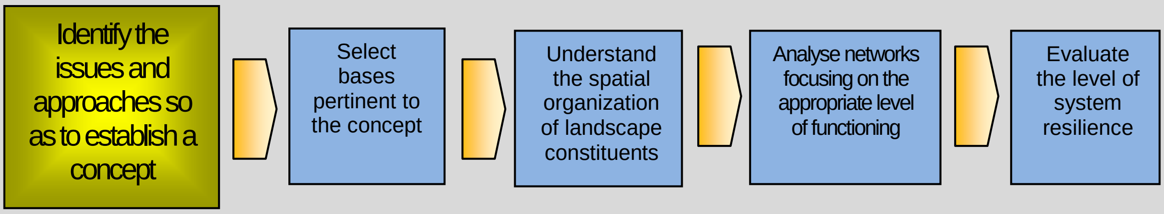
CHAPTER I

Introduction



Summary

The overall goal of the ECONNECT project is to establish a network of protected areas at the scale of the whole alpine regions and with the framework of the Alpine Convention.

The purpose of this methodological guide is to present the raft of basic methodologies of the "ecological network" tool that has been developed in practical application over the last ten years or more in a number of different contexts in Switzerland and France. The purpose is to share the knowledge acquired about the networking of protected areas with a view to its subsequent application in pilot zones throughout the alpine region.

As an introduction to the presentation of the approach, it is necessary to:

- *Explain the origins of the eco-systemic understanding of landscapes and of the exploitation of their resources — as described by the Conference of Signatories to the Convention on Biodiversity;*
- *To situate the various approaches already in use in Europe in an attempt to counter the problem of increasing loss of biodiversity.*

Regarding ecological networks, the experience of the one established in the French department of the Isère was the first in terms of its global, progressive and anticipatory approach. The Isère network has, over the last ten years, allowed the development of a number of local and regional application projects. It provides an example of a pragmatic implementation of the national strategy for the protection of biodiversity. It is, moreover, also coherent at the international scale, inasmuch as it contributes reliably to the three pillars of the European strategy for landscape and biological diversity comprising the NATURA 2000 network, the ESMERALD network and the pan-European ecological network.

This notwithstanding, the method remains uniquely innovative in its approach, inasmuch as it postulates that it is the pre-existence of a global ecological network — much of whose substance is contained in what are termed "ordinary" landscape elements, which, properly managed, must provide for the needs of strategic natural networks, which are termed "remarkable".

The challenge obviously lies in the ability to propose a pertinent analytical tool that is sufficiently convivial and progressive to be adopted for use.

1.1 The ECONNECT Project

The international ECONNECT[1] project is financed by the European Union within the framework of the INTERREG programme for the alpine region. It aims to establish a wide alpine ecological network. The six alpine nations came together in association with the goal of promoting a proactive approach to the conservation of the common alpine heritage. The ECONNECT project has been operational since September 2008 and will continue until August 2011. Its activities contribute to the implementation of the Alpine Convention (Art. 12 of the protocol on natural preservation) that the signatories have undertaken to uphold in accordance with international law.

Deploying an **integrated, combined and sectorial approach to the protection of the biodiversity** of the ecological continuum of the alpine region constitutes the project's principal objective. The effect of the need to overcome physical and institutional barriers with regard to cross-border needs should serve to increase the degree of ecological connectivity.

As a result, the project aims to achieve the following goals:

- To harmonize in a shared vocabulary all geographical and biological data;
- Leveraging the results of recorded research, to build up a methodological and operational corpus for the use of all the participants in the management of biodiversity throughout the alpine region;
- To define useful connection corridors within and throughout the alpine region.

A number of working groups were set up to deal with the broad themes of the project's implementation. The concept of six pilot sites employing the prescribed methodological approaches and unified data should serve to implement those actions aimed at improving, restoring or creating ecological connectivity.

A notable role of the "internal and external knowledge transfer in the alpine region" group is to furnish information necessary to a common understanding of the project's objectives by means of the dissemination of all the information acquired. It is as part of this function that the creation of a methodological guide to the elaboration of a natural heritage management tool based on the mapping of hierarchically organized ecological networks is intended to serve. Such a tool has already been experimented and developed over a period of ten years in the French ECONNECT pilot region, that of the department of the Isère.

1.2 The Guide's Objectives

The objectives set for the guide are to furnish the theoretical bases to an eco-systemic approach to natural areas, to furnish a detailed description of the methods employed, and to furnish a comprehensive account of what has been learned from the implementation of the concept in Switzerland and in the Isère.

This methodological guide brings together — in the form of reports or references — all the scientific principles able to serve as a basis for the modelling of natural eco-systemic infrastructures in the field. It also provides the technical approaches — especially cartographic approaches — that were employed to establish the real ecological interactions, or simulations of those interactions, of a particular landscape.

Each stage of the approach is illustrated in the guide by examples of the solutions applied according to standardized or particular situations.

The proposed approach is the result of a long process of experiment in application. This has allowed the cartographical and analytical methods described in the guide to be optimized. The modelling work is based on the use of GiS and further leverages the development of numerous measurable criteria, which should serve to allow the evaluation of the roles of three fundamental factors of the potential ecological value of the spatial unit under consideration. The eco-systemic model that results is progressive in terms of quality of the results obtained and of the new criteria that can be integrated into the system.

[1] For more information, go to: www.econnectproject.eu

Box 1

12 Principles of the Eco-systemic Approach

Extract of decision V/6 of the Conference of the Signatories to the Convention on Biological Diversity, Kuala Lumpur, February 2004 [2]

Principle 1: Management objectives for land, water and biological resources are a matter of societal choice.

Principle 2: Such management should be decentralized and thus brought as close as possible to its object.

Principle 3: Managers of ecosystems should consider the actual or potential effects of their activities on adjacent or other ecosystems.

Principle 4: Given the potential benefits of management, it is important that ecosystems should be understood within an economic context.

Any programme should:

a) Reduce market distortions that negatively influence biological diversity;

b) Harmonise measures of encouragement aimed at promoting the conservation and sustainable use of biological diversity;

c) Wherever possible, integrate costs and benefits within the given managed ecosystem.

Principle 5: The conservation of the **structure and dynamics of ecosystems,** so as to preserve the services they provide should be a principal objective of an eco-systemic approach.

Principle 6: **Management of ecosystems** should be **achieved within the limits of their dynamics**.

Principle 7: The eco-systemic approach should only be applied according to appropriate scales.

Principle 8: Given the timescales and the variability of overlaps characteristic of ecological processes, ecosystem management should always **fix long-term objectives**.

Principle 9: All management should incorporate the fact that change is inevitable.

Principle 10: The eco-systemic approach should always seek the appropriate balance between the conservation and the utilization of biological diversity.

Principle 11: The eco-systemic approach should hold information of all types to be pertinent, including both scientific and local knowledge, as well local knowledge, innovation and practices.

Principle 12: The eco-systemic approach should involve all sectors of society and all scientific disciplines.

The method constituted by the mapping of **"hierarchically organized ecological networks"** that is presented in this guide is based on a number of more-or-less well known theoretical principles: It will be useful for the reader to be familiar with them, so as to properly understand the relatively complex and technical approach that will be later described.

[2] For more information, go to: http://www.unep.org

1.3 The Eco-systemic Vision of Landscapes

The conservation of sites of particular interest and the conservation of the habitats of heritage species have always played a large, not to say crucial, role in the history of the protection of natural resources, both in Europe and the rest of the world. Starting more than a century ago, the majority of exceptional natural species have been designated and placed under protection. This selective strategy has often enough succeeded in avoiding the extinction of certain threatened species or the disfigurement of certain sites.

The 1992 Rio summit provided the opportunity to lay out the record of worldwide environment accounts. It notably drew attention to the catastrophic reduction in biodiversity caused at once by the general impoverishment of the environment and by the failure of an over-reductionist strategy for the management of natural spaces.

The 1995 European strategy for the protection of biodiversity and landscape constituted the starting point of a new approach to the problem based on a more global comprehension of landscape and the management of natural spaces organized as networks: the Pan-European Ecological Network, the NATURA 2000 Network and the ESMERALD Network.

Only at the Vilm Conference in 2005 did the experts of the NATURA 2000 network define the principles of ecological coherence and concordance, along with the necessity to re-establish an adequate functional connectivity.

Before that, in 2004, the conference of the signatories to the Convention on Biological Diversity (CBD) published the detailed principles for an approach by ecosystem that would be applicable to any project or development plan aiming at the sustainable management of natural heritage and biodiversity. The twelve published principles (see Box 1) allowed the stated aims of the CBD to be better understood. Accompanying commentaries have made the complementarities and synergies between the three existing environmental conventions — on desertification (CCD), biodiversity (CBD) and climate change (CCC) — more apparent. The signatory conference quite **clearly adopted the eco-systemic approach**, implying an effective taking into account of functional biological connectivity. It underlined the need to protect all biodiversity, including the ordinary, non-heritage types, along with the need for **instruments "combining the management of networks of protected areas, of biological networks and of zones excluded from these areas"**. The 2006 signatory conference further stated the urgent necessity of conserving biodiversity and notably recommended that the signatories should make environmental impact evaluation obligatory for "activities occurring in biological corridors recognized as important for ecological and evolutional processes", so as to counter the consequences of climate change.

Strategic applications of these principles resulted in propositions for methodological and cartographical approaches that differed on the bases of varying perspectives on the factors of interconnectivity and, in the final analysis, on the functioning of ecological networks. These different approaches are examined below.

1.4 Different Functional Approaches to Landscape

1.4.1 Definition of landscape elements relying on interconnection

Depending on the eco-systemic approaches to landscape employed, the elements of interconnection will vary as a function of the desired goals and notably as a function of the heritage importance of the sites to be conserved. Thus the following notions successively emerged:

- Networks of protected areas, or in need of protection, that relied on the traditional notion of the protected site or the nature reserve but which still encouraged networking by means of the proliferation of sites protected so as to gain proximity effects. The creation of physical corridors to guarantee the continuation of biological exchanges.
- Biological or ecological corridors with a view to developing the conservation or restoration of functional spaces within a landscape increasingly fragmented by the effects of urbanization and the proliferation of transport infrastructures.

- Ecological grids laid out with the aim of not destroying the principal landscape structures that allow the connectivity indispensible to the functioning of the landscape.
- Ecological networks allowing as complete an interpretation of the landscape as possible and a global vision of existing habitat ensembles generating natural activity, along with their connections allowing the continuation of biological flows.

The above-mentioned approaches can be resumed in terms of three strategic axes:

Axe 1. Select and conserve those habitats and species prioritized by the community (policy of the conservation of protected areas).

Axe 2. Indentify and conserve the spatial interconnectivity indispensible to the survival of exceptional habitats (Adjunction of priority biological corridors linking protected areas).

Axe 3. Understand and manage global landscape potentials and so generate biological diversity (Analysis of ecological networks).

Although each of these strategic approaches possesses its own programme and criteria of priority, they are in principle complementary as long as they are all articulated around the same eco-systemic vision of biological diversity, i.e. the organization of landscape in multiple, partially interactive, ecological networks.

1.4.2 The network of protected areas

Ordered by the European Union from 1995 onwards, the development of the NATURA 2000 network is based on the Birds Directive (79/409/CEE) and the Habitats Directive (92/43/CEE). In their appendices, these furnish lists of species and habitats worthy of being protected at the European scale. These benchmark habitats and species gave rise to the creation of regional inventories of sites of exceptional interest. And these inventories are periodically updated. Thus these sites are placed under the surveillance of the state, which decides on their definitive protection, their management or their disappearance in any case where conservation measures are superseded by priority development. The strict application of relative directives requires decision making based on the evaluation of possible incidences of any disturbing projects or activities. The approach also requires that direct and indirect impacts on the habitats of the species populations cited in the appendices be thoroughly examined. Further it requires that connections necessary to exchange transfers with other seasonal habitats should be taken into consideration. Several guides to implementation of incidence analysis of projects on NATURA 2000 sites have been published (European Commission 2001; IEEP 2007)

This approach remains a selective one and aims to prioritize the conservation of sites of exceptional interest selected with regard to the habitats and species listed in the appendices I and II of the 1992 “Fauna, Flora and Habitats” directive.

It should be remembered that the governing principles of NATURA 2000 also apply the ESMERALD Network agreed to by the forty-five countries signatory to the Convention concerning the conservation of European wildlife and natural milieu.

1.4.3 Biological or ecological corridors

The concept of biological corridors was proposed so as to highlight the importance of the interconnections between large natural habitats in a way that would remind us of those functional aspects present in a given landscape, functions underlined by the mechanisms of fragmentation generated by spreading urbanization and by the construction of transport infrastructures to service the ever greater volumes of automobile traffic. The publication of a map of biological corridors, whether at a regional or a local scale, thus seeks to define potential conflict zones for fauna and to define the palette of infrastructure measures that might serve to alleviate them. Switzerland has published such a map of faunal corridors as a preamble to the proposed maps of the national ecological network (Holzgang & al, 2001). The region of the Lyon conurbation has also published such a map to the 1/50’000th of ecological corridors (UrbaLyon, 2008).

Presently the approach remains selective, prioritizing information about the nexus of interconnections used by fauna and about obstacles created by the development of urbanization and transport networks. It does not, however, address the question of the maintenance of living areas for fauna and flora as a whole.

1.4.4 Green lines and green and blue lines

Green or green and blue lines often appear to constitute a compromise between the two previous approaches, inasmuch as they are generally based on the presence of the potentially useful green areas and hydrographical networks (standing water and wooded watercourses, hedgerows and wooded hedges, copses, etc.) that structure urban or agricultural spaces and which enable the reconstitution of a relatively well-connected and balanced ensemble of natural or installed areas. Generally speaking, these landscape lines are defined so as to conform to the rules of territorial planning and the needs of urban development, but also with a view to accepted ecological principles. The comprehensive identification of the various ecological networks is not necessarily a condition in the definition of these lines.

In France, it is usual to speak of green and blue lines (TVB in french) according to a definition of the term that has yet been definitively fixed. Thus the TVB application guidelines are still pending validation by the Operation Committee (COMOP).

Box 2

Definition of Key Ecological-Network Terms Applied to Green and Blue Lines*

Biodiversity reservoir: These are the areas in which biodiversity is at its richest and best represented. In them, the conditions for the maintenance and functioning of biodiversity are assembled. Thus a given species can here live out its entire life cycle (appropriate flora, feeding, reproduction, migration, resting, as well as the appropriate natural habitats to ensure its functioning). Such areas constitute either source zones or core zones from which individuals of species present in the zone can disperse, or areas that bring together milieus of particular interest or representative habitat areas. The term “biodiversity reservoir” will be employed in a practical way to designate “natural spaces and wet zones that are important for the preservation of biodiversity”, in the sense intended by article L. 371-1 of the Environment Code.

Ecological corridor: These are the routes employed by flora and fauna that link biodiversity reservoirs. These functional connections between ecosystems or the habitats of a given species, allow the dispersion and migration of the species in question. They are generally classified in three principal types:

- Linear structures: hedgerows, paths and verges, riparian woodlands, etc.;
- Stepping-stone structures: punctuation of relay spaces with refuge islands, marshes, copses, etc.;
- Matrix landscapes: landscaped-type milieu, artificial, agricultural, etc.;

Watercourses constitute both biodiversity reservoirs and corridors. Inasmuch as this is the case, protection regulations concerning both natural milieus and the need to restore ecological continuity apply to them.

Ecological continuities: Elements of the meshing of spaces or of milieus constitutive of an ecological network. In conformity with articles L. 371-1, and following, of the Environment Code (and thus with the present guide) the expression corresponds to all biodiversity reservoirs, ecological corridors and natural and artificial watercourses.

* According to guide TVB n°1, 15/12/2009

1.4.5 Ecological networks

Setting up ecological networks answers the need to visually identify the types characteristic of landscape space — where those characteristics are defined by particular ecological conditions (climatic, edaphological and anthropogenic) that function according to complex interactions to produce a particular landscape matrix. Such matrices often appear in the form of a mosaic of habitats: a mosaic whose exchange flows constitute a real system of relationships, even if these are often so diffuse as to be effectively imperceptible to human observation.

The first function of the analysis of ecological networks is to answer the need to understand existing landscapes with respect to their diversity and functioning in order to enable their management: if possible without depreciating them, and where necessary by revitalizing them. The paramount aim of the approach is, as precisely as possible, to model the structures and the functional systems of the landscape so as to place species and their habitats in their appropriate contexts.

Mapping ecological networks constitutes a basic tool with which to organize data furnished by a landscape and with which to analyze the numerous interactions generated be the relative connectivity of the different compartments that constitute that landscape. The hierarchically-organized-ecological-network method presents itself as a preparatory analytical and eco-prioritizing approach to the subsequent definition of any ecological network — whether global or partial — that may be adopted by general consensus.

The approach is materialized in a given landscape by the definition of organizational models of habitats. Properly managed, these models are able to serve as tools for the effective analysis and management of landscapes, tools with which to insure the integrated, combined and sectorial protection of natural continua in each region.

1.4.6 The Isère model of ecological networks

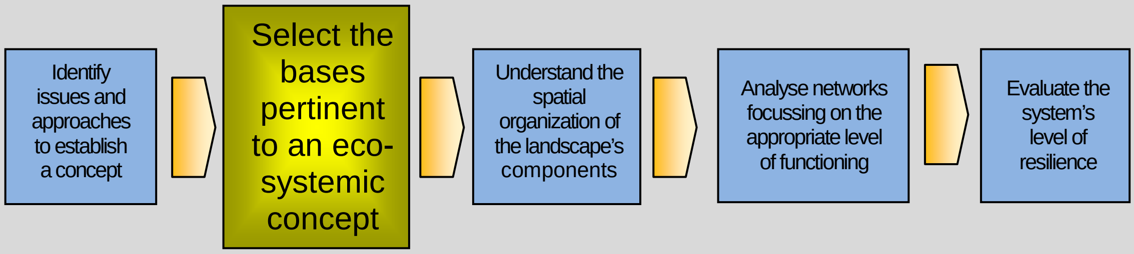
The Isère experiment into the establishment of ecological networks has taken place over a period of ten years. The experiment is innovative in a number of ways.

- The **approach is global**, because the mapping of ecological networks it produces are concerned with the synoptic identification of characteristic continua, corridors and obstacles. In the example provided by the Isère project, the precise definition of internal extension zones and nodal zones was not carried out, as the objective was to make an outline of the natural infrastructures present in the area available as quickly as possible. It is planned that the work, carried out in eight months, will serve as the basis for a programme of rehabilitations targeting the protection of the major corridors crossing urban zones and the installation of protected crossing passageways for fauna.
- It is **proactive and innovative** inasmuch as it seeks to implement empirically in the field the principles — at the time still under discussion — related to the European strategy for biological and landscape diversity and its application in the NATURA 2000 and pan-European ecological networks. At the time of the project's launch in 1999, the governing idea was to provide, as quickly as possible, a synthetic cartography of the departmental ecological network, making optimum use of extent digital data concerning terrain occupation and knowledge of natural sites.
- The approach is also **progressive**. This is because it has enabled the development of a number of subsidiary local and regional projects, which, in turn, have necessitated the development of specific methods of data collection, treatment and use, as well as the automation of digital cartography adapted to the different scales required by the particular projects in hand. These projects are outlined in Chapter 6.
- Another originality if the approach consists in its systematic application of the **"top-down, bottom-up"** principle, which servers to reinforce the initial eco-systemic models.
- Finally, **the establishment of a network of corridors is not driven by the existence of or need for conserved spaces, but rather by the pre-existence of a global ecological network that is largely made up of "ordinary" landscape elements, but which should, if correctly managed, be able to meet the needs of those strategic networks considered to be of exceptional interest.**

Thus, the hierarchically-organized-ecological-networks method, developed in Switzerland from 1995 and then applied in the Isère from 1999, perfectly corresponds to the criteria for eco-systemic approaches recently set out by the conference of signatories to the CBD and by the EU's experts committee for the development of the pan-European ecological network. Its principal strength, however, lies in its ability to provide an effective analytical and policy-making tool for the restoration and management of natural milieus.

