RESEARCH ARTICLE

The Pan European Ecological Network: PEEN

**Rob H. G. Jongman · Irene M. Bouwma ·
Arjan Griffioen · Lawrence Jones-Walters ·
Anne M. Van Doorn**

Abstract The pan European biological and landscape diversity strategy (PEBDLS) was developed under the auspices of the Council of Europe in order to achieve the effective implementation of the convention of biological diversity (CBD) at the European level. A key element of PEBLDS has been the development of the Pan European Ecological Network (PEEN) as a guiding vision for coherence in biodiversity conservation. PEEN has been developed in three subprojects: Central and Eastern Europe, completed in 2002; South-eastern Europe, completed in 2006; and Western Europe, also completed in 2006. The methodology of the development of the three maps has been broadly comparable but data availability, differences in national databases, technical developments and geographical differences caused variations in the detailed approach. One of the challenges was to find common denominators for the habitat data in Europe; this was solved differently for the subprojects. The project has resulted in three maps that together constitute the PEEN. They differ in terms of ecological coherence and the need for ecological corridors; for example, in Central and Western Europe corridors are essential to provide connectivity, while in Northern, Eastern and South-eastern Europe larger, coherent natural areas still exist. The future steps in developing PEEN should include the implementation of national ecological networks and, in particular, the pursuit of international coherence through the development of trans-European ecological corridors. The big challenge is to develop a common approach among the over 100 European-wide agencies that are responsible for biodiversity conservation.

Keywords Ecological network · Europe · Ecological corridors · Indicator species · Habitat suitability · Ecological data

R. H. G. Jongman (✉) · I. M. Bouwma ·
A. Griffioen · A. M. Van Doorn
Alterra, Wageningen UR, PO Box 47, 6700 AA
Wageningen, The Netherlands
e-mail: rob.jongman@wur.nl

L. Jones-Walters
European Centre for Nature Conservation (ECNC),
PO Box 90154, 5000 LG Tilburg, The Netherlands

Introduction

The concept of ecological networks is not new. Ecological networks have been developed over a number of decades in several European countries; beginning in Estonia and former Czechoslovakia in the 1980s and in The Netherlands in 1989 (Jongman et al. 2004). In these countries a strong land use planning tradition created the institutional environment for allocating functions, including the recognition of nature as a designation with its own value.

One of the main drivers for the development of ecological networks is that biodiversity in Europe was continuing to decline due to a decrease of habitat quality, habitat extent and increase in fragmentation. The ecological consequences of these processes are the destabilisation of landscape level processes, diminishing ecosystem functions, declining populations of natural species and a threat to their collective sustainability (Rodoman 1974; Jongman 2002; Mander et al. 2003). There was therefore a realisation that for many natural species the existing area and distribution of nature reserves and national parks was too small and fragmented (Somma et al. 2004; Hepcan et al. 2009).

The concept of ecological connectivity is implicit in several international conventions such as the Ramsar convention and the Bern convention, European agreements (habitats and species directive) and related EU policy implementation (Natura 2000). It has become operational in national strategies (national ecological networks) and at European level through the pan European biological and landscape diversity strategy (PEBLDS), Council of Europe 1996). The PEBLDS was Europe's response to the need for effective implementation of the convention of biological diversity (CBD) at the European level; the Pan European Ecological Network—PEEN formed one of its central delivery mechanisms. The indicative map of the pan-European ecological network was developed in the context of the following aim (Council of Europe 1996): 'The pan-European ecological network addresses the development of an ecological network at a European level. It will consist of core areas, corridors and buffer zones. Restoration areas will be identified where they are considered necessary. The pan-European ecological network aims to conserve the full range of ecosystems, habitats, species and landscapes of European importance and to counteract the main causes for decline by creating the right spatial and environmental conditions'.

The aim of establishing ecological networks is therefore the protection of nature and biodiversity. Their development has been stimulated by a combination of science and nature management practice.

In the USA and some European countries (e.g. Portugal), the ecological network is termed 'Greenway' (Ahern 2004) and it attempts to integrate wider societal interests with biodiversity conservation such as outdoor recreation and builds on the tradition of greenbelt planning and parkway planning (Jongman and Pungetti 2004). Bennett and Wit (2001) and Bennett (2004) define an ecological network as, "A coherent system of natural and/or semi-natural landscape elements that is configured and managed with the objective of maintaining or restoring ecological functions as a means to conserve biodiversity while also providing appropriate opportunities for the sustainable use of natural resources". The aims of the pan-European ecological network were further elaborated to ensure that (Rientjes and Roumelioti 2003):

– a full range of good quality ecosystems, habitats, species and landscapes of European importance is conserved;
– habitats are large enough to guarantee key species a favourable conservation status;
– sufficient opportunities exist for dispersal and migration of species;
– damaged parts of the key environmental systems are restored; and
– the key environmental systems are buffered from threats.

The Pan European Ecological Network presents a vision for the development of coherency in ecological networks throughout Europe and its implementation by national and regional governments. A method was therefore developed to take into consideration both a European perspective and national ecological networks and, when applicable, to include regional networks developed within countries.

The Pan European Ecological Network project was developed in three stages. The first PEEN subproject was carried out for Central and Eastern Europe (Bouwma et al. 2002) and had to deal with restricted data availability. This was also the case for the second subproject in South-eastern Europe that covers the Balkan, Greece and Turkey (Biró et al. 2006). Although there was not a perfect set of data for the third subproject in Western Europe, this subproject was able to make use of developments in data availability and new ancillary data (Jongman et al. 2006a).

The indicative map of the pan-European ecological network in Central and Eastern Europe (PEEN-CEE) was presented at the fifth 'Environment for Europe' ministerial conference in Kyiv, in May 2003,

where the results were received as an important contribution to the establishment of PEEN and the promotion of ecological networks in general. At the Belgrade ministerial conference in 2007 the whole process and all three maps were reported (Bonnin et al. 2007).

This paper presents the common approach and regional differences in relation to the PEEN project for the development of the PEEN vision and maps for Central and Eastern Europe (PEEN-CEE), South-eastern Europe (PEEN-SEE) and Western Europe (PEEN-WE). It presents the results and discusses the differences.

