Design of an ecological network for Piano di Navelli (Abruzzo)

Research in cooperation with: Regione Abruzzo, L'Áquila, Italy

# Design of an ecological network for Piano di Navelli (Abruzzo)

## Networks for LIFE

**E. A. van der Grift**
**T. van der Sluis**

**In cooperation with:**
**K. Hulsteijn**
**M. Jansen**
**H. Kuipers**

**Alterra-report 764A**

**Alterra, Green World Research, Wageningen, 2003**

ABSTRACT

Grift, E.A. van der & T. van der Sluis, 2003. *Design of an ecological network for Piano di Navelli (Abruzzo); Networks for LIFE*. Wageningen, Alterra, Green World Research. Alterra-report 764A. 44 pp.; 23 figs.; 2 tables; 19 refs.

This report provides a design for an ecological network at Piano di Navelli, Abruzzo, Italy. The design is based on habitat and corridor requirements of five indicator species: green lizard (*Lacerta bilineata*), Italian crested newt (*Triturus carnifex*), water shrew (*Neomys fodiens*), hedgehog (*Erinaceus europaeus*) and red squirrel (*Sciurus vulgaris*). Corridor dimensions, guidelines for habitat development within the corridors, and suggestions for wildlife passages at locations where the ecological network crosses roads are given. The ecological network is mapped for each species. An artist impression visualises the future situation of Piano di Navelli.

Keywords: corridor, ecological network, habitat construction, wildlife passage

ISSN 1566-7197

This report can be ordered by paying € 23,- into bank account number 36 70 54 612 in the name of Alterra, Wageningen, the Netherlands, with reference to report 764A. This amount is inclusive of VAT and postage.



Project 12132 [Alterra-report 764A/JATW/06-2003]

# Contents

# Preface

This report has been prepared on request of Regione Abruzzo. It follows directly from a study done for the entire region of Abruzzo: *An ecological network analysis for the brown bear (Ursus arctos) - and indicator species in Regione Abruzzo* by Van der Sluis & Baveco, published in 2003. This study gives guidelines to protect biodiversity in the area, and is meant to stimulate ideas and initiatives for further development of an ecological network.

We would like to thank project leader Antonio Perrotti and Maurizio Calabrese, who advised in the project and showed us around in the corridor area. We hope that the report will be of use in the planning of an ecological network at Piano di Navelli, and will contribute to maintain biodiversity in the much valued landscape of the Apennines!

The authors

# Summary

The Piano di Navelli is located between two protected nature reserves: Regional Park Sirente-Velino and National Park Gran Sasso-Monti della Laga. Although both areas are of considerable size, and many animal species are able to develop large viable populations within the boundaries of these parks, linking the parks together may increase the long-term survival of species and thus species diversity within the areas. That was why Piano di Navelli was pointed out as an area where an ecological corridor between the two parks should be developed.

In the present situation Piano di Navelli is mainly used for agricultural purposes. The function as an ecological corridor between some of the largest nature reserves of Abruzzo should be integrated in this existing form of land use. Instead of aiming for rigorous and large-scale changes in land use on the plateau, we suggest to develop a *network* of relatively small ecological corridors throughout the plateau in order to facilitate wildife movement across the area. This ecological network should be designed in such a way that a diversity of animal and plant species will be able to use it as a means to dispers between the nature reserves north and south of the Piano di Navelli. Furthermore, this ecological network will create ecological linkages on a local scale: corridors between isolated habitat patches on the plateau itself. This way the ecological network may play an important role in wildlife population viability on both a local and regional scale.

This report provides a design for an ecological network at Piano di Navelli, Abruzzo, Italy. The design is based on habitat and corridor requirements of five indicator species: green lizard (*Lacerta bilineata*), Italian crested newt (*Triturus carnifex*), water shrew (*Neomys fodiens*), hedgehog (*Erinaceus europaeus*) and red squirrel (*Sciurus vulgaris*). Corridor dimensions, guidelines for habitat development within the corridors, and suggestions for wildlife passages at locations where the ecological network crosses roads are given. The ecological network is mapped for each species. An artist impression visualises the future situation of Piano di Navelli.

# 1 Introduction

## 1.1 Piano di Navelli

The Piano di Navelli (High Plateau of Navelli) is located in the heart of Regione Abruzzo between the villages of Barisciano, southeast of L'Áquila, and Navelli, northwest of Pópoli. The plateau is about 20 km long and has a width of about 4-6 km (figure 1). The altitude differs roughly between 700 and 1000 m. At the northeast the plateau borders the foothills of the Monti della Laga and Gran Sasso mountain ranges. In the southwest the plateau is separated from the River Aterno valley by a low mountain ridge (altitude circa 1250 m). The plateau is mainly used for agriculture, i.e. potato, safrano and wheat production, and orchards. The plateau is over the full length bisected by a main road (Road 17). Smaller roads link the small, and often medieval, mountain villages with this main road. Overall road density on the plateau is low.

*Figure 1. Piano di Navelli (Photograph: Edgar van der Grift)*

## 1.2 Why an ecological corridor?

Biodiversity is highly dependent on the spatial cohesion of natural areas. When nature areas become fragmented, e.g. as a result of urban sprawl, growing industries, construction of infrastructure, or an increase in agricultural land use, wildlife populations become more or less isolated from each other. This affects the viability of these populations. If all exchange of animals between nature areas is inhibited, the chances are high that one of these populations becomes extinct due to sudden events (e.g. severe winter, drought, disease) or just due to demographic stochasticity. Linking different nature areas by ecological corridor zones or a sequence of ecological 'stepping stones' (small habitat patches) may be an effective measure to avoid such impacts on wildlife populations.

The Piano di Navelli is located between two protected nature reserves: Regional Park Sirente-Velino and National Park Gran Sasso-Monti della Laga (figure 2). Although both areas are of considerable size, and many animal species are able to develop large viable populations within the boundaries of these parks, linking the parks together may increase the long-term survival of species and thus species diversity within the areas (Romano & Tamburini 2002; Van der sluis et al. 2003). The development of robust ecological links between large nature areas is also part of European policy (Natura 2000; EU-Habitat Directive 1992).

*Figure 2. Corno Grande in National Park Gran-Sasso-Monti della Laga, one of the areas that will benefit from an ecological corridor across Piano di Navelli (Photograph: Edgar van der Grift)*

## 1.3 What species will use the corridor?

Large mammals, such as brown bears (*Ursus arctos*) and lynx (*Felis lynx*) are usually very vulnerable to habitat fragmentation because of their large home ranges, and relatively low reproduction rate. A landscape linkage between the Appenine ranges north and south of the Piano di Navelli is therefore an important objective for these species (Van der sluis et al. 2003). However, also smaller wildlife species, such as lizards, snakes, mustelids, rodents or invertebrates, may profit from a connection between the nature areas that border the plateau.

## 1.4 How to design the corridor?

In this study we used the habitat and spatial requirements of a few indicator species to assess the design of such an ecological network on the Piano di Navelli. To do so, we started with the analysis of corridor designs ('blueprints') and habitat requirements for the separate species. Furthermore, suggestions for wildlife passages are given in order to counteract habitat fragmentation by infrastructural barriers. Finally, we integrated these species-specific corridor designs and translated the more or les schematic blueprints into a geographically explicit ecological network at Piano di Navelli.

*Figure 3. Land use at the Piano di Navelli is mainly agricultural (Photograph: Edgar van der Grift)*

In the present situation Piano di Navelli is mainly used for agricultural purposes (figure 3). The function as an ecological corridor between some of the large nature reserves of Abruzzo should be integrated in this existing form of land use. Instead of aiming for rigorous and large-scale changes in land use on the plateau, we suggest to develop a *network* of relatively small ecological corridors throughout the plateau in order to facilitate wildife movement across the area. This ecological network should be designed in such a way that a diversity of animal and plant species will be able to use it as a means to dispers between the nature reserves north and south of the Piano di Navelli. Furthermore, this ecological network will create ecological linkages on a local scale: corridors between isolated habitat patches on the plateau itself. In this way the ecological network may play an important role in wildlife population viability on both a local and regional scale.

## 1.5 Selection of indicator species

To design an ecological network for the corridor at Piano di Navelli we selected 5 focal species (table 1). We limited ourselves during the selection to species that are most vulnerable to habitat fragmentation. Hence only terrestrial (non-swimming, non-flying) species were selected, excluding fishes, birds, bats and most insects. Furthermore, species with limited dispersal capacities were selected above very mobile species (such as wolves). For the latter it is assumed that they will be able to cross the plateau also in a less optimal (ecological) situation. We selected species that already inhabit the area, and preferably those for which a population viability analysis in Regione Abruzzo had been carried out (Van der sluis et al. 2003).

The selected species represent both small and medium sized mammals, amphibians and reptiles. We selected species with different habitat requirements (forest- versus grassland species, species that require water in their habitat as well as more or less water-indifferent species, etc), in order to be able to develop a network design that will facilitate a wide range of species.

