Comparative analysis of formulation techniques for national and regional ecological networks

As part of its mission to assist the Ecology ministry in setting up the National ecological network, Cemagref carried out a comparative analysis on network formulation methods to assist in the establishment of national guidelines. This article presents the salient points.

Efforts to counter biodiversity loss became a well publicised issue on the international level during the Earth summit in Rio in 1992. In France, the issue was addressed by the national strategy for biodiversity in 2004 (Ministère de l'Écologie, de l'Énergie,du Développement durable et de l'Aménagement du Territoire, 2004). The strategy signalled recognition of the problem by France and its commitment on the international level, notably via the Convention on biological diversity. French society as a whole is aware of the issue that was discussed during the Grenelle environmental meetings in 2007. One of the major causes of biodiversity loss is the destruction of habitats and the resulting ecosystem fragmentation. To reduce fragmentation, the Biodiversity group during the Grenelle meetings recommended creating a national ecological network.

The development of urbanisation, linear infrastructure (roads, etc.) and natural-resource management techniques that are harmful to biodiversity has led to a significant reduction in the surface area of natural habitats and their fragmentation. The latter increases the difficulty for species to move from one habitat to another. Confinement of populations to insufficiently large sites leads to inbreeding and sensitivity to disturbances (high predation, disease, lack of food, unfavourable weather, etc.) that can result in their local extinction. Isolation of a species' habitat means it cannot be recolonised. It follows that maintaining the capacity of a species to move is necessary to preserve populations. The approach to environmental protection based on preserved "islands" has consequently been integrated in the vaster project of an "ecological network" comprising the islands, corresponding to core areas, and the corridors linking them.

The Pan-European biological and landscape diversity strategy (PEBLDS, 1995) is one of the first international documents to clearly present the concept of ecological networks. Its stated goal is to create the Pan-European ecological network (PEEN). Many European countries have already launched procedures to set up an ecological network. At the end of the 1990s in France, the first ecological-network projects were initiated by various regions, departments and communal structures.

Grenelle and a positive political context

During the Grenelle environmental meetings, an operational committee (COMOP TVB) was set up to discuss how to create ecological networks in France. The Grenelle II law establishes a three-level system.

• COMOP TVB sets national guidelines for preserving and restoring ecological continuity. The guidelines are contained in a framework document comprising two guides.

• Regional ecological-continuity plans (SRCE) lay out and map the ecological network on the regional scale, in compliance with the national guidelines.

• Towns and intercommunal structures must take the SRCE into account in their zoning documents.

During the work by COMOP TVB, the Ecology ministry asked Cemagref to coordinate the drafting of the framework document titled *National guidelines for preserving and restoring ecological continuity*. The National museum of natural history and Onema (National agency for water and aquatic environments) were also invited to participate, thus widening the available competencies and enhancing the discussions. The framework document comprises two guides (plus an additional guide to assist State services in incorporating ecological continuity in national linear transport-infrastructure projects, that was drafted by Cemagref, the Research department for transportation and roads, and the Ecology ministry).