Data and methods

All three of the pan European networks maps were developed at a scale of 1:3,000,000. For the design of the map data were used that were consistently available for Europe or the project area. Species with a widespread occurrence in Europe, but for which data were not available for all Europe or at least for the project area, were not used. They would have been confused with species or habitats with a regionally specific distribution. In the development of the maps two lines of analysis were followed: (1) the analysis of habitats; and (2) the analysis of species requirements in relation to habitat size, quality and extent. Both lines were integrated in the final stage (Fig. 1). The core of the methodology was the same for all three maps. Adaptations were made in the methodology to take the differences between regions into account. For PEEN-CEE the land cover data that were used for the determination of core areas of the network were only available at different levels of accuracy; this caused differences in overall accuracy of determining habitats (Table 1). Three land cover databases were used: CORINE 2000 (http://www.eea.europa.eu) for the EU (then candidate) countries; PELCOM (Mücher et al. 2001) for Belarus, Ukraine and the western part of Russia; and the IGBP-DIS for the eastern part of European Russia (Loveland and Belward 1997). The IGBP-DIS was used as common denominator as it is the most general map for analysis. In PEEN-WE the Norwegian and Swiss national land cover maps had to be integrated with the CORINE land cover map to develop a composite habitat map. General habitat categories (GHC's),
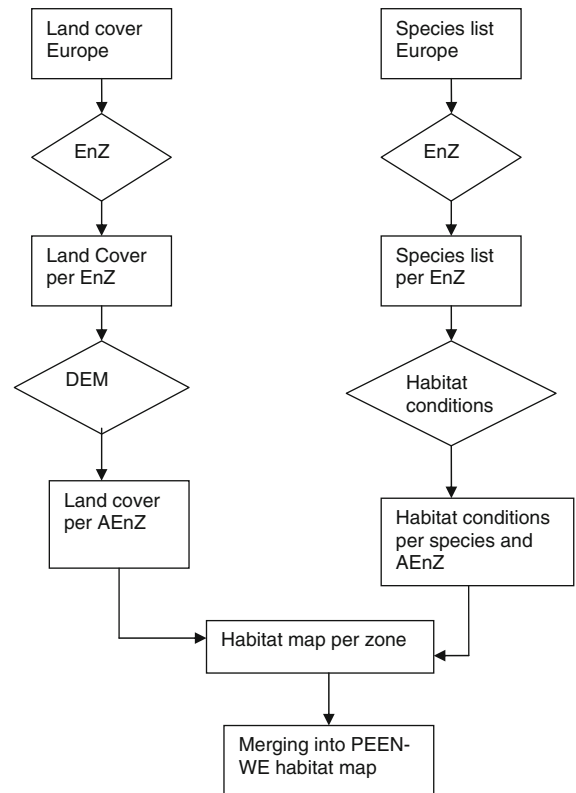

Fig. 1 Procedure for identifying core areas for the PEEN-WE region

Bunce et al. 2008) have been used to develop a common legend. In all phases of the projects intensive interaction was maintained with stakeholders from policy and science in order to check the validity of the scenarios and ecological content.

The PEEN is based on habitat maps showing existing non-fragmented natural and semi-natural areas that are considered large enough to sustain viable populations of large species and species of European importance requiring large areas. The subproject PEEN-WE includes Europe from the Polar Circle in Norway through to Crete, Sicily and Gibraltar. Madeira and the Canary islands have not been included as they are a separate biome (Macaronesian) and are situated at a large distance from the European mainland. However, for nature conservation they are of utmost importance because of their tertiary island endemics. The area needed for the survival of species differs largely (from one to another) in particular due to climatic and geographical conditions. Habitat maps had to be developed

Table 1 Data used in the PEEN projects

Dataset	Source	Used for	Coverage
Topographic information			
Digital elevation model	USGS Data centre	Habitat types	All
Hydrology (rivers, lakes)	ESRI, WDBII, Bartholomew	Corridors	All
National borders	ESRI, WDBII	Background	All
Towns and cities	GEOnet Names Server	Background	All
Roads	ESRI	Counterchecking corridors	All
Rivers	Bartholomew	River corridors	All
Internationally protected areas			
Ramsar sites	UNEP-WCMC	Protected areas	All
World heritage sites	UNEP-WCMC	Protected areas	All
Man and biosphere reserve sites	UNEP-WCMC	Protected areas	All
Natura 2000	European Environmental Agency	Protected areas	EU15
Protected areas norway	UNEP On line GIS and map database	Protected areas	Norway
Internationally acknowledged areas			
Important bird areas	BirdLife International	Protected areas	All
Prime butterfly areas	Butterfly foundation	Protected areas	All
Landcover information			
PELCOM	Alterra	Habitat types	Russia (not entirely to Ural)
IGBP-DIS global land cover	IGBP	Habitat types	Eastern Russia
Corine land cover (CLC2000)	European environment agency	Habitat types	EU15
LC Database Norway	Nijos	Habitat types	Norway
LC database Switzerland	WSL	Habitat Types	Switzerland
Peatlands	Wetland International	Habitat types	CEE-region
Coastal systems of Europe	EUCC	Habitat types	West and Central Europe
Boreal forests	Taiga rescue network	Habitat types	Russia
Other			
Biogeographical regions	European environment agency	Habitat types	All
Potential natural vegetation	Alterra	Habitat types	All
Soil map	FAO-Unesco Soil Database	Habitat types	All
European environmental stratification	Wageningen UR	Habitat types	All

based on land cover data and ancillary data, such as digital elevation models, protected areas databases and important bird areas; this was because land cover maps do not deliver sufficient ecological information as most data they provide are too general and do not include species dynamics and geographical and biogeographical differences (Table 1). For PEEN-WE (Jongman et al. 2006a) use was made of the environmental stratification of Europe (Metzger et al. 2005) so that habitats in different biogeographical regions could be identified. As mountain ranges play an important role use was also made of a digital elevation model (DEM) of Europe in order to distinguish between high mountains and lowlands.

In the PEEN-CEE and the PEEN-SEE subprojects shortcomings were observed by experts reviewing the results. These were mainly that the method applied might underestimate the value of fragmented landscapes and small scale (hedgerow) landscapes; only large unfragmented landscapes are identified in land

cover maps. In the PEEN-WE subproject, where this is even more important, small scale areas have been analysed separately for their connectivity function. Here regional expert knowledge was an important source of information as land cover data deliver insufficient information; it was used specifically for a second round of analysis to check for connectivity especially in urbanised and small scale agricultural landscapes (Denmark, Germany, The Netherlands).

