, (2) the same caveats may apply to the estimate of patch carrying capacity, as to the National Park’s estimate. For instance, the carrying capacity for patch 11, of which Gran Sasso / Monti della Laga is just a small part, is estimated at 167 (see Table 21) when applying the Posillico model. It is hard to check the realism of such an estimate, as a correction based on empirical data is not possible due to the presumed absence of bear in this area. Larger than realistic carrying capacity will lead to a too large number of dispersers produced annually. Finally, (3) no dispersal mortality is accounted for: arrival probabilities obtained from the movement model are used, but individuals that do not arrive at another patch within the dispersal period are assumed to return to the last visited patch (and not to be lost).

5.5 Corridor effectiveness

The applied movement model is based on limited empirical data. The boundary transition probabilities are largely based on expert judgement. Analysis of actual movement paths from telemetric studies, is required to improve the quality of model predictions. However, such an analysis is outside the scope of the present project. Analysis of movement data would both improve the classification of the landscape with respect to its impact on bear movement, and improve the reliability of the used movement parameter values.

Due to these limitations, our estimate of arrival probabilities can not be considered an accurate prediction. More interesting is the use of the model in a comparative way, for instance evaluating the expected relative increase in connectivity due to the implementation of corridor zones, in different configurations.

The assumption underlying the “corridor” scenario is simplistic: all class 2 landuse is converted into class 3.2. In reality there are many more options of landuse changes in the context of the implementation of the corridors, and a mosaic of landuse including (extensive) agricultural use will surely remain. However, given the assumptions underlying the transition probabilities, conversion of landuse 2 into landuse 3.2 is not the most optimistic case: measures removing infrastructure and building (converting class 1 into class 3) would probably have an even larger impact, especially in the Navelli corridor.

We conclude that a thorough investigation of corridor effectiveness will require a much more detailed specification of measures to be taken and the resulting (spatially explicit) landuse changes. Such an investigation should however start with a compilation and analysis of available empirical data on Brown bear movement, to be able to produce a reliable description of movement at the appropriate spatial scale and to capture the relevant details of the impact of the landscape on movement behavior.

6 Conclusions and Recommendations

6.1 Conclusions

The study in Abruzzo should be seen as a basis to assess the ecological network. It shows prospects for developments, it presents ideas and might form a good basis for further development of the ecological network.

The habitat requirements for many species are still met. This shows that the Region has no serious fragmentation problem at the moment. Obviously, the 50% of natural habitat (par. 2.2) is sufficient for most species at present. This means that with little investments a well functioning sustainable ecological network can be realised, so now it is the time to propose an optimised ecological network. Through the development and consolidation of an optimised ecological network good opportunities are created for the long-term future development.
This network should become an integral part in the territorial planning system. An officially established ecological network will preserve biodiversity, our natural heritage, for tomorrow. The ecological network concept can go hand in hand with agricultural development, high quality food production (slow-food) and be attractive for tourism development. A proposal for such a network is prepared in par. 6.2.1.

A second challenge is that such an ecological network is extended, since a network for large carnivores requires intensive cooperation across regional boundaries. Abruzzo can be one of the leading regions in Italy for development of such a national ecological network, targetting at e.g. Lynx, Wolf, Brown bear as indicator species for sustainable ecological development. In a way the Regione is a spider in the network, with the core areas and highest part of the Apennines within its territory. Such a project should be linked with other national initiatives like the Appenino Parco d'Europa (APE) project.

In prioritising corridors to be developed or improved, the short corridors in between the national and regional parks should get priority, above the larger terrestrial corridors.

6.2 Recommendations

General recommendations:

- It is recommended to design and protect by law a consolidated ecological network and safguard this from fragmentation effects such as road construction and urbanisation

Recommendations regarding **woodland** habitat:

- Optimal protection is required for the remaining woodlands, which are core area in the ecological network
- Strict woodland species with larger habitat requirements might not reach minimum habitat standards, and will not form MVPs. For these species the areas should be linked to the larger forests. in neighbouring regions

Recommendations regarding **grassland & steppe habitat**:

- Management should be directed towards optimal conditions for the flora and insect fauna. This will benefit most of the bird populations studied in this analysis. One of the measures should be maintenance of old pastoral grazing regimes.

Recommendations regarding **wetlands**:

- For the species assessed now, the situation is reasonable; however, it would be advisable to have more particular wetland species assessed, since wetland is an important habitat for almost all wildlife species.
- It is recommended to establish stepping stones. For amphibian species (which is most limited in dispersal possibilities) it would be advisable to create ponds at distances of (at most!) 300 m apart. The ponds should be surrounded by terrestrial habitat as well (e.g. shrubs and rough growth), also to prevent pollution of the water by spray of chemicals
- For marshland bird species (e.g. critical species like the fan-tailed reed warbler or the great reed warbler) old reedland areas are required. At present these wetland areas have not been properly assessed. It is recommended that a further assessment of wetland species is done.

More specific recommendations regarding **corridors**:

- Specific 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).
- The Autostrada still forms a barrier for a number of species. Especially for barrier-sensitive species like the **Italian crested newt** and **Hedgehog**, as might be expected. It is recommended to increase the number corridors across the Autostrada, since very few corridors are present. Opportunities such as reconstruction of roads, should be utilised to realise some improvements for wildlife. Special mitigating measures might be required, like tunnels, culverts etc. to allow crossing in some strategic areas.
- It is recommended to implement the two corridors as planned at present
- The river Pescara at present does not function as a corridor, so the riverine habitats are not linked with the Apennines. Measures should be considered for this river, to improve the functioning as a corridor. Despite the fact that the rivers go through densely populated areas, examples elsewhere show that even in the limited area available improvements can be made, in the form of e.g. vegetated areas or reeds along the rivers.