*Table 1. Selected animal species for the design of an ecological network within the corridor at Piano di Navelli*

| Species group | Species | |
|---|---|---|
| Mammals | Hedgehog | *Erinaceus europaeus* |
| | Water shrew | *Neomys fodiens* |
| | Red squirrel | *Sciurus vulgaris* |
| Reptiles | Green lizard | *Lacerta bilineata* |
| Amphibians | Italian crested newt | *Triturus carnifex* |

## 1.6 Corridor design for each species

An ecological corridor may consist of three elements: (1) key patches, (2) stepping stones, and (3) dispersal corridor (Broekmeyer & Steingröver 2001). A *key patch* is a relatively large habitat patch with a viable population ('key population') under the condition of at least one immigrant per generation (Verboom et al. 2001). In other words: a patch with a strong population which is not likely to disappear soon due to environmental conditions or demographic fluctuations. Within an ecological corridor these patches form strongholds from which animals may dispers to other areas. A *stepping stone* is a habitat patch with the size of 1/10 key patch (Broekmeyer & Steingröver 2001). Species are not able to survive in these patches in the long-term, but they provide a 'rest area' for dispersing animals. A *dispersal corridor* is a narrow, but continuous strip of land in which suitable habitat is constructed for the species concerned. The habitat corridor is of such dimensions that it is not big enough to enable a species to live permanently within the zone. It is merely a conduit corridor through which animals move quickly (Foppen et al. 2000).

To develop a blueprint for the corridor of a species, six spatial characteristics were determined for each species, based on Broekmeyer & Steingröver (2001), Van Rooij et al. (2003) and Van der Sluis & Baveco (2003):

1. Minimum area key patch (ha)
2. Maximum distance between key patches (m)
3. Minimum area stepping stone (ha)
4. Maximum distance between stepping stones (m)
5. Minimum width dispersal corridor (m)

## 1.7 Integration of designs

The blueprints of the individual species are combined to develop an integrated corridor design for all species together. Where habitat requirements and spatial dimensions are more or less similar, the combination of designs will decrease the total required area for the ecological network. Where such an overlap does not exist, larger corridor dimensions are required to allow for the development of the different habitat types. For each situation one may consider whether the integration of designs is profitable or not, which is also dependent on the location of the corridors.

## 1.8 Mapping the corridor network

Based on the blueprints of the species-specific corridor designs, for each species a map of an ecological network at Piano di Navelli is worked out. These species-specific networks are integrated into one map with a network design for all species together. We emphasize that this network is just an example of what an ecological network on the plateau may look like when species requirements are considered. However, alternative network designs are possible. The exact placement of habitat or dispersal corridors, stepping stones and key patches is dependent on many factors, such as abiotic conditions, land ownership, spatial developments other than the construction of an ecological network, etc. All these factors were not included during the mapping of the ecological network. The map does provide though a practical starting point to plan and develop the ecological network at the Piano di Navelli in further detail.

# 2 Corridor design

## 2.1 Green lizard

### 2.1.1 Habitat of the species

The green lizard (*Lacerta bilineata*) preferably inhabits dense bushy vegetation with good exposure to sun: open woods, hedgerows, forest and field edges, bramble thickets (Arnold 2002). Furthermore the species occurs in meadows and on grassy slopes, in roadsides and along river banks. It thrives in agricultural landscapes, as long as enough suitable habitat occurs between the cultivated fields. Woodpiles, piles of dead branches, stone walls and other rocky places are also frequently used (Biondi & Tete 2002; Cabela et al. 2001). Arid areas are avoided. In the southern part of its distribution range, the green lizard can be more frequently encountered at higher altitudes (Gasc et al. 1997).

### 2.1.2 Spatial dimensions corridor

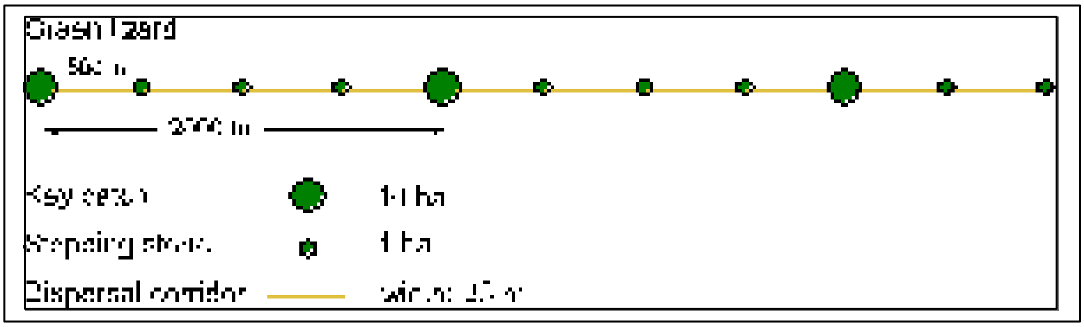
Green lizards usually have small home ranges of about 75-125 $m^2$. Mobility is low; often the animals stay their entire live within an area with a 30-50 m radius (Sound & Veith 2001). Maximum density of green lizards is estimated at 1000 RU / 100 ha[1]. Minimum size of a key population is 100 RU (Van der sluis et al. 2003).

| | |
|---|---|
| Minimum area key patch: | 10 ha |
| Maximum distance between key patches: | 2000 m |
| Minimum area stepping stone: | 1 ha |
| Maximum distance between stepping stones: | 500 m |
| Minimum width dispersal corridor: | 25 m |

### 2.1.3 Corridor design

Based on the rules of thumb for the spatial dimensions of the corridor, the blueprint for the design of the corridor is:

[1] RU = Reproductive Unit; minimum number of animals necessary to breed, usually 1 male and 1 female, but sometimes this includes also one or more individuals that do not participate in breeding, e.g. when animals live in social groups.




### 2.1.4 Habitat construction

Within the corridor both dense shrub vegetation and more open vegetation types, i.e. grassland, rocky areas and ruderal vegetations, should be developed. The development of forest should be avoided. However, single trees may add to the diversity in microclimate within the ecological zone. The edges of the shrub vegetation should be a gradual transition zone with a variety of ruderal and meadow plant species. A combination with a water course is preferable due to their preference for habitat in the vicinity of water. Stone walls may be part of the corridor. These provide cover and suitable spots for hibernation during the winter.

*Figure 4. Artist impression of habitat within the dispersal corridor of the green lizard*

### 2.1.5 Wildlife passages

Roads form serious barriers for green lizards, especially when traffic intensity is high. This may result in inefficient habitat use or even the isolation of populations. Mortality of green lizards on roads due to animal-car collisions may further impact lizard population viability, especially in the areas adjacent to roads.

Little is known about the use of fauna passages by lizards. The use of small underpasses was seldom recorded (Vos & Chardon 1994; Yanes et al. 1995). Wildlife overpasses with suitable lizard habitat are expected to be efficient measures, but only applicable in larger ecological corridors, where the combination can be made with the construction of a passage for large animals. A suitable alternative may be to combine a wildlife underpass with an (existing) underpass for hydrological purposes. Preferably, the embankment of the water course is reconstructed to allow the development of vegetation throughout the length of the passageway. If lack of sunlight or water inhibits plant growth in the passage, a row of tree stumps may be added to provide cover for migrating animals (figure 5).

*Figure 5. A row of tree stumps and branches provide cover for migrating lizards while crossing roads through underpasses (Photograph: Edgar van der Grift)*

### 2.1.6 Other species that will benefit

Most other lizards (e.g. wall lizards), as well as snakes (e.g. viper, smooth snake) will benefit from a corridor design as described for the green lizard. Also small to medium sized mammals, such as mice, stoat, weasel and polecat, and a variety of invertebrates (e.g. butterflies with low dispersal capacity) will encounter suitable habitat and dispersal conditions within the corridor.

## 2.2 Italian crested newt

### 2.2.1 Habitat of the species

The Italian crested newt (*Triturus carnifex*) is found in a wide range of habitats, but prefers habitats with an abundance of open water, such as streams, ponds, small lakes or marshland (Arnold 2002). The species is also found in man-made water basins or drinking places for cattle and sheep. A well developed submerse aquatic vegetation as well as abundant plant cover on the embankment are important habitat requirements for newts. Suitable land habitat, e.g. broad-leafed woodland and meadows, should be near the aquatic habitat. In Abruzzo the Italian crested newt is found up to altitudes of 1800 m (Gasc et al. 1997), however, it generally occurs between 400 and 1400 m (Biondi, personal comment).