In order to identify existing non-fragmented natural and semi-natural areas considered large enough to sustain viable populations of species of European importance the following steps were conducted (Fig. 1):

– development of a combined land cover map for the entire region (CORINE, Switzerland and Norway for PEEN-WE; CORINE, PELCOM and IGBP for PEEN-CEE);
– development of a simplified but ecologically interpreted habitat classification map based on land cover data and ancillary data;
– identification of habitats of sufficient size according to the working scale of the map, in order to identify size classes based on indicator species;
– identification of Emerald Network sites (the Council of Europe in 1996 launched the Emerald Network, which is based on the same principles as the legally binding Natura 2000 network within the European Union (Council of Europe 2009), Zapovedniks (nationally protected sites in Russia, Ukraine and Belarus (Sobolev et al. 1995) and NATURA 2000 sites [protected under the EU Species and Habitats Directive, Commission of the European Communities (2003)];
– identification of Ramsar sites, important bird areas (IBAs) and prime butterfly areas;
– identification of area requirements of indicator species;
– linking indicator species to the identified habitats; and
– estimation of the area required in order to maintain sustainable populations of the indicator species.

In all three subprojects the first step was to develop a combined land cover map for the region based on the existing land cover data. In Western Europe the integration was made by using general habitat categories (GHC's) that allowed the three maps to

be linked (Bunce et al. 2008). Based on the compiled land cover map of the region, habitats were identified by overlaying various land cover classes with additional information about the environmental zones of Europe (EnZ), (Fig. 2), altitude and soil information (wet soils, calcareous soils, etc.) using:

– size of the habitat area;
– naturalness for the biogeographic region/environmental zone; which in practice meant that most coniferous forests in the Continental and Atlantic zones were not included as their function is predominantly for wood production, while the coniferous forests in the high Alpine region were included because they are natural; and
– importance for natural species occurring in the region.

The next step in the identification of large non-fragmented areas was the selection of indicator species and then to link them to the identified habitats (Fig. 1). This was done by analysis of existing priority species data and the habitat requirements of their populations. Experts in various countries were consulted about certain species and about the basic lists. Given the scale of the map, the grain of the land cover information and the available species data, it was decided to consider only larger mammal and bird species as possible indicator species for PEEN-WE and PEEN-SEE. Migrating fish were included for PEEN-CEE through an assessment of the accessibility of rivers and the presence of existing barriers. In PEEN-SEE they have not been included; in PEEN-WE they were substituted by the occurrence of natural, non-regulated larger rivers that are considered as a proxy for the existence of migrating fish (in both subprojects these measures were taken because of a lack of harmonised European data).

For PEEN-WE it was possible to use the European environmental stratification (Fig. 2) to select different habitat sizes for species in different parts of Europe; for example, the potential density of wolf and brown bear is lower in boreal Scandinavia than in the Iberian Peninsula and the Balkan (Swenson 2000). Moreover habitats do differ between different altitudinal bands. This means that within the environmental stratification for identification of habitats substrata have been identified (altitudinal environmental zones, AEnZ) based on the DEM for Europe (Jongman et al. 2006b). Grasslands at higher altitudes

Fig. 2 Environmental stratification of Europe (Metzger et al. 2005). The zones are *ALN* Alpine North, *ALS* Alpine South, *ATN* Atlantic North, *ATC* Atlantic Central, *LUS* Lusitanian, *BOR* Boreal, *NEM* Nemoral, *CON* Continental, *PAN* Pannonian, *MDN* Mediterranean North, *MDM* Mediterranean Mountains, *MDS* Mediterranean South

Environmental Stratification of Europe

Environmental Zone

- ALN - Alpine North
- BOR - Boreal
- NEM - Nemoral
- ATN - Atlantic North
- ALS - Alpine South
- CON - Continental
- ATC - Atlantic Central
- PAN - Pannonian
- LUS - Lusitanian
- ANA - Anatolian
- MDM - Mediterranean Mountains
- MDN - Mediterranean North
- MDS - Mediterranean South

500 km
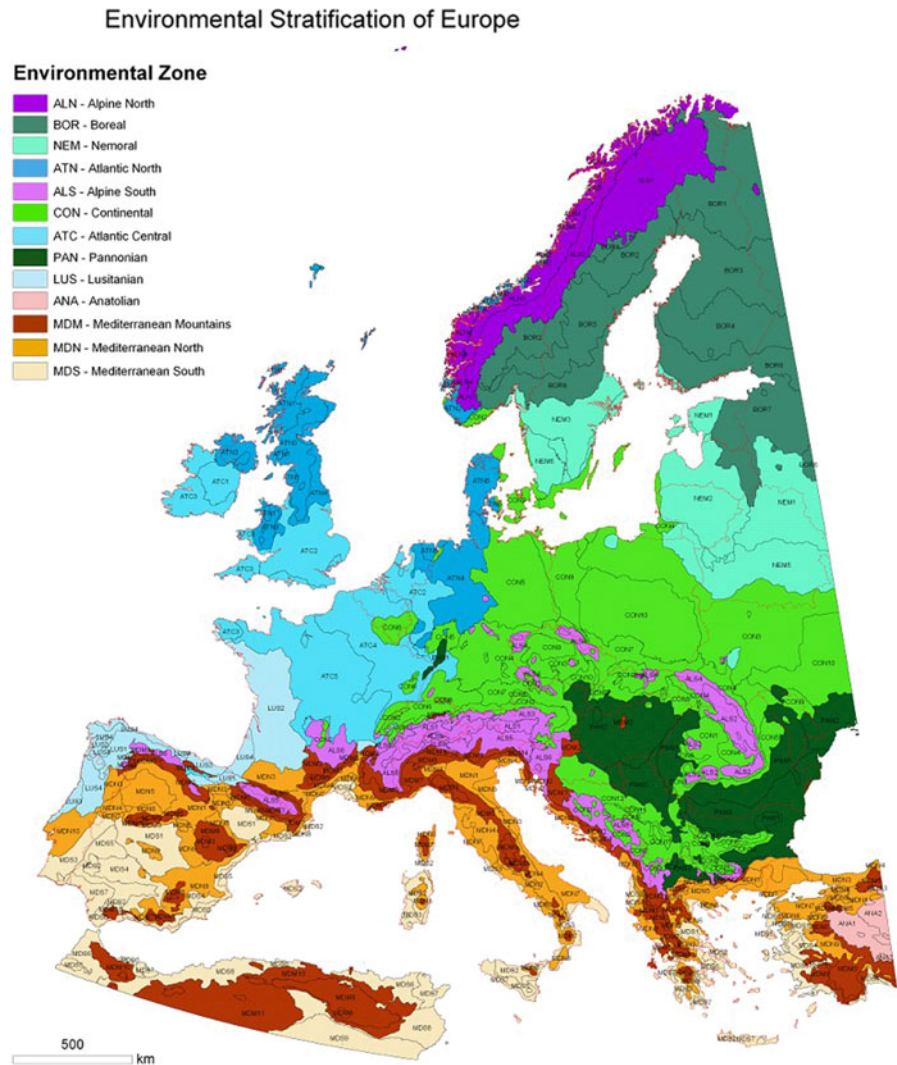
are identified as alpine grasslands, but these altitudes are different for different latitudes. For Alpine North (ALN, Scandinavia) the border between low and high has been identified at 400 m altitude, while in Alpine South (ALS, eg. Alps, Pyrenees, Carpathian) three zones have been identified below 700, from 700 to 1200 m and above 1200 m. In the Mediterranean mountains zone (MDM) the difference between low and high is identified at 1000 m. Various types of grasslands such as calcareous grasslands have been identified by interpreting the CORINE land cover map with help of the ancillary data such as the national soil maps and geological data.