6.2.1 Development of the Ecological network

Based on the spatial cohesion for the ecoprofiles used in this analysis, a lay-out for a possible ecological network has been prepared (fig 21). This lay-out is for terrestrial corridors, i.e. for the forest, shrubland and grassland ecosystems.
The lay-out should be seen as a safety measure, to guarantee also in the future sufficient spatial cohesion, and to minimise further fragmentation, since it is obvious

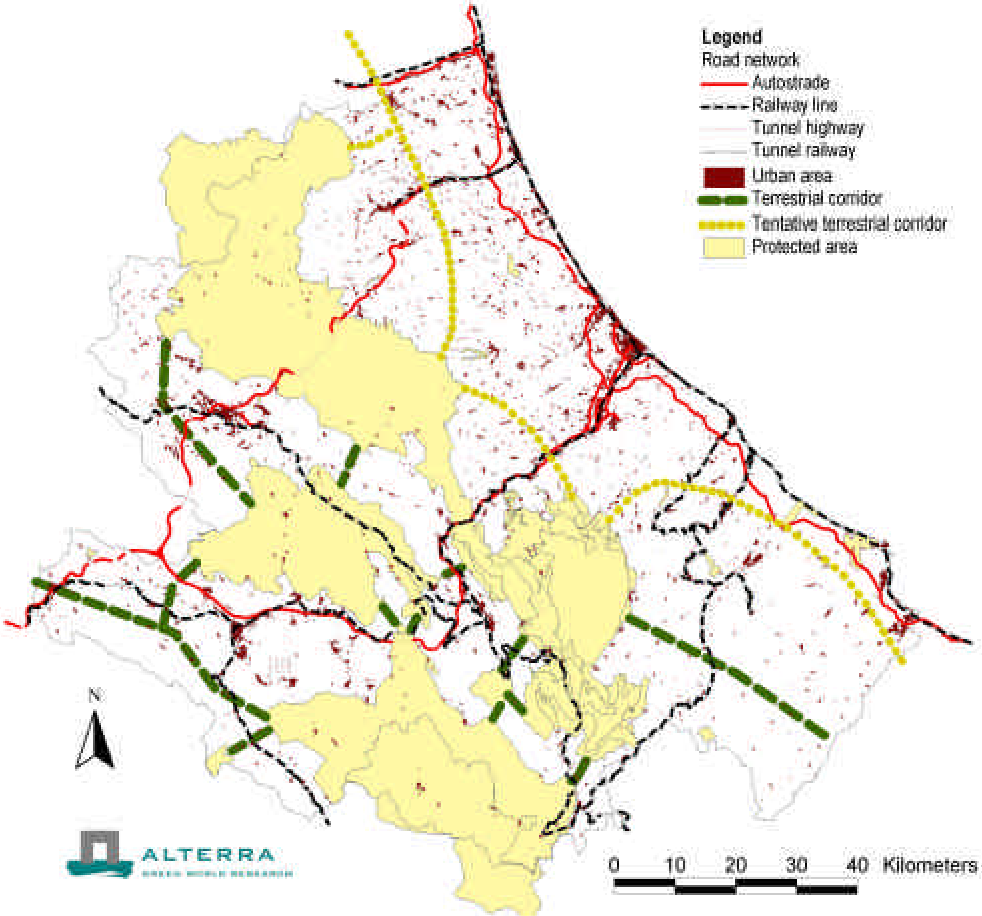

Figure 21: Proposed dryland corridors (forest with open shrubland and grassland), based on analysis of Spatial Cohesion – indicative map

from the coastal plain that this can be very limiting to wildlife populations.
This network is based on areas with the best potential for realising corridors (based on habit present already), and taking the present national parks as a basis, the 'core-areas' for the ecological network. As mentioned, the habitat is sufficient for viable networks of the considered species. However, the corridors are essential to maintain the high quality of nature as we find it in Abruzzo. The corridor areas should be protected for further development. In these identified corridors activities like roads construction should always go with mitigating, and sometimes compensating measures. The corridors should in part be improved, by planting hedges, woodrows, to guide and facilitate wildlife movements from one park to the other.

Considering the species for which corridors should be developed, one might think of wide, robust corridors of 250 m. wide, with upgoing vegetation that provides cover, shelter and reduces exposition for migrating animals (ALTERRA 2001).
In particular for the short corridors, which form connections between the national parks, one might consider 2 km wide bufferzones, in which a mosaic of different functions are combined. Besides protective vegetation, forests, also small-scalee organic farming could be allowed, including orchards, grain, etc. This will provide food for migrating species. In the event of damage farmers should be compensated.

6.3 Recommendations Corridor design and corridor functioning

6.3.1 Location of the corridors

The locations of the two corridors (par. 1.2 and 4.1) were identified on the bases of best opportunities to realise corridors, and in particular in regard of the distance that needs to be covered. It seems therefore, that ecological factors were less important in this choice.

ALTERRA made several field trips, in part also with the Regione, to inspect the designated areas.
It was realised that the Navelli corridor is currently a rather open, barren agricultural plain. The road runs mainly level with the plain, and might therefore conflict with the corridor. Only the location south-east of Navelli, where the road winds between the hills, corridors might be easier to realise. However, here it is very near to the human settlement, with all coinciding disturbance, which is disadvantageous.

The spatial analysis with LARCH shows presence of habitat in the vicinity of the corridors. It was found that the area just to the west of the current corridor, near the little hill, opposite the village of Barisciano might offer better opportunities. South of this area it is densely forested with a deep ravine and forests along the slopes, so the connection to Sirente Velino will be no problem.

Since here the road is situated at the foot of a slope, it might be possible to mitigate the road itself with construction of a tunnel.
North of the road care should be taken that the corridor stays clear from habitated areas, e.g. turning to the east. Near the village of Barisciano the slope is barren and eroded. Here cover might be required with adequate protective vegetation.

The second corridor at Cocullo/Carrito seems to be located in a good spot, with less problems of fragmentation. Still also here measures are required to provide more cover and protection for migrating animals.

6.3.2 Design of the corridors

The following guidelines apply to both corridors, at Navelli and Cocullo.

From the literature it becomes clear that the Brown Bear has specific demands regarding its corridors: a corridor should give cover and protection. Bear keeps its distance from man and human activities. The corridors that are planned should not function as a part of the natural habitat, considering the risks of accidents and disturbance. It might be better that the corridors only are used for what they are meant, for migration and movements of wildlife.