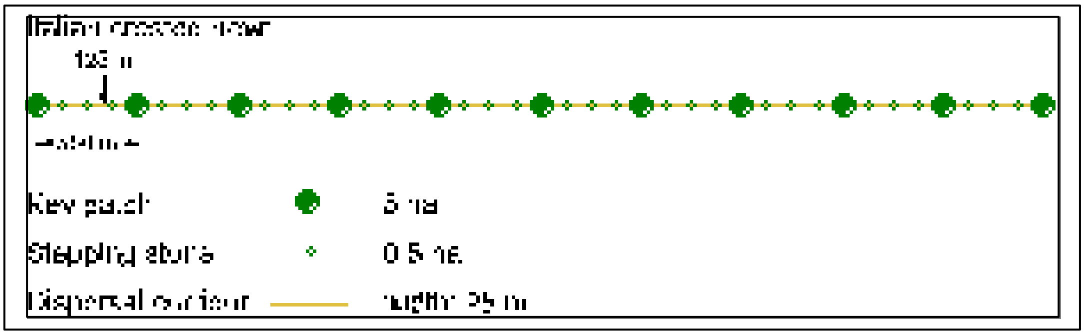
### 2.2.2 Spatial dimensions corridor

Italian crested newts usually have home ranges of about 250 $m^2$. Mobility is low; although several hundreds of meters may be covered to reach suitable land habitat. Maximum density of Italian crested newts in land habitat is estimated at 400 RU / 100 ha. Minimum size of a key population is 100 RU (Van der sluis et al. 2003). However, the number of large water bodies (reproduction sites) seems more important to set the size of a key patch than the total area of land habitat (Broekmeyer & Steingröver 2001).

| | |
|---|---|
| Minimum area key patch (land habitat): | 5 ha |
| Number of large water bodies within key patch: | 5 |
| Maximum distance between key patches: | 500 m |
| Minimum area stepping stone: | 0.5 ha |
| Number of large water bodies within stepping stone: | 1 |
| Maximum distance between stepping stones: | 125 m |
| Minimum width dispersal corridor: | 25 m |

### 2.2.3 Corridor design

Based on the rules of thumb for the spatial dimensions of the corridor, the blueprint for the design of the corridor is:




### 2.2.4 Habitat construction

Within the stepping stones and key patches ponds should be constructed with a minimum size of 250 $m^2$. The water depth varies between 0.5 and 2.5 m. Submerse aquatic vegetation should be well developed. The water banks consist of species-rich wetland vegetations that provide cover. In the surroundings of the ponds, within the key patches and stepping stones, land habitat is constructed. This is a mosaic of broad-leaved forest (mainly beech) and meadows. The dispersal corridor between the stepping stones and key patches is preferably located adjacent to a natural stream or agricultural ditch. Furthermore, the dispersal corridor consists of wetland vegetation at the banks of the stream, species-rich meadows, and spots with more ruderal vegetation or shrubs.

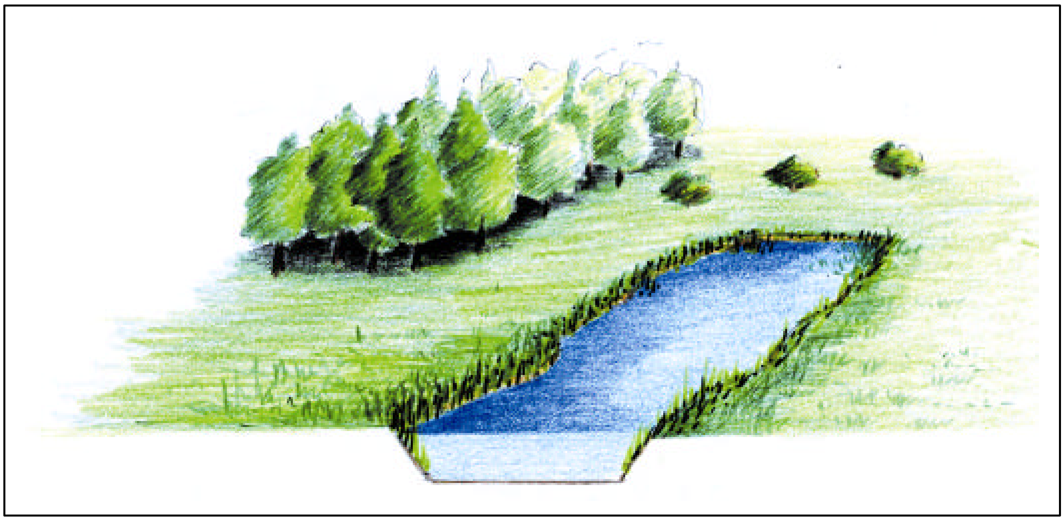


*Figure 6. Artist impression of habitat within the stepping stones of the Italian crested newt*

### 2.2.5 Wildlife passages

Roads inhibit the movements of newts and are a mortality risk when crossed (Vos & Chardon 1994; Van der Sluis & Vos 1996). Therefore wildlife passages should be installed at all locations where the ecological network is bisected by roads. Suitable passages for newts are the construction of continuous water course banks in culverts or under bridges, similar to these described for the green lizard. If space in a culvert or under a bridge is limited, the construction of ledges (wooden or stone) along both walls of the underpass may be an effective alternative (Brandjes et al. 2001). If no water course is available, small underpasses may enable newts to cross roads.

*Figure 7. Small fauna underpasses proved to be effective means to help amphibians cross roads safely (Photograph: Edgar van der Grift)*

*Figure 8. Ledges on both walls of a culvert enables newts to pass infrastructure (Photograph: Edgar van der Grift)*

### 2.2.6 Other species that will benefit

The corridor design for the Italian crested newt will be an effective defragmentation measure for most amphibian species for which a series of ponds is essential to allow animal migrations. But also many invertebrate species, like dragonflies and aquatic macrofauna, will benefit, as well as mammal species that are attracted by water (and its inhabitants) as a food source (e.g. polecat, water shrew, water vole).

## 2.3 Water shrew

### 2.3.1 Habitat of the species

The water shrew (*Neomys fodiens*) is a mammal species that inhabits clean, fast flowing to non-flowing water courses with well developed vegetations both in the water and along the water banks. Water shrews are seldom found more than 500 m away from water (Lange et al. 1994). Its land habitat is very diverse, but always characterised by abundant ground cover. The species can be found up to an altitude of 2000 m.

### 2.3.2 Spatial dimensions corridor

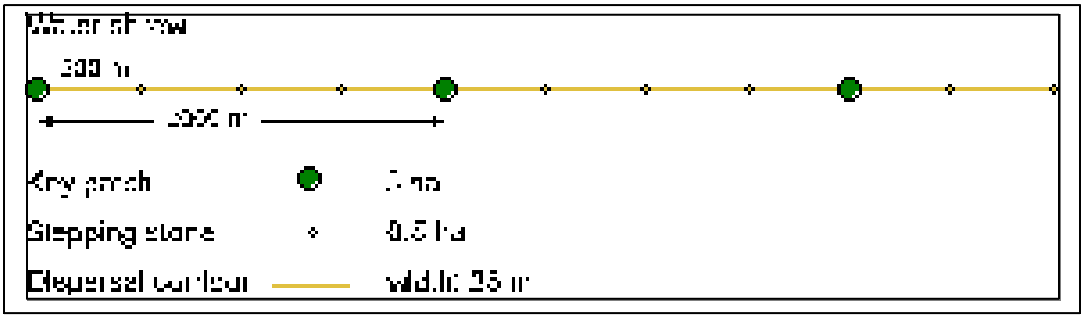
Home ranges of water shrews are usually linear, parallel to the banks of a water course. Home range size is 200 $m^2$. Minimum size of a key population should be 100 RU (Verboom et al. 2001). Because we consider only the aquatic part of the key patches optimal habitat, and the terrestrial part as sub-optimal, the guideline for key patch size is a little overdimensioned.

| | |
|---|---|
| Minimum area key patch (land habitat): | 5 ha |
| Maximum distance between key patches: | 2000 m |
| Minimum area stepping stone: | 0.5 ha |

| | |
|---|---|
| Maximum distance between stepping stones: | 500 m |
| Minimum width dispersal corridor: | 25 m |

### 2.3.3 Corridor design

Based on the rules of thumb for the spatial dimensions of the corridor, the blueprint for the design of the corridor is:



### 2.3.4 Habitat construction

The water shrew dispersal corridors should consist of a network of both natural streams and agricultural water courses. The water courses should contain water year-round. Vegetation is abundant, both in the water and along the banks. No trees should be planted within the corridor, but occasional shrub vegetation results in some extra cover and variability in microclimate. Furthermore on both sides of the water ruderal and species-rich meadow vegetations will be developed.

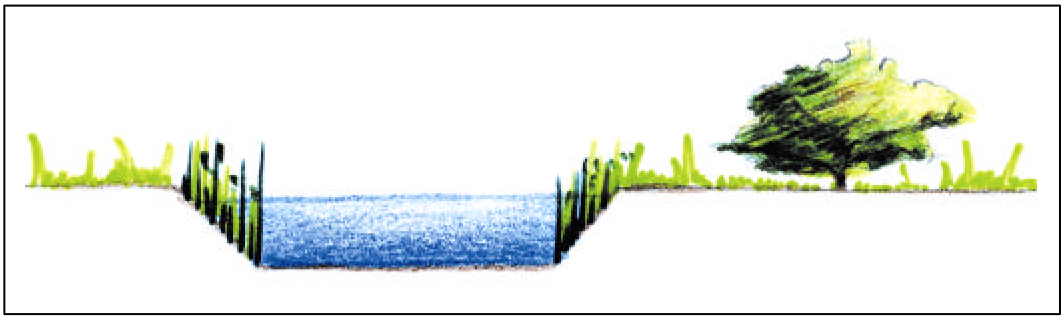


*Figure 9. Artist impression of habitat within the dispersal corridor of the water shrew*

### 2.3.5 Wildlife passages

Roads, even local roads, can be severe barriers for most small mammal species. Also mortality due to car-animal collisions may form a risk during road crossing. However, mitigating measures are rather simple to take because of the 'willingness' of many small mammal species to use fauna passages. For the water shrew a fauna passage in combination with a water course is prefered, e.g. a walking strip on the water bank or a ledge along the walls of a culvert (see also Italian crested newt). If the combination with a water course cannot be made fauna tunnels/pipes may form an effective alternative.