Mammal and bird species have been selected on their existing international protection status: species occurring in the annexes of the EU Habitats and Birds Directives (Commission of the European Communities 2003), cross checked with the Bern Convention—Annex II and the vulnerable-extinct status of species according to EBBC or IUCN. For Western Europe in total 84 bird species and 14 mammal species were selected and then differentiated for EnZ's. For South-eastern Europe 90 bird species and 20 mammal species (Biró et al. 2006) and for Central and Eastern Europe 115 bird species and 19 mammal species were selected (Bouwma et al. 2002).

The importance of species for PEEN was identified in relation to their occurrence in European habitats. For PEEN-WE the occurrence of habitats

Table 2 Simplified habitat classification for forest habitats of Western Europe based on CORINE 2000, Norwegian land cover and the Swiss land cover

Forest	Land cover database	Habitat	Environmental Zone
Scandinavia	CORINE	Broad-leaved forest	ALN, BOR, ATN
	CORINE	Coniferous forest	ALN, ATN
	CORINE	Mixed forest	ALN, NEM, BOR, ATN
	Norway	Non-productive forest. A lot of mountain forest	ALN, BOR, NEM
	CORINE	Transitional woodland-shrub	ALN, BOR, NEM
Others	CORINE	Broad-leaved forest	ATC, ATN, LUS, MDM, MDN, MDS, PAN, CON, ALS
	CORINE	Coniferous forest	ATC, ATN, MDM, MDN, MDS, PAN, ALS
	CORINE	Mixed forest	ATC, ATN, LUS, MDM, MDN, MDS, PAN, ALS, CON
	CORINE	Burnt areas	MDM, MDN, MDS, ALS, LUS
	Switzerland	Forests	ALS, MDM, CON
	CORINE	Transitional woodland-shrub	ATC, ATN, LUS, MDM, MDN, MDS, PAN, ALS
	Switzerland	Scrub and/or herbaceous vegetation associations	CON

The codes of the environmental zones (EnZ) are given in Fig. 2 (Metzger et al. 2005)

was specified for EnZ's (Table 2). Within these zones species were linked to habitat types including the threshold estimated for survival of a population per region (Table 3). All the threshold areas were identified for the environmental zones and later merged into the joint legend for European habitats as there are differences in carrying capacity between boreal and mediterranean regions.

The size thresholds for different habitat areas were determined to support sustainable populations according to a number of steps. First species were linked to the identified habitat type and habitat types were identified for each EnZ. Then standards were assigned to each species based on the minimum population size considered large enough to be sustainable in the long-term. This allowed the minimum size of the areas needed to support viable populations of all selected species, per habitat type, to be estimated (Table 3). For determining the viability of species different thresholds in area size per habitat type were set, related to estimated population size. 'Very large areas' are defined as: "greater than five times the minimum area required to make the long-term survival of all populations of the selected species quite probable". 'Large areas' (defined as:

"two times the minimum area required to make the long-term survival of all populations of the selected species quite probable") make it possible for the present population of the selected species to occur in that location. However, when isolated, these areas may suffer the loss of some species and immigration might be required; connection to other areas or area enlargement is therefore recommended. Areas with a sub-optimal size were estimated to maintain a maximum of 70% of the selected species populations; the most demanding species can only be maintained or restored by either enlarging habitat size or by making connections with comparable habitats by corridors, or both.

The required minimum area sizes (considered as sub-optimal for the various habitats) range from: 50 km^2 for wetlands, peat lands and grasslands; to 300 km^2 for different types of forests. Habitat area size has been calculated in three classes. The spatial patterns of habitat types that exceed each of the thresholds were assessed in a GIS analysis.

The identification of corridors for the pan-European ecological network in PEEN-CEE was based on the location of forested landscapes, known bird migration routes, mountain ranges and river related

Table 3 Mammal species, their occurrence in environmental zones and the estimated claim on habitat

EnZs		ALN 1	ALS 2	BOR 3	NEM 4	CON 5	ATN 6	ATC 7	LUS 8	PAN 9	MDN 10	MDM 11	MDS 12
Castor fiber	Beaver	**4**	4	**4**	**4**	4	4	4					
Alopex lagopus	Polar fox	7											
Lutra lutra	Otter		4	4	4	4	4	4	4	4	4	4	4
Mustela lutreola[a]	European mink					5		5					
Canis lupus[a]	Wolf	7	6	**7**							6	6	6
Gulo gulo[a]	Forest dormouse	8											
Lynx lynx	Lynx	8	8	8									
Lynx pardina[a]	Pardel lynx		8								8	8	8
Rupicapra rupicapra	Gems/chamois		5										
Capra hircus (aegagrus)	Ibex		5									5	
Ursus arctos	Brown bear	**8**	8	**8**								8	
Cervus elaphus corsicanus	Red deer											6	
Alces alces	Moose				7	7							
Ramgofer taramdis femmicus	Reindeer	8											

The *bold* values are excluded in Annex 1 of the European Habitats and Species Directive and therefore not included here