Some experts have mentioned a corridor width of 2 km (P. Tetè) which seems sensible. It might not be necessary that all the area is densely vegetated. Knauer mentions a width of 500 m. which is related to the length of the corridor of some kilometers, with dense forest and shrubs of some 500 m. width, as well as a mosaic landscape with orchards, shrubs and hedges surrounding it to give the required shelter.
In the central corridor a variety of indigenous, tall, upgoing tree species should be planted, e.g. Pinus species as well as Fagus sylvatica.

The levels of activity should be low in the entire corridor, to minimise disturbance. The management of the agricultural area should not be intensive. With orchards present there is a risk that crops are raided once in a while and farmers should be compensated in the event that that happens. Here, again, care should be taken that not too large quantities of food are present, since the presence of the road and people can make them vulnerable.

6.3.3 Defragmentation

Ecoducts were made before for bears, e.g. the Green Bridge at Dedin in Croatia. Knauer was with other researchers involved, and it was shown that use was made of these ecoducts, besides the Brown bear also Roedeer, Red deer, Wild boar and Wolf made use of the ecoduct (26 tracks of bear counted, forming 9 % of total number of crossings). Also in Banff national park (Canada) some experience was gained on corridors (Clevenger c.s.).

The road at Navelli should be covered by a tunnel, at least over a distance of some 200 m. Expert advise should be sought whether guiding measures are required to prevent bears from crossing the roads, or whether they will naturally avoid the roads.
Also monitoring of wildlife movements and utilization of the corridor is strongly advised, e.g. by the Corpo Forestale, since little practical experience is available on this aspect.

The roads plan should go hand in hand with a Public relations campaign aimed at creation of sensitivity, consideration for wildlife, and PR for the project as well. A

name might be helpful, like the 'Alligator alley' (US) or Cerviduct (deer-passage) or Ecoduct in the Netherlands: Orsoduct/Ursuduct?
The mitigation required for the road means that the roads department and users are first responsible for this project. In addition regional and possibly European funds might be used.

6.4 Recommendations for further research

It is recommended to collect data on distribution of target species and to monitor population and distribution trends, to be able to adjust regional environmental policies and launch further conservation plans.

Landscape ecological data is required to assess 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 e.g. universities should be stimulated.

On the basis of these results we conclude that the LARCH model is suitable for application at this scale, in this region. It is advised to continue with a large-scale study for the entire Apennines, since in particular the large carnivores, so important for Abruzzo, benefit from these large scale networks.
For aquatic ecosystems more relevant species could be selected, to improve the current work.

With use of the present results a design can be prepared for corridors, detailing specific site locations where corridors should be developed, as well as some corridor designs based on the specific requirements of species (Opdam *et al.* in press). This would detail more precisely the optimal solutions, in the planning context of Abruzzo, an approach which was also applied in Cheshire and Provincia di Modena & Bologna (Van Rooij *et al.* 2003a). It is recommended to pursue the development of such a plan that further details the network design.

Very little is known about the ecology of the **Green lizard**. Further research might shed light on further protection requirements for this species.

It should be assessed what the effect is of the planned windmills on wildlife populations and wildlife movements. A literature review is available (Campedelli & Florenzano); this might be followed by further research in the field.

Literature

ALTERRA, 2001.
Handboek robuuste verbindingen. ALTERRA/LNV directie Natuurbeheer. Wageningen, The Netherlands.

Akçakaya, H.R., 1998.
RAMAS GIS: linking landscape data with population viability analysis (version 3.0). Applied Biomathematics, Setauket, New York.

Andrén, H., 1994.
Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. OIKOS 71: 355-366.

Bergers, P.J.M. & W. Nieuwenhuizen 1999
Viability of hedgehog populations in Central Netherlands. Lutra 42: 65-75

Bernoni, M., 2002
L'Avifauna delle due aree di studio del progetto LIFE-Econet nella regione Abruzzo: aspetti gestionali e prospettivi di conservazione. Bracciano, Italy.

Biondi, M. & Tete, P., 2002
Aspetti faunistici. Università di L'Aquila, L'Aquila, Italy.

Bressi 1992
Progetto atlante anfibi e rettili Abruzzo

Cabela, A., H. Grillitsch & F. Tiemann. 2001
Atlas zur verbreitung und Ökologie der Amphibien und Reptilien in Österreich. Federal Environment Agency, Vienna, Austria.

Caputo V., Guarino F. M. & Mazzarella G., 1993.
Guida alla erpetofauna del Cilento (Campania). Ediz. Dell'Alento. Regione Campania, 64 pp.

Chardon, J.P., R.P.B. Foppen & N. Geilen, 2000.
LARCH-RIVER, a method to assess the functioning of rivers as ecological networks. European Water Management 3 (6): 35-43.

Corsi, F., E. Dupre & L. Boitani, 1999.
A large-scale model of Wolf distribution in Italy for conservation planning. Conservation Biology, Vol. 13 (1), pp. 150-159

Cramp, S & J. Brooks, 1992
The Birds of the Westerns Palearctic, Volume VI – Warblers. Oxford University Press Oxford, UK

Doncaster, 1994
Factors regulating local variations in abundance: field tests on hedgehogs, Erinaceus europaeus. Oikos 99: 182-192.

Fahrig, L., 2001.
How much habitat is enough? Biological Conservation 100 (200) pp. 65-74

Ferri, V., M.R. Pellegrini, & A.R Di Cerbo, 2000.
Il progetto Atlante degli Anfibi e Rettili dell'Abruzzo. In: C. Giacoma (ed.): Atti del I congresso nazionale della Societas Herpetologica Italica, Torino 1996. Museo regionale di scienze naturali, Torino 2000, p. 577-585

Foppen, R, N. Geilen & T. van der Sluis, 1999a.
Towards a coherent ecological network *for the Rhine*. IBN-research report 99/1, ISSN: 0928-6896

Foppen, R., C.J.F. ter Braak, J. Verboom & R. Reijnen, 1999b.
Dutch Sedge Warblers Arcocephalus schoenobaenus and West-African rainfall: empirical data and simulation modelling show low population resilience in fragmented marshlands. Ardea 87: 113-127.