CHAPTER II

Understanding the Eco-Systemic Functioning of Habitats



Summary

The eco-systemic landscape method is based on a progressive approach to the high levels of complexity of the interactions that function in the biosphere. These interactions are employed in the method so as to produce geo-referenced interactive models relating to landscape sectors. Thus, in a given landscape, the purpose is to account as well as possible for the distribution and the productive potential of available ecological niches, and form this to assess the survival or development probabilities of the various biocenoses as a function of the transformations generated either by human activity or by natural phenomena.

A number of principles of landscape ecology can be used to achieve this modelling of ecological networks:

- *The positive relationship that exists between the surface areas of habitats, the number of habitats, the number of species and the number of individuals present is what provides the basis for evaluating a habitat mosaic;*
- *The effects of both insularity and mosaic constitute the factors that indicate the degree of accessibility or separation between the recorded habitats;*
- *The organization of flows and modalities of propagule migration allow the definition of virtual functional spaces, which are complementary to the empirical spaces containing real habitats;*
- *The meta-populational functioning of many species combined with natural and artificial compartmentalization of the landscape allows the understanding of the often random-seeming organization of populations;*
- *The evolutionary dynamics of landscape coupled with anthropogenic disturbances allow the explanation of progressive depreciation of the environment.*

All of these known principles can be applied to establish relational models of the functioning of biocenoses.

The models used for the analysis of the ecological incidences of transport infrastructures and traffic on neighboring biocenoses, along with the cartographical simulation of the anthropogenic ecological footprint, allow — using a process of superposition — to take account of the deterioration of natural networks.

2.1 Ecological Principles Pertinent to the Eco-Systemic Approach to Landscape

The eco-systemic approach to landscape, applied in the form of a mapping of ecological networks, is the result of more than thirty years of practice in the field. That practice is the sum of numerous studies in various domains: the territorial and migratory behaviour of many species; the mapping of habitats; biotope inventories; management planning; the conception of natural re-installations; and, especially, the production of a large number of impact studies for large-scale transport-infrastructure projects, all of which have progressively fostered the development of analytical and cartographical methods founded basic notions of landscape ecology.

Many of the rules cited below are individually familiar; the originality of the approach lies in the combination of a number of simple principles in a coherent concept eco-systemic modelling to constitute an innovative tool for the mapping and evaluation of ecological networks.

2.1.1 Effect of the habitat surface area

The relative size of the surface area of a habitat plays a role both in its specific diversity and its hosting capacity for populations. The positive correlation between the number of species of birds and the surface area of available habitats is a frequently used example of this (Fig. 1). Thus, the greater the surface area, the greater the diversity. This relationship has been demonstrated through any number of studies and for many floral and faunal groups. The correlation graphs obtained show that for a linear increase in specific diversity, a logarithmic increase in the surface area of a habitat is required. The same is also true for fluvial milieus (Fig. 2).

Haila (1983) summarized the concept by demonstrating that the relationships linking “surface area, number of habitats and number of individuals” are positively correlated and that this constituted a general rule applying to all habitats (Fig.3).

It is also clear that the extent of the surface area determines the size of resident populations. So, for example, the number of nesting bird couples is a direct function of the surface area of their habitat. Studies of the populations of large-scale habitats, however, have revealed the limits of this rule, by demonstrating the effects of inter-species competition. Thus, MacArthur has posited a law of the random distribution of species in a population. The law shows that specific diversity varies in accordance with competitive aptitude (broken-stick model): in a given volume of nests (practically referred to as preferential habitat surface area), when confronted with the installation of new species, less competitive species maintain stable population levels, while the populations of more competitive species decline.

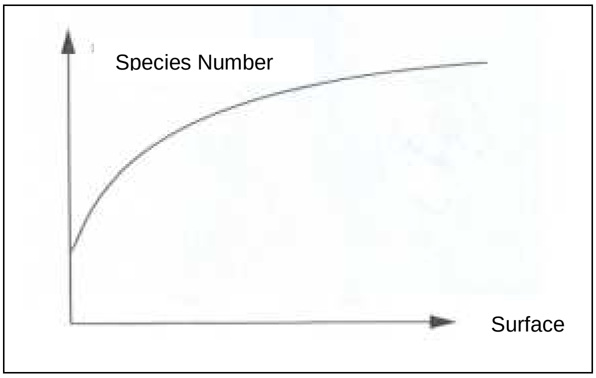


Figure 1.

Relationship between the surface areas of forest habitats and the number of species of nesting birds.

Source:
Forman & al. (1976)

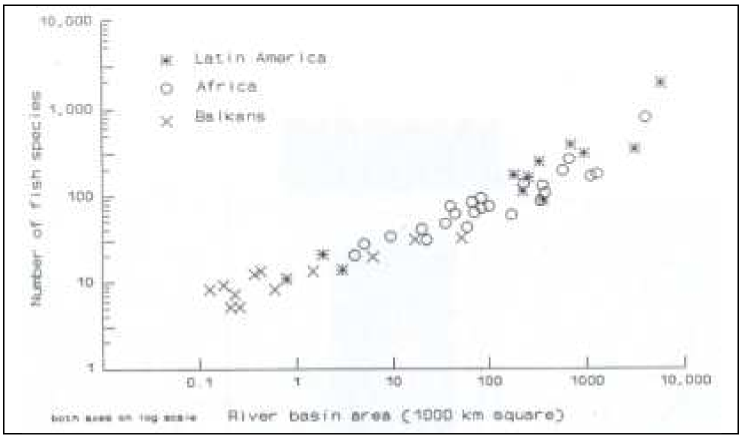


Figure 2.

Relatioship between the surface area of river basins and the number of fish species.

Source: Welcomme (1990), after Daget & Economidia, (1975)

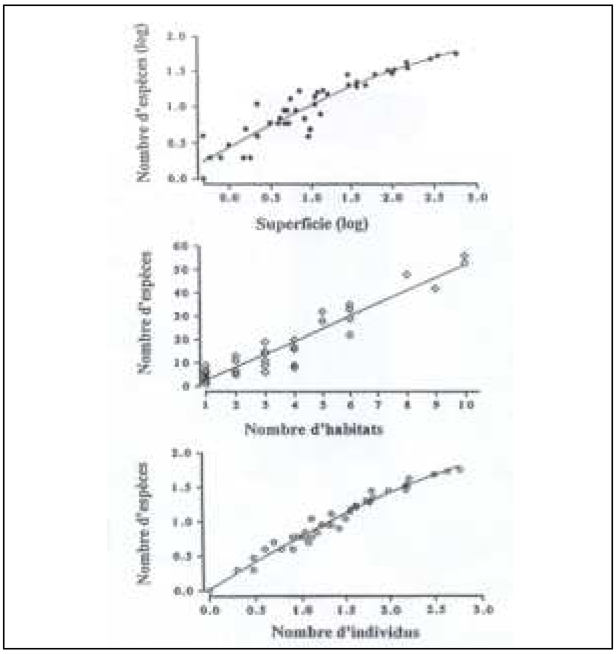


Figure 3.

Direct relationships between the surface area of a habitat, the number of species and the number of individuals. The relationships are positive not only between the surface area and the numbers of habitats, species and individuals, but also between the number of species and the number of individuals.

Source: Haila (1983)

2.1.2 The insularity effect

This effect combines the parameter of habitat surface area and distance from a reservoir zone. In the case of isolated habitats (either a real island or a continental one, i.e. one surrounded by hostile habitat types) the dynamics of species populations follows the same rules: the number of resident species is established as a result of the distance separating the habitat in question from a resource habitat playing the role of species reservoir (Fig.4).

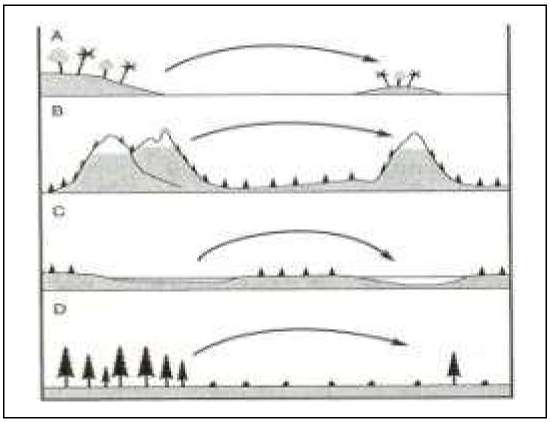


Figure 4.

Homology of the insularity criteria of true islands (A) and continental islands (B, C, D) such as isolated mountains, isolated lakes and forest islands surrounded by agriculture. In each case, the greater the intervening distance, the less the potential for exchange effects between populations.

Source: Blondel (1986), In Ramade, (1993) According to MacArthur and Wilson (1963), the index number expressing the effect is equivalent to the equilibrium state between the probabilities of colonization and extinction (Fig. 5). In every case figured above, the possibility for species exchange is lower the greater the separating distance. The rules for ascertaining the equilibrium point between immigration and extinction are as follows:

- The rate of immigration is related to the surface area of the habitat and the proximity of the habitat source. The rate will diminish as more new species install themselves, thus saturating the available ecological niches.
- The rate of extinction will be higher the smaller the habitat area.

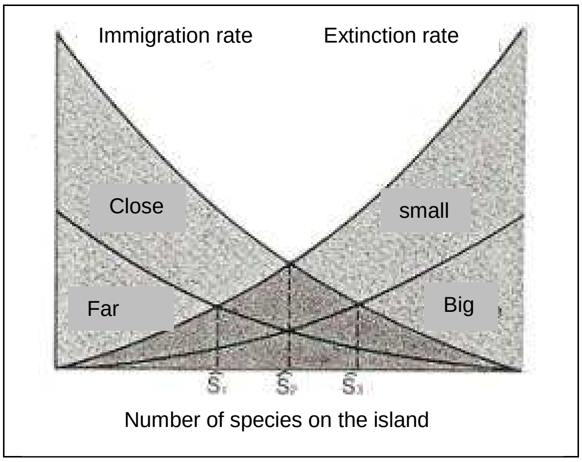


Figure 5.

MacArthur and Wilson's theory of insular populations, establishing the relationship between specific diversity, rate of immigration and rate of extinction.

Source:
MacArthur & Wilson (1963), In Ramade (1993)

2.1.3 Habitat mosaic effect

This theory was developed to counter MacArthur's island theory. It posits the fact that terrestrial habitats are always arranged as complex mosaics (Fig. 6) and that their diversity conforms to the following rules:

- A mosaic comprising large homogenous habitat areas containing a certain number of habitat types will always be less diverse in species than mosaics comprising small areas of the same habitats;
- The immigration rate is higher in mosaics of small areas than in those of large areas.

These principles are always true, but apply principally to continental habitats that are less isolated than true islands. In the latter case, the same type of biodiversity does not apply as the mosaic effect — which is the driver of biodiversity — in most cases only concerns ubiquitous and ecotonal species.

2.1.4 Distribution of inter-habitat exchange flows

Originally developed to describe the way electrical currents circulate through composite semi-conductor substrates, the **theory of information** was taken up by Godron (1966 and 1982) to describe the functional aspects of ecological systems in landscapes. It strongly supports the approaches to the ecology of landscape developed notably Baudry and Burel (1983), Phipps and Dumanski (1983) and by Baudry and Forman (1991). In this context, it is used to model the **propagule flows** circulating within a landscape (Fig. 6).

The basic principle states that moving animal propagules (dispersion, migration and exploration) only distance themselves from their original habitat after numerous precautions circumscribed by their locomotive and cognitive capabilities. And indeed, careful, empirical observation has shown that propagules do indeed, when undertaking their movements, always follow a number of simple rules of economy of energy, of safety and of ecological preference.

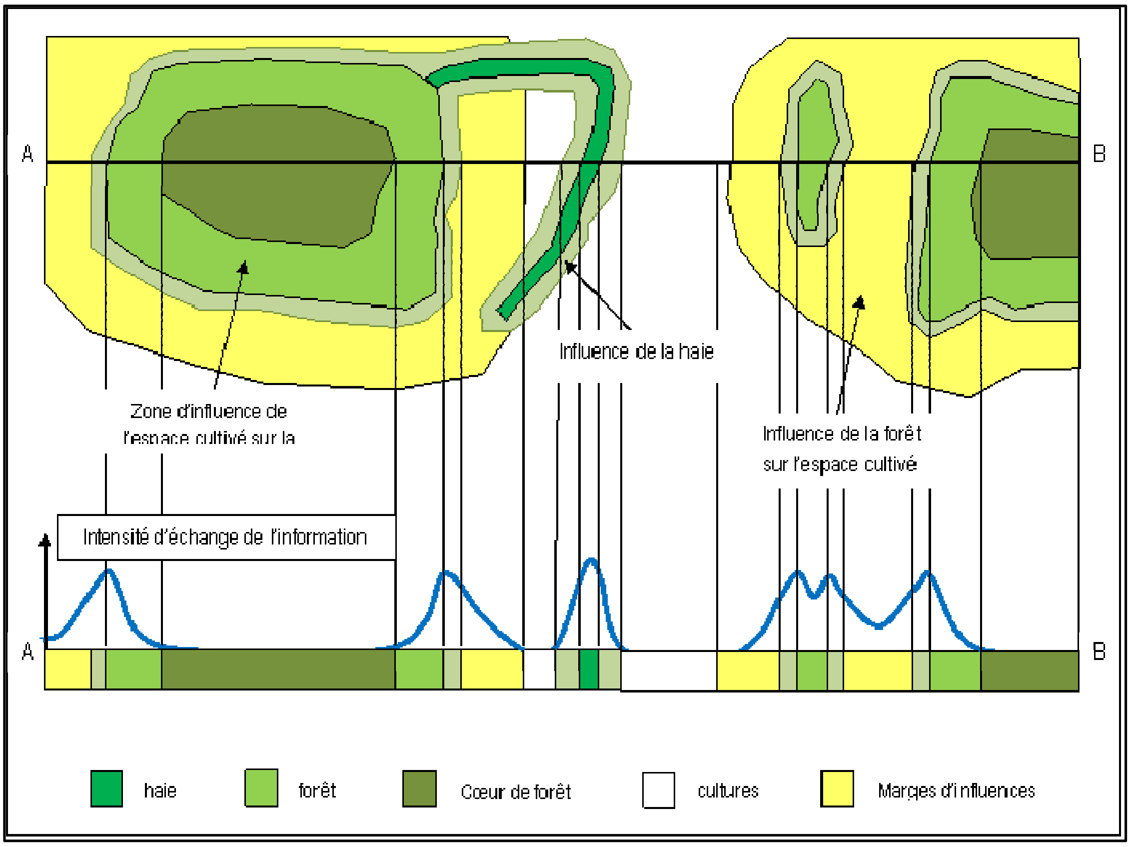


Figure 6.

Diagram of the distribution of information exchanges between the various components of a landscape. The intensity variation of exchange flows is visualized in projection on the cross-section.

Source: after Baudry and Burel (1985)

2.1.5 Percolation through a landscape matrix

Different types of animal movement need to be distinguished: daily or regular movements that serve to exploit a territory or a living area, and more-or-less long-distance seasonal or occasional movements that involve a significant change in activity zone. In the case of this latter type of movement, we are talking about migration or the colonization of new territories. Such movements are not individually organized, but, more often than not; conform to a group logic based on long-range visual bearings or a learnt knowledge of the path to follow. In this case, we speak of percolation through a landscape matrix. And the rules governing movements here are different: there is greater risk taking; the search for refuge habitats; and the alternation of waiting periods and rapid movement. The animals in question make use of well-situated guiding structures or move forward by stages over more or less favourable terrains. Movement by percolation is neither the result of chance, nor of encountered opportunities, but conforms to a selective logic of progress by trial and error, which pushes the species to use more or less the same corridors and shelters every year. From all this two criteria can be deduced:

- The variability of resistance to progress is a function of the type of milieu crossed;
- The mode of progression by the choice of the appropriate path constitutes a constraint on progression.

Even in cases of occasional dispersions, a more intimate understanding of individual animals or groups of individuals (i.e. expert knowledge based on detailed and prolonged study of their locomotive behaviour) often allows a traditional pattern of impregnation of a reduced sector of the animal's potential range-space as defined by the two above criteria to be ascertained. This particular use of space also conforms to rules of probability that can be useful in the modelling of ecological networks.

2.1.6 Functioning as meta-populations

The theory of meta-population posits a group of populations of the same species that occupies a fragmented habitat but which continue to interact with each other regularly or occasionally. This theoretical model was used by Levin (1969) to describe insect populations that constituted agricultural pests. It has been widely adopted and developed to account for numerous species submitted to the eco-landscape fragmentation of their habitats, notably by Hanski (1991) and Fahrig (1991).

The discontinuous distribution of a meta-population is caused by geographical fragmentation and by the alternation of favourable and unfavourable habitats, both of which cause the animals to take supplementary risks in their movements from one location to another (Fig. 7). Thus it is to be remarked that in areas reduced to critical size, populations that are left too isolated are condemned to extinction. The survival of a meta-population depends therefore on periodic recolonizations by dispersion, on condition that the rate of recolonization be higher than the rate of extinction.

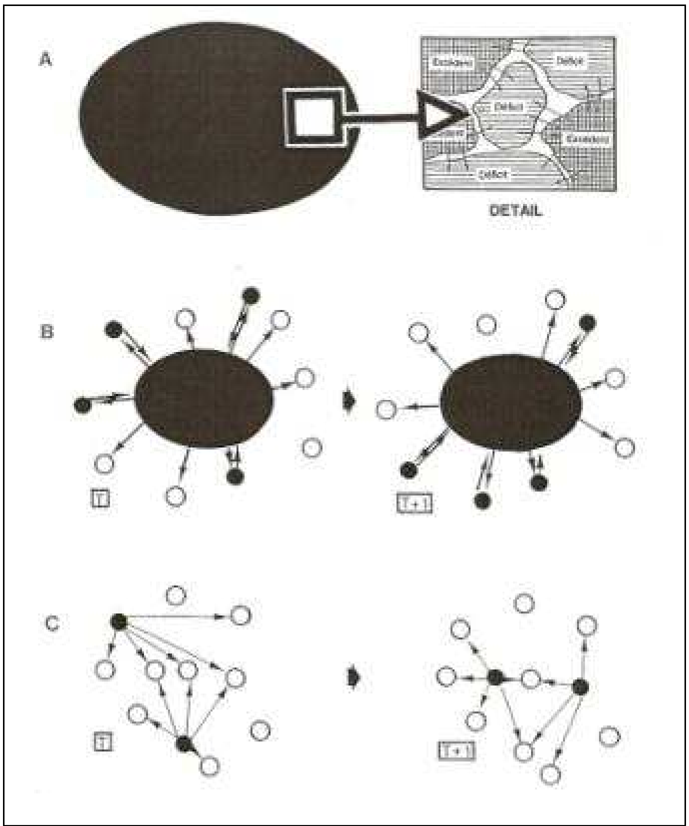


Figure 7.

Transformation stages of a compact population organized in meta-populations.