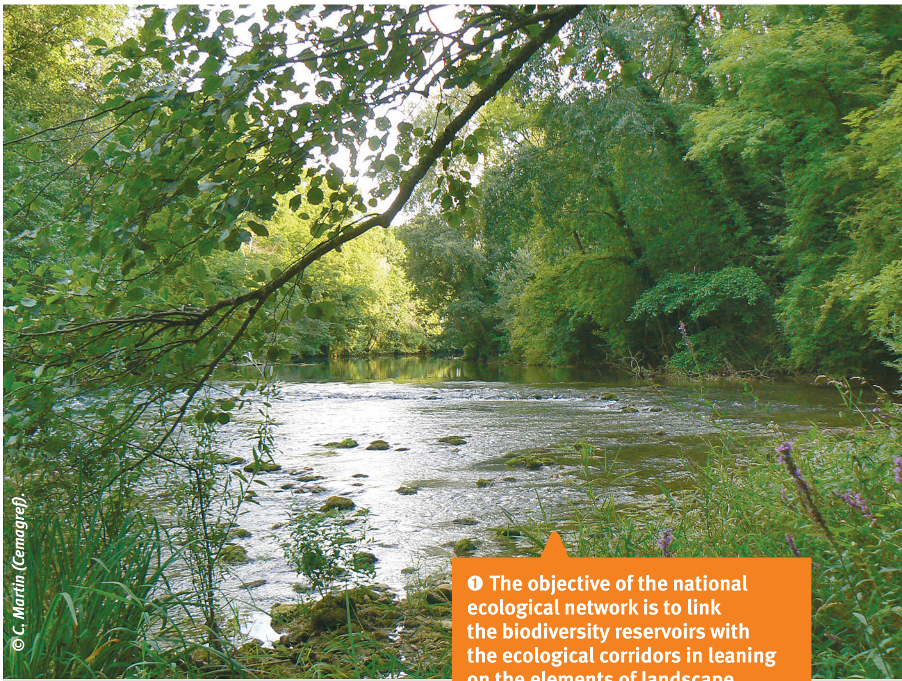
• The first guide is intended for a large audience (elected officials, technicians, stakeholders, etc.). It presents the basic principles and issues of ecological networks as well as the strategic decisions taken to preserve and restore ecological continuities.

• The second is more for technicians working for the State services and the regions on drafting the SRCEs. It presents the national criteria intended to maintain consistency that the regions must observe in drafting their SRCEs, makes recommendations on methods for regions that have not yet launched the ecological-network procedure and a number of suggestions on SRCE implementation (contracts, regulations, real-estate issues, etc.). In that some regions have already prepared their ecological-network project, it was decided that the guide should not impose a single method for all regions. The national consistency criteria are the only mandatory element in the guide. The other elements are recommendations.

There are a number of approaches and methods to formulate ecological networks. There is no "absolute" scientific certainty or "miracle" method in preparing an ecological network, on the contrary, research on the topic is fairly recent. Given this context, Cemagref was asked to carry out a comparative analysis on ecological-network design methods to take advantage of the experience gained by pilot projects, prior to drafting recommendations for the methods guide. The analysis closely examined eight regional and national projects, in France and Europe. It presents the criteria and methods used to identify the main components in ecological networks.

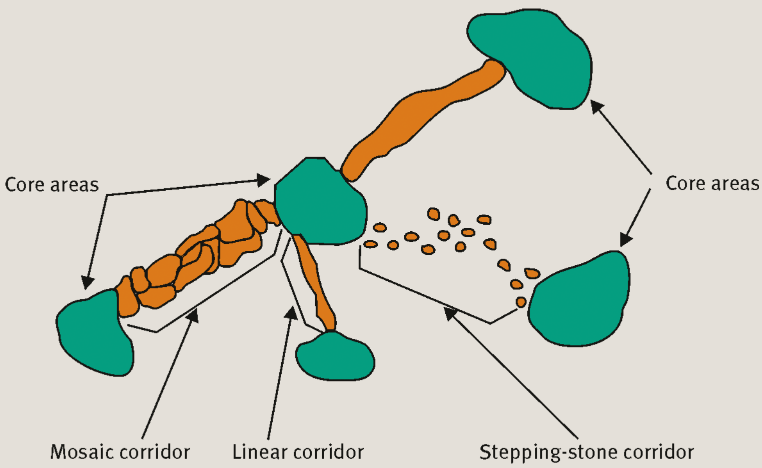
What are ecological networks?

Ecological networks are generally understood to comprise three elements. The terms core area and ecological corridors are used primarily for land, but also for wetland environments (see figure ❶). Rivers are the third element (see photo ❶). In some ecological networks, there is a fourth element called a transition zone intended to protect the core areas and corridors from potentially harmful external influences. It is these three elements taken together, forming the mesh of areas and environments making up an ecological network, that constitute ecological continuities as per the terms of article L. 371-1 and following in the French Environmental code.