Foppen, R.P.B., I.M. Bouwma, J.T.R. Kalkhoven, J. Dirksen & S. van Opstal, 2000.
Corridors of the Pan-European Ecological Network: concepts and examples for terrestrial and freshwater vertebrates. Alterra and ECNC. ECNC Technical Report, ECNC, Tilburg.

Forman, R.T.T., 1997.
Land mosaics: the ecology of landscapes and regions. Cambridge: Cambridge University Press. 632 p.

Giunta Regione Abruzzo, 1999.
Carta dell'Uso del Suolo, Scala 1:25.000. Giunta Regionale Regione Abruzzo. Digital map, topographical map in 47 sheets, Note Illustrative. ATI, Firenze, Italy.

Gasc J. P., A. Cabela & Crnobrnja-Isailovic J. (Eds.), 1997.
Atlas of Amphibians and Reptiles in Europe. Societas Europaea Herpetologica & Muséum National d'Histoire Naturelle, Paris, 496 pp.

Giacoma C., 1988a.
The ecology and distribution of newts in Italy. Annuar. Ist. Mus. Zool. Univ. Napoli, 26: 49-84

Giacoma C., Picariello O., Puntillo D., Rossi F. & Tripepi S., 1988b.
The distribution and habitats of the newt (Triturus, Amphibia) in Calabria (Southern Italy). Monitore zool. ital.(N.S.) 22: 449-464.

Glenz, C., A. Massolo, D. Kuonen & Schlaepfer, 2001.
A wolf suitability prediction study in Valais (Switzerland). Landscape & Urban Planning 55, p. 55-65.

Groot Bruinderink, G.W.T.A., T. van der Sluis, D.R. Lammertsma & P. Opdam, 2003.
Designing a coherent ecological network for large mammals in Northwest Europe. Conservation Biology 17 (2): 549-557

Günther, R. 1996.
Die amphibien Deutschlands. Fischer Verlag, Jena, Germany.

Haddad, N.M. 1999a.
Corridor and distance effects on interpatch movements: a landscape experiment with butterflies. Ecological Applications 9(2): 612-622.

Haddad, N.M. 1999b.
Corridor use predicted from behaviors at habitat boundaries. American Naturalist 153(2): 215-227.

Hagemeijer, W.J.M., M.J. Blair, C. van Turnhout, J. Bekhuis, R. Bijlsma, 1997.
EBCC atlas of European breeding birds : their distribution and abundance. Poyser publishers, London, UK.

Hanski, I. & M.E. Gilpin, ed., 1997.
Metapopulation biology: ecology, genetics, and evolution. Academic Press, London, UK.

Huijser, M.P. 1999.
Human impact on populations of Hedgehogs Erinaceus europaeus through traffic and changes in the landscape: A review. Lutra, vol. 42 pp. 39-56,

Joger U., Amann T. & M. Veith (2001)
Phylogeographische und genetische Differenzierung im Lacerta viridis / bilineata Komplex. – In: Elbing K. & H. K. Nettmann (Hrsg.) „Beiträge zur Naturgeschichte und zum Schutz der Smaragdeidechsen (Lacerta s. str.)“, Mertensiella 13: 60-68.

Knauer, F. 2000.
Ausbreitungsmuster von Braunbären in den Ostalpen. Dissertation Technische Universität München.

Langton, T., C. Beckett, J. Foster, 2001
Great crested newt conservation Handbook. Froglife, Mansion House, Suffolk UK.

Levins, R., 1970.
Extinction. In: Gerstenhaber, M. (Ed.) Some mathematical problems in biology. American mathematical society, Providence, pp. 77-107.

Mazzotti, S., G. Caramori & C. Barbieri, 1999.
Atlante degli Anfibi e dei rettili dell'Emilia-Romagna (Aggiornamento 1993-1997). Atlas of amphibians and reptiles in Emilia-Romagna region (Southern Po river basin - North Italy).

Nöllert, A. & C. Nöllert, 1992.
Die Amphibien Europas: Bestimmung,- Gefärdung – Schutz. Franck-Kosmos, Stuttgart, Germany.

Opdam, P., R. Foppen & C. Vos, 2002.
Bridging the gap between ecology and spatial planning in landscape ecology. Landscape Ecology 6:767-779

Opdam, P., E. Steingröver, D. Prins & S.A.M. Van Rooij (in press)
Ontwerpen van ecologische netwerken in de ruimtelijke planvorming – een wegwijzer voor ecologen. Alterra report, in press. Wageningen

Posillico, M. 1999.
Definizione dell’area di conservazione dell’orso bruno (Ursus arctos, L. 1758). Elaborazione di un modello di idoneità ambientale. Progetto LIFE Natura, Conservazione dell’orso bruno nell’Appennino centrale. LIFE99NAT/IT/006244.

Pouwels, R, R. Jochem, M.J.S.M. Reijnen, S.R. Hensen & J.G. van der Greft, 2002.
LARCH voor ruimtelijk ecologische beoordeling van landschappen. ALTERRA-report 492, ISSN 1566-7197, Wageningen, the Netherlands.

Romano, B., 2000.
Continuita ambientale. Pianificare per il riassetto ecologico del territorio. Environmental continuity. Planning for the ecological re-organisation of territory. Universita d’ Aquila. Andromeda editrice, Colledara, Italy.

Romano, B. & G. Tamburini, 2002.