[a] European priority species. Habitat size classes for a sustainable population: 1: <10 km², 2: 10–50 km², 3: 50–150 km², 4: 150–300 km², 5: 300–600 km², 6:600–1000 km², 7: 1000–2000 km², 8: >2000 km². *Mustela lutreola*: Normandy, Brittany and Lunebürger Heide; *Canis lupus*: all EU 15 except Finland; *Lynx lynx*: all Europe except Finland and Baltic states; *Lynx pardina*: only Iberian Peninsula; *Cervus elaphus corsicanus*: only Corsica; *Rangifer tarandus fenicus*: only Finnish forest Reindeer. The following mammal species have not been considered as they are marine mammals: *Monachus monachus, Phoca hispida* (Botnica and saimensis), *Halichoerus grypus, Phoca vitulina*. For the legend of the EnZ see Fig. 2

wetlands. All corridors were discussed with regional experts. For PEEN-WE corridors were based on:

- bird migration routes;
- the need for connectivity between core areas, based on their size required to support the connectivity needs of mobile species that had been identified as related to the habitat;
- relative forest density per km² in areas between large habitat blocks and smaller areas and between small habitat blocks based on forest presence in the land cover map;
- location of hedgerow landscapes (small scale farming areas) based on expert information and situated mainly in CORINE land cover classes 20, 21, 22—that include small scale agricultural landscapes potentially functioning as corridors between core areas;
- location of mountain ranges (part of habitat classes);
- location of natural or semi-natural rivers;

- expert judgment (project members and consulted experts); and
- comparison with existing national networks (core areas and corridors).

Results

PEEN project has resulted in three maps: the map for Central and Eastern Europe (PEEN-CEE), (Fig. 3); the map of South-eastern Europe (PEEN-SEE), (Fig. 4); and the map of Western Europe (PEEN-WE), (Fig. 5). All three maps have a comparable legend showing the three categories for habitat size needed for population survival (marginal, 100%, greater than five times population size). In all three maps existing protected areas have been included such as: Zapovedniks in Russia, Belarus and Ukraine; Natura 2000 (European Union); and Emerald sites (Berne Convention outside European Union); official
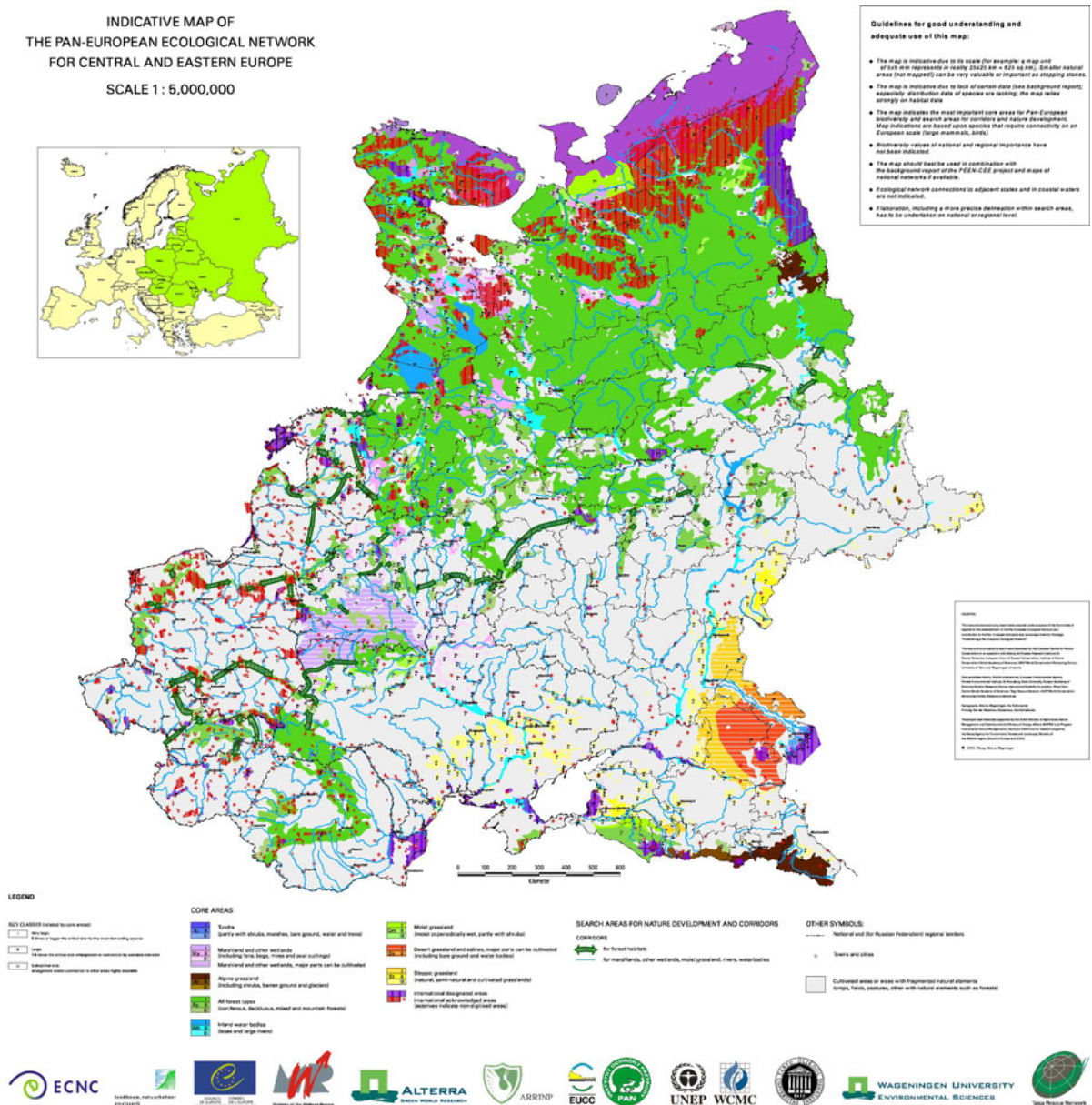
Fig. 3 The map of PEEN for Central and Eastern Europe (Bouwma et al. 2002)

Ramsar convention sites. Sites known to be important but not protected, such as important bird areas (IBA's) and prime butterfly areas, were not included but were used for checking the accuracy of the maps. When needed the map was corrected and the correction was checked with local experts.