*Figure 10. Walking strips in a culvert provide connectivity for migrating small mammals between habitat patches bisected by infrastructure (Photograph: Edgar van der Grift)*

### 2.3.6 Other species that will benefit

The measures proposed for the water shrew provide also suitable corridors for other shrew and mice species, such as the Mediterranean water shrew (*Neomys anomalus*), bicoulored shrew (*Crocidura leucodon*), lesser white-toothed shrew (*Crocidura suaveolens*) and bank vole (*Clethrionomys glareolus*). Also small to medium sized mammal species such as polecat and weasel (*Mustela nivalis*). Amphibians, such as the common toad (*Bufo bufo*) will also benefit from a corridor design as described for the water shrew.

## 2.4 Hedgehog

### 2.4.1 Habitat of the species

Hedgehogs utilize a great variety of habitats. They prefer small-scale agricultural landscapes with hedgerows, small woodlots and meadows, as well as suburban areas (gardens), parklands and ruderal fields near settlements (Lange et al. 1994; Huijser 2000). A requirement is the availability of abundant ground cover. The species often occurs in edge habitats, i.e. forest edges, grasslands near hedgerows, stone walls etc. It hibernates in shrub vegetations or forested areas, with an abundance of dead plant materials to provide cover. Hedgehogs are found up to an altitude of 2000 m.

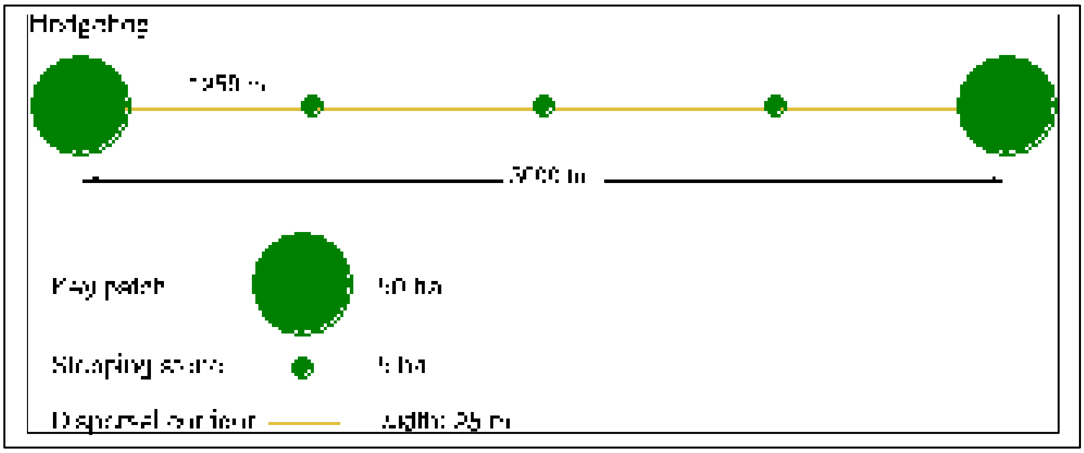
### 2.4.2 Spatial dimensions corridor

The hedgehog is a mobile species. Distances of up to 5 km may be covered during nightly foraging movements. Usually hedgehogs stay within a radius of 2 km. Minimum key population size is estimated at 100 RU (Van der sluis et al. 2003).

| | |
|---|---|
| Minimum area key patch (land habitat): | 50 ha |
| Maximum distance between key patches: | 5000 m |
| Minimum area stepping stone: | 5 ha |
| Maximum distance between stepping stones: | 1250 m |
| Minimum width dispersal corridor: | 25 m |

### 2.4.3 Corridor design

Based on the rules of thumb for the spatial dimensions of the corridor, the blueprint for the design of the corridor is:



### 2.4.4 Habitat construction

The dispersal corridor for hedgehogs consists of small-scale linear landscape elements with trees, shrubs, ruderal vegetation and grassland. The corridor is characterised by a gradient of high vegetation in the center of the ecological zone to low vegetations at the edges. A water course is not needed. Stone walls may add to the variety of habitats within the corridor zone.

*Figure 11. Artist impression of habitat within the dispersal corridor of the hedgehog*

### 2.4.5 Wildlife passages

Hedgehogs are frequently killed on roads (Huijser 2000). This may result in lower hedgehog densities in habitats along roads, the isolation of populations, or even in local extinction of populations. The impact of roads can be counteracted by the construction of wildlife passages, such as small fauna tunnels or overpasses.

*Figure 12. Small wildlife underpasses facilitate hedgehogs to cross roads safely (Photograph: Edgar van der Grift)*

### 2.4.6 Other species that will benefit

The corridor design for hedgehogs will benefit a variety of other small to medium sized mammals (e.g. weasel, polecat, red fox (*Vulpes vulpes*)), amphibians (common toad (*Bufo bufo*), reptiles (snakes and lizards) and invertebrates.

## 2.5 Red squirrel

### 2.5.1 Habitat of the species

The red squirrel (*Sciurus vulgaris*) is a species of coniferous, broad-leaved and mixed forests. The species also occurs in wide hedgerows and small woodlots in agricultural areas, as well as in gardens and parks in forested (sub)urban areas. Red squirrels are found up to an altitude of 2500 m (Lange et al. 1994).

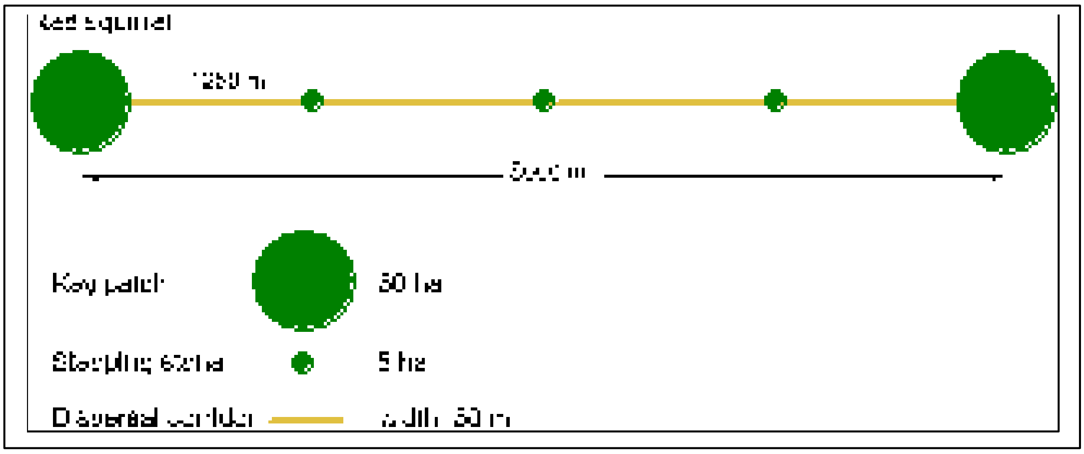
### 2.5.2 Spatial dimensions corridor

Home ranges of red squirrels differ greatly, varying between 2 and 50 ha (Lange et al. 1994). Distances covered during foraging also show a great difference between locations. Minimum size of a key population is 40 RU.

| | |
|---|---|
| Minimum area key patch (land habitat): | 50 ha |
| Maximum distance between key patches: | 5000 m |
| Minimum area stepping stone: | 5 ha |
| Maximum distance between stepping stones: | 1250 m |
| Minimum width dispersal corridor: | 50 m |

### 2.5.3 Corridor design

Based on the rules of thumb for the spatial dimensions of the corridor, the blueprint for the design of the corridor is:



### 2.5.4 Habitat construction

Within the dispersal corridor for red squirrels forest is the main habitat type. The forested strip in the center of the ecological zone should be accompanied by shrub vegetations at both edges.

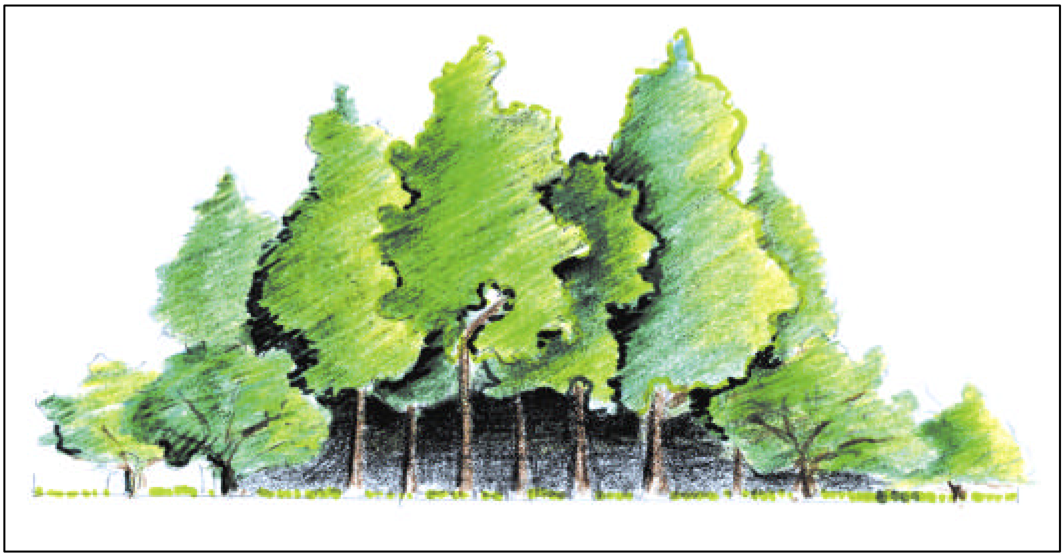


*Figure 13. Artist impression of habitat within the dispersal corridor of the red squirrel*

### 2.5.5 Wildlife passages

Observations of fauna passage use by red squirrels are rare. They are known to use wildlife overpasses and sometimes small fauna tunnels (Brandjes et al. 2002). Specially designed "rope-bridges" may provide effective alternatives (Bekker 2002).