Pianificare L'assetto ambientale. Contributi delle scienze del territiorio per la rete ecological regionale dell'Abruzzo. Università d' Aquila, Andromeda editrice, Colledara, Italy.
Shaffer, G.B., 1981.
Minimum population size for species conservation. Bioscience 31: 131-133
Schmid, H., R. Luder, B. Naef-Daenzer, R. Graf & N. Zbinden, 1998.
Schweizer Brutvogelatlas. Verbreitung der Brutvögel in der Schweiz und im Fürstentum Lichtenstein 1993 – 1996. Schweizerische Vogelwarte. Sempach, CH.
Smit, C. J., and A. Van Wijngaarden, 1981.
Threatened mammals in Europe. Akademische Verlagsgesellschaft, Wiesbaden, 259 pp.
Sound, P. & Veith, M., 2001
Radiotelemetrische Untersuchungen zu Raumbedarf, Habitatwahl und Innerhabitatbewegungen der Westlichen Smaragdeidechse (Lacerta bilineata DAUDIN 1802) im Mittelrheintal, mit Vergleichen zwischen Männchen und Weibchen. - In: Elbing, K., Nettmann, H.-K. (Hrsg.), Beiträge zur Naturgeschichte und zum Schutz der Smaragdeidechsen (*Lacerta* s. str.)., Mertensiella 13:195-203.
Street, D., 1979
The reptiles of Northern and Central Europe. Batsford Ltd. London, UK.
Tischendorf, L. & Wissel, C. 1997.
Corridors as conduits for small animals: attainable distances depending on movement pattern, boundary reaction and corridor width. Oikos 79: 603-611.
Tischendorf, L., Irmler, U. & R. Hingst, 1998.
A simulation experiment on the potential of hedgerows as movement corridors for forest carabids. Ecological Modeling 106: 107-118.
Van der Sluis, T. & C.C. Vos, 1996.
Amfibieën en verkeerswegen. Een patroonanalyse in Gelderland en Noord-Brabant. (Amphibians and Roads; a pattern analysis). Directoraat-Generaal Rijkswaterstaat, DWW, IBN-DLO. Rep. nr. W-DWW-96.115. pp. 41.
Van der Sluis, T., & J.P. Chardon, 2001
How to define European ecological networks. Proceedings Ecosystems and Sustainable Development ECOSUD III, Alicante, Spain. Ed. Y. Villacampa, C.A. Brebbia, J-L. Usó, pp. 119-128, Wessex Institute of Technology, Southampton, UK.
Van der Sluis, T. van der, B. Pedroli & H. Kuipers, 2001a
Corridors for LIFE. Ecological Network Analysis Regione Emilia-Romagna - the plains of Provincia di Modena & Bologna. ALTERRA report 365, Wageningen, the Netherlands.
Van der Sluis, T., S.A.M. van Rooij & N. Geilen, 2001b
Meuse-Econet. Ecological networks in flood protection scenarios: a case study for the river Meuse. INTERMEUSE report no. 4, Irma/Sponge. RIZA/ALTERRA, Wageningen, the Netherlands
Van der Sluis, T., H. Kuipers, J. Dirksen & R.G.H. Bunce, 2003.
Networks for life; Ecological network analysis for Cheshire County (UK). Internal report Alterra Green World Research. Wageningen.
Van Opstal, A.J.F.M. 1999.

The architecture of the pan European ecological network. National Reference Centre for Nature Management, Wageningen. 100 p.

Van Rooij, S.A.M., T. van der Sluis & E.G. Steingröver, 2003a.
Networks for life. Development of an ecological network for Persiceto (Emilia-Romagna, Italy). Alterra report nr. 729. Alterra, Green World Research. Wageningen.

Van Rooij, S.A.M., E.G. Steingröver & P.F.M. Opdam, 2003b.
Networks for life. Scenario development of an ecological network in Cheshire County. Internal report. Alterra Green World Research. Wageningen.

Verboom, J., J.A.J. Metz & E. Meelis, 1993.
Metapopulation models for impact assesment of fragmentation. pp. 172-191, in: C.C. and P.F.M. Opdam, editors. Lanscape ecology of a stressed environment. IALE studies in Landscape Ecology 1. London: Chapman and Hall.

Verboom**,** J., R. Foppen, P. Chardon, P. Opdam & P. Luttikhuizen**,** 2001.
Introducing the key patch approach for ecological networks with persistent populations: an example for marshland birds. Biological conservation 100 (1), pp. 89-101

Vermeulen, H. J. W. 1995.
Road-side verges: habitat and corridor for carbid beetles of poor sandy and open areas. PhD dissertation, Wageningen, The Netherlands.

Vos, C. C., Baveco, H., & Grashof-Bokdam, C. J., 2002
Corridors and species dispersal. In: Concepts and application of landscape ecology in biological conservation, ed. Gutzwiller, K. J., Springer Verlag, New York, p. 84-104.

Vos, C.C. & J.P. Chardon, 1994.
Herpetofauna en verkeerswegen; een literatuurstudie. Project versnippering 24. Min. van Verkeer & Waterstaat, DWW, Delft.

Vos, C.C., J. Verboom, P.F.M. Opdam & C.J.F. Ter Braak, 2001.
Towards ecologically scaled landscape indices. The American Naturalist 183 (1), pp. 24-41.

Vos, C. C. 1999.
A frog's-eye view of the landscape. PhD thesis, Wageningen University. Also published as IBN Scientific Contributions 18, 144pp., DLO Institute for Forestry and Nature Research, Wageningen.

Wiegand, T., K.A. Moloney, J. Naves & F. Knauer 1999.
Finding the missing link between landscape structure and population dynamics: a spatially explicit perspective. American Naturalist 154 (6): 605-627.

Wiegand, T., Knauer, F., Kaczensky, P., and Naves, J. in press.
Expansion of brown bears (Ursus arctos) into the Eastern Alps: a spatially explicit population model. Biodiversity and Conservation 00: 000-000.

Wiegand, T., Revilla, E., Knauer, F. in press.
Dealing with uncertainty in spatially explicit population models. Biodiversity and Conservation 00: 000-000.

Zimen, E. & L. Boitani 1979
Status of the wolf in Europe and the possibilities of conservation and reintroduction. In: Klinghammer, E. (Ed.), 1979. The behavior and ecology of wolves. Proceedings of the symposium on the behaviour and ecology of wolves held on 23-24 May 1975 at the annual meeting of the Animal Behaviour Society in Wilmington, N.C. Garland. STPM Press, New York & London.