The PEEN-CEE map (Fig. 3) shows ecological coherence in the Russian taiga forest and tundra that still can act as a coherent ecological system. The wetlands of Pripjat and Polesia also function as a major core area as do the steppe grasslands in southeast European Russia around the delta of the Volga. Alpine habitats only occur in the Carpathian and Ural mountains. In general, towards the south and the west fragmentation has occurred and for ecological coherence ecological corridors are needed. They have been
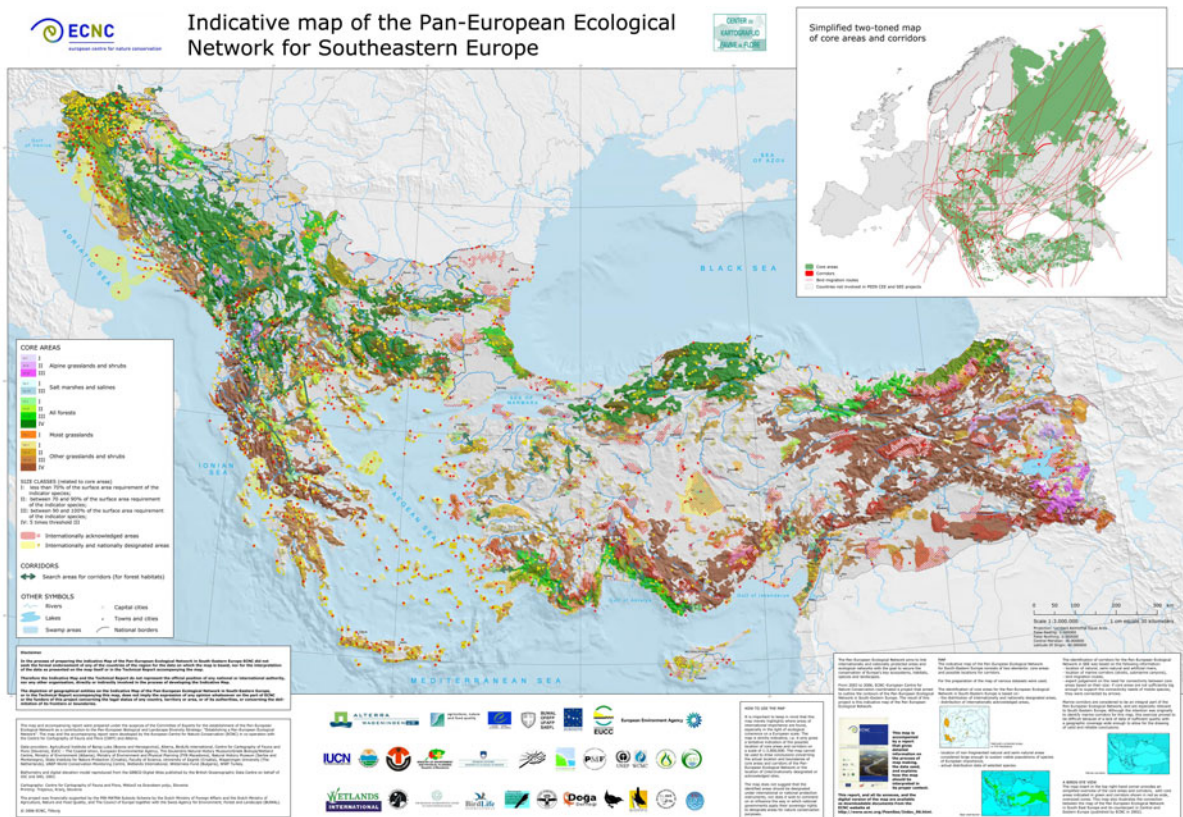
Fig. 4 The map of PEEN for South-eastern Europe (Biró et al. 2006)

indicated on the map by lines. Two types of corridors are indicated: forested corridors; and river and wetland corridors.

In PEEN-SEE (Fig. 4) the major habitat types that form core areas are forests, saline marshes and other marshlands, various types of grasslands and mountain habitats. Alpine habitats are restricted to the eastern part of Turkey, the Rodopi and Balkan Mountains and the Dalmatian Alps. Forest and grassland habitats are dominant. Fragmentation is regional and partly due to differences in natural habitats. All terrestrial corridors are forest corridors as this is the major habitat type. These are indicated by arrows. The major species corridors, however, are the long distance migration corridors for birds from Central and Eastern Europe over the Bosporus and the Caucasus to Africa and western Asia.

The PEEN-WE (Fig. 5) map includes major core areas of rivers bogs and wetlands, forest, heathlands and Mediterranean scrub, several grassland types and alpine habitats. Fragmentation is much stronger than

in the PEEN-CEE and PEEN-SEE. The major coherent nature areas are found in Scandinavia, the Alps and in the Iberian mountain ranges. Western Europe is highly urbanised and therefore nature is highly fragmented. The structure of the network contains many more ecological corridors than in the other two subprojects. However, this process of fragmentation is already clearly visible in the western part of PEEN-CEE (Fig. 6).

In all three subprojects ecological corridors have been identified. In PEEN-CEE and PEEN-SEE these have been mainly indicated on the basis of habitat pattern and following consultation with regional experts. In PEEN-WE experts were consulted but use was also made of existing national ecological network (NEN) plans that, in that period, were partly available and included ecological corridors. That means that the ecological corridors in PEEN-WE have different origins. For Denmark ecological corridors were proposed based on habitat information; these were then discussed and decided upon in

Fig. 5 The map of PEEN for Western Europe (Jongman et al. 2006a)