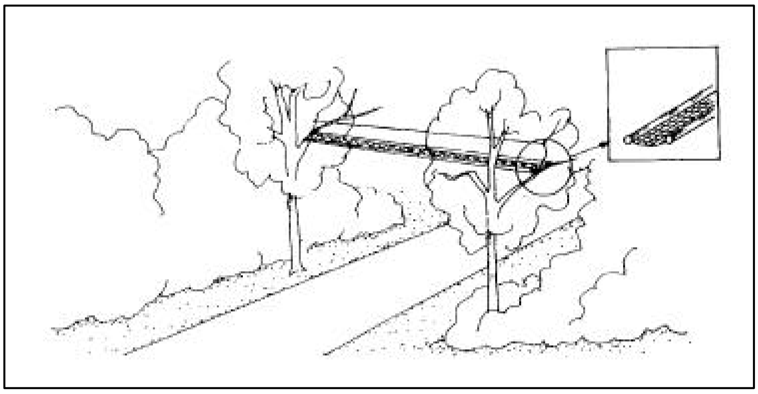


*Figure 14. A rope-bridge crossing a road to facilitate a save passage for red squirrels (Source: Bekker 2002)*

### 2.5.6 Other species that will benefit

A variety of fauna species of forested and edge habitats will benefit of the corridor design for the red squirrel, such as hedgehog, common shrew (*Sorex araneus*), pygmy shrew (*Sorex minutus*), bank vole, wood mouse (*Apodemus sylvaticus*), hazel dormouse (*Muscardinus avellanarius*) and badger (*Meles meles*). Also bats may use these corridors to forage and migration zones between habitats.

# 3 Corridor design all species

## 3.1 Integration of species-specific corridor designs

If corridor designs are integrated it may result in significant reduction of the total area needed due to overlap in habitat types. Figure 15 visuals the integration of corridor designs of the five indicator species. In order to calculate the size of key patches, stepping stones and dispersal corridors in case corridor designs are combined, we used the following rules of thumb:

*Table 2. Overlap in habitat types between corridor designs of the five indicator species. Figures indicate the percentage of the habitat within the corridor of species 1 that will also be suitable for species 2*

| species 1 | species 2 | | | | |
|---|---|---|---|---|---|
| | lizard | newt | shrew | hedgehog | squirrel |
| green lizard | - | 100% | 50% | 20% | 20% |
| Italian crested newt | | - | 50% | 20% | 20% |
| water shrew | | | - | 20% | 0% |
| hedgehog | | | | - | 50% |
| red squirrel | | | | | - |

The reduction of needed area in case the five indicator species are combineds is more than 40%.

## 3.2 Geographic design of the corridor network

For the green lizard, Italian crested newt and hedgehog we used the results of the LARCH viability analyses as starting point for the design of an ecological network at the Piano di Navelli (Van der sluis et al. 2003). These analyses show where minimum viable populations (MVPs), key populations, and small populations are located. With the network design we aimed for:

1. Connecting strong viable populations (MVPs) with each other across the plateau;
2. Connecting isolated key populations or small, non-viable populations with nearby MVPs.

Van der Sluis & Baveco (2003) show in their study the requirements for a forest corridor for brown bear. The width of this corridor should be at least 500 m of dense vegetation, which offers protection and cover for the migrating bears. Such a corridor obviously benefits species which are presented in this study as focal species, such as the red Squirrel and hedgehog, and to some lesser extent perhaps the Italian crested newt (land habitat) and green lizard (forest edges).

No viability analyses were conducted for the water shrew and red squirrel. For these species we used the land use map as starting point for the design of an ecological network on the plateau. For these species the design was based on the intention to connect major habitat patches for the species concerned.

Figures 16-21 show the geographic design of the ecological network at Piano di Navelli for the five indicator species and all species together. An artist impression of Piano di Navelli is shown in figure 22 (present situation) and figure 23 (with the ecological network).