Appendix 1 SmallSteps Model description

Short description

SmallSteps is a movement simulation model, in which movement is represented by a correlated random walk, or variants thereof. Movement may occur through a heterogeneous landscape, of arbitrary complexity, consisting of (many) different landscape elements. Movement may be influenced either by the linear elements in the landscape, or the surface-shaped elements, or by both. The landscape itself is represented by data in a vector format, although grid-based data can be incorporated. Comparable approaches to the simulation of movement are applied by Tischendorf and Wissel (1997), Tischendorf *et al.* (1998), Vermeulen (1995), Haddad (1999a,b), and in the Polywalk model. An early description of the model and its use is given in Vos (1999); a more elaborate description will become available at http:\\www.movement.alterra.nl.
The main parameters of the model are the parameters of the walking pattern, i.e. the distribution of the movement step size (velocity), and the parameters defining the behavior at boundaries between elements of different types, referred to as boundary *transition probabilities*. For each type of landscape element movement parameters have to be defined; between each possible pair of types, transition probabilities are required.
Output statistics are in terms of parameters of population spread or in terms of arrival probabilities. The first may be useful in answering questions related to the conductivity of the landscape (e.g., how the presence of corridors affects the conductivity); the second estimates are useful in a metapopulation context, where the probability of colonization of isolated habitat patches is a critical parameter.
The landscape is obtained from standard Arc\Info coverages, and can be of arbitrary scale and complexity. SmallSteps has been applied for many species, including Tree frog and other amphibians, Root vole, Reed warblers, Lynx, Pine marten, at many different spatial scales. The framework has been extended to include migration and foraging movements.

Parameters used

Random walk parameters

From Knauer (2001) we obtained an estimate of the movement parameters. At the landscape scale underlying his study, Knauer found that the pattern fitting best on the observed movement paths was a plain random walk. The average covered distance (per day), was 2500 meters. The best representation of the distribution of daily distance covered (movement step size) was found to be a lognormal distribution. However, for our landscape, the combination of a one-day step duration and 2500 m average movement step size resulted in far too large steps relative to the 'grain' of the landscape (inside a single step many boundaries were hit). Also the lognormal distribution was problematic, as it generated frequently very large steps, e.g. 25 km.
For the habitat connectivity simulations, we scaled down the movement to steps of one-hour duration by applying the formula (for a random walk):

$$H \cdot 12^{0.5} = D \cdot 1^{0.5}$$

where H refers to the mean hourly covered distance, D to the mean daily covered distance (when there are 12 hours of dispersal activity per day). The hourly mean covered distance thus amounts to:

$$H = D \cdot \left(\tfrac{1}{12}\right)^{0.5} = 2500 \cdot 0.289 = 722$$

In the simulations we used this mean step-size of 722 m per hour, assuming a negative exponential distribution.
For the corridor effectiveness simulations the movement was further scaled down, applying the same conversion, to a time-step of 5 minutes, producing a mean movement step-size of 208 m (= 2500*v(1/144)).

Boundary transition probabilities for habitat connectivity simulations

A. The "moderate" matrix of probabilities

Table 18: Transition probabilities between habitat of different quality ("moderate" set).

From/To	HQ1	HQ2	HQ3	HQ4	HQ5	HQ6	HQ7	HQ8	HQ9	HQ10
HQ1	1	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
HQ2	0.45	1	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
HQ3	0.4	0.45	1	0.55	0.6	0.65	0.7	0.75	0.8	0.85
HQ4	0.35	0.4	0.45	1	0.55	0.6	0.65	0.7	0.75	0.8
HQ5	0.3	0.35	0.4	0.45	1	0.55	0.6	0.65	0.7	0.75
HQ6	0.25	0.3	0.35	0.4	0.45	1	0.55	0.6	0.65	0.7
HQ7	0.2	0.25	0.3	0.35	0.4	0.45	1	0.55	0.6	0.65
HQ8	0.15	0.2	0.25	0.3	0.35	0.4	0.45	1	0.55	0.6
HQ9	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	1	0.55
HQ10	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	1

When quality is equal on both sides of a boundary, the probability to cross the boundary is 1 (transparent boundaries). We calculate the other values using the following expression:

$$P_{ij} = 0.5 - \left(\frac{i-j}{2n}\right)$$

where i is row number; j is column number; n is the number of classes.

B. The "extreme" matrix of probabilities

Table 19: Transition probabilities between habitat of different quality ("extreme" set).

Fr/To	HQ1	HQ2	HQ3	HQ4	HQ5	HQ6	HQ7	HQ8	HQ9	HQ10
HQ1	1	0.666667	0.8	0.888889	0.941176	0.969697	0.984615	0.992248	0.996109	0.998051
HQ2	0.333333	1	0.666667	0.8	0.888889	0.941176	0.969697	0.984615	0.992248	0.996109
HQ3	0.2	0.333333	1	0.666667	0.8	0.888889	0.941176	0.969697	0.984615	0.992248
HQ4	0.111111	0.2	0.333333	1	0.666667	0.8	0.888889	0.941176	0.969697	0.984615
HQ5	0.058824	0.111111	0.2	0.333333	1	0.666667	0.8	0.888889	0.941176	0.969697
HQ6	0.030303	0.058824	0.111111	0.2	0.333333	1	0.666667	0.8	0.888889	0.941176
HQ7	0.015385	0.030303	0.058824	0.111111	0.2	0.333333	1	0.666667	0.8	0.888889
HQ8	0.007752	0.015385	0.030303	0.058824	0.111111	0.2	0.333333	1	0.666667	0.8
HQ9	0.003891	0.007752	0.015385	0.030303	0.058824	0.111111	0.2	0.333333	1	0.666667
HQ10	0.001949	0.003891	0.007752	0.015385	0.030303	0.058824	0.111111	0.2	0.333333	1

Values are set by applying the following expression:

$$P_{ij} = \left(2^{i-j} + 1\right)^{-1}$$

where i is row number; j is column number; n is the number of classes.

Both matrices express the concept that an individual will prefer to go from a lower-quality site to a higher-quality location. The first matrix lets the probabilities increase linearly with the difference in quality. The second matrix defines the steepest increase in probability to occur around the quality difference of zero (see figure A1).