A. The population consists in a stable raft of sub-populations maintained in the same habitat by internal exchanges.
B. The meta-population is articulated around a stable core. External habitats are alternatively occupied by sub-populations.
C. The meta-population is organized around variable cores. Only favourable habitats are exploited, randomly, by sub-populations

Source:
Berthoud & Müller (1994);
After Boorman & Levitt (1973)

This mode of population distribution is very common in our transformed landscapes. A state of affairs that has given rise to numerous studies aiming to define, for every heritage species for example, the minimal size and the necessary rate of exchange to guarantee the survival of the populations studied.

Unfortunately, there is currently still an insufficient understanding of population dynamics to be able to compile catalogues of specific limiting parameters that would be useful to the survival of species.

2.1.7 Theory of hierarchy

Landscapes are the loci of a whole range of ecological phenomena, each of which operates at its pertinent spatio-temporal scale. According, notably, to Allen and Starr (1982) and Baudry & al (1991), the theory of hierarchy constitutes the appropriate conceptual framework within which to treat the whole range of ecological phenomena that take place at a number different scales of space and time.

Koestler (1967) stated that a self-evident correlation exists between spatial and temporal scales with regard to functioning speeds:

- Phenomena occurring over large spaces are much slower than those which occur at a local one;
- These processes are not connected and, as they do not share the same origins, they are relatively little interconnected. The global system can, therefore, be separated into different organizational levels (Auger & al, 1992).

A number of authorities define levels of perception and **levels of biological organization** in order to analyse and define biological populations (Long, 1974; Lebreton, 1977; Blondel, 1986). In their hierarchical organization, they generally consider the following levels of scale to constitute the significant levels of analysis: site, biotope, sector, region and biome. Further, they note that bio-ecographical processes can be considered as functions of three dimensions: time, space and change. Though they constitute separate fields of activity, the different levels of scale (distinguished above) are interdependent because of the transfers of information that occur between one level and another (cf. chap. 3.2).

Burel and Baudry (1999) rendered a schematic version of this hierarchical principle of spatio-temporal phenomena by referring to speeds of functioning (Fig. 8) and to the scales of the functional interactions of all the ecological processes involved in the spatial distribution of populations.

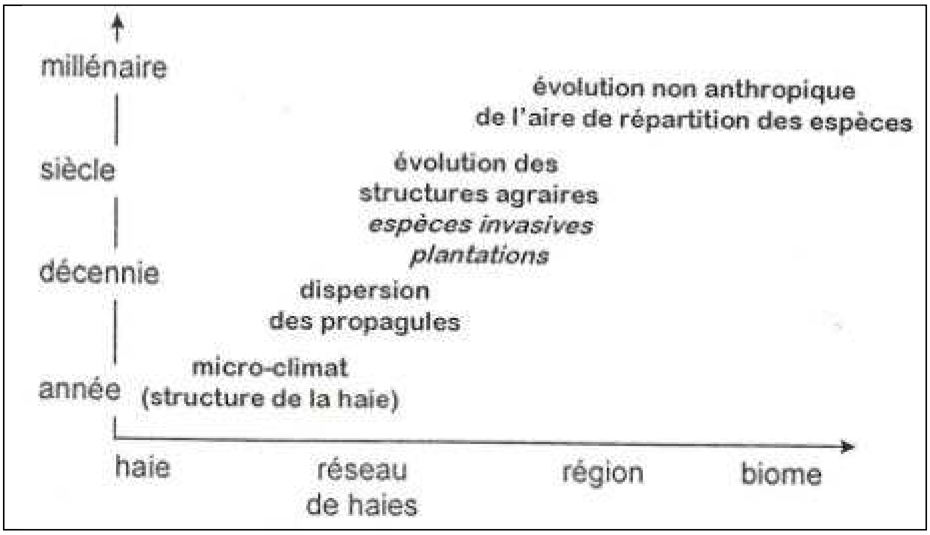


Figure 8.

The spatio-temporal scales of ecological functioning of ecological processes: processes involved in the spatial distribution of animal species.

Source: Burel & Baudry (1999)

2.1.8 Principle of interlocking of spatio-temporal levels

Starting from the recognition of progression by change of spatio-temporal scale — which correspond to different levels of biological organization — the concept of ecological networks employs the idea of interaction bands defined by variations in exchange volumes (information flows). Thus, Berthoud & al (1989) propose the use of these spatio-temporal bands of biological process operation as an information reference system having a “successively interlocking” structure which allows the importance of ecological issues to be grasped as a function of each of the different bands in question. In this case the following principle is applicable:

- **The evaluation of what is at stake at a given level of spatial scale is only possible if the global context is known: i.e. the ecological conditions pertaining to the next level upwards** (Fig. 9).

So, for example, a proper understanding of the efficiency of the marshland habitats in a given sector is only possible if there exists a global understanding of this habitat type at the regional scale. This principle becomes crucially important in the context of impact studies for development projects such as linear transport infrastructures.

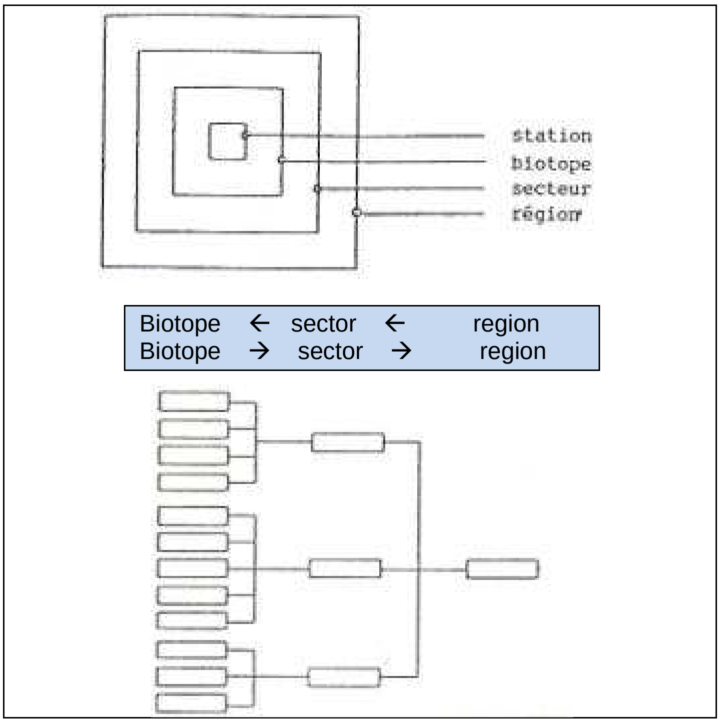


Figure 9.

Diagram of the interlocking of information as a function of functional bands.

While data gathered by sampling always informs a particular level of the biological organization, it remains interactive with other levels. Each organizational level provides data useful to a more global analysis. It is, on the other hand, an understanding of the global situation that determines the importance of a local site.

Source:
Berthoud & al. (1989)

So it is that the analysis of the fragmentation effects of a landscape — created by artificial obstacles — will necessarily involve the cartography of several different levels of scale and the creation of inventories respective of the same levels: within the zone subject the direct impacts of a given project, within the zone subject to direct and indirect impacts and within the reference zone — which contains all the landscape sectors involved.

In this case, the use of supra-local or regional ecological networks allows us to understand the global impacts of a given project and, especially, the risk that real biological discontinuities will result.

2.2 Eco-systemic Function within a Landscape

2.2.1 The progressive dynamics of landscape

Whether it be in a natural landscape or an anthropogenic one, habitats are functionally organized according to the potential allowed by spatial structures and their reciprocal ecological affinities. Thus, for example, there may exist powerful functional synergies organized around a significant geomorphological feature (e.g. a watercourse, a slope, wooded vegetation, etc.), but these synergies may also be organized as a function of tensions created by functional impediments (wooded/open milieus, dry/wet, etc.), or again by processes of levelling by uniformization of vegetation (forest, scrubland, grassland, steppe, cereal cropping, etc.). As a result, the progressive dynamics of landscape constitutes a universal and natural phenomenon to which species are adapted according to reactivity gradient that connects the action of waiting many years without any apparent development, at one end to propagating as rapidly and possible whenever conditions allow, at the other.

As they are all more-or-less able to seek new, favourable habitats, faunal and floral species are necessarily adapted to the need to manage changes in their environment. Indeed they have developed demographic strategies that predispose them to cope with change. These strategies can be roughly categorized as follows: **“K strategies”,** which generally include large-sized species whose biotic potential is limited and which are to be encountered mostly stable ecosystems, and **“r strategies”**, which, on the other hand, concern small-sized species whose biotic potential is great and which tend to populate young and rapidly evolving ecosystems. Taken globally, these two strategies are not exclusive, but imply dynamic equilibrium biased towards on or other of the two depending on the speed at which the environment is evolving.

2.2.2 Propagules dispersion flows

The individuals comprising a biocenosis and which are in a dispersion phase (colonization or dispersion) are known as propagules. Almost all plants and animals are obliged to move a certain distance so as to populate an ecologically favourable site and so develop their life cycles. These movements are usually rapid and can cover variable distances (from several to hundreds of kilometres) depending on their mode of locomotion or transport. Propagule flows are therefore considerable, although my not be perceptible to uninitiated observers.

As described by De Gennes (1990), the theory of percolation allows the description of this random phenomenon of species dispersion to be accounted for according to the saturation threshold of the ecological niche available for each species — the saturation threshold being what determines whether dispersion over distance will take place in a given landscape or not. It is therefore the interaction of two factors that drives the dispersion phenomenon: that of landscape transformation, and that of the variability of favourable habitats.

In an eco-systematic approach, global functioning of the elements of a given landscape is approached via the spatial distribution of propagule flows: this distribution being strongly influenced by specific choices.

2.2.3 Modalities of faunal movement

Several rules can be deduced from the observation of faunal movements through the natural environment:

- **The rule of the least risk (safety factor) is applicable:**
  - By using those habitats that are ecologically similar in their morphology and microclimate;
  - By staying close enough to the original habitat to render rapid return possible (safety);
  - By moving only during daily or seasonal times that are the most likely to reduce the risk of predation;
  - By expending a large amount of energy so as to be able to move quickly;
  - By always selecting the shortest route possible outside the habitat;

- **The rule of the least effort (energy factor) conforms to the following principles:**
  - The shortest possible route is always preferred;
  - The shallowest slope is always preferred;
  - An obstacle (natural or artificial) is only crossed when it cannot be avoided without too much effort or risk.

- **The rule of motivation (physiological factor) is pertinent in the following contexts:**
  - A voluntary movement always results from a vital necessity (feeding, reproduction, shelter, etc.) that may involve levels of risk taking and effort up to what is feasible;
  - An involuntary movement is caused by repeated disturbance. It involves levels of risk beyond the limits of safety and effort; its results are unpredictable in terms of survival.

These first observations allow us to state that **animal movements are never a matter of chance, but always rather the result of the combination of a number of choices**.

Depending on the species and the circumstances, the factors of risk, effort and motivation will not have the same values in specific combinations; and the results of those combinations will not, therefore, be the same. Animal behavioural specialists are as a rule able to predict the most likely route or exploration zone for a species, or for a group of species sharing similar ecological affinities and locomotive capabilities.

Observation of the use made of continua margins by fauna is most instructive for our understanding to functioning of biocenoses. In all types of biotope, the installed biocenosis is constantly generating a cloud of propagules which circulate beyond the perimeter of the habitat, taking advantage of available extra space. The extent of this functional habitat envelope can be smaller or larger depending on the species involved and also varies according to its specific characteristics. The general phenomenon can be termed the **envelope effect**: its intensity varying according to habitat type.

In the cases of deciduous woodland, natural grassland and wetland zones bordering cultivated fields, ecotonal vegetation — constituted by shrubs and grassy bands, twenty metres wide on average — not only contains virtually all species of forest invertebrates, small mammals, reptiles and amphibians, but also plays host to half the ruderal species present in the neighbouring (Fig. 10). The breadths decided for these agricultural borders (50 or 100 m) result from research carried out in the context of the Swiss national ecological network (Berthoud & al, 2004) and have been confirmed by field inventories.

If the cultivated space is replaced with natural grassland, the border zone inhabited by forest species broadens to 100 m or more. The more mobile species such as ungulates, mustelidae, foxes or hedgehogs will often roam across a space of more than 300 m.

In a situation where real territorial usage by fauna has never been researched in detail, we can for practical purposes approximate the potential functional envelope surrounding every habitat, whatever the terrain type, to a breadth of 100 m.

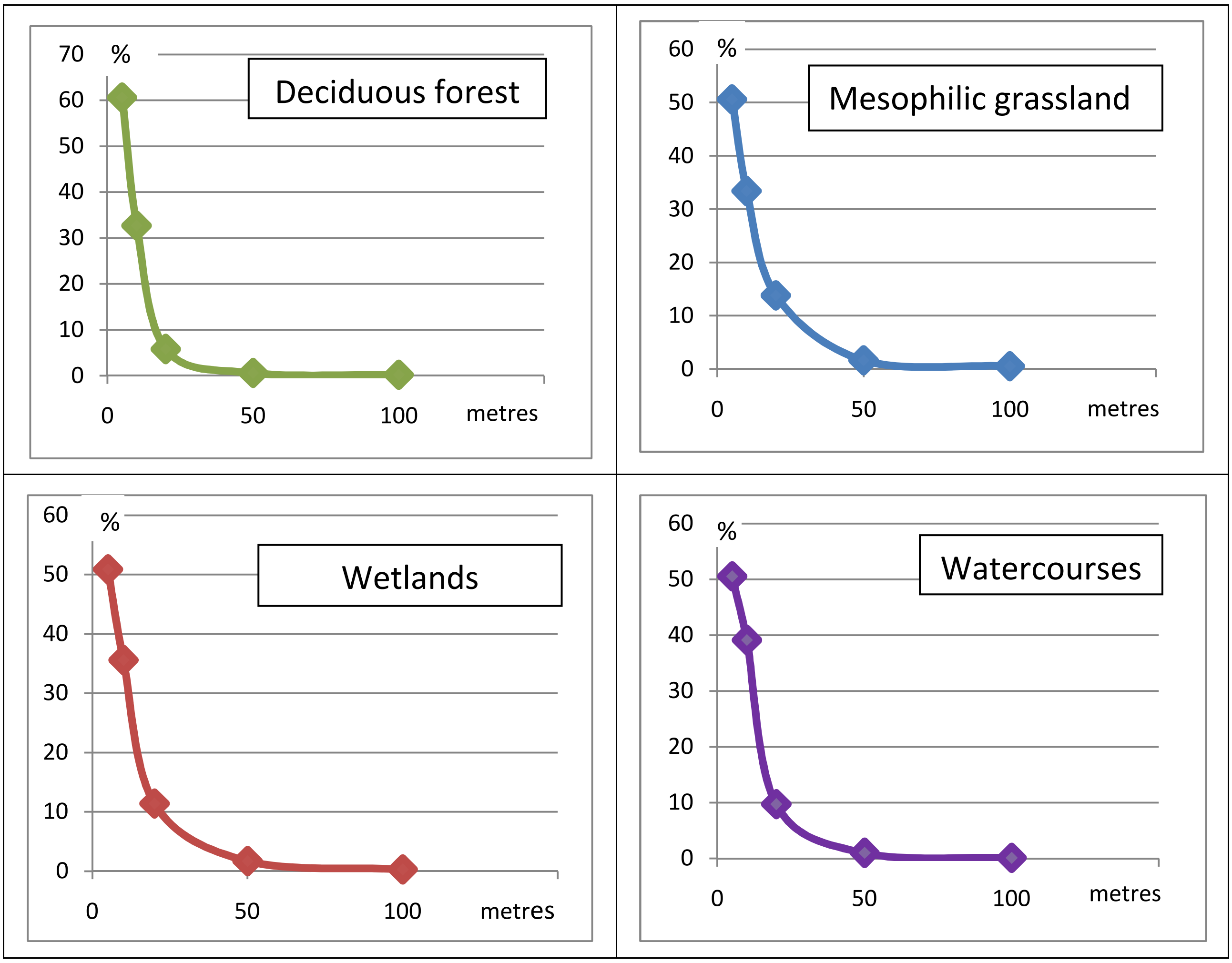


Figure 10.

Distance of propagules starting from the edges of different milieus in agricultural areas: The number of contacts obtained by periodic trapping and the observation of tracks during the growing period in the Limpachtal, Swiss Plateau (cf. Appendix 1).

Source: Berthoud & al. 1989

In reality, within zones subject to intensive human exploitation, this ecotonal margin is reduced to only a few metres. This fact highlights the usefulness of attempting to weight real functioning in respect to potential functioning. Within a cartographical approach, the original habitat, along with its ecotonal margin, together constitute a spatial ensemble know as a **“vital continuum”** or an **“ecological continuum”**.

2.2.4 Exchange modalities between habitats

There are numerous dispersion processes of propagules; their relative efficacy is variable. The following modalities are generally distinguished:

– Active dispersion by air, land or water:

– Passive dispersion leveraging a transport vector such as wind (anemochoric), animals (zoochoric) and water (hydrochoric);

– Direct transportation by humans or indirect by his forms of transport: a mode that is ever more important.

Box 3

Are ecological networks also pertinent to flora?

Theoretically a marked difference ought to exist between faunal and floral taxons with regard to their dispersion. What is actually observed, however, is as follows:

- Active dispersion in plants searching for convivial ecological factors is possible by edaphic and micro-climatic taxis. It is limited to a few dozen metres at most.
- Passive dispersion by gravity — which creates falling movements towards slope bases and soil erosion — is not negligible for numerous heavy seeds.
- Passive dispersion by anemochory or hydrochory is highly developed and probably constitutes the great majority dispersion movements in plants. These two vectors are often combined with soil and plant roughness (tussocks and shrubs) to create capture structures capable of trapping propagules.
- Transport by animals is also very important. Seeds attach themselves to fur or are ingested. Zoochory has indeed served as an experimental model to demonstrate the existence of forest, grassland and paludal corridors (etc.).
- Transportation on vehicles along human transport axes is spectacular. It is also often problematical inasmuch as it constitutes one of the principal ways by which invasive exogenous plants are dispersed.
- Finally, intended translocation by human beings of numerous ornamental and other plants, which have subsequently acclimatized.

To summarize, **floral dispersion mechanisms are very similar to those of fauna.** If there a clear difference in favour of animal it consists solely in the visibility of the phenomena in question. In the final analysis, one need only refer to the observations made of successful successful installation achieved by numerous animal and plant populations to realize there is in the end very little difference in dispersion speeds throughout ecological networks. The only applicable rule is.

➢ **Propagule dispersions, random or organized, are necessarily both combined and synergetic. Thus generally speaking plants contribute to the eco-systemic functional processes as animals.**

In reality these various processes are often combined to constitute random means of transport — always potentially possible but only efficient in the long term.

In a model aiming at a global eco-systemic approach, two tendencies in the quantification of propagule dispersion can be distinguished:

– **Random dispersion** occurs in diffuse flows and is of limited effectiveness, yet it remains a real long-term option as long as the management of a territory will tolerate the installation of a new species;

– **Organized dispersion** functions according the ecological preferences and locomotive capabilities of the species concerned: produces significant and efficient flows which regulate the global functioning existing ecological networks.

2.3 Environmental factors governing the development of ecological networks

Functioning in ecological networks is generated by the heterogeneous nature of landscape. The environmental factors that inform this general organizing principle of preferential propagule routing are as follows:

- A sufficiently dense and heterogeneous habitat mosaic;
- A sufficiently varied geomorphology allowing routes of least effort (valley bottoms, alluvial plains, uncovered ridges, foothills, etc.);
- Natural or artificial obstacles that are sufficiently forbidding to force animals to renounce crossing them;
- A heterogeneous structure generated by the simple progressive dynamics of an initially homogenous habitat, such as untended forest or grassland brush, which is rapidly exploited by ungulates and then interlinked by tracks.