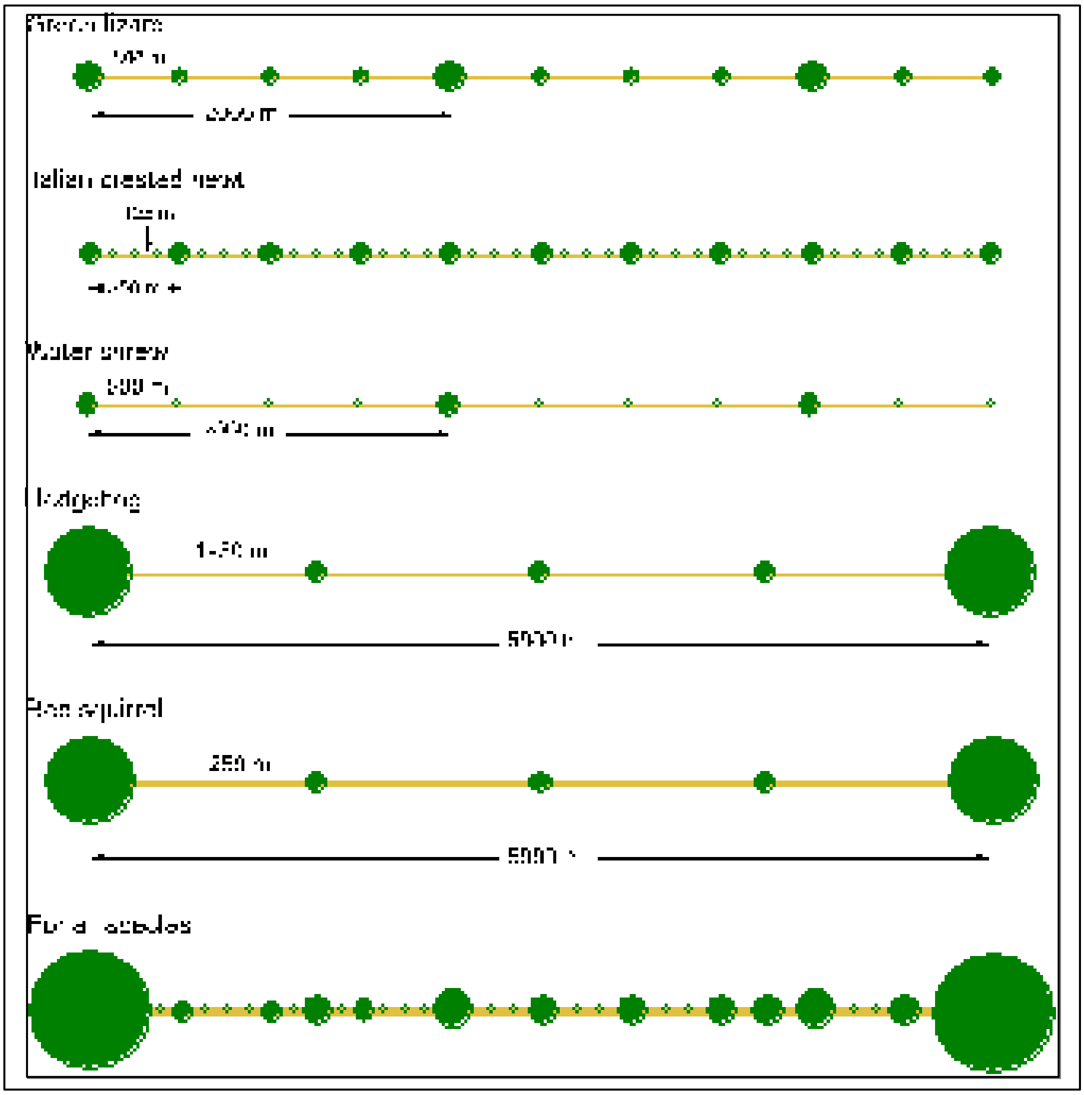



*Figure 15. Integration of five species-specific corridor designs*

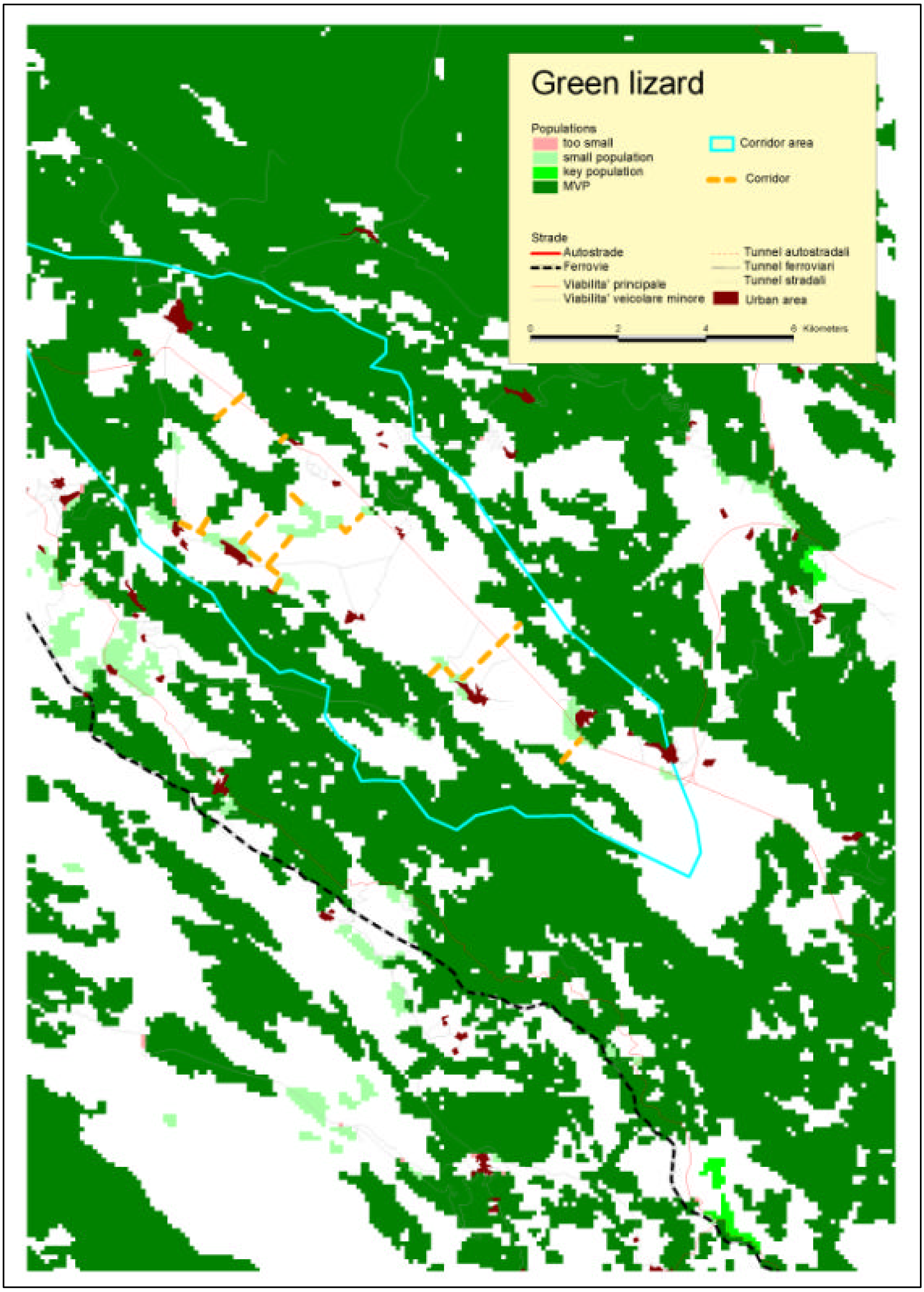



*Figure 16. Ecological network for the green lizard at Piano di Navelli*

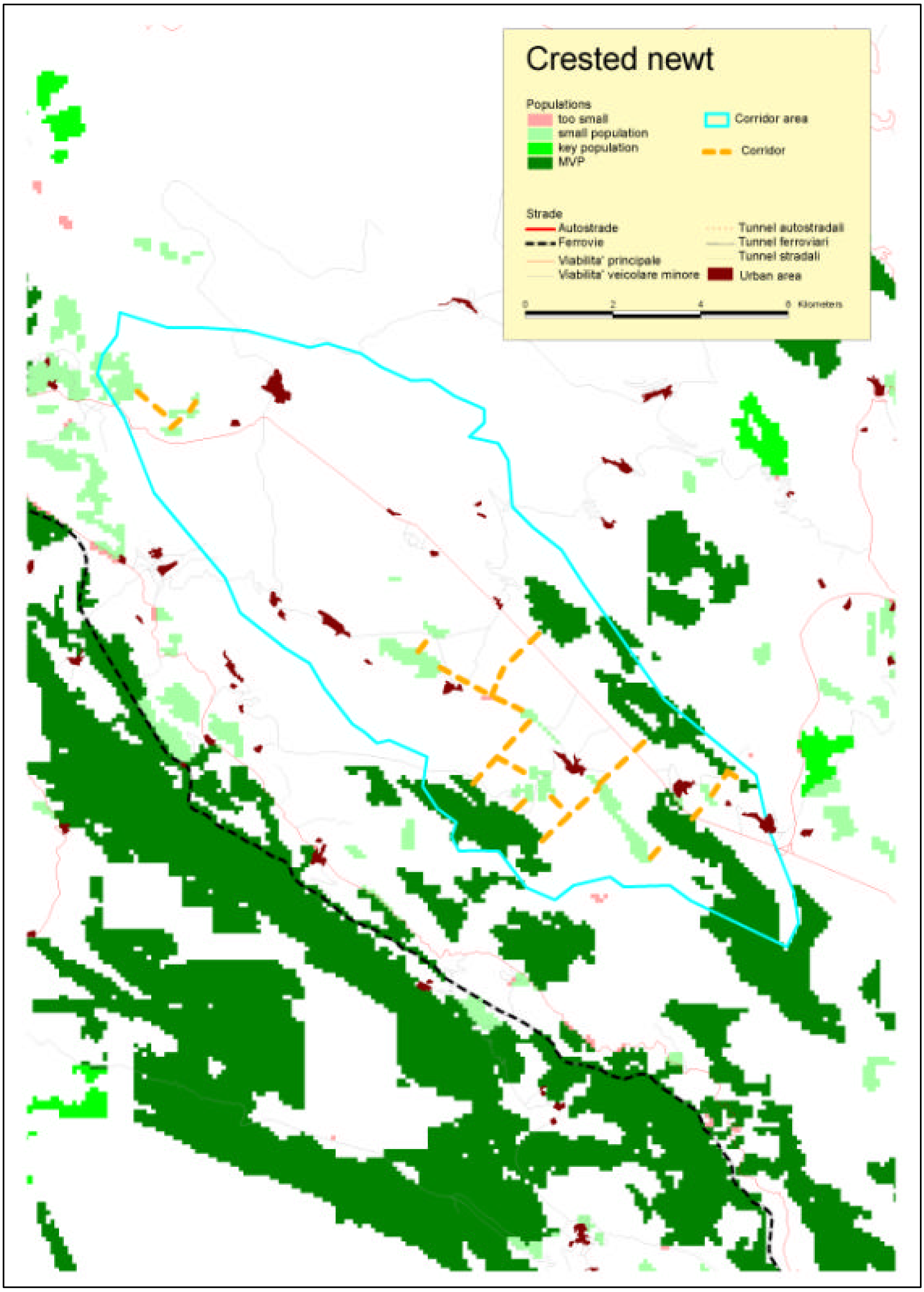



*Figure 17. Ecological network for the Italian crested newt at Piano di Navelli*

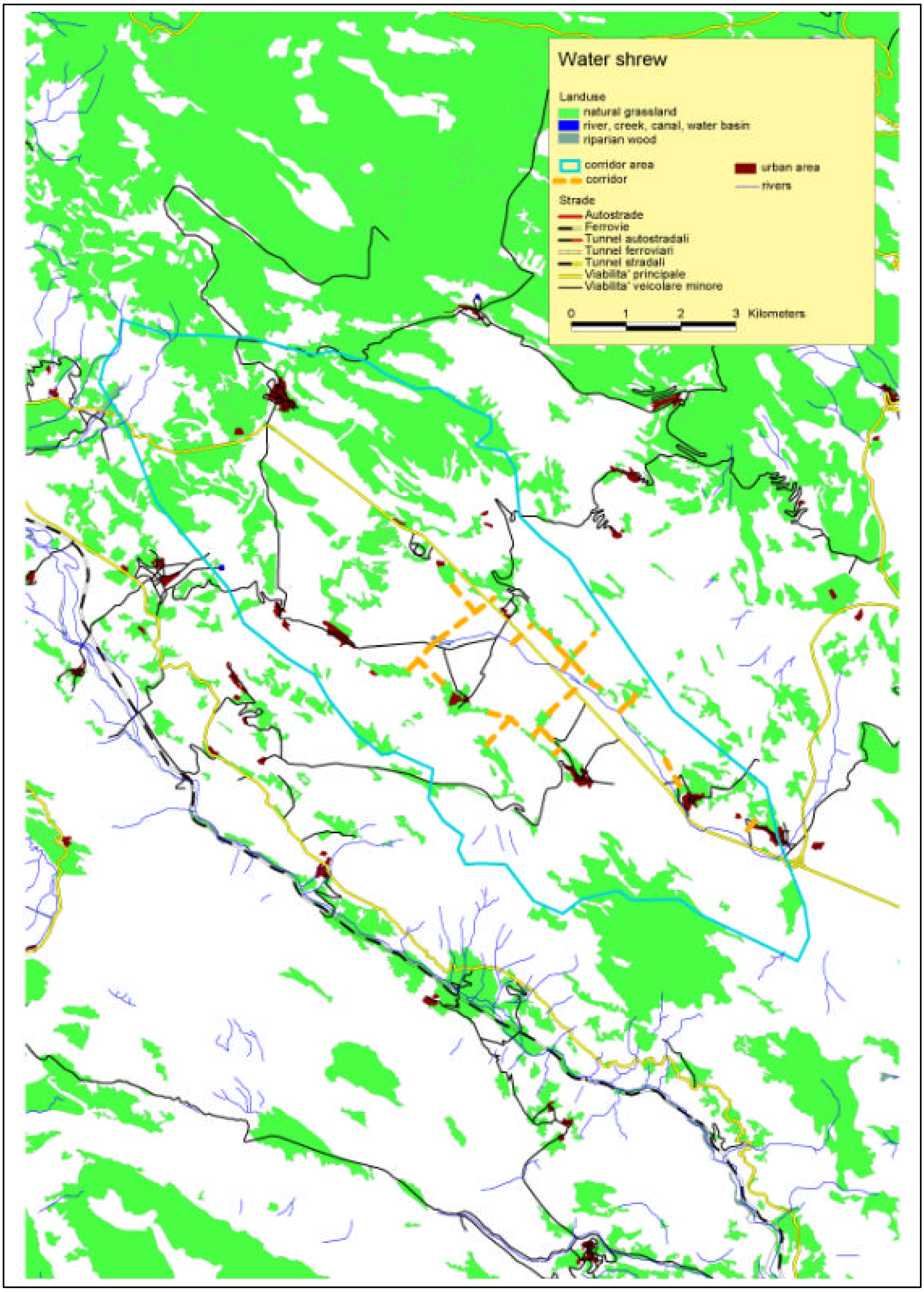



*Figure 18. Ecological network for the water shrew at Piano di Navelli*

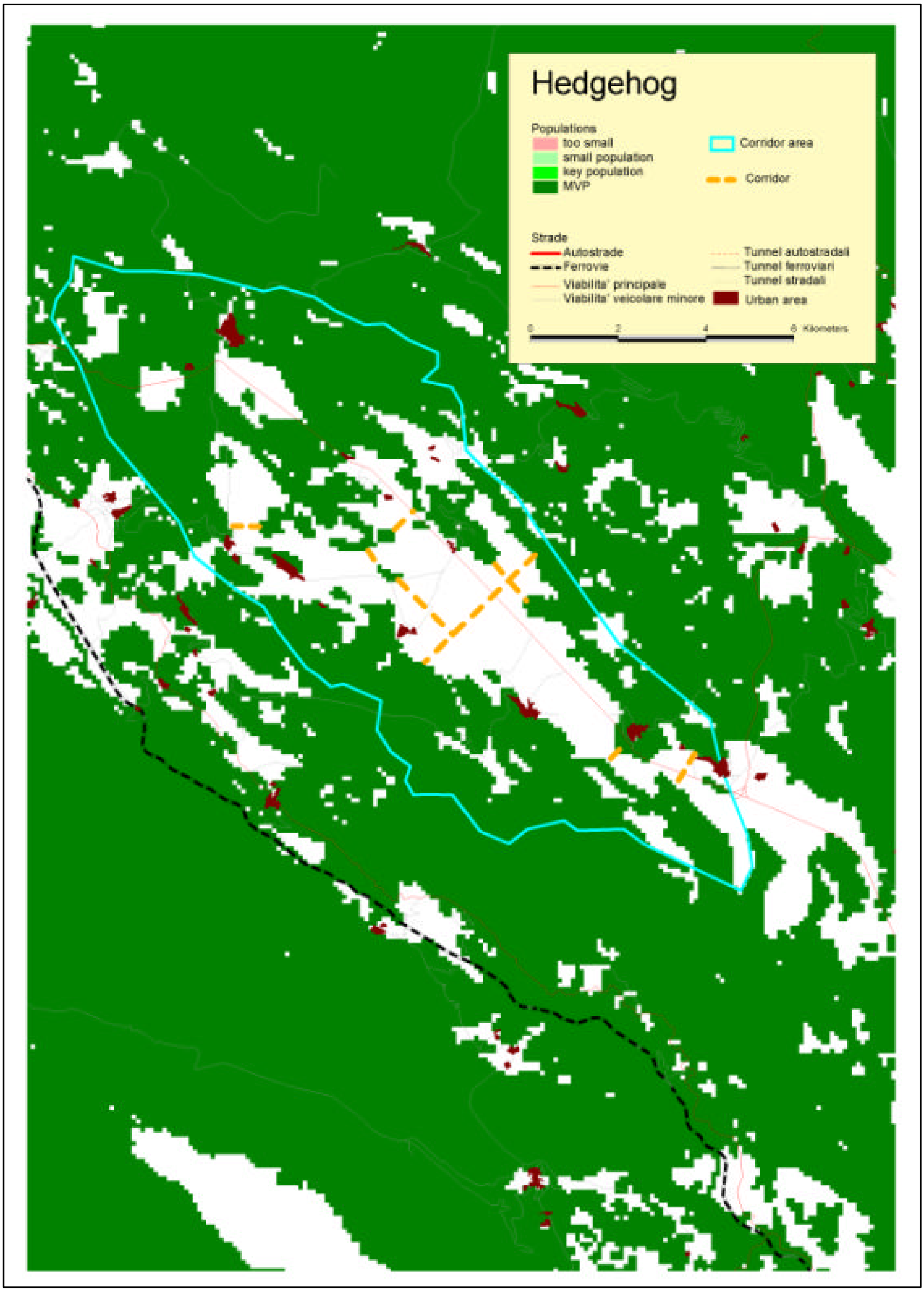



*Figure 19. Ecological network for the hedgehog at Piano di Navelli*

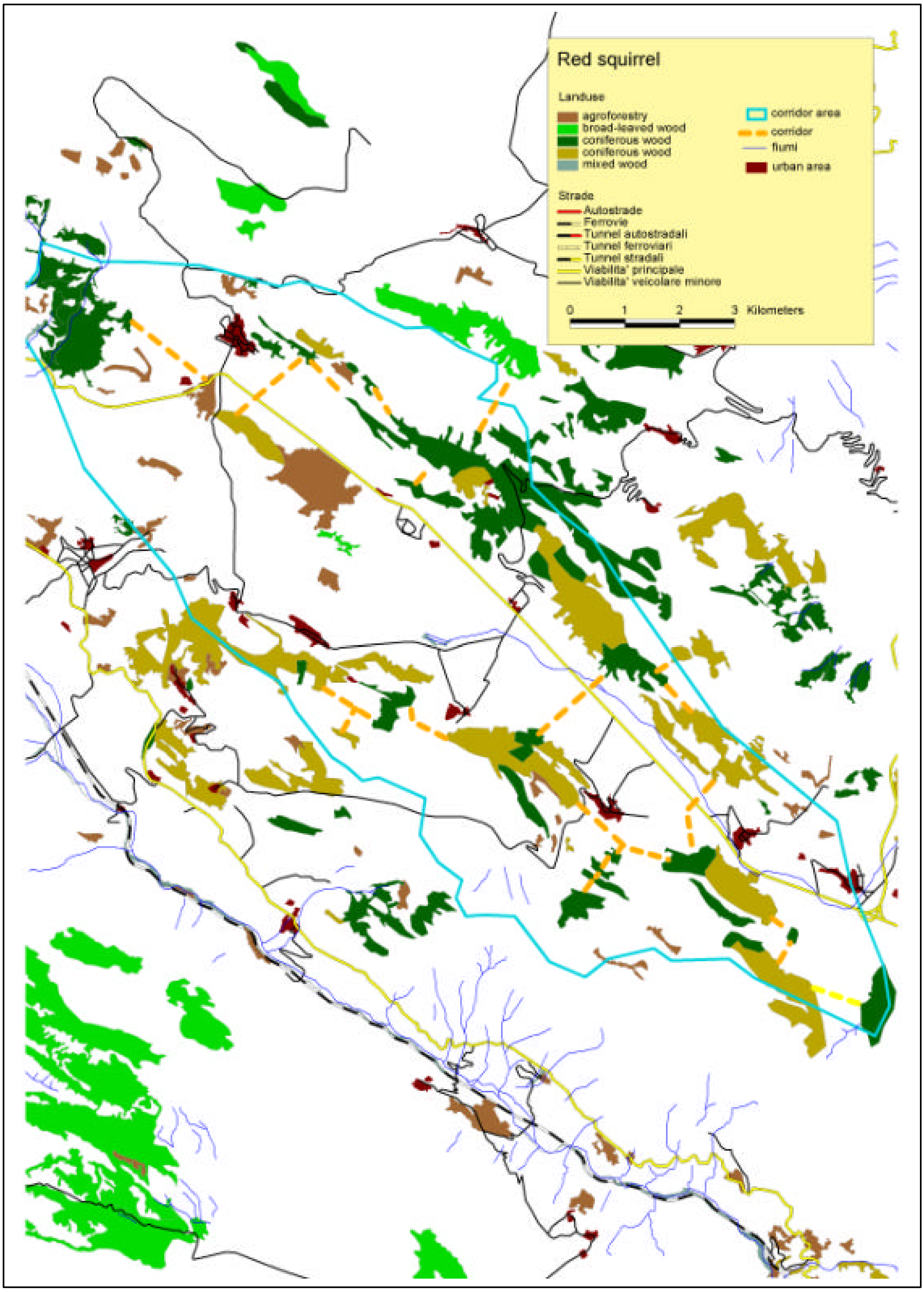



*Figure 20. Ecological network for the red squirrel at Piano di Navelli*

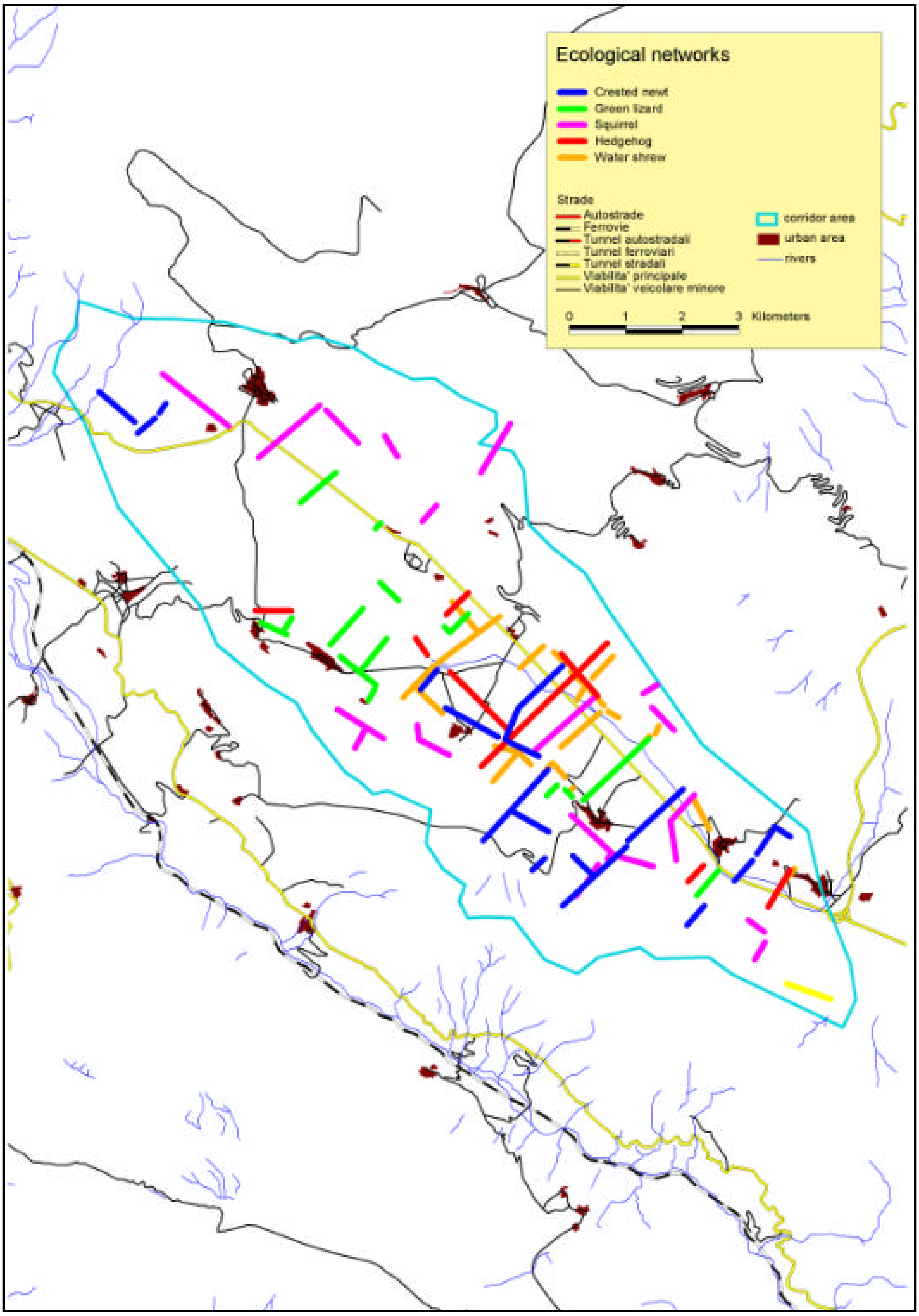



*Figure 21. Ecological network for all five indicator species at Piano di Navelli*

*Figure 22. Artist impression of the present situation at Piano di Navelli*

*Figure 23. Artist impression of an ecological network at Piano di Navelli*

# References

Arnold, E.N. 2002. A field guide to the reptiles and amphibians of Britain and Europe. HarperCollins Publishers, London, UK.

Bekker, H. 2002. Lopen op hoogte. Hoe steken in bomen levende zoogdieren wegen over? [Walking high. How do arboral mammals cross roads?] Zoogdier 13 (4): 3-8.

Biondi, M. & P. Tete 2002. Aspetti faunistici. University L'Áquila, L'Áquila, Italy.

Brandjes, G.J., G. Veenbaas, I. Tulp & M.J.M. Poot 2001. Het gebruik van faunapassages langs watergangen en onder rijkswegen. Resultaten van een experimenteel onderzoek. Report W-DWW-2001-026. DWW Ontsnipperingsreeks 40. Rijkswaterstaat, Dienst Weg- en Waterbouwkunde, Delft, The Netherlands.