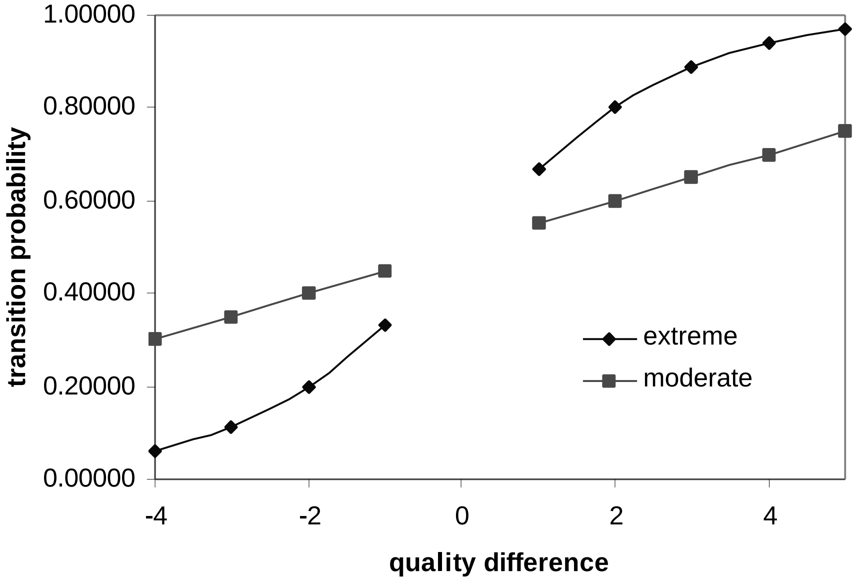

Figure 22: All possible probabilities of crossing a boundary between (and from) a habitat location with quality 5 to neighboring locations with higher or lower quality, for both parameter sets.

Boundary transition probabilities for corridor effectiveness simulations

The boundary transition probabilities are assumed to reflect preferences for (or avoidance of) parts of the landscape, and to be predominantly related to human presence in or intensity of exploitation of the landscape. For the (semi)natural areas the openness of the landscape is assumed to be an additional factor determining preference. The resulting transition probabilities for the different CORINE land-use classes are shown in table A3.

Table 20: Boundary transition probabilities at boundaries between areas belonging to different CORINE landuse classes

from\to	CORINE1	CORINE2	CORINE31	CORINE32	CORINE33
CORINE1	1	1	1	1	1
CORINE2	0.4	1	1	1	1
CORINE31	0.05	0.1	1	0.8	0.6
CORINE32	0.05	0.1	1	1	0.8
CORINE33	0.05	0.1	1	0.8	1

Simulation setup

In the habitat connectivity simulations we ‘released’ from each patch a large number (10000) of individuals. For each starting patch we used 100 different starting coordinates randomly distributed within the patch. A complete connectivity matrix (12 patches) is thus based on 120000 simulated movement paths. Each simulation run (3000 steps) represents a period of 250 or 300 days, depending on whether we assume 12 or10 movement steps made per day.

In the corridor effectiveness simulations we released 10000 individuals at 4 locations within the protected areas of the Abruzzo region. Each time-step represents five minutes; simulation duration amounted to 3000*12=36000 time-steps (one dispersal period).

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Figure 23: A sample of movement paths, generated in the habitat connectivity simulations.

Appendix 2 METAPHOR Model description

Short description

METAPHOR is a framework for developing spatially explicit models of metapopulation dynamics. The resulting metapopulation models take into account the position and size (and to some extent the shape) of local habitat patches. Geographic information is obtained from GIS, and processed to render a representation of habitat as 'islands in an empty landscape matrix'. METAPHOR is very similar to other spatially explicit models applied in population viability analyses (PVA), including RAMAS (Akçakaya 1998); however, METAPHOR models are usually more species-specific (tailor-made).
The dynamics of the metapopulation are modeled as a cyclic sequence of events: periods of within-patch dynamics alternate with periods of between-patch dispersal. The sequence of events is tailored to the life history of the species concerned; for some species we may find more than one reproductive period within a year. Within-patch population dynamics are the result of stochastic birth and death processes. Local populations are age-structured and consist of both males and females: birth and death rates are age- and sex-specific. Density-dependence may affect vital rates on the local population level; it is a function of local patch carrying capacity. Besides demographic stochasticity (probabilistic birth and death), environmental stochasticity leads to fluctuations in birth and death rates, simultaneously in all local populations. Environmental variability with a low frequency but high impact, catastrophes, can also be incorporated. Exchange of individuals between local populations is divided in several subprocesses: emigration, affected by local population density and by local patch size, the dispersal itself (selection of and transition to a target patch), affected by the distance between patches, and immigration, affected by target patch local density. Examples of the use of METAPHOR for another species group can be found in Foppen *et al.* (1999b).

Landscape

In the simulations the identification of habitat patches is based on a habitat suitability model (Posillico, 1999), applying the criterion of probability of occurrence higher than 0.7 for core habitat. Carrying capacity for each patch is calculated by comparing the area-weighted average quality of a patch to the average quality of the NP d'Abruzzo/Majella patch. For the latter we assume a maximum density of 0.05 individuals per km^2. Thus, carrying capacity C_i amounts to:

$$C_i = \frac{H_i}{H_{20}} \cdot 0.05 \cdot A_i$$

where H_{20} refers to the average habitat quality of patch 20 (Abruzzo/Majella), H_i to the average quality of patch i and A_i to the total area (km^2) of patch i. Patches below the minimum size of a Brown bear home-range (5000 ha) are discarded. The resulting patches, their size and estimated carrying capacity are shown in table B1. Carrying capacity refers to the total number of female and male territories in the patch.

Model parameters

In table B2 an overview is given of the parameters used in the METAPHOR model, as applied to the Brown bear.