❶ The objective of the national ecological network is to link the biodiversity reservoirs with the ecological corridors in leaning on the elements of landscape as edges, talus, valleys.

❶ **Examples of network elements, core areas and types of land corridors.**



Source : Cemagref, according to Bennett 1991.

It is in the core areas that biodiversity, in both its remarkable and ordinary forms, is the richest and best represented. The indispensable conditions exist for its preservation and functioning. Species can live their entire life cycle, including feeding, reproduction and rest, and the natural habitats function correctly. The core areas effectively serve as reservoirs from which the species disperse or as zones grouping environments of high value.

An ecological corridor links the core areas and serves as a means used by fauna and flora to move. This functional link between ecosystems and the habitats of a species enables its dispersal and migration.

Rivers comprise both the core areas and the corridors. As natural zones, they are already covered by protection rules and commitments to restore their ecological continuity.

The wealth of ecological networks lies in the diversity of the environments present in the studied area. For each type of environment, there is a subnetwork. For example, there are forest subnetworks, wetland subnetworks, aquatic (flowing water) subnetworks, subnetworks for extensive agricultural zones, etc. and it is the set of these subnetworks that together form the overall ecological network of the area (see figure ❷).

Drafting an ecological-network guide based on prior projects

Gathering information on projects

The first step was to identify existing ecological-network projects on the regional and national scales. In view of the subsequent comparative analysis, the projects had to have already achieved a sufficient degree of progress to be selected. The minimum level of progress was deemed to be a set of maps based on an evaluation of the ecological networks. The prerequisite for maps is a work method that will be the topic of this analysis.

Even though the final goal is to propose recommendations on how to set up an ecological network on the regional level, some national projects were also selected. This is because Germany and Switzerland are forerunners in ecological networks, particularly in terms of the methods employed. Given the small number of existing projects in 2008-2009, the foreign projects were considered indispensable.

A total of eight projects were selected in the French regions of Alsace, Franche-Comté, Nord-Pas de Calais, Picardie and Rhône-Alpes, as well as in Germany, Switzerland and the Spanish Basque country.

Documental investigations were accompanied by interviews with the people in charge of the ecological-network projects to gain information not always available in the documentation.

The collected information was then placed in a table, organised by topic and project steps. Each column lists the elements of the method employed for an ecological-network project. The columns were approved by the people in charge of the network projects.

The documental research revealed that there existed documents describing the various methods used to prepare ecological-network projects, but that no comparative analysis of methods had been carried out.

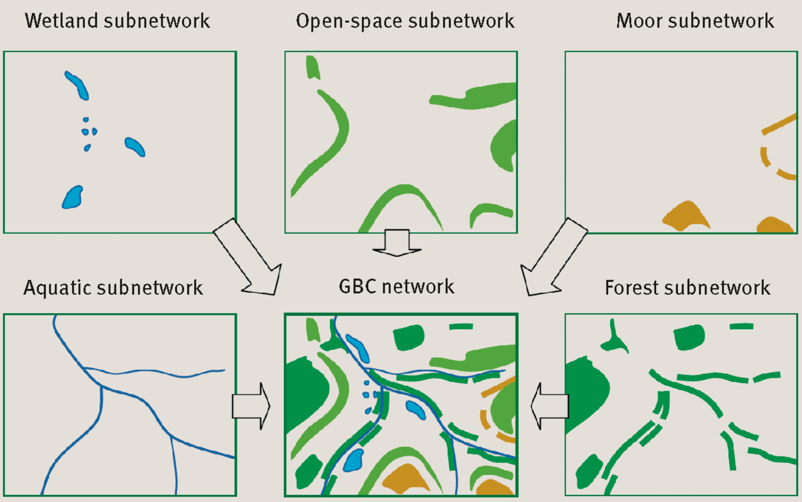
Method used for comparative analysis

The selected organisation of the information in the table made it possible to identify the topics and steps in the methods in order to compare them.