Indicative map of the Pan-European Ecological Network for Western Europe
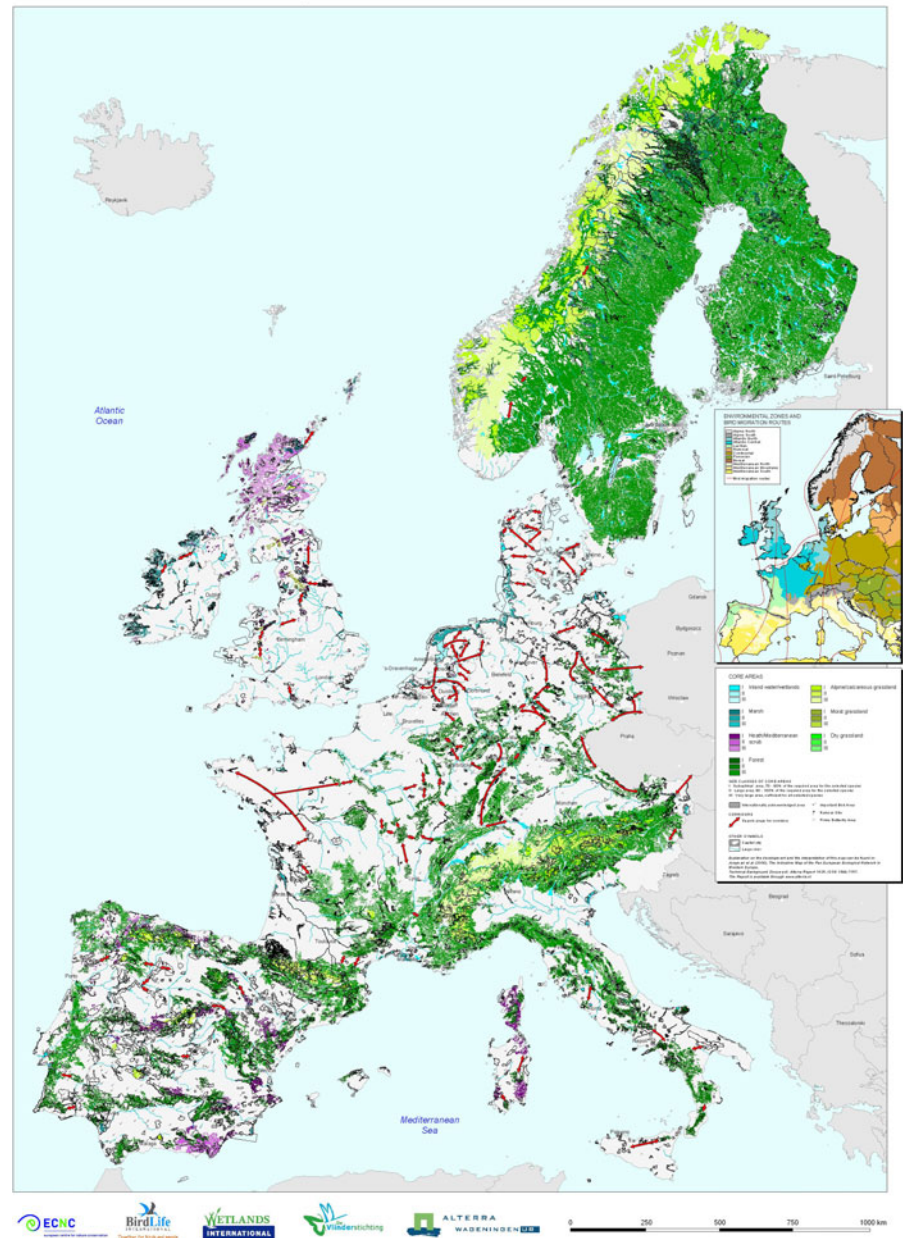
consultation with landscape planning experts. For The Netherlands use was made of the national ecological network and its robust corridors which were included in the rural development plan (Ministry of ANF 2006). For Germany the parallel process of developing the ecological networks for the regional units represented by the Bundesländer was utilised (see Ssymank et al. 2005). Use has also been made of NGO projects such as the Alpine corridor project of WWF. As the maps are 'live' documents not all information, particularly about ecological corridors, could be integrated. For Great Britain the information developed by Natural England became available too late to be included (Catchpole 2007).

Fig. 6 Main ecological corridors in Poland for mammals such as wolfs (Jedrzejewski et al. 2005)

Discussion

The PEEN project was initiated during a period of great political and related policy change in Europe; the data that could be used and its quality was therefore very much dependent on the sources and the moment in time that it was abstracted. The land cover data, especially for the PEEN-CEE map, had different sources with different pixel sizes and legends and direct habitat interpretation was not possible. The available land cover categories had to be utilised, but resulted in coarse habitat categories. It was therefore only possible to use the lowest common denominator in order to develop a common legend. In this case it was the IGBP-DIS, used for eastern part of European Russia (Loveland and Belward 1997).

The land cover data used for PEEN-WE also had three different sources: CORINE Land cover; the Swiss land cover map; and the Norwegian land cover map, each with a different legend. This required the development of a series of interpretation steps that would lead to harmonised habitat maps. Other databases, such as soil maps, river basin maps, geomorphological databases and geological maps could not be used at the European level due to differences in approach between European countries; however, it was possible to use certain specific information, such as for calcareous soils.

It is generally assumed that to provide for the adequate protection of biodiversity, a specified area of land in any country should be designated; thus, in the convention on biological diversity (CBD) 10% is mentioned as a minimum area of the land that should be in protected areas per country. This figure is, however, a political construct and its effectiveness for biodiversity conservation has not been proven. As figures tend to live a life of their own in a policy environment, it is now set as a target in the plans for ecological networks of the German Bundesländer (Von Haaren and Reich 2006).

Land use change, infrastructure planning and climate change are important challenges for the development of effective ecological networks worldwide. International (cross-border) cooperation and renewal of national and regional strategies for biodiversity, as well as evidence of their effectiveness, is required. This presents a challenge for policy makers, land managers and planners, as well as for the research community that supports them. This is clearly the key challenge for the implementation of ecological networks as, at present, within the European Union, Norway and Switzerland around 120 regional and national governments and agencies share the responsibility for biodiversity conservation. Real ecological networks are being developed at the country or regional level, but at the European and global level there are mainly visions. In general the size of network components serves as a criterion of the network hierarchy (Mander et al. 2003). Thus, mega-scale ecological networks can be considered at global level such as the Atlantic flyways (Boere et al. 2006); and the macro-scale of ecological networks is represented by macro-regional-level plans such as PEEN (Bouwma et al. 2002; Jongman et al. 2006a), the Wildlands project (Noss 1992) or national level projects within larger countries such as Russia (Sobolev et al. 1995). Most ecological networks have been planned at the mesoscale, and these include examples such as the Cheshire ECONET (http://www.cheshire.gov.uk/SREP/NHE_Econet_index.htm) and the Dutch Ecological Network (Jongman et al. 2006a). The most detailed analyses and implementation schemes have been undertaken at a microscale, for example increasing the accessibility of streams for Salmonid fish (see http://www.tweed foundation.org.uk) or adapting forest management to prevent fragmentation (Harris 1984).

PEEN does fulfil a role in developing a vision for coherence in natural habitats for Europe, The Convention on Migratory Species (CMS) aims to conserve migratory species throughout their range. One of the agreements under the aegis of the CMS focuses on 'African–Eurasian Migrant Waterbirds'. The flyways of birds as a whole must be considered as ecological networks linking Siberian, European and African wetlands. Flyways are defined as: the entire range of a migratory bird species (or groups of related species or distinct populations of a single species) through which it moves on an annual basis from the breeding grounds to non-breeding areas, including intermediate resting and feeding places as well as the area within which the birds migrate (Boere et al. 2006). This links Siberian and Greenland habitats to those in Western Europe and Africa and, in this way, emphasizes the importance of coherency in European nature. PEEN gives that coherency a territorial basis.