Table 21: Potential Brown bear habitat patches in the Appenine mountain region, with their size and estimated carrying capacity

CLUSTER_ID	CLUS_AREA km^2	CC/KMQ	CC(INDIVIDUALS)
2	1250	0,0495	62
3	58	0,0446	3
4	80	0,0441	4
5	1406	0,0463	65
6	92	0,0453	4
10	55	0,0446	2
11	3433	0,0487	167
17	778	0,0488	38
19	184	0,0447	8
20	1603	0,0500	80
22	642	0,0497	32
28	219	0,0477	10

Table 22: METAPHOR demographic parameters

parameter	value	dimension	explanation
survival	0.65 (1), 0.82 (2 –5), 0.87 (6-17), 0.74 (=18)	yr^{-1}	Annual survival rate for the different age-classes (between brackets)
juvenile	1	yr	Duration Juvenile stage
subadult	2	yr	Duration Subadult stage
Dispersal probability	1	ind^{-1}	Probability of dispersing of not-yet-settled (sub)adult
Settling probability	1 (female) 0.75 (male)	ind^{-1}	Probability of settling in encountered, available habitat (dispersing individuals only)
Reproduction probability	0.6	ind^{-1}	Probability of producing a litter (adult female only)
Litter size probability	2 cubs: 0.44 3 cubs: 0.56		Probability of producing a litter of size 2 or 3

Simulation setup

For each scenario 200 replicate runs are performed. Each run starts with 40 individuals in patch 20 (Abruzzo/Majella); duration each run amounts to 150 years.

Appendix 3 Gross list of indicator species

Italian name	English name	Scientific name
Orso bruno	*Brown bear*	*Ursus arctos*
Lupo	*Wolf*	*Lupus canis*
Capriolo	*Roedeer*	*Capreolo capreolo*
Cervo	*Red deer*	*Cervus elaphus*
Tasso	*Badger*	*Meles meles*
Tritone crestato meridionale	*Italian crested newt*	*Triturus carnifex*
Natrice dal collare	*Grass snake*	*Natrix natrix helvetica*
Ramarro occidentale	*Green lizard*	*Lacerta bilineata*
Raganella	*Treefrog*	*Hyla arborea*
Viper orsini	*Orsini's Viper*	*Vipera orsini*
Signale	*Wild boar*	*Sus scrofa*
Damigella	*Banded demoiselle*	*Calopteryx splendens*
Arvicola d'acqua	*Water vole*	*Arvicola terrestris*
Moscardino	*Dormouse*	*Muscardinus avellanarius*
Martora	*Pine marten*	*Martes martes*
Puzzola	*Polecat*	*Mustela putorius*
Azurro?	*Common blue*	*Polyommatus icarus*
Anthocaris	*Orange tip*	*Anthocaris cardamines*
Rana esculenta	*Green frog*	*Rana esculenta synklepton*
Aquila	*Imperial eagle*	Aquila helica
UCELLI	*BIRDS*	*AVES*
Poiana	*Buzzard*	*Buteo buteo*
Falco di palude	*Marsh harrier*	*Circus aeruginosus*
Quaglia	*Quail*	*Coturnix coturnix*
Picchio verde	*Green woodpecker*	*Picus viridis*
Picchio rosso maggiore	*Great spotted woodpecker*	*Dendrocopus major*
Torcicollo	*Wryneck*	*Jynx torquilla*
Tortora	*Turtle dove*	*Streptopelia turtur*
Colombaccio	*Woodpigeon*	*Columba palumbus*
Barbagianni (*)	*Barn owl*	*Tyto alba*
Civetta (*)	*Little owl*	*Athene noctua*
Allocco (*)	*Tawny owl*	*Strix aluco*
Succiacapre (*)	*Nightjar*	*Caprimulgus europaeus*
Calandro	*Meadow pipit*	*Anthus campestris*
Tottavilla	*Woodlark*	*Lullula arborea*
Allodola	*Skylark*	*Alauda arvensis*
Pettirosso	*Robin*	*Erithacus rubecula*
Merlo	*Blackbird*	*Turdus merula*
Codirosso spazzacamino	*Black redstart*	*Phoenicurus ochrurus*
Codirosso	*Redstart*	*Phoenicurus phoenicurus*
Culbianco	*Northern wheatear*	*Oenanthe oenanthe*
Saltimpalo	*Stonechat*	*Saxicola torquata*
Rigogolo	*Golden oriole*	*Oriolus oriolus*

Italian name	English name	Scientific name
Averla piccola	*Red-backed shrike*	*Lanius collurio*
Scricciolo	*Wren*	*Troglodytes troglodytes*
Pigliamosche	*Spotted flycatcher*	*Muscicapa striata*
Fiorrancino	*Firecrest*	*Regulus ignicapillus*
Sterpazzola	*Whitethroat*	*Sylvia communis*
Capinera	*Blackcap*	*Sylvia atricapilla*
Luì piccolo	*Chiffchaff*	*Phylloscopus collybita*
Cannareccione	*Great reed warbler*	*Acorcephalus arundinaceus*
Rampichino	*Short-toed treecreeper*	*Certhia brachidactyla*
Picchio muratore	*Nuthatch*	*Sitta europaea*
Cinciallegra	*Great tit*	*Parus major*
Cinciarella	*Blue tit*	*Parus caeruleus*
Codibugnolo	*Long-tailed tit*	*Aegithalos caudatus*
Cardellino	*Goldfinch*	*Carduelis carduelis*
Verdone	*Greenfinch*	*Carduelis chloris*
Storno	*Starling*	*Sturnus vulgaris*
Passera italia	*House sparrow*	*Passer domesticus italiae*
Passera mattugia	*Tree sparrow*	*Passer montanus*
Cornacchia grigia	*Hooded crow*	*Corvus corone cornix*
Gazza	*Magpie*	*Pica pica*
Taccola	*Jackdaw*	*Corvus monedula*
Strillozzo	*Corn bunting*	*Miliaria calandra*
Ortolano	*Ortolan bunting*	*Emberiza hortulana*
Zigolo giallo	*Yellowhammer*	*Emberiza citrinella*

Appendix 4 Map transformations for LARCH

The habitat module of LARCH requires grid maps of ASCII format. A resolution was chosen of 100 meter. Per land use type an ASCII map a cell-value was assigned for the area of the respective land use type

The vector map ‘Land use” was transformed to a 10 meter grid, the cell values refer to the land use type. The Land use grid was aggregated per land use type to a 100-m grid. The cell values of these grids reflect the area of the land use type within the cell, and are based on the number of 10-m grid cells of land use within the 100-m. grid cell.