Moreover, and more often than not, these factors of heterogeneousness generate the organization of homologous habitats arranged in continuities or strings. This tendency reinforces the emergence of corridor effects — or even of genuine continua of particular habitats such as wet or dry grassland hillsides, or riparian woodland along watercourses.

It is obvious that, by recuperating any accessible surfaces for its use, agricultural activity is bound to exacerbate such organizational structure.

2.3.1 In low-altitude plains

In our latitudes, virtually all relatively flat spaces at low altitudes have been cleared, drained or irrigated so as to be converted to agricultural use. Only lower-lying wetlands and the margins of watercourses have conserved at least some of their spontaneous vegetation.

Isolated farmhouses, followed by villages and then towns — along with their retinue of transport infrastructures — sprang up and expanded, occupying part of the agricultural land and agglomerating along the rivers that provided their water.

As this process occurs, the following resulting features are to be observed more often than not:

- Significant development of an agricultural continuum that is more or less fragmented by the extension of transport networks;
- Hydrographical and alluvial networks that are to varying extents canalized, depending on flood risks and irrigation needs;
- Networks of residual woodlands either in clumps or as linear structures of hedgerows and along watercourses.

Generally speaking, certain dispersed habitats, such as orchards or gravel pits, serve secondary roles in the landscape structure, without ever gaining significant ecological functions. Even in such habitats, however, once a certain frequency threshold is passed, the “habitat network” effect becomes operative with the rapid increase of some ubiquitous species. This is notably the case in some alluvial plains, such as that of Bièvre in the Isère, with the proliferation of gravel pits, which favours the development of biocenoses associated with dry wasteland.

2.3.2 In hilly regions

In zones of mid-altitude hills, geomorphological factors become important, both in limiting the scope for arable farming and in increasing that for stock rearing with pasture and meadows. Sunny hillsides alternate with cooler, shadier slopes and slopes whose declivity is so great that, depending on the their geology and specific climate, they are left to the forest or given over to vineyards. Rivers and streams flow through valley bottoms that are wooded or very partially occupied by pastures and orchards.

In these conditions, what is generally to be observed consists in the development of continua structured in pockets or more-or-less dense mosaics, in which one generally encounters wooded, agricultural or aquatic continua, and less commonly rocky continua depending on the regional geology.

2.3.3 In mountain regions

Mountain regions are characterized by an abrupt relief and by altitudes to high to allow arable farming. Grazing and the concomitant pasture are, however, developed wherever slope declivity is sufficiently low to be accessible to stock. Different types of forest cover steeper slopes and rock in the form of bluffs and scree occupy the steepest. A nival zone, generating glaciers, appears at the highest altitudes.

The combination of high altitudes and steep slopes creates a horizontal dissection of vegetation into bands, whose coherence is interrupted only by geological faults and the erosion cones that form the headwaters of drainage basins. Glacial valleys have created deep furrows through ranges, furrows that constitute obstacles to biological exchanges between mountain massifs.

The mountain context informs the development of a particular type of continuum structured by altitude — but also by exposure to sunlight — into horizontal bands of vegetation.

The following continua can be enumerated:

- High-altitude forest continuum;
- Moorland and pasture continuum;
- Rock continuum, bluffs and scree;
- Nival continuum;
- Valley-bottom grassland continuum;
- Aquatic continuum, watercourses, ponds and lakes;
- Fluvial-alluvial continuum, along riverbanks.

Finally, in mountain regions, contacts between continua are subject to situational constraints which result in a regularity in the relative proximity of the various continua. Thus, for example, we always find the same succession of continua as the altitude increases: forest, moor and pasture and then rock. As a result, numerous species have developed vertical living areas to take advantage of the complementarities this allows.

2.4 Transformation and the deterioration mechanisms of natural spaces

Modifications to natural spaces are numerous. They result as much from natural as artificial causes. It is logical, as a result, to ascertain the capability of and the speed at which the organization and the functioning ecological networks adapt to such changes. What is principally at stake here is the need to define mechanisms that cause deterioration and the parameters of the resilience of different habitat continua.

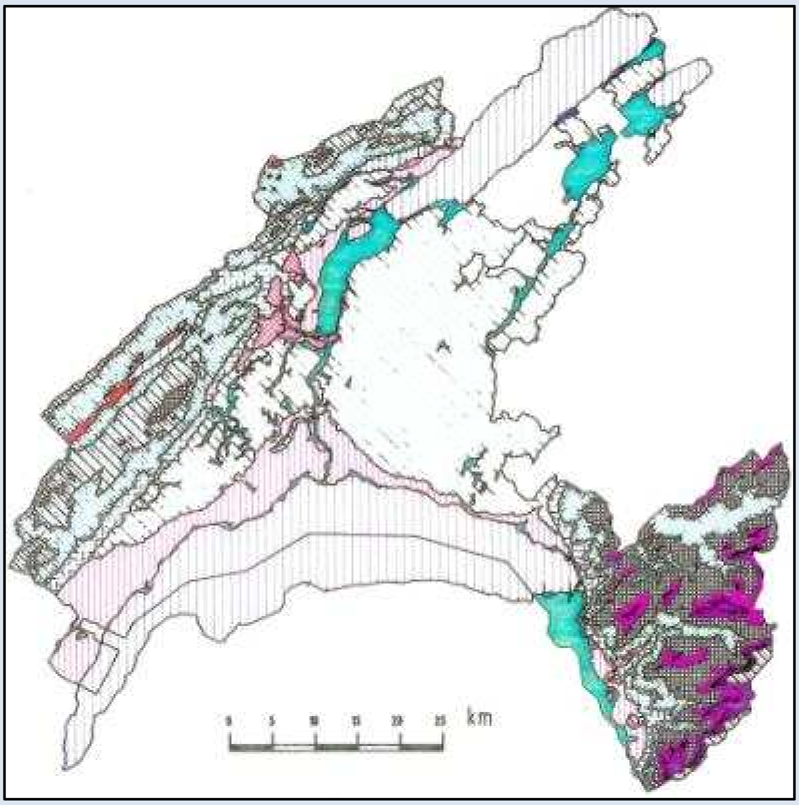
The chief aspects of the transformation of landscapes are explored below in a way that allows these aspects to be taken account of in the modelling of ecological networks.

Box 4

Reduction of wooded areas in Canton Vaud in comparison with their potential ecological development and the situation in 1990

After drawing up, over a period of ten years, a detailed, commune by commune cartography of the habitats and their biocenoses of Canton Vaud (Switzerland), we have established a map of potential vegetation with a view to defining what is in fact at stake with regards to the protection of the natural environment (Fig. 12). In comparison with the current situation, it can clearly be seen that the reduction in surface areas is what constitutes the principal protect issue. Thus, the habitats that have suffered the greatest deterioration are, in order: meso-thermophilic oak-beech woods, alluvial forests and mesophilic beech woods on a molasse substratum. The disappearance of wet zones are not calculated in this approach, but approaches 90%.

Landscape type	Potential initial surface area	Current surface area (1990)	Loss of surface area
Alluvial forest	211 km^2	47 km^2	- 77 %
Meso-thermophilic oak-beech woods	333 km^2	9 km^2	- 97 %
Dry beech woods	44 km^2	33 km^2	- 25 %
Calcicole meso-thermophilic beech wood	173 km^2	130 km^2	- 25 %
Mesophilic beech wood on molasse	970 km^2	250 km^2	- 75 %
Beech wood with pine	509 km^2	400 km^2	- 20 %
Beech wood with maple	168 km^2	83 km^2	- 50 %
Lower sub-alpine spruce forest	261 km^2	81 km^2	- 68 %



Source: ECONAT 1991

Figure 11.

Map of potential vegetation landscapes of Canton Vaud (Switzerland), established by extrapolation of current vegetation as revealed by communal inventories of flora and fauna in zones where the same ecological conditions prevail.

Legend:

2.4.1 Destruction of natural spaces by human activity

The consummation of space to meet the needs of human activities is considerable everywhere. It is actually possible to state that at the continental scale, virtually all arable land across Europe has been cleared, virtually all floodable areas have been drained and irrigated, all forests are exploited for timber, etc..

Thus in Europe, unfortunately, virtually all landscapes consist in transformed natural habitats, of which only non-urbanized surfaces — attributed overwhelming to agriculture — could any areas possibly, and only on a small-scale in certain places, be recuperated, in the sense of a reconstitution of natural milieus.

The agricultural draw back apparent in many regions has, however, led to increases in the forest areas to the detriment of grasslands, pasture and numerous water meadows that once were mown.

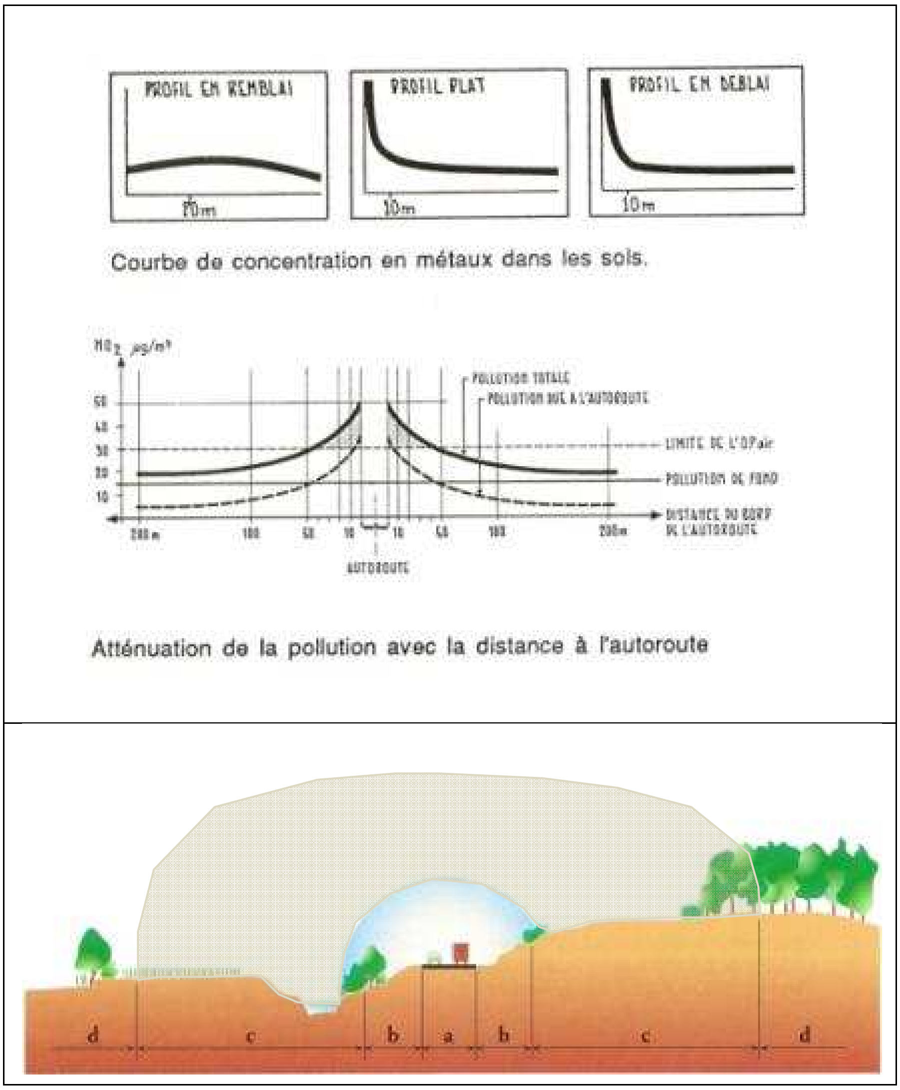


Figure 12.

Dispersion models for metallic dust and gas along the length of motorways, drawn up from numerous samplings of pollutant traffic emissions. These allowed the establishment of standard outline of the probable effects of such emissions on natural milieus.
The amplitude of ecological effects varies according to traffic volume.

→ When traffic is >10'000 vehicles a day, the extent of ecological disturbance (c) is at least 100m

Le diagram distinguishes between:

a) Direct effect
b) Highly disturbed zone
c) Ecologically disturbed zone
d) Unaffected zone

Source: Swiss Federal Office for Roads (2000)

Larges natural landscape entities have not all been subjected to transformation in the same way. This variability is due notably to differences in their accessibility and their natural resource potential. It is possible to create an estimated accounting of the relative destruction of floral landscapes by drawing up maps of the development potential of different vegetation entities. Any decent phytosociologist is capable of recreating a model of an original landscape examining the soils, slope declivities and water circulation and by extrapolating from the few relic vegetation elements still present in the current landscape (Box 3). This exercise is very useful if we are to judge the relative importance of the issues involved in the possible reconstitution of original habitats.

2.4.2 Disturbances generated by anthropogenic activities

Although complete habitat destruction is very difficult to reverse, it does constitute a process that is at least directly visible and, thus, theoretically simple to control in the context of a well conceived territorial planning programme — one which would be based on legal constraint concerning recognized natural species. Far more difficult to perceive and circumscribe, on the other hand, are the disturbances generated by anthropogenic activities in peripheral spaces, such as: physical and chemical pollutants, the presence and frequency of traffic, people and domestic animals. Through the empirical practise of impact studies, however, some tools have been developed.

There are numerous tools for the physical modelling of the dispersion of noise, vibration, dust and gas emanating from known sources. All such models take local conditions such as slope, reflection and wind distribution into account, so as to create correction factors influencing the original distribution. During large-scale projects, survey maps of pollutants by emissions measurements that reinforce theoretical models of pollutant emissions are often produced.

Dispersion models for noise, dust or gaseous emissions are the most common (Fig. 12). A synthesis of data on pollution effects of road traffic has been produced by Reck and Kaule (1992) (Fig. 13) and by Forman (1995).

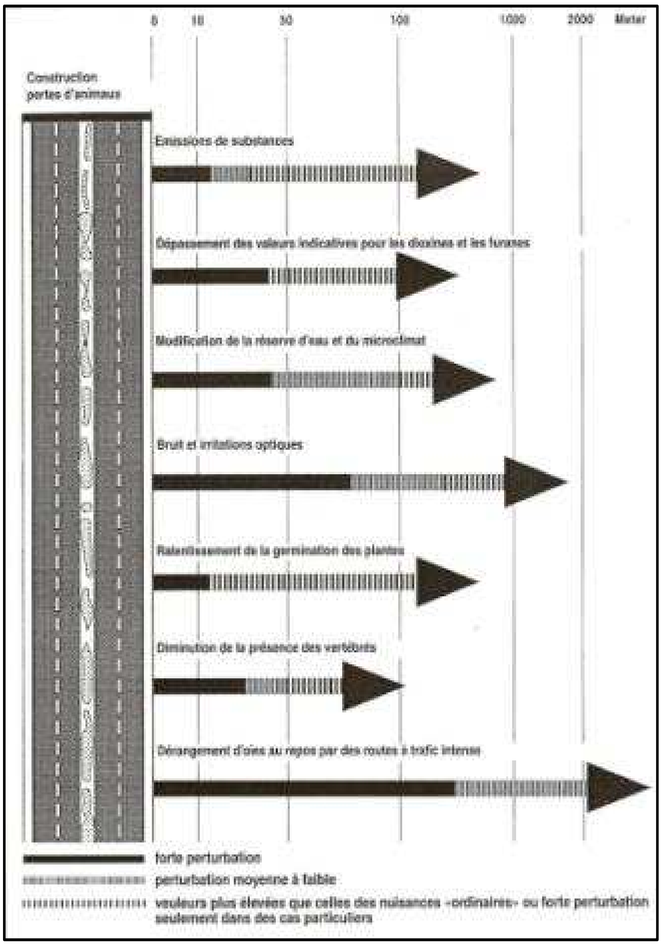


Figure 13.

The ecological effects of roads

Disturbances are not confines only to the road surface itself. Rather they penetrate into neighbouring zones, diminishing the further they reach. Data in the literature allows the establishment of reference distances for known effects.

Source: Reck & Kaule (1992)

The appearance of an ecologically disturbed zone on either side of a transport route, as well as around an urbanized zone, will result in two principal consequences for the fragmentation of the landscape:

- The increase in the size of the disturbed area;
- A progressively greater spatial compartmentalization.

2.4.3 Spatial fragmentation and its ecological consequences

The progressive increase in transport networks and traffic have resulted in a rapid process of spatial fragmentation — known as the barrier effect — which quickly became a cause for concern for both biologists and engineers because of the number of animal-vehicle collisions that result from it. One of the first consequences of that concern has been the installation of safety fencing specially designed to hold back the large fauna that is most dangerous to motor traffic. On the other hand, it has taken more than twenty years properly to understand and to disseminate the principles governing the construction effective road-crossing infrastructures for fauna. The results of this research are presented in numerous documents. Suffice it here to cite the most complete account, published by the SETRA (Carsignol, 2005), along with the remarkable summary of the problematics at the international scale, published in the context of the European Union's COST 341 project (Luell & al, 2003).

The present guide has no remit to discuss or criticize the technical solutions proposed in the above-mentioned documents. It is necessary, however, correctly to analyse the consequences of the resulting landscape fragmentation — particularly with regard to the effects of the infrastructures that are logically likely to result from a synthesis of the issues raised by accidents involving animals. It is effectively tempting for those involved in territorial planning or the management of natural spaces to rapidly set up a priority action programme based on spectacular measures such as the construction of a crossing way for fauna or the establishment of a biological corridor. It is just as important, however, to properly understand the whole raft of consequences of the progressive transformation of landscape as a result of the ever-increasing pressure of urbanization or infrastructure projects.

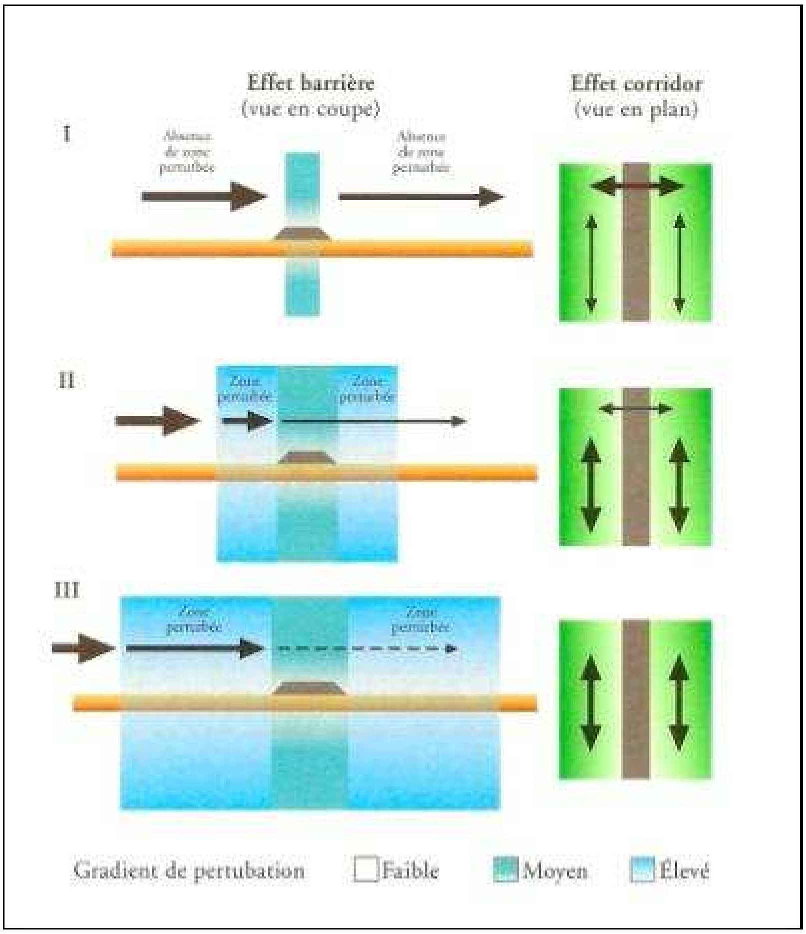


Figure 14.