At the pan-European level, the convention on the conservation of European wildlife and natural habitats (Bern convention, adopted in 1979) binds contracting parties to the protection of habitats and species of European concern and promotes cooperation between countries for the protection of migratory species. The recommendation, adopted within the convention, on the conservation of natural areas outside protected areas specifically addresses these issues (Recommendation 25, adopted in 1991). It encourages the conservation and, where necessary, the restoration of ecological corridors, habitat types and landscape features that are important for wildlife conservation.

Connectivity can have several forms. It can be flyways as for migratory birds including stepping stones, but also terrestrial or river corridors. The most obvious terrestrial corridors are forest corridors, but they can also exist as wetland/river related corridors or mountain corridors.

The Species and Habitats Directive and the Birds Directive form the main legal framework for protecting nature and biodiversity in the EU; together they implement some of the international requirements outlined above, including the Bern convention (Commission of the European Communities 2007). Article 3 of the Habitats Directive states that "where they consider it necessary, member states shall endeavour to improve the ecological coherence of Natura 2000 by maintaining, and where appropriate

developing, features of the landscape which are of major importance for wild fauna and flora, as referred to in Article 10".

Connectivity is considered a task of national or regional competent authorities. It is recognised that the implementation of connectivity measures may be constrained by the lack of detailed knowledge of the ecological requirements of species and habitats. Article 18 of the Habitats Directive therefore calls for research and exchange of information. It specifically states that: "Particular attention shall be paid to scientific work necessary for the implementation of Articles 3 and 10, and transboundary co-operative research between member states shall be encouraged". Conservation actions under other EU legislation may also help to deliver connectivity measures required under the Birds and Habitats Directives. In particular, the Water Framework Directive (WFD) includes measures, such as the development of river basin management plans that will help to maintain and restore connectivity in the wider environment (Commission of the European Communities 2007). However, this also means that no authority has the responsibility for continental European corridors. Their development depends solely on the willingness of countries and regions to cooperate. This is not an effective approach as countries have an inside focus and there is no incentive for European cooperation. National and regional ecological networks are always defined and constructed within a complex interaction of specific political, social, economic, and natural conditions resulting in specific cultural traditions. Thus, perceptions of nature and interpretations of the same words differ across borders. The key is therefore to focus on interactions that might occur between regions, levels, hierarchies, organisations, NGOs, and departments. A European initiative is needed for the implementation ecological connectivity at the European level as national initiatives will only cross one border and do not have a European view.

A further complication of present conservation policy is that, although the EU Habitats Directive recognises that priority habitats and species need to be conserved, it does not provide any accommodation for the changes that can take place to ecosystems over time, through succession and inherent ecosystem dynamics (Evans 2006), and does not give guidelines for the design of ecological corridors. Some research

has been done on how species respond to the cumulative effects of land use and climate change (Devictor et al. 2008). Site-based conservation strategies, whether local or linked to the Natura 2000 network, may not be written to provide a response to such challenges. A shifting climate could result in species extinctions within designated areas or movement of species populations towards sites not optimally designed for the delivery of conservation objectives or within other countries. Well designed ecological corridors are therefore also required for the ecological network of Europe and the first studies have been carried out (Vos et al. 2008).

Ecological corridors can be designed or make use of existing landscape structures. However, proof is needed that these structures might function as such. For many centuries transhumance has existed in Europe as part of the agricultural system (Bunce et al. 2004). For Spain this has resulted in a network of north–south drove roads (Cañadas), hundreds of kilometres in length, which have been functioning as corridors for species and propagules (Manzano et al. 2005). In the framework of the PEEN-WE project a study has been carried out on the role of the Cañadas as north–south corridors, but so far no conclusions could be drawn in relation to their actual function as their condition is unknown (Bunce et al. 2006). Part are still functioning, part have changed their function. They have therefore not been included.

Corridors are being developed at the national level and terrestrial ecological corridors at the European level only exist at the conceptual level of PEEN. Ecological corridors are being developed for national purposes (Fig. 6). Initiatives however do exist to coordinate within countries (between regions) and between countries; as is evident from the outcomes of the Vilm meeting (Ssymank et al. 2005) and the Bialowieza meeting (Jedrzejewski and Jedrzejewski 2008) which convened in order to explore such issues.

The different levels of implementation of ecological networks imply that data requirements are different and that different parties are involved as stakeholders. For ecological networks to be implemented the inclusion of the right stakeholders at the right level is therefore essential. For the international, European level agreements equivalent to those for flyways do not yet exist, but they are needed. Success in biodiversity conservation and sustainable development requires not only that a diverse range of planning initiatives should be developed for the design and management, in this case specifically of ecological networks, but also that a range of stakeholders and land use and management interests should be involved.

Conclusion

The PEEN project was successful in reaching its goal to promote the idea of a pan-European vision of biodiversity conservation through a European ecological network. However, there are three important challenges for the further development of a coherent ecological network. Knowledge transfer is needed as well as new knowledge especially in relation to the impact of changing environmental and land use conditions on species and habitats in the wider countryside. Climate and global change will affect the patterns of many ecological and other relationships in the landscape, potentially leading to a level of complexity that may prove intractable and difficult to resolve. Research on changing population patterns in relation to landscape permeability should be directed towards the provision of essential knowledge needed for the limitation and prevention of irreversible damage, adaptation and mitigation measures. In the present situation, where countries are pursuing national initiatives at the expense of international and cross boundary cooperation, the major problem is that European ecological corridors are not being developed; a situation that is only exacerbated because there is presently no responsible institution or coordination mechanism in place. That means that coherence between countries and regions is hard to realise in practice.

Developing connectivity is one of the recommendations of the CBD Conference of Parties in Nagoya (Japan) in October 2010. Ecological networks need to be developed at the field and regional scales, and at the national and trans-national scales. Monitoring habitat diversity, and not just connectivity, is a key element in any biodiversity strategy for agricultural landscapes. Quantifying the economic benefits of ecological networks and making them explicit through interdisciplinary research and integrated long-term research on the social, economic and ecological mechanisms that maintain biodiversity and its ecological services is a clear necessity.

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