Brandjes, G.J., R. van Eekelen, K. Krijgsveld & G.F.J. Smit 2002. Het gebruik van faunabuizen onder rijkswegen. Resultaten literatuur- en veldonderzoek [Use of small wildlife underpasses at roads. Results of a literature study and field research]. Report DWW-2002-123. DWW Ontsnipperingsreeks 43. Rijkswaterstaat, Dienst Weg- en Waterbouwkunde, Delft, The Netherlands.

Broekmeyer, M. & E. Steingröver (eds.) 2001. Handboek Robuuste Verbindingen; ecologische randvoorwaarden [Manual Robust Corridors; ecological guidelines]. Alterra, Wageningen, The Netherlands.

Cabela, A., H. Grillitsch & F. Tieman 2001. Atlas zur berbreitung und ökologie der amphibien und reptilien in Österreich. Federal Environment Agency, Vienna, Austria.

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. ECNC Technical Report. Alterra, Wageningen / European Centre for Nature Conservation, Tilburg, The Netherlands.

Gasc, J.P., A. Cabela & J. Crnobrnja-Isailovic (eds.) 1997. Atlas of amphibians and reptiles in Europe. Societas Europaea Herpetologica & Museum National d'Histoire Naturelle, Paris, France.

Huijser, M.P. 2000. Life on the edge. Hedgehog traffic victims and mitigation strategies in an anthropogenic landscape. PhD thesis. Wageningen University, Wageningen, The Netherlands.

Lange, R., P. Twisk, A. van Winden & A. van Diepenbeek 1994. Zoogdieren van West-Europa [Mammals of Western Europe]. Stichting Uitgeverij Koninklijke Nederlandse Natuurhistorische Vereniging, Utrecht, The Netherlands.

Romano, B. & G. Tamburini 2002. Pianificari L'assetto ambientale. Contributi delle scienze del territiorio per la rete ecological regionale dell'Abruzzo. University L'Áquila, Colledara, Italy.