Progressive shift from the barrier effect and towards the corridor effect as a function of the increase in traffic.

Case I. *Low-intensity traffic (<1000 vhc/day) only affects terrestrial fauna. Numerous animals will be killed.*

Case II. *Average-intensity traffic (1'000 to 10'000 vhc/day) is perceived as a danger by fauna. The disturbance zone is equivalent to the breadth of the road. Exchanges across the road remain partially feasible.*

Case III. *High-intensity traffic (>10'000 vhc/day) renders the route impassable. The disturbance zone is equivalent to at least twice the breadth of the road. Only a percentage of animals venture into it. Only few animals are killed. The separation effect is complete; a majority of animals will, however, range along the side of the road.*

Source:
Berthoud & Müller (1994), cited by Swiss Federal Office for Roads (2000) and SETRA (2005)

Two mechanisms contribute the lion's share to the processes of landscape fragmentation:

- The progressive installation of vast agricultural or sub-natural zones whose biocenoses are constantly subjected to significant levels of ecological stress. While these disturbed zones are able to conserve a relative biodiversity for a long time thanks to the presence of distant reservoir zones, they are no longer in any position to play a principal role in the general functioning of ecological networks. As a result, they do in fact take on the status of biologically deteriorated zones.

- The increase in traffic and its associated pollutants rapidly establishes a barrier effect in the functioning of the landscape. This is accompanied by a progressive shift, from a predation effect on animal populations (by collision with vehicles) and towards an interruption effect on the exchanges between the habitats located on either side of the transport route (Fig.14).

This separation effect is usually accompanied by a secondary effect, known as the **derivation effect.** This incites many animals disturbed by the obstacle of the road, its traffic and often by fences as well to range as far as is possible for them along the obstacle in search of a way around it. The distances covered in this way are variable depending on the attractiveness of the plant structures that are most often planted for aesthetic reasons and only rarely for fauna. This vegetation should imperatively be managed in such a way as not to cause the proliferation of sink sites (cul-de-sacs, one-way corridors or that open onto secondary thoroughfares).

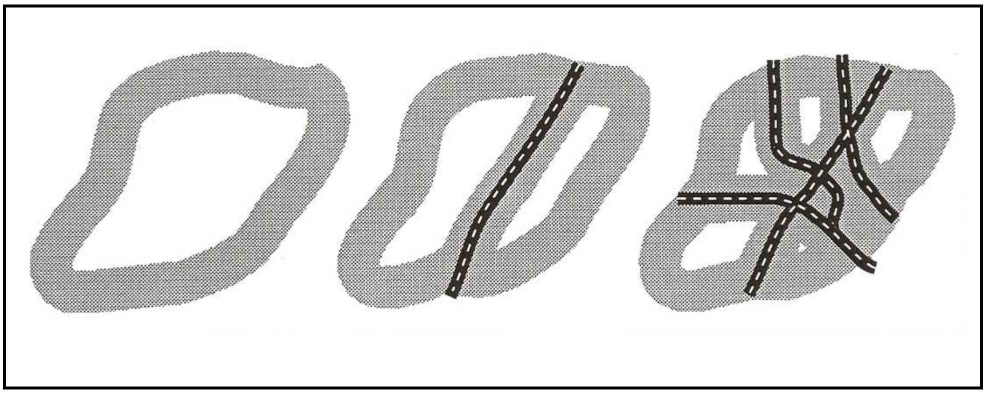


Figure 15.

The areal relationship between undisturbed core zones and disturbed marginal zones changes rapidly to the detriment of the cores with the number of bisecting infrastructures.

Source: Mader (1983)

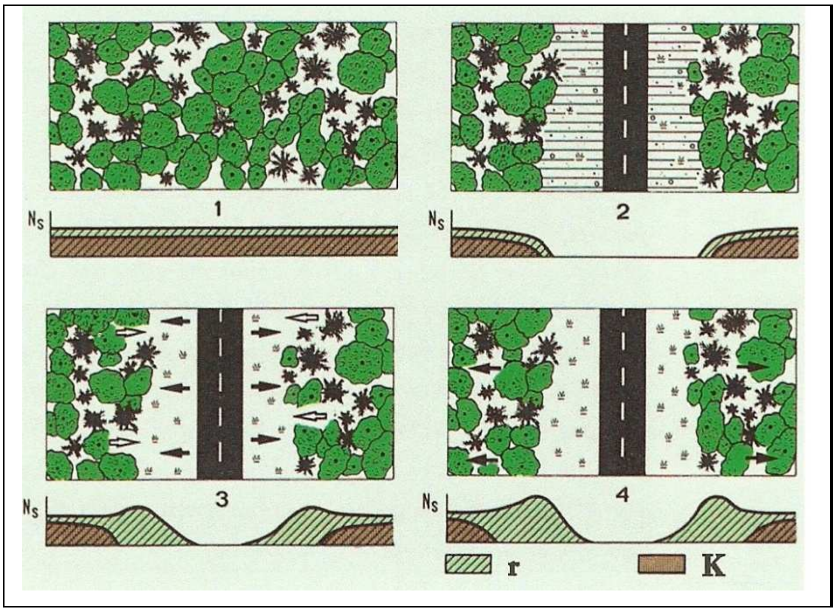


Figure 16.

*The progressive reduction of usable surface areas, due to the alteration of marginal surfaces, favours species with **r** reproduction strategies over those with **K** strategies.*

Source:
Mader (1983), in Bernard (1985)

In point of fact, this deviation effect constitutes a fundamental behaviour in the functioning of ecological networks: the edge effect, which means that any animal leaving its own territory will spontaneously range along the side of a structure (natural or artificial) that it finds convenient.

Other consequences of landscape fragmentation have been revealed by Mader (1983). They are notably:

- The disproportionate reduction of zones free of any disturbance due to the mechanism of the fragmentation of the landscape, which provokes significant weakening of the population dynamics of certain animal species (Fig. 15);
- Marked microclimatic changes close to transport routes leading to modifications in the biocenoses affected (Fig. 16);

- Modifications in species composition: generally speaking, specialized species are reduced, although in some circumstances some rare species may become temporarily dominant. In all events inter-species balance is significantly disturbed.

Taken all together, these changes result in obvious consequences for the parameters of ecosystem functioning. These must be taken account of in the modelling of ecological networks.

2.4.4 Invasions of foreign species

The installation of invasive species in a landscape, and more particularly in landscapes significantly transformed by human activity has become a serious preoccupation for the environment. At the European scale, it is currently estimated that there are more than 10,000 invasive faunal and floral species, of which 13% have some identified negative economic impact.

The costs of this are estimated to be several billions of euros per annum.

Terrestrial vertebrates have a powerful ecological and economic impact, but it is in fact terrestrial invertebrates that are the cause of the most damage to crops and forests. Exotic terrestrial and aquatic invertebrates have proliferated exponentially over the last few years.

The European DAISIE project, carried out from 2005 to 2008, aimed to set up international collaborations and databases in order to fill the gaps in our knowledge of the problem.

The resulting databases on the subject can be accessed online at http://www.europe-aliens.org.

The planning of ecological networks and biological corridors are frequently taxed with facilitating the dispersion of exogenous species. It is therefore important to be able to answer such criticism.

Elements of the response are to sought in the fact that ecological networks are invariably pre-existent in any landscape and that planning articulated around the restoration of eco-systemic structures can only improve the functioning of pre-existing natural networks in which invasive species only spread to a very limited extent.

In point of fact, the real problem of the rapid growth of exotic species is linked to the ill-considered development of artificial networks that are side effects of building and anthropogenic activities. Infrastructures that are badly conceived with regard to their integration in the natural environment or which are poorly managed with regard to episodic and brutal actions (clearing, stripping, burning, herbicidal treatment) create ideal conditions for invasive species.

Disturbed and non-stabilized milieus of this type are very common in the wider outskirts of large urban areas:

- Industrial wasteland, building sites awaiting construction, fragmented and abandoned agricultural land, sites under development;
- The margins of all transport infrastructures (railway lines, motorways, multiple-carriageway roads, service areas, outside storage parks);
- Road sides maintained by flail mowers, by burning or herbicide;
- Inert dumpsites for stone and earthy materials, old demolition landfills, etc.

In a generally unplanned — and certainly uncontrolled — way, the rapid development of urbanization and transport infrastructures has created enormous numbers of ecologically non-stabilized areas. Taken together, these constitute a vast “secondary eco-anthropogenic network” that provides an ideal environment for the propagation of invasive floral species, as well as, to a lesser extent, for invasive fauna.

- Managed to an outrageous extent with recourse to mechanization, agricultural milieus produce much the same outcome: both for invasive fauna and for invasive vegetation. In these milieus, however, control of exogenous elements is possible, if expensive, by recourse to phytosanitary products.

Box 5

Conditions necessary for the installation of invasive species

Characteristics of invasive species:

- Preponderance of r reproduction-type strategies
- High dispersion rate
- Varied diet (polyphagous species)
- Wide variety of habitats (generalist species)
- Widely and naturally distributed

Characteristics of communities susceptible to invasion:

- Low diversity, therefore non-stabilized
- Simple trophic networks
- Absence of natural enemies for invaders
- Absence of native species occupying the same ecological niche,
- Repeated anthropogenic disturbance maintains community instability

Agro-ecosystems, alluvial zones, les naturally open zones subjected to erosion, frequently reorganized zones, but not gardened, and earthworks all correspond well to the above definitions and descriptions. Such milieus do effectively constitute ideal installation terrains for the vast majority of invasive species.

The invasion of aquatic and paludal milieus has in the past always progressed by way of amphibian fauna, particularly water birds. With the increase in maritime and fluvial traffic, however, species transfers now take place by means of the filling and flushing of tanks with water drawn from the natural aquatic milieu. The successful development of populations of invasive species also always depends on the invaded milieu's being unbalanced at the outset by pollutants, artificial infrastructures, overfishing, etc..

Mountain milieus of forest, moorland and pasture are not spared, but are less notably affected because the host milieus are usually more closed. On the other hand, it is likely that climate changes will speed invasion processes because of increased drought, more marked erosion zones or simply because warming will adversely affect endogenous species adapted to a ruder climate.

The eco-systemic approach to landscape — via a better understanding of the functioning of specialized ecological networks — indubitably constitutes own of the keys to a more effective control of invasive species. In any event, the mapping of ecological networks and grids will make a efficacious, and hopefully rapid, contribution to ascertaining the amplitude of the parasite networks installed my humanity.

2.4.5 Is a habitat network linked by corridors bound to result in an Allee effect?

In population dynamics, Allee (1956) described the positive relationship between all measurable components of individual fitness, population density or the number of conspecific relationships. Thus, for example, if a given population is of low density, there will necessarily be reduction in individual fitness, which will in turn lead to a reduction in the growth-rate of the population, possibly resulting in extinction.

Three biological processes are responsible for causing the Allee effect:

- The reduction in the encounter efficiency of mating partners;
- A non-optimal environment;
- A reduction in social-interaction benefits.

When combined, these factors cause a genetic impoverishment by consanguinity. This genetic drift will in turn further reduce individual fitness.

Given our understanding of this vicious circle, it is reasonable to ask whether a system of habitats interconnected by corridors will lead to an Allee effect. A number of arguments are possible:

- Though the do constitute the week point of a habitat network, yet corridors are not directly the problem. For while the Allee effect certainly is globally applicable both to continuum systems and to any separately analysed habitat, the survival of populations essential depends on nodal zones, which must be adequate in terms of quality, capacity and functioning to allow the development of a given population;
- The formation of a population broken up into multiple meta-populations, implies that the sum of the increase in all the populations issued from each habitat fragment is sufficient to compensate the mortality risks associated with travelling;
- Organized and concentrated movements are always more efficient than dispersed and random ones. The choice of one movement mode, however, does not exclude the possibility of the other. On the contrary, field observation demonstrates that the two modes always coexist in parallel.

Thus, pushed to its logical conclusion, the group mode, often preferred when it comes to moving, is always the result of a combination of learning and impregnation (or even genetic programming) which results in repeatedly successful undertakings over many generations. This winning formula implies, however, that the landscape, or the spatial organization of habitats, remain as little altered as possible.

On the other hand, insular colonization mechanisms imply that random dispersion is also the rule.

My own experience of over fifty years of tracking animal movements by tagging (birds, bats, batrachians, reptiles, Diptera and Lepidoptera) permits me to advance an empirical estimate that states that as a general rule governing all species, about 90% of individuals in movement conform to foreseeable behavioural patterns in undertaking organized journeys in groups. A fringe element of some 10% of individuals practicing unforeseeable, random movement, however, always exists. This minority is almost invariably made up of young, inexperienced individuals or individuals whose movements result from accidents due to exceptional circumstances (storms, floods, involuntary transportation, etc.).

In any modelling of dispersion, it is essential that both modes be taken into account.

As a result, when one is in presence of a more or less stable natural landscape structure, the first category of organized individuals will reap substantial benefits by minimizing risks, whereas the second category of non-organized individuals will necessarily take considerable risks whatever the configuration of the terrain to be crossed — and notably whether corridors exist or not.

In a landscape subject to rapid transformation, however, the “risky and random” movement type may well prove to afford a fitness advantage to the second category.

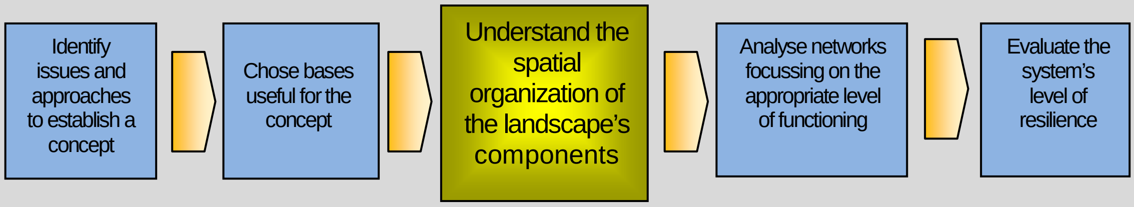
A simple rule of the management of natural spaces in a landscape can be deduced from these observations:

- Landscape transformation is unfortunately inevitable. A large proportion of species are, however, quite capable of adapting as long as the changes in question take place progressively and that the organization of resulting new natural infrastructures is coherent for biocenoses: i.e. that it conforms to normal rules of ecological functioning for biocenoses with respect to resource accessibility and habitat complementarity. The new organization must allow sufficient development capacity — at least equal to the preceding situation — in terms of quality, hosting capacity and connectivity between complementary habitats.

To put it another way, the Allee effect does indeed exist, but only at the scale of overall habitat ensembles. The presence or absence of corridors is immaterial. The weakening of populations, or even the reduction of biodiversity, is not absolutely inevitable. Understanding of the survival parameters of species should necessarily force us to rethink the way we organize the utilization of territory.

CHAPTER III

The Principles of an Ecosystemic Approach to Landscape



Summary

*Ecosystemic landscape modelling is a concept for the multi-scale analysis of the different ecosystemic situations to be found in landscapes. It is based on the mapping of functional elements of landscape called **"continua"** or "ecological continuities". These entities are themselves often fragmented by natural or artificial obstacles so as to form sub-entities known as **"ecological sectors"**.*

*The definition of a specialized continuum implicitly corresponds to the **definition of a certain development potential of particular biocenoses**. At the same time, the concept of the ecological network usually corresponds above all to the possible interactions between the various continua. The two approaches are complementary inasmuch as many species are only partially specialized or are adapted to ecological niches constituted by the overlapping or juxtaposition of different types of continua (mosaic, interfaces or dual habitats).*

*As a result, **different but complementary natural infrastructures** furnish — according to the manner of their combination — a wide range of different possibilities for the development of particular biocenoses. Climate, orography and successive transformation also inform the hierarchies and complexity of a given landscape.*

This ecological potential is not evenly distributed in a landscape unit. And the resulting unevenness allows the basic functional zoning of each continuum to be ascertained. The recognition of this differential zoning has led to the identification of areas of particular natural interest, which has often formed the basis for the creation of protected areas. This approach has now, however, demonstrated the limits of its usefulness. For indeed, a complex of networked habitats never maintains its original vitality when relying only on the conservation of such zones of particular interest.

Approaches based on the analysis of the effects of development projects — devised especially to carry out impact studies for transport infrastructure projects — have necessitated the elaboration of analytical approaches more open to natural spaces, by the systematic analysis of landscape considered as an ensemble of interactive habitats, which are not necessarily either of particular interest or protected, but which are organized in more or less complex networks.

The simple recognition of the pertinence of specialized networks constitutes the first, useful and informing step towards their effective management. A hierarchical organization employing weighted criteria has been sought to allow a better understanding of functioning and the ability to track the evolution of ecological networks.

3.1 The Conceptual Elements of Ecological Networks

There are several possible approaches to the description of the biosphere:

- The eco-geographical approach is concerned with the spatial distribution of large biomes and the characterization of natural and transformed landscapes. It notably provides the levels of scale at which the principal biocenoses function;
- The socio-economic approach considers natural phenomena as potential economic resources depending on the profitability of their exploitation and their accessibility;
- The ecosystemic approach is concerned with the spatial distribution of habitats and species in such a way as to define the different organizational levels that characterize landscapes and to evaluate their ecological potential.

It is this last approach that will provide a common theme throughout this exploration of the methodology of hierarchical ecological networks.

In an ecosystemic approach, the biological diversity of a landscape unit is expressed in numerous measurable parameters such as taxonomic diversity, biocenotic diversity and the diversity of niches.

The principal factors producing biodiversity are:

- All the elements that constitute the biological resources in a given habitat: species guilds, lists of biocenoses and populations;
- The complexity of the organizational structures of a landscape in terms of spatial distribution, interconnectivity and interactions;
- The efficiency of systems in terms of functioning, progressive dynamics, development limitations and resilience.

The concept of ecological landscape networks employs all these different notions linked to the ecosystemic approach.

3.1.1 Ecologically homologous habitat networks

The idea of habitat networks emerged as a result of the recurrent proximity of a number of similar habitats, and also by way of the idea of accessibility by percolation through other types of habitats. For a network to exist, ecological processes, such as functioning in meta-populations, must be possible.

The grouping of a number of different types of vegetation — with ecological characteristics sufficient homologous to be able the formation habitat assemblies — is not new. It is the same phenomenon as the assembly of complementary milieus useful to ecologically proximate floral and faunal groups — i.e. groups similar with regard to a number of preponderant physiognomic and geographical factors (climate, orography, hydrography, vegetation, etc.). The principle has notably been used widely by phytosociologists to describe vegetation in the form of habitat mosaics — a form close to the notion of ecosystem but possessing functional coherence operative in this case at the large scale. Lefeuvre & al (1979), and then Blandin and Lamotte (1985), for example, employ the term, **"eco-complex",** to describe the assembly of those habitats that are demonstrate good stability and permanent interactions.

At the scale of a given landscape, Ducruc (1980) proposes a cartography of ecological systems based on homogenous morphological and topographical criteria, which enables the definition of the **elementary units of landscape**.

The principles of symphytosociology developed by Béguin and Hegg (1975) first permitted the identification of sigmassociations, and then the description of numerous geo-sigmassociations, which bring together vegetation groups in a topographical series (catenae). The establishment of numerous biotope inventories in Switzerland, and particularly in Canton Vaud (Berthoud & al. 1991), provided the opportunity to describe vegetation landscapes based on these very general phytosociological units.

The matched analysis of faunal vital spaces would require a further widening this phytosociological perspective of landscapes towards a vision of the biocenotic entities of landscape through the description of **continua**, which could be termed **natural infrastructures** in that they effectively bring together the principal ecosystemic structures and processes in a landscape.

Beginning in 1999, the term “**continuum**”, or “**ecological continuity**”, has been used to establish the Swiss national ecological network. The term is the result of a combination of the cartographical notion of assemblies by eco-complexes with the idea of exchange flows between groups of species sharing the same ecological affinities. This combination allowed a number of independent but partially superimposed functional networks to be distinguished.

In the description of a landscape, functional entities allow the biocenotic ensembles (flora and fauna) representative of the landscape studied to be identified. Thus when establishing the Swiss national ecological network, Berthoud & al. (2004) employed six large networked-landscape units:

- The forest continuum
- The aquatic continuum
- The paludal continuum
- The grassland continuum
- The agricultural coontinuum
- The anthropogenic continuum

The same continua were also used to describe the ecological network of the Department of the Isère in France (ECONAT 2001). The idea of landscape continua has been taken up for the majority of the methods proposed for the establishment of ecological grids all over France: the ecological corridor method used for the Regional Natural Parks (Girault, 2005), for example, as well as the ecological network mapping method in the Rhône-Alpes (Région Rhône-Alpes, 2009).

Other types of continua can be integrated into the overall model in response to cartographical requirements so as to describe the whole landscape more accurately. One could, for example, refer to:

- A rock continuum in all mountainous regions;
- A nival continuum in high altitude zones,
- A maquis (scrub) continuum in Mediterranean regions;
- A steppic continuum in semi-arid zones;
- A dune continuum in flat dry zones.

According to this perspective, each of these largely autonomous entities corresponds to an ecologically functional infrastructure of the landscape. The overall ecological network is merely the result of the cartographical overlapping of all these different networks (Fig.17).

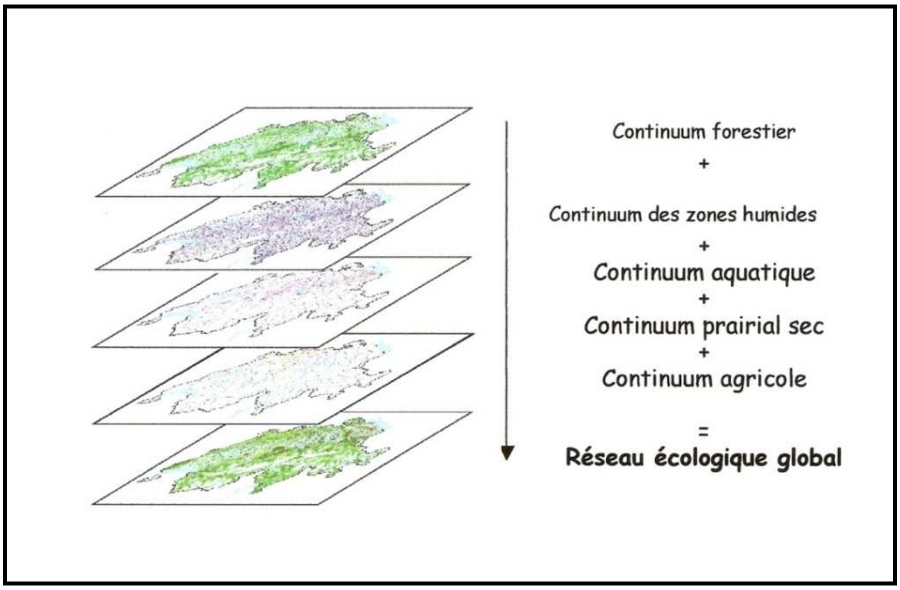


Figure 17.

Organisation of a global ecological network constituted by the superimposition of several specialized sub-networks.

The resulting global network is complex with numerous multipurpose sectors.

Source: Berthoud & al. (2004)

Properly understanding the idea of the autonomy of specialized networks is important for management strategies. Synergies are possible through the overlapping of continua, but recurrent antagonisms can also exist and these must be taken into account.

3.1.2 Functional spaces

How does one go beyond the level of easily identifiable vegetation entities so as to address the imprecise boundaries of marginal areas subject to diffuse and often indiscernible ecological processes? And why would it be necessary?

In the reality of the field and given that they are subject to a ecological gradient that gives rise to the progressive reduction of characteristic species, the majority of habitats are often imprecisely drawn. It is also notable that, where the edge is abrupt (as with agricultural landscapes), habitats are continually surrounded by a halo of propagules in movement. From an ecological perspective, this space, virtual but functional, processes essential significance because of its development potential and especially in relation to exchanges towards accessible neighbouring sites. Taking this ecological envelope into account allows the definition of the ensembles of habitats functioning in meta-populations and so, in the end, the constitution of continua. Nonetheless, until the real distribution of exchange flows has been examined in greater detail, the continuum remains a heterogeneous space that is virtually functional as a whole.

3.1.3 Modelling ecological landscape networks

The ecosystemic approach implies the definition of a landscape model of habitat networks that is both functional and non-selective.

The model used in Switzerland and in the Department of the Isère in France is based on an ecological zoning of the various surface-area elements which best characterize the functional structures, real or virtual, that have been identified in the field (Fig. 18). The model distinguishes five elementary types of surface constitutive of a specialized network: nodal zones, extension zones, development zones, continua and corridors.

Markedly similar to the model proposes by BENNETT (1985) that was adopted for the pan-European strategy for the conservation of biological and landscape diversity, the model adopted for the hierarchically organized ecological networks method differs in the fact that **the general approach to the landscape is non-selective inasmuch as it is not aimed at the protection of sites of particular natural interest**.

While the concept proposed by the pan-European strategy is selective in nature and conforms to the following diagram:

> *Priority species and habitats → sites of particular natural interest → buffer zones → connection corridors → networks of sites of particular interest →- landscape?*

Any ecological network concept is founded on an approach to landscape based on a non-selective homological assembly of habitat continuities, and corresponds to the following diagram:

> *Complementary homologous habitats → Continuum → ensemble of homologous continua → Specialized ecological networks → general ecological network → landscape units → landscape.*

In this model, the definition of the different zones constituting a network are as follows:

- **Nodal zones:**

The ensemble of milieus favourable to an ecological group of floral and faunal species (guild) that constitutes an adequate vital space for the accomplishment of all the developmental phases of the populations of characteristic species. The nodal zone is determined independently of its legal status. It is often administratively recognized by an official inventory attributing to it the status of a biotope of regional or national importance, but it can also be designated by the simple opinion of experts on the basis of its diversity or the size of its populations. Nodal zones carry out a function of "**reservoir zones**" for the conservation of populations and the dispersion of species towards other vital spaces in the network.

- **Extension zones:**

An extension zone presents some ecological analogies with nodal zones. Its quality or its surface area is not, however, sufficient to allow its designation as such. Globally speaking we are talking about the same milieu, but characteristic species are more dispersed. According to the type of continuum considered, an extension zone can be very extensive (the case for exploited forests) or, on the contrary, very limited (case of wet zones and dry grassland). In its cartographical representation, **the extension zone contains all homologous habitats** (actually observable in the field), all wooded milieus for example. A generic term proper to the specialized continuum is attributed to this assembly of habitats.

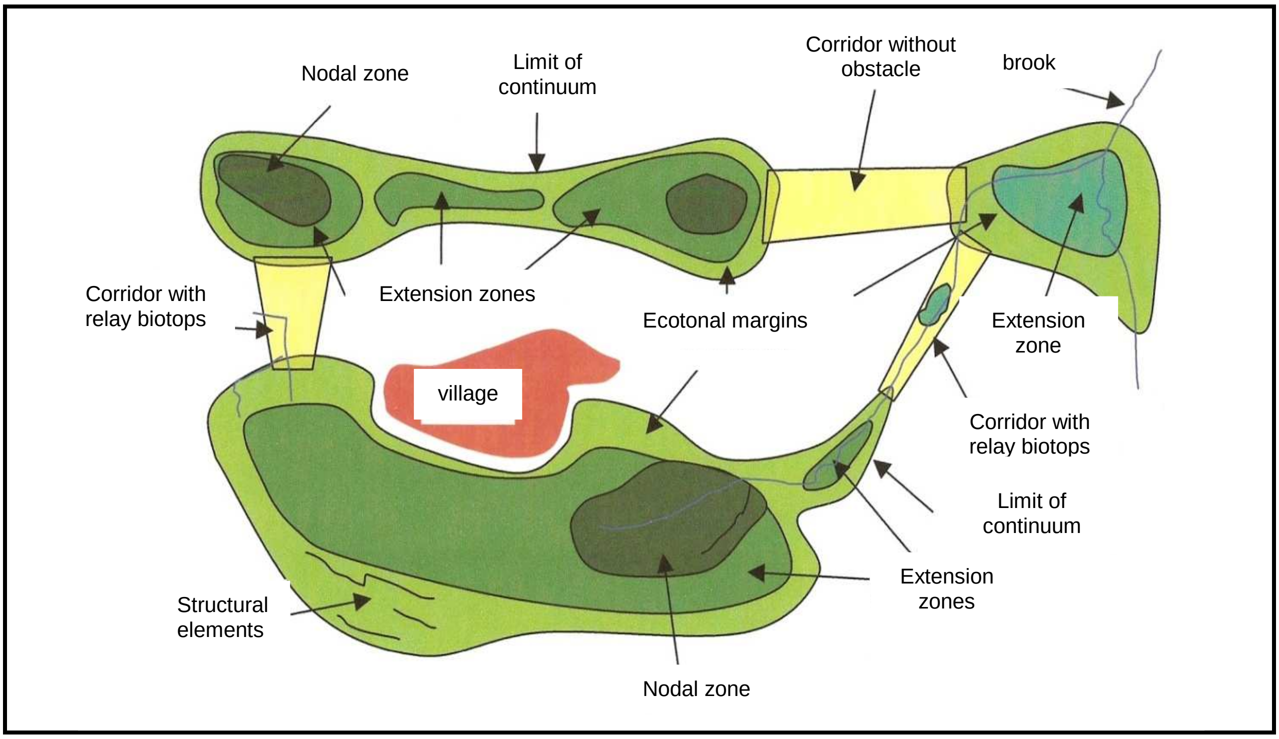


Figure 18. *Diagrammatic cartographical representation of the habitat elements of a specialized forest-type network. In the absence of a nodal zone, the extension zone (*) should be considered as a zone of restoration or development.*

Source: Berthoud & al (2004)

- **Development zones:**

Ensemble of milieus favourable to guild species, they constitute vital spaces, partially adequate for the development phases of characteristic biocenosis' populations, but spaces in which **no nodal zones are to be found**. **In their structure and composition, development zones appear identical to extension zones**. They are located outside the functional network, being inaccessible because of distance or of the presence of obstacles.

- **Specialized Continua:**

The continuum, or ecological continuity, constitutes the functional envelope surrounding nodal and extension zones, but to which are added all **heterogeneous complementary milieus and buffer zones,** which are frequently used simply because of their proximity with the original habitats. The cartographical representation of **a continuum's external boundary is not simple to define given that it constitutes a virtual ecotonal margin** (buffer zone) whose breadth is defines according to an estimation of what is necessary to its functioning. By definition, a continuum constitutes the ecological coherence linkage within an ensemble of dispersed habitats. The continuum is the referential functional spatial entity of ecological networks. It is the vital space of all the biocenoses brought together by the assembly of habitats t contains.

Remarks: a generic name — such as forest continuum or paludal or grassland continuum, etc. — is attributed to each continuum in function of the analytical cartographical level required. At a local level, notably for prospective studies on the vital spaces of species of particular interest, more precise continua — such oak-beech wood, meso-thermophilic, xeric beech wood, maple wood with pine continua, etc., — are distinguished, the better to define the ecology of these spaces. Such phytosociological units are not yet available in numerical form, unfortunately.

- **Ecological corridors:**

In the hierarchically organized ecological network approach, **a corridor is always a space outside the continuum**, free of obstacles and offering exchanges opportunities between separate nodal or development zones. From the cartographical point of view, **a corridor is a virtual space, defined by appreciation, that is useful to the ecological functioning of continua**. It would be justified to consider corridors apart from all the other elements constituting a continuum. Indeed, the presence of favourable habitats is not indispensible to the constitution of a corridor. Only the presence of a propagule flow is required for its localization. On the other hand, corridors are generally speaking more or less structured by natural or sub-natural elements which increase their functional capacities. In certain cases, corridors can be constituted only by free spaces, lacking any obstacles, which allow the most mobile species to move occasionally.

3.2 The Fragmentation of Ecological Networks by Obstacles is what Defines Biological Organizational Levels

The mechanism of the fragmentation of landscape by transport infrastructures and human activities has been the subject of numerous publications. The most recent and most complete of these is that of the COST 341 project (Luell & al. 2004) which proposed a synthesis of all current knowledge of the problem and all the solutions applied in European countries.

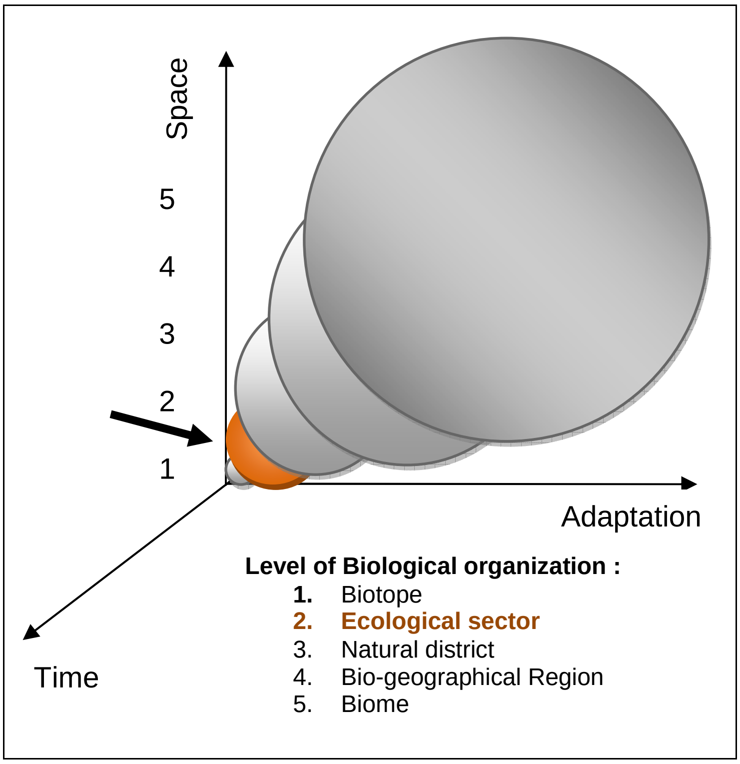


Figure 19.

Diagram of ecosystemic functioning by levels.
The fragmentation of the landscape by human activities brings about the creation of a new level of biological organization:
***the ecological sector**, Which is generally situated betweenthe level of the biotope and that of the natural district.*

Source:
Modified from Blondel's model (1986)

Though the problem is hardly new, it has grown considerably over the last few decades, to the point where it is now considered to constitute one of the principal factors of change in biodiversity — along with the pollution of ecosystems and climate change.

Cartographically speaking, landscape fragmentation is accounted for by the superimposition of the “obstacle layer” (extension zone and impact zones) on top of the various continua used in the analysis. The zones of anthropogenic take-out are subtracted form the buffer zones and corridors, while the impact zones designate modification areas whose consequence is a qualitative and functional reduction of the affected polygons.

Natural physical obstacles such as lakeshores, large rivers, cliffs, rock bars and high altitude zones are considered as partial obstacles whose crossability is subject to a high resistance coefficient.

The process of landscape fragmentation by urbanization and the development of transport infrastructures constitute a mechanism for the complete fissuration of the landscape — through the spatial fragmentation of still-intact habitat ensembles that leads in the end to a veritable decomposition into numerous ecological sectors. Ecological sectors constitute separate landscape compartments, creating particular functional entities whose exterior contacts are articulated around a few exchange points on their periphery (Berthoud & al. 1989). This artificial compartmentalization of the landscape implies the necessity of taking account of a new organizational level in ecosystems: **the ecological sector**. This is located between the habitat (biotope) and the natural district (Fig. 19), with regard to the hierarchical biological systems structured according to the scales of space and time specific to each level as described by Blondel (1986). For practical purposes, however, will maintain that the concept of “**natural districts**”, as defined by Lebreton (1977), designates “those geographical entities presenting a good level of physical (geological and climatic) and biological (principally vegetation) homogeneity and where the relief constitutes the chief criterion of discontinuity”. The concept of ecological sector is here reserved for a more limited landscape entity which empirically contains the habitat areas resulting from fragmentation caused by physical objects — natural or artificial.

The notion of ecological sector is therefore a **minimal spatial entity for the functioning of an ecological network**.

3.3 Taking Account of Biodiversity

The utilization of the diversity of faunal and floral species is complex but also huge in the wealth of information that it is capable of providing.

The efficiency of ecological networks can be analysed with regard to a number of more or less ambitious objectives, such as their capacity to maintain the following:

- An optimal biological diversity;
- A stable biomass;
- A guild of rare and threatened species;
- Species indicative of networks (TVB determining species)

Whatever the objectives, it would unfortunate to not take advantage of the numerous indicators that biodiversity can provide throughout the elaboration of the ecosystemic landscape model.

Achieving a global understanding of the biodiversity of a habitat, a site or a territory (presuming that it is possible to find specialists capable of carrying out exhaustive inventories) requires a considerable investment in time that is incompatible with the establishment of a network model. Data about the relative wealth of certain groups of easily identifiable indicator species, however, can prove useful when it comes to comparing habitats or habitat complexes.

The commonly used indicator species are:

- Higher plants;
- All vertebrae, particularly birds;
- Certain invertebrate groups depending on the milieus researched.

Each chosen indicator group provides its part of the necessary information about the quality and ecological functioning of the researched habitats.

The most effective approach consists in combining the three groups in a sampling programme. It is possible, however, to rely only on data concerning flora and vertebrates. Field research always constitutes a sizable investment in money and people. It is necessary therefore that it should be optimized so as to correspond to as many exploitable criteria as possible when it comes later to the analysis of ecological networks.

Thus a programme of naturalist inventories by sampling destined to document the establishment of an ecological network should always conform to a number of basic rules. These rules are defined by the need to characterize a basic surface area entity useful for the analysis of networks as precisely as possible. This entity is generally constituted by the habitat at the scale of local analysis, but it can just as well be extended to a group of habitats — for example, to a continuum when the analysis is at the regional scale.

These organization rules are as follows:

- **Collected data should be related to a precisely circumscribed habitat or group of habitats**, so that it can later be related to the different functional landscape entities;
- **Data concerning different indicator groups should be rendered comparable** by being related to the same habitat units;
- **Faunal and floral data should not be selective** (all species, rare and common are noted). Sampling is carried out over a number of different site visits so as to take all possible species — spring or summer, nocturnal or diurnal — present on the site into account;

- **Data is quantitative**, by recording the number of observed taxons (number of individuals and mating pairs, or the extent of plant cover);
- **Data also concerns the biological status** of the observed species on the site (reproduction, feeding, rest, travel, in expansion, in regression, etc.).

Once introduced to databases, these inventories, representative of the habitats of the territory studies, will remain forever a usable reference, for comparison with other similar, inventoried sites, or for extrapolation to other sites in a territory for which no reference inventory exists (such as in the case of a new project for the establishment of ecological networks or a development project in a region that is ecologically fragile but insufficiently researched).

Even in the case of the most sophisticated programmes, taking account of global biodiversity is impossible, given the lack of research means and, especially, the lack of suitable specialists capable of identifying the collected taxons.

The use of guilds of characteristic species dependent of a particular group of habitats is practical in terms of the description of milieus and of their potential for accommodating the particular species. In the field, however, and at the level of the empirical presence of species in each habitat, this criterion proves to be delicate to manipulate, as the specialized species are to a large extent dominated by more banal, widely distributed species (ubiquitous species) which also have their place in the general biodiversity of the sector in question.

The identification of heritage species (those accorded protected status or noted in regional or national lists with regard to the degree to which they are considered threatened) also constitutes an interesting vector of information concerning the general quality of the study zone. But the value of this information is much less than that of non-selective inventories.

Without doubt then, the best option is that of drawing up non-selective inventories limited to a few indicator groups easily identifiable by direct observation.

3.4 Versatility, Synergy and Functional Limitations in a Networked System of Habitats

An ecosystemic network always contains numerous information redundancies in the form of the versatility of milieus and functional synergies and antagonisms. Such redundancies illustrate the functional dynamics of systems structured in habitat mosaics. The complexity of natural phenomena is at its greatest in connection with propagule flows generated by the organization of milieus in landscapes. These flows are not associated with spaces that are completely defined. Rather they are distributed according to variable frequency gradients as a function of disturbance factors or seasonal micro-climatic conditions (the case of forest edges and all ecotones in general).

The superimposition of different continua in order to obtain a map of the general ecological network provokes the appearance of numerous multi-functional surfaces, on which species should theoretically accumulate to create zones of high biodiversity.

Multifunctional maps do indeed show zones of high versatility at the level of the ecotones. Thus this situation theoretically produces the mixing of species flows with multiple origins. The results observed on inventoried sites, however, bear out these theoretical projections only partially. The reasons are as follows:

- Species flows through ecotonal (buffer) zones are mostly of ubiquitous species. An enrichment of slightly specialized species originating in different continua does take place, but its extent is limited.
- Open habitats, recently created in multifunctional zones, are indeed rapidly colonized by pioneer species, whereas closed, stable habitats (sub-climax vegetation) experience virtually no change in their biodiversity. This mechanism of partial enrichment has notably been demonstrated in the Plaine de Bièvre study (Fig.20). Thus it can be supposed that a passing species flow effect does exist, but that it does not necessarily lead to new population installation.
- This theoretical mixing of flows of ecologically different species is, moreover, beneficial to predatory species which take advantage of this permanent source of migrating prey. There is a not insignificant demographic sink effect which significantly weakens the functioning in meta-populations of certain species. In a complex ecological network, the increased fragmentation of the territory, exacerbated by the proliferation of open, multifunctional zones, certainly constitutes a

serious limitation to the propagation and maintenance of numerous specialized species that are dependent on nodal zones characterized by more stable and less disturbed milieus.

To summarize, the observation of a high level of versatility in the landscape elements of a general ecological network indeed corresponds to a high level of functioning. Nonetheless, there exists an antagonism with islands of ecological stability required by specialized species. Thus high versatility can also give rise to global deterioration of the network as a whole. **For this reason, in the hierarchically organized ecological networks method, the indicator of versatility is not considered sufficient in itself. It is therefore combined with the direct connectivity of habitats, which indicates a direct relationship with the proper functioning of networks by highlight source zones.**

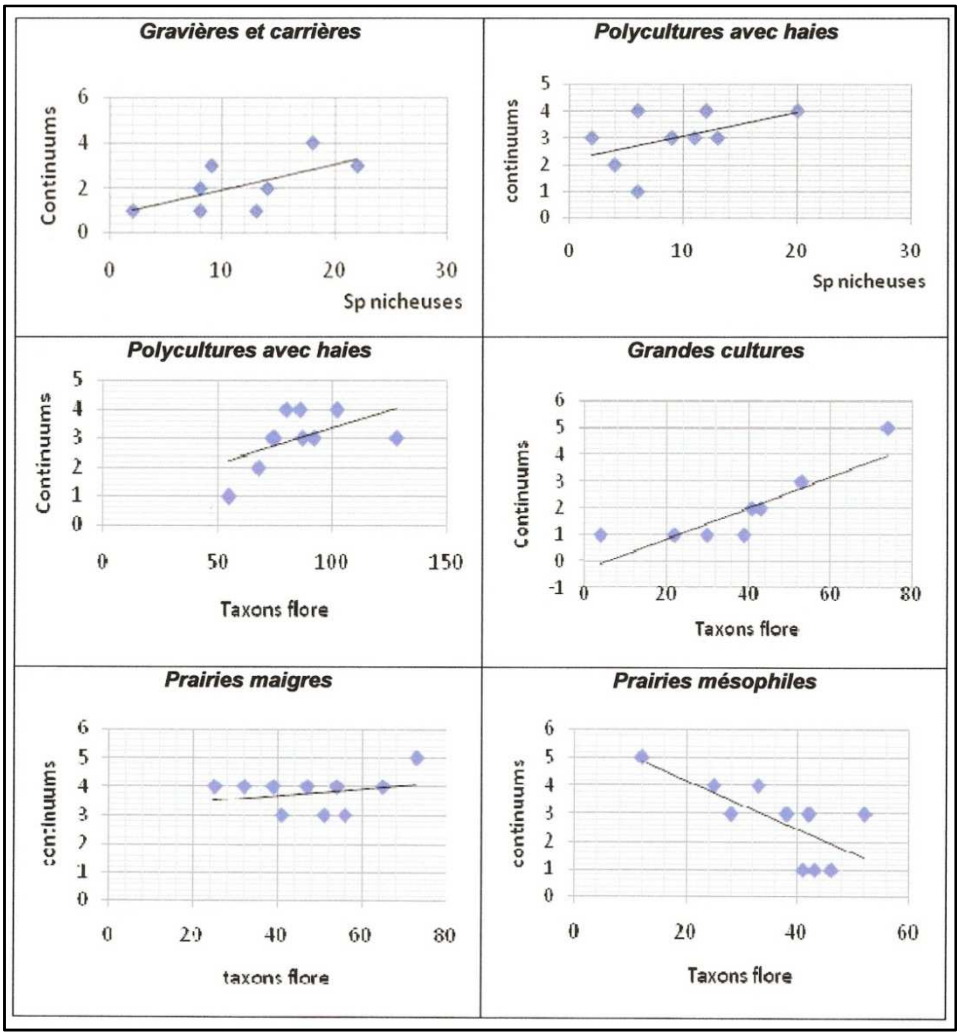


Figure 20.

Influence of the versatility of continua on the diversity of floral and faunal species.

From the analysis of counts carried out in the Pays Bièvre-Valloire.

Source: ECONAT-Concept & al. (2010)

3.5 Modelling of Disturbance Activity Impacts

The mapping of ecological networks conforms to a certain number of rules based on previous practice drawn from numerous transport infrastructure and territorial planning impact studies.

The ecosystemic approach to landscape is in this case not only useful, but indispensible, if we are to acquire a complete picture of natural or transformed habitats, as well as an as precise as possible idea of the diversity of species in the landscape compartments through which they travel. It should by no mean be selective. The approach considers in this regard that the landscape matrix *as a whole* contributes to the progress (or regress) of natural heritage zones. Local applications of the approach and the practice of impact studies has clearly demonstrated the need for the availability of a tool for the analysis of project impacts that is applicable in the landscape according to an ecosystemic basis.

Practically speaking, the modelling of the impacts of a development project follows the same stages as those needed to elaborate a map of ecological networks. Nonetheless, the cartographical approach to the former aims only to illustrate the project's impact zone. The holistic perspective of local ecological networks is not obtained. Rather what is obtained is a detailed picture of the zone subjected to significant landscape transformations and of the interactions between affected biocenoses. **It is this particular approach (of impact studies) that historically is the starting point of the cartography of hierarchically organized ecological networks**.

➢ The mapping of project impacts method

In order to illustrate the modelling of project impacts method, we have chosen to present an outline account of the approach usually employed in the context of the impact study for a motorway project. The approach is here applied to a local sector (Fig. 21), selected at random from the proposed route, though it is clear that it applies to the whole of the project's study zone.

The cartographical stages are as follows:

Stage 1: *Cartography of the forest continuum*

Generally speaking, the forest continuum constitutes the dominant natural infrastructure present in any landscape. So it is this continuum that is chosen here as the starting point, though other continua might just as well have been chosen.

The forest continuum can defined either manually or automatically with the help of GDS, by employing buffer zones of 50 or 100 m, which correspond to the **complementary margins** usually used by forest fauna.

These margins are modified in mapping according to the positive (wooded structures, isolated trees, orchards) or negative factors (zones of disturbing activity, natural or artificial obstacles) observed in the field. With the help of inventories and field observations, the forest areas are defined, and the **nodal and development zones** — which contain the best habitats for forest species — are distinguished from the, more or less transformed, extension zones, which offer a reduced potential in terms of habitat quality.

Connection corridors between forest zones are defined by observation and by relative access probability. If the majority of species never travel further than a few dozen metres beyond edges, a few highly mobile species can cover a kilometre or more outside their forest habitat. When a significant road network is present, these corridors are often advertised by the presence of dead animals on the roads.

Stage 2: *Cartography of those milieus complementary to forest milieus*

A number of milieus serve to reinforce the forest network mesh by providing useful structures of ecotonal types. Natural grasslands, wet or dry, as well as watercourses, with their bank-side vegetation, significantly increase the functioning of the forest network and must, therefore, be mapped systematically.

Given that species proper to these margins are often in the majority in strongly transformed regions, it is sometimes useful to define an independent ecotonal network so as to better understand the functioning of populations dependent on edge zones (e.g. reptiles, hedgehogs, mustelidae).

Stage 3: *Cartography of the grassland continuum*

In certain zones at altitude, nonconvivial to large-scale cropping, mown meadows and pasture occupy large surface areas and present hygrophilic and xeric gradients. From a cartographical perspective, the most significant ecological poles in the landscape are defined so as to produce complementary networks, or the most representative grassland pole is chosen (e.g. thermophilic dry grasslands).

In the case of dry grassland continua, secondary areas constituted by road and railway embankments or by the borders of cultivated terraces can often be added to exploited areas as they constitute essential complements acting as dispersion corridors for the specialized continuum in the ecological mesh.

Stage 4: *Cartography of the aquatic continuum*

The hydrographical network is the most obvious of all ecological networks, but the aquatic network does not function without its own complementary milieus constituted by wet zones, riverside vegetation, alluvial zones and riparian woodlands. Even if some of these areas are already integrated into other types of network (e.g. forest or grassland continua), they still constitute essential components of the aquatic continuum. Every modest section of a watercourse is an indissociable element of the hydrographic network of a drainage basin. Intact habitat zones are distinguished from deteriorated ones and physical or chemical obstacles present in its flow are identified. The most diverse sections are designated as nodal zones.

Stage 5: *Cartography of the agricultural continuum*

Contrary to other continua, the agricultural network is obtained by the subtraction of open spaces from those of forest, grassland and alluvial milieus containing steppic-type open spaces or copse-type semi-open spaces. “Steppic” areas present their own specialized species such as hares, Eurasian stone curlews, bustards, larks, etc.. Whereas mixed-farming and copse areas are rich in ecotonal species but poor in specialized ones.

Thus extension and nodal agricultural zones are designated, but not a specialized continuum partially overlapping with forest, grassland or marshy zones. Agricultural nodal zones are not influenced by other continua and their corridors only constitute poor-quality extension zones. A continuum made up of open residual species and in nature rather like a negative photograph, as it were, is thus obtained.

Stage 6: *Defining anthropogenic areas*

Built-up and inhabited zones can be considered as transformed habitats containing their own specialized species, commensal with humans. The majority of surface areas, however, including influence zones in close proximity to built-up areas, must be considered as demographic sinks for wild fauna. These zones are then subtracted form natural habitat areas and natural continua.

Anthropogenic zones, including extant transport infrastructures, constitute the principal elements of landscape fragmentation, to which certain natural obstacles, such as rock bluffs, large watercourses and altitude zones, should be added.

The superimposition of these five cartographical layers (forest, grassland, aquatic, agricultural and obstacles) provides **a cartographical basis representative of the initial global ecological network** of the landscape in question. This is the tool which will be employed to study all project variants: the impacts of the different effects produced, the probable landscape transformation and, finally, the integration and compensation measures considered with regard to the project’s impacts.

Stage 7: *Installation of the motorway route and its impact zone*

The project — here a motorway — fragments the landscape by its take-outs from the different types of terrain occupation space which characterize the landscape. The disturbances connected to construction sites and work traffic will result in strongly deteriorated ecological spaces that take the form of a modellable ecological footprint — possibly reduced by any reduction measures that may be implemented. The gross footprint for traffic flowing at over 10,000 vehicles a day spreads to 50 to 100 m from the edge of the road surface (Luell & al. 2003). Once deduced from the technical project and modelled, these footprints are superimposed on the initial ecological network. The mapping of the network locates not only the take-outs from habitats, but also the deterioration zones that need to be accounted for in the project’s impacts.

Impacts are quantifiable in terms of destroyed surface areas, qualitative losses, reduction in functioning, and are calculable in the form of the reduction of potential ecological value in an ecological network (Berthoud & al. 1989).

Stage 8: *Environmental measures resulting from the infrastructure project*

All the reduction and compensation measures are logically the product of the amplitude of observed impacts:

- Crossing infrastructures that allow connectivity between priority habitats to be partially conserved;
- Loss of habitats of particular natural interest are compensated by the qualitative revitalization of deteriorated habitats;
- Some new pioneer habitats may be installed (ponds, rockeries, shrubbery, etc.) on sectors presenting little ecological interest but offering good potential with regard to their position in the ecological network;
- Taking advantage of natural structures, refuge habitats and the presence of residual or potential faunal flows, biological corridors can be installed;
- Faunal transit passages.

Cartographical impact stages in a motorway project impact study

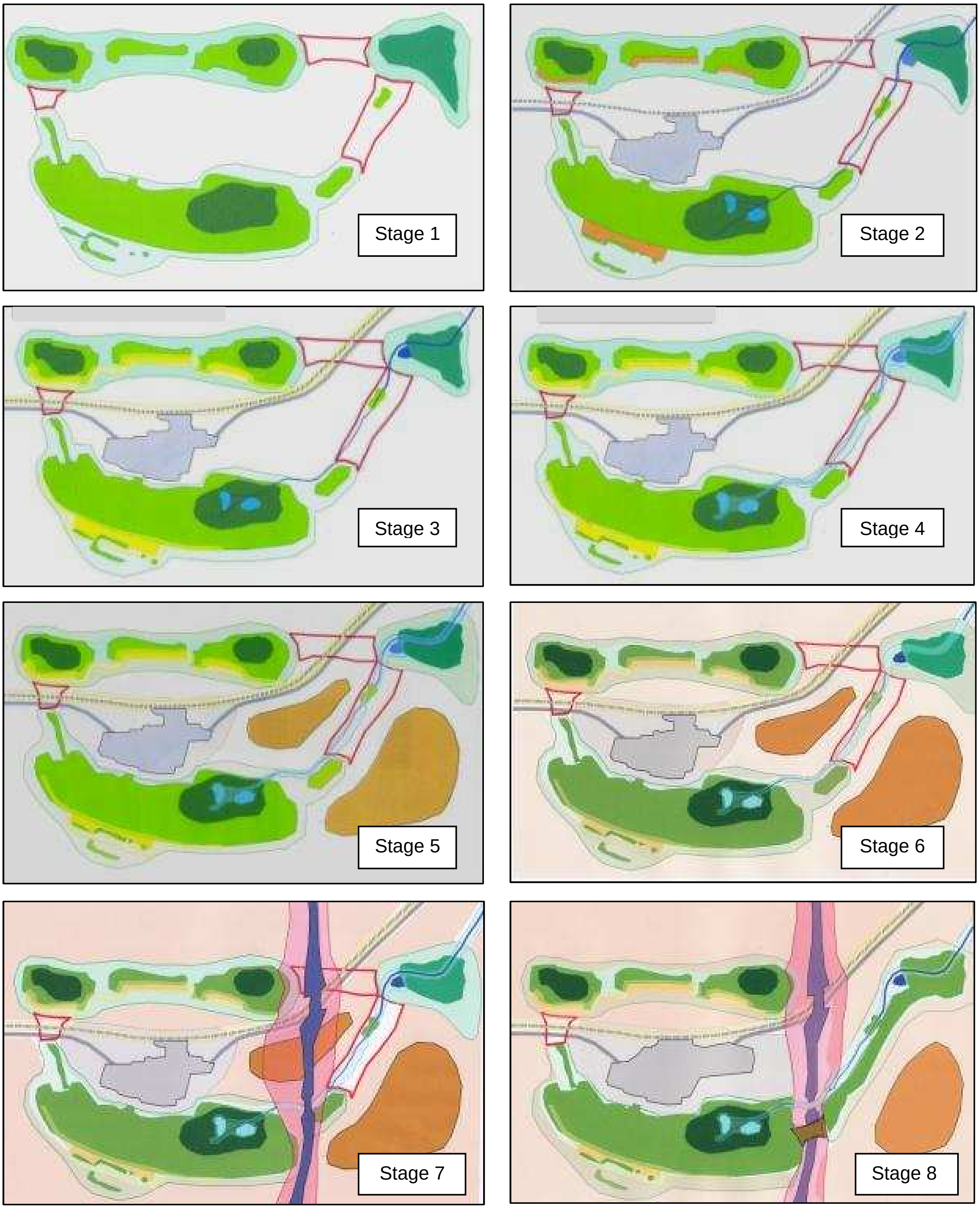


Figure 21. *Modelling stages of the ecological footprint of a motorway route on a local ecological network. Environmental measures are defined so as to integrate the transformation of the ecological network. Source: Berthoud (2007).*

Legend: dark green = forest reservoir zone; light green = extension zone; yellow = grassland; beige = agricultural zone; brown = agricultural reservoir zone; blue = watercourses and wet zones; grey = built-up zones; mauve = motorways; pink = biological disturbance footprint; red frame = biological corridor..

This raft of environmental measures (Fig. 21 stage 8) aims at the constitution of a new ecological network in a transformed landscape that contains habitats and species of equal particular interest (in the sense of ecological coherence), rather than just the conservation (partial but acceptable?) of these particular-interest values without any consideration of ecological coherence in terms of the functioning and long-term viability of the newly installed landscape network.

The list of species of particular interest present on the site has been established so as to be able to choose those spaces of particular importance with regard to the implementation of the project. Each species (or group of species) has been the object of dispersion tests starting from occupied habitats or from those potentially favourable at the initial reference state of the project site.

This approach implies the definition of the zone of study and of the project's implementation that extends beyond the habitual direct take-out zones associated with such projects (the case for example of zones of Déclaration d'Utilité Publique in France). The planning of environmental measures associated with the project will describe a series of measures, some of which are carried out directly by the project's principal contractor, while others will need to included in subsidiary projects such as fragment regrouping or the outline directives of territorial planning.

Indeed, beyond the specific case of the project analysed here and given that the ecological network is a progressive and dynamic concept based above all on the development potential of habitats in the landscape, it is essential that the same management that the same conceptual approach to landscape transformation be applied to any and all development projects likely to influence the territorial organization in the zone concerned — both at local and regional scales.

Comments:

- Reduction and compensation measures are the logical result of landscape transformations expressed in terms of modifications to the ecological network;
- Habitat losses are compensated by the revitalization of deteriorated areas and by support for extensive types of farming;
- Ecological network connections are re-established by the construction barrier crossing infrastructures and by the reinforcing of pre-existent corridors.

3.6 Conflict Points in a Regional Ecological Network

The consideration of a given space, defined by its priority seasonal propagule exchange functions, is a delicate exercise, and one that is frequently contested by uninitiated observers who are only rarely aware of the issues involved in episodic flows that generally are hard to spot and take place over a very short lapse of time. Such migrations do indeed constitute a biological phenomenon characterized by its rapidity and also by its exceptional amplitude. They are, moreover, indeed unobtrusive, often taking place at night. But they are also spectacular in how they cause the massive mobilization of specific populations. Generally speaking, they have been ascertained by repeated observation, although the object of such observation is constituted more often than not by the presence of road kill. Conflicts between fauna and traffic have been the subject of many publications, so that the principles of the phenomenon are well known. The Swiss examples provided the works of Müller & Sigrist (1981) and Burnand & al. (1985) on the behaviours of fauna in the vicinity of roads, and which are the fruit of thousands of hours of data patiently accumulated over some twenty years, can be cited. These studies constituted the starting point for the report on faunal corridors in Switzerland (Holzgang & al, 2001), report which preceded the publication of the national REN maps (Berthoud & al, 2004).

In the Isère, a study that proceeded by soundings of employees of road services and hunting federations following field observations fed into a database used to set up the REDI (ECONAT 2001). This was recently followed up an update (EVINRUDE & ECONAT, 2007).

Thus, in the complete elaboration process of a cartography of ecological networks, one would always proceed by a cartographical simulation justified by comparison with field observations.

In the adopted methodology, the cartographical designation of corridors always corresponds to the same definition:

- A corridor is a particular space used by one or several animal species groups at a particular juncture in their annual cycle (seasonal migration) or during a development phase (pre-adult dispersion), both of which pushes the animals in question to quit their usual vital territory in search of more favourable temporary or permanent habitats. A corridor does not in itself constitute a favourable habitat, but merely an acceptable space through which to rapidly reach such another favourable space. It is, therefore, always a tenuous prolongation — located outside the boundaries of living spaces — that is chosen for transits answering only to the criteria of safety, rapidity of movement and the absence of major obstacles. A corridor is not necessarily multi-specific, but can easily become so if the refuge structures it contains are numerous and various.

It is noticeable that the definition adopted here is somewhat different to those developed for NATURA 2000 and the pan-European ecological network. These two concepts attributed the status of corridor to all spaces allowing protected sites or sites designated as priorities within the EU to be connected. This restrictive approach to landscape functioning is regrettable inasmuch as it gives rise to confusions. The aim of the EU is to establish a certain number of priority spaces for the protection of the natural environment linked each to each other by connective spaces serving as corridors. What is really necessary at both regional or local levels, however, is the identification of the pre-exsisting ordinary ecological network in the landscape — which contains various types of continua, connected or not by corridors — only part of whose elements would be eligible for inclusion in the pan-European ecological network, and only certain continua groups and corridors of which would be attributed the title of “priority corridors”.

This very restrictive description of ecological network does not correspond to the systemic approach recently defined by the CDB.

3.7 The Need to Identify the Issues at Stake in the Conservation of Natural Heritage

The definition of the issues concerned with the conservation of biodiversity and the ecological coherence of habitats indispensible to the maintenance of natural heritage in any landscape necessarily involves an evaluation of the factors that determine the ecological efficacy of landscape compartments.

With respect to these problematics, analysis must at the very least concern itself with the quality of available habitats, with their hosting capacity for biocenoses and with the efficacy of their multiple interactions within network-structured spatial systems. For indeed, the functioning of habitat networks are not limited merely to their spatial connectivity, nor to their heritage value based only on their biological diversity, nor on the presence of species or habitats deemed to constitute priorities in a natural protection strategy. In this area of research, the analysis of infrastructure impacts that disturb or destroy natural habitats — in the context of project impact studies made obligatory by environmental legislation — has driven considerable progress.

Indeed it is interesting to note that, even if the two problematics are closely related, the drive to difine different priority action levels has always historically taken precedence over the need to understand interactions involved in habitat connectivity. So it is that the common practise employed for environmental impact studies since 1980 has resulted in the necessity of evaluating the consequences of the various type of actions and of planning of the natural and human habitat.

This preoccupation with the identification and evaluation of issues at stake — notably with regard to transport networks — also implied the need to distinguish the different natural habitats involved: which sometimes play host to species of particular interest and sometimes to transformed habitats occupied for the most part by banal species and the need to acquire an understanding of exchange flows — physical and chemical as well as biological — in the impact area. This analysis should firstly address a limited area (the zone of the direct impacts of the construction site) and then a wider one, so as to integrate all natural functions (drainage basins, vital territories for fauna, resource accessibility, etc.).

The first local cartographies of ecological networks, whose purpose was to evaluate the environmental impacts of development projects, were developed at this time (Fig. 22).

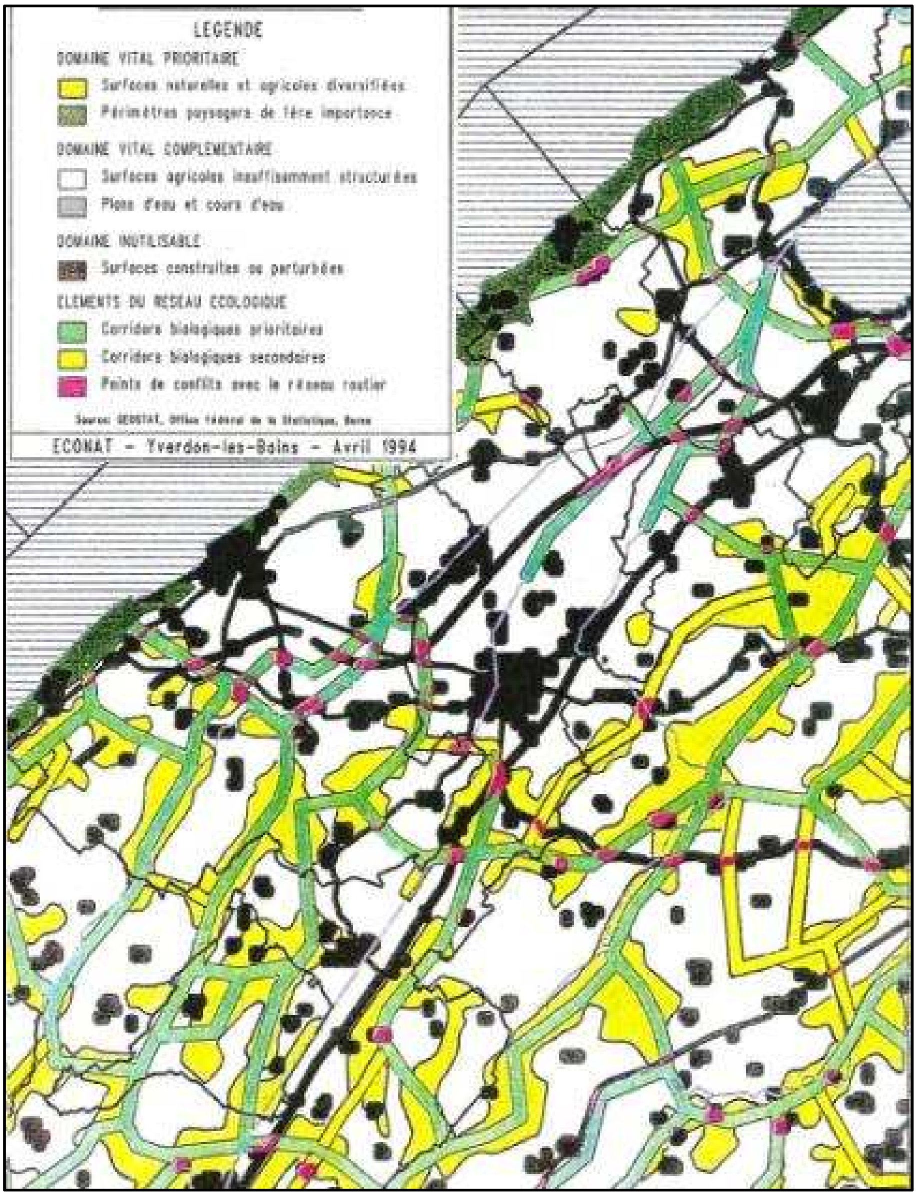


Figure 22.

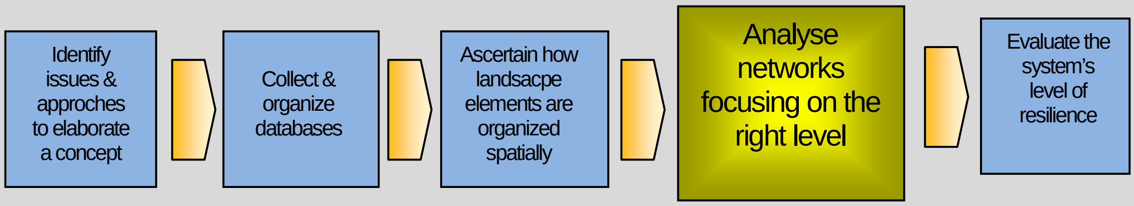
Archive extract of a map of ecological networks drawn up as first step in the definition of a motorway route in Switzerland. Study for possible routes for the N1 on the Yverdon – Avenches sector.

Biological corridors are here figured by theoretical axes bisecting priority living areas

Source:
Berthoud (1994)

CHAPTER IV

Establishing an Ecological Network Map



Summary

Establishing a map of ecological networks (EN) consists in the graphical translation of landscape elements and their functional relationships within a system structured by multiple networks. Because of their high levels of autonomy, each of these networks is partially independent; but they are also strongly interactive through the effects of synergy and antagonism.

The identification of an ecological network in the form of an ecological landscape grid does not result from territorial planning, but rather and solely as the result of the analysis of the existing, residual or emerging (though in all cases functional) natural infrastructures that underlie the landscape.

The concept of "ecological networks" adds to the landscape the dimension of the interactions between its natural or transformed habitats.

The EN map that we seek to establish merely constitutes a simplified model of those visible and invisible elements of the mosaic of habitats that are the organized flows of living elements which link habitats each to each other. Thus we can really speak of an ensemble of natural infrastructures that are organized in networks. Such infrastructures function according to the preferential networks chosen by groups of flora or fauna.

This first, and still rough, synthetic model is progressive with respect to the different levels of analysis applied, but also with respect to the quality of the data used. It is, moreover, doubly progressive inasmuch as improvements in knowledge leads to the introduction of new pertinent elements (new connections or new habitats for particular species populations), and inasmuch as the model remains subject to the numerous landscape changes that occur, whether their origin be human or natural.

The following chapter describes the procedures employed to establish a map of this type.

The process is based on the use of a Geographical Information System (GIS) that permits not only the rapid integration of continually occurring environmental changes, but also the elaboration of perspective scenarios by the introduction of probable modifications caused by a given development (urbanization, infrastructures, traffic, etc.) or by foreseeable trends (resource use, climate change, etc.).

The EN map constitutes a **basic source of information** about which there is little to discuss other than the question of its improvement through the leveraging of new databases. At this level, however, the ability to define issues beyond the most rudimentary—destroy, conserve or restore—remains limited without the further introduction of a functional hierarchy of elements or networks as a whole.

4.1 The Hierarchical Ecological Networks Concept

The establishment of an eco-systemic map engages the use of number of different types of information and methods:

- The **cartography** of an ecological network is the finished product of a complex process. Although it needs to be usable at different scales, it must nonetheless be clearly focused on the scale at which it was established. It must be able to inform its higher level so as to form an ensemble of coherent information based on compatible approaches and criteria. It must also be capable of serving as a basis for the creation of more detailed maps at the local scale. This cartography is subject to operational objectives whose limits and constraints must be clearly understood. It must be applicable at a regional or national scale. Such cartography is made far easier by the use of a GDS, but it may nonetheless be carried out manually at the local scale using information from a national-scale map for example. Thus such maps are able to present both the cartography of thematic analyses and synthetic data.

- The **hierarchical ecological network method** is based on principals which, even if they are not always uniform or universal, are always theoretically coherent. Through the establishment of probabilistic models, it is as well able to distinguish aspects of terrain occupation and the functioning of populations as the interconnectivity of habitats.

It necessarily deploys an iterative and participatory method. Thus:

- **Application processes** must be logical and comprehensive;

- **Results** must be acceptable, so as to obtain consensual agreement, and pragmatic, in order to be capable of generating practical tools (for analysis and follow up) and to serve the strategic planning of natural heritage.

4.2 The Process of Establishing Eco-Systemic Maps

The use of a process for the creation of landscape modelling based on **progressive iteration of the type "analysis-hypothesis-validation"** is pertinent for the grasp of a cartography as complex as that of ecological networks. Indeed the task will need to articulate a number of convergent approaches. In these different approaches, however, the collection of data at different levels does not necessarily need to be absolutely coordinated. In any event, it is necessary to assemble:

- General data defining the eco-geographical context of a given landscape sector. This context should be in the form of a potential regional ecological infrastructure;

- Local data providing qualitative and quantitative indicators of spatially homogenous entities. These indicators should take the form of biological inventories capable of serving as reliable reference.

This approach will permit more and more precise landscape network models to be developed progressively as the need for knowledge expands. The precision of the models is gauged in terms of the information contained but also in terms of their functional structures and their operational performance.

A **"top down / bottom up"** process offers the particular advantage of facilitating the rapid generation of debate about what is at stake in the global management of landscape space while still being capable of carrying out targeted verifications. Such verifications are necessary at the level of the mechanisms of biological evolution, a level whose understanding is always complex and costly in terms of the collection of data—incidences of anthropogenic disturbance, evolving dynamics of species populations as a function of environmental parameters, importance of interactions between biological different communities.

Although it is often judged to be not scientific enough, the approach has proven itself to be indispensible in the field of applied research, inasmuch as territorial development projects usually unfurl at a faster pace than that of the accumulation of scientific certainties. Thus the approach allows incertitude to be managed and work to be carried forward on options presenting the least environmental risk.

The "top down / bottom up" process constitutes an integral part of the hierarchical ecological network mapping method inasmuch as it provides reliable but simplified and progressive modelization of the complex ecological phenomena taking place in the landscape.

4.3 The Choice of Analysis Scale for the Ecological Network

The methodological principles for the mapping of ecological networks or of green or blue grids—in the form of regional maps to a scale of 1/100,000 or to a national scale of 1/500,000÷have been outlined in a number of recent publications. To mention just some examples: *The Rhône-Alps Ecological Network*, Rhône-Alps Region, 2009) or the *Methodological Guides of the Operational Committee "Blue and Green Grid"*, Grenelle de l'environnement (2009).

The chosen approach of the present guide is to explore **analysis at a supra-local scale of 1/25,000**. This scale poses concrete problems of application by confronting the realities of a specific territory—such as the conservation of corridors—to the management of significant habitats or the creation of transit passages for fauna.

The 1/25,000 scale is appropriate to achieving a global vision of local problems related to human activity. It constitutes exactly that **level of detail necessary to analyze**, on the one hand, the interface between global and regional levels of detail—whose ecological grid maps are drawn to a scale 1/100,000—and, on the other hand, the local level, whose maps are drawn to a scale of 1/10,000 (or even 1/5,000). It is furthermore a scale that allows useful information about ecological networks to be represented on zonal plans so as to inform local territorial planning and the management of natural spaces.

The scale 1/25,000 is ideal for achieving the **detailed analysis of the natural infrastructure of landscapes**, as even the smallest habitation is visible on maps at this scale. It is ideal too for making complete evaluations of the ecological potential of the various constituent elements of a network because an overall view of landscape issues is possible at this scale.

4.4 Organization of the Cartography

Working method must be adapted to the spatial organization of ecosystems by taking into account the multi-scale functioning of both the landscape and of the levels of scale implicated in the analysis (see Chapter 2.2.4). To put it another way, the data necessary to the process is not the same depending on whether the scale is that of the local or of the regional. On the other hand, however, an analysis focused on a limited area must necessarily take account of data available at a greater level of scale—district or region—if it is to be pertinent.

- The general methodology to be followed should be clearly explained to all project partners, stating precise objectives and the technical limits of the undertaking.
- The required basic data is of three types: geographical data base, biological data base (inventories) and anthropogenic milieus data base.

4.5 Eco-Systemic Entities in a Landscape

The groups of milieus that compose a given landscape consist of levels of functioning that can be differentiated according to the ecological affinities that exist between the different milieus, but which can also be differentiated according to their qualitative characteristics and their hosting capacity. Thus we will be able to discern continua of homologous habitats that may or may not be interconnected by corridors to constitute networks.

4.5.1 Identification of Determinant Landscape Groups

There is nothing new in making groups of different types of spatial occupation whose ecological factors are sufficiently close that they form habitat groups or ensembles of complementary milieus exploitable by ecologically proximate faunal or floral groups—i.e. linked by certain preponderant physiognomic and geographical factors (climate, orography, soil, hydrography, vegetation, etc.). The same principle has been particularly widely employed by phytosociologists to describe the vegetation present in the landscape in terms of a mosaic of habitats that are close to being ecosystems but which possess large-scale functional coherence. Lefeuvre & al (1979), and then Blandin & Lamotte (1985) employ the term “eco-complexes” to describe habitat groupings that present both a relatively high level of constancy and permanent interactions. The concept of “ecological continuity” or “continuum” that was used from 1999 on to establish the Swiss National Ecological Network was the result of crossing the cartographical concept of groupings based on eco-complexes with the observation of exchange flows between species groups possessing the same ecological affinities. This allowed a number of independent but partially superimposed functional networks to be distinguished.

The most common generic continua are as follows:

- Forest continuum
- Aquatic continuum
- Marshland continuum
- Meadowland continuum
- Agricultural continuum
- Anthropogenic continuum

Other types of continua can be added where the cartographical requirements demand it so as to be better able to describe the landscape as a whole. One could refer for example to:

- Rocky continuum in all mountain regions
- Nival continuum in high-altitude zones,
- Shrubland continuum in Mediterranean regions
- Steppic continuum in semi-desertic zones
- Dune-like continuum in flat dry zones
- Etc. The list is not exhaustive

As a comparison (Table 1), the study of the Rhône-Alpes ecological network (Région Rhône-Alpes, 2009) employs an enriched version of the range of continua used in the study of the ecological network of the department of Isère (ECONAT 2001), whereas the study of the ecological network of the Pays de Bièvre-Valloire (ECONAT et al. 2009) is even more comprehensive but deals with a predominately non-mountainous region.

Continua used in the REDI (2001)	**Continua used in the RERA (2009)**	**Continua used in the REPBV (2009)**
Low-altitude forests High-altitude forests and pastures -- -- Aquatic and damp milieus Natural pastures: thus dry thermophilic milieus Agricultural milieus: thus extensive agricultural milieus Obstacles (anthropogenic)	Low-altitude forests High-altitude forests and pastures High-altitude moorland and lawns Rocky zones Aquatic and damp milieus -- Dry thermophilic milieus Agricultural milieus extensive & marginal Obstacles (anthropogenic)	Forests -- -- -- Aquatic and damp milieus -- -- Flatland agricultural milieus Slopeland agricultural milieus Anthropogenic milieus

Table 1. *Convergence of the continua employed to describe different research zones.*

REDI = Departmental Ecological Network of the Isère; RERA = Rhône-Alpes Ecological Network; REPBV = Pays de Bièvre-Valloire Ecological Network

The first two studies prioritize the richest natural continua, making best use of available numerical data. But, from the experience gained, it appeared preferable in the case of the third study not to be selective but rather to treat all the various types of terrain occupation, even where available data on certain natural values was insufficient. This is usually the case, especially with regard to anthropogenic and extensive agricultural milieus and rocky or glacial and permanent névé zones.

Thus, the crucial step of the approach is to treat all the large synthetic and functional groups present in the landscape together in a way that covers all available terrain surfaces, for within a global accounting, even those