- Identification of the subnetworks. Which ones? Why?
- Identification of core areas: criteria, data used, methods, etc.
- Identification of corridors: criteria, data used, methods, selected width, etc.
- Other identified elements: continua, buffer zones, relay natural zones, etc.
- Rivers
- Targeted species
- Participative methods
- Scale
- Data used
- Monitoring / assessment

In that the elements concerning identification of the core areas and corridors are the most difficult to compare, analysis took the form of a mind map and consisted in organising and structuring the various elements of the ecological-network methods.

❷ Example of an ecological network made up of specific ecological subnetworks.



Source : Cemagref.

Differences in the methods employed

Selection of the subnetworks

In the analysed projects, the number of subnetworks varied from 3 to 10. It would appear that this great diversity is the result of decisions made following analysis of territorial characteristics and issues, and of the data used, which was occasionally a limiting factor.

Identification of core areas

Many diverse methods were used to identify the core areas and it is necessary to simplify and group the techniques in order to present them in table form (see figure ❸).

Three general types of information were used to identify core areas.

❶ **Zoning for inventory, conservation, regulatory or management purposes,** e.g. ZNIEFF ((high-value ecological zones), Natura 2000 sites, nature reserves, etc. Zoning is indicative of the natural-heritage value of a territory. Certain projects decided to base their selection exclusively on Natura 2000 sites, others included type-1 ZNIEFFs or other zoning classifications. There were major differences in the manner in which zoning was taken into account.

❷ **The presence of certain species or habitats** (heritage, remarkable, threatened, etc.). Use of the species/habitat criterion is very diverse among the projects. It depends on the availability of naturalist data, the ambitions of the managing entity, etc. Some projects use data on a small number of species, others have extensive lists of species and habitats to be taken into account.

❸ **Environmental quality,** via an assessment based on a single criterion of environmental permeability, or on a set of criteria.

The first environmental-quality analysis method concerns the potential permeability of the environment to different species or groups of species, a concept also known as landscape permeability and which serves as the basis for one of the methods to define ecological corridors. This concept deals with the ease of movement of species, which differs depending on the species and the environment in question. For a given type of environment, the common habitats of the species dependent on the environment obviously constitute the core areas for those species and they are considered the most permeable environments (also called "structural environments" and "high-potential environments").

The second analysis method for the ecological potential of environments is based on three factors, each grouping a number of criteria.

❶ An **"ecosystem-quality"** factor, comprising three criteria:

- general diversity of fauna and flora,
- presence of heritage species or habitats,
- the naturalness of the site containing the environments or its degree of conservation.

❷ An **"ecosystem-capacity"** factor, comprising two criteria:

- site surface area. If a site is deemed too small for a core area, it may, if possible, be attached to another nearby core area or to a corridor. For example, it may be considered a stepping stone in a corridor. (Concerning site size, it should be noted that certain methods rank core areas according to the relative territorial importance of the project, i.e. national, regional or local. The minimum surface area required to constitute a core area is greater for a national project and lower for a local project.),
- habitat structural complexity.

❸ An **"ecosystem-functionality"** factor, comprising three criteria:

- proximity of surrounding core areas. A site near other core areas likely offers more exchange possibilities and its value in terms of biodiversity is greater,
- particular use of a site, e.g. reproduction colonies, feeding grounds, rest areas, etc.

It should be noted that in all methods, species are taken into account either directly, due to their presence, or implicitly, via the protection zoning or via the species used to define the permeability gradient of the environment.

Identification of corridors

Numerous constraints (size of study area, access to field data, available means and study time limits) generally make it difficult to carry out in-depth identification of the ecological corridors on the basis of observations checked in the field. On the regional and higher levels, the identified corridors linking core areas are often shown as double-headed arrows or as loosely defined, relatively large areas called ecological-connection zones. Identification is carried out using, often in conjunction, different techniques and approaches to analyse the natural and artificial ecological continuities and discontinuities of a territory (see figure ❹).

Analysis of ecological continuities

Ecological continuities are analysed in each subnetwork using one of three methods, visual interpretation, dilation-erosion and permeability analysis, where the last two call on GIS (geographical information system) techniques.

❸ Summary of the information used to identify core areas in the analysed projects.

Core areas	Zoning for inventory / regulatory purposes	Presence of species and/ or habitats	Environmental quality – Environmental permeability (EP)	Environmental quality – or Multi-criteria analysis (MCA)
Alsace	✓			✓
Nord-Pas-de-Calais	✓	✓		
Franche-Comté	✓	✓	✓	
Pays basque espagnol	✓	✓		
Picardie		✓		✓
Germany		✓	✓	
Switzerland		✓	✓	
Rhône-Alpes				

❹ Summary of elements in the methods used to identify corridors in the studied projects.

Analysis of ecological continuities: Visual interpretation (VI) or Dilation-erosion (DE) or Environmental permeability (EP) + Conflict analysis between ecological continuity and elements of fragmentation (roads, urban areas, railroads, etc.) + (option) Expert knowledge: Opinion or Field

Corridors	VI	DE	EP	Conflict analysis	Opinion	Field
Alsace	✓			✓		
Nord-Pas-de-Calais	✓			✓	✓	
Franche-Comté			✓	✓	✓	
Pays basque espagnol			✓	✓		
Picardie		✓		✓	✓	
Germany		✓		✓		
Switzerland			✓	✓		✓
Rhône-Alpes			✓	✓	✓	

❶ **Visual interpretation.** Ecological continuities are identified using photo interpretation of aerial photos and/or land-use maps. The most direct paths linking two separate natural areas are "manually" defined and plotted, whereby the path is adjusted to take into account land use.

❷ **Dilation-erosion processing.** This technique calls on GIS tools to "automate" analysis of the distances between two natural areas and thus reveal the most direct paths linking the areas. This technique, developed in the framework of mathematical morphology where it is also known as morphological closing, is applied to each subnetwork in two steps (see figure ❺) :

- Patches in the studied subnetwork are "dilated" with a buffer whose width is set arbitrarily or corresponds to the common dispersal distance of a given species. During this step, the buffers of some patches touch and merge, thus signalling a potential corridor whose length is at most twice the selected dilation width.
- The dilation step may be followed with an erosion (or contraction) step equal in distance to the dilation, after which the potential connection zones between patches appear. All the zones in the dilation buffer that do not serve to connect two patches are "deleted".

❸ **Analysis of environmental permeability to movement by target species groups.** During movement from one point to another, a target species successively encounters different environments whose permeability determines the ease of movement. For a given subnetwork, one or more (target) species are selected and permeability coefficients are assigned to the environments that they are likely to move through. On the basis of the patches in the subnetwork, calculations using GIS data define the potential movement zone of the target species, called the "continuum". Practically speaking, a continuum is often made up of several spots requiring corridors to link them.

Width of corridors

Analysis of the various projects reveals a lack of precise information on corridor widths. On the regional and national levels, ecological corridors are generally not precisely defined. Projects use either double-headed arrows as a minimal representation of corridors or loosely defined, relatively large areas called ecological-connection zones. Very large corridors are occasionally called "liaison areas" (Germany, Spanish Basque country). Generally speaking in these zones, connections are a possibility and there are plans for efforts to encourage use by a maximum number of species. In the studied projects, lower echelon local governments are generally requested to determine the precise location of corridors. It should be noted that ecological networks are multi-scalar, with a national component (regional ecological continuities having supra-regional value), a true regional component and one or two more local network echelons. These local networks are fundamental in that they irrigate local landscapes and provide for connection needs on the local scale, while also connecting to higher-echelon networks which enable movement over longer distances.

Franche-Comté is the only region stipulating a width (linear or areal) for corridors which must be at least 100 metres wide in subnetworks of thermophilous and wetland environments and extensive-agriculture zones, and at least 200 metres wide for forest corridors.

Conflict analysis

Each of the three ecological-continuity analysis methods presented above is coupled with an analysis of the elements of fragmentation corresponding to either natural discontinuities (wide rivers, cliffs, etc.) or anthropogenic discontinuities (urbanisation, linear transportation infrastructure, etc.). Confronting ecological continuities with fragmentation elements is the means to analyse their functions and identify the areas of conflict. These areas correspond to the precise meeting points between networks fragmenting the territory (roads, railroads, etc.) and the main ecological continuities that exist or must be recreated. Areas of conflict are sometimes ranked according to their level of priority.

Expert knowledge

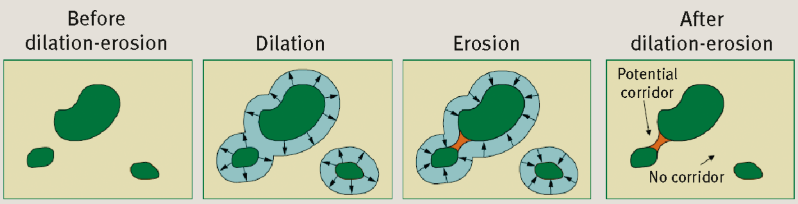
Most often, the maps produced by the previous steps are submitted to naturalists or regional managers who refine, correct, complete and validate the ecological-continuity maps based on their knowledge of the field. Only the Swiss project carried out additional field inventories to confirm the corridor maps or obtain more precise data, particularly in the sectors where fewer naturalist data were available.

Other identified elements

Some projects identified other elements, in addition to corridors and core areas.

- Liaison or staging zones (Spanish Basque country). These are natural environments traversed by corridors having ecological value certified by an inventory.
- Buffer zones (Spanish Basque country). Predominantly agricultural or agroforestry zones located around corridors and core areas. Buffer zones are almost systematically shown on the theoretical diagrams for ecological networks, but on the national and regional scales, only the Spanish Basque country project identified such zones.
- Restoration zones (Spanish Basque country). Degraded zones that must be restored to consolidate connections.
- Relay natural zones (Nord-Pas de Calais). Areas having vegetation considered useful for corridor "stepping stones", but for which there is no information on their biological and ecological characteristics.

❺ Steps in dilation-erosion processing (source : Cemagref**).**



NB : For certain projects, it was decided to use only the dilation step.

- Core areas requiring confirmation (Nord-Pas de Calais). These areas have interesting biological and ecological characteristics, but do not yet warrant inclusion as core areas. Additional inventory work is required to determine their status.
- Extension zones (Switzerland, Rhône-Alpes, Franche-Comté). Environments that are considered attractive, but infrequently used by fauna.

Rivers

Identification techniques for rivers included in ecological networks are poorly developed in all the studied projects. Though the main hydrographic network is indicated on ecological-network maps, the issues surrounding river ecological continuity are not discussed or shown on maps, whereas problem zones for ecological continuity in land environments are often indicated.

Scale

For a majority of the regional projects studied, the working scale is 1/25 000. Scales for the final, summary maps vary from 1/100 000 to 1/250 000, again for the regional projects.

Monitoring / assessment

There is very little information on monitoring and assessing ecological networks in the studied projects. Only the Alsace region indicted that it intends to set up two types of monitoring.

- Quantitative monitoring of habitats by analysing changes in land use, via the drafting of maps every five years and calculation of indicators, e.g. average surface areas, natural areas, fragmentation, etc.
- Qualitative monitoring by analysing changes in the population of indicator species. The species are selected for each major type of environment as a function of their capacity to serve as bioindicators on the operation of ecological networks and based on their overall patrimonial value.

Conclusion : An issue of national consistency

Analysis of regional and national ecological-network projects revealed that the methods employed comprise a small number of elements and steps, each having a certain number of variations and options. Decisions in terms of the method were made depending on territorial issues, the overall goals of the managing entities and on the available data. In the context of efforts to formulate guidelines for the National ecological network, the above observations justified not imposing a single method. The selected approach consisted of setting up national criteria to maintain consistency, occasionally adopting, with adaptations, certain variations or options encountered during the comparative analysis (e.g. the criterion for zoning based on inventories or labels, or the criterion for "ecological-network decisive" species and habitats (COMOP, 2010b). ■

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