Rooij, S.A.M., T. van der Sluis & E.G. Steingröver 2003. Networks for LIFE: Development of an ecological network for Persiceto (Emilia-Romagna, Italy). Alterra-report 729. Alterra, Wageningen, The Netherlands.

Sound, P. & M. Veith 2001. Radiotelemetrische untersuchungen zu raumbedarf, habitatwahl und innerhabitatbewegungen der westlichen smaragdeidechse (*Lacerta bilineata* Daudin 1802) im mittelrheintal, mit vergleichen zwischen männchen und weibchen. In: K. Elbing & H.K. Nettmann (eds.). Beiträge zur naturgeschichte und zum schutz der smaragdeidechsen (*Lacerta* s. str.). Mertensiella 13: 195-203.

Van der Sluis, T. & C.C. Vos 1996. Amfibieën en verkeerswegen. Een patroonanalyse in Gelderland en Noord-Brabant [Amphibians and roads: a pattern analysis]. Report W-DWW-96.115. DWW-Versnipperingsreeks 28. Rijkswaterstaat, Dienst Weg- en Waterbouwkunde, Delft / Instituut voor Bos- en Natuuronderzoek, Wageningen, The Netherlands.

Van der Sluis, T., H. Baveco, G. Corridore, H. Kuipers, F. Knauer, B. Pedroli, R. Jochems & J. Dirksen, 2003. Corridors for LIFE: Ecological network analysis Regione Abruzzo. Alterra-report 697. Alterra, Wageningen, The Netherlands.

Verboom, J., R. Foppen, J.P. Chardon, P.F.M. Opdam & P.C. Luttikhuizen 2001. Introducing the key patch approach for habitat networks with persistent populations: an example for marshland birds. Biological Conservation 100 (1): 89-100.

Vos, C.C. & J.P. Chardon 1994. Herpetofauna en verkeerswegen: een literatuurstudie [Herpetofauna and roads: a literature review]. Report W-DWW-94.730. Versnipperingsreeks 24. Rijkswaterstaat Dienst Weg- en Waterbouwkunde, Delft, The Netherlands.

Yanes, M., J.M. Velasco & F. Suarez 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biological Conservation 71: 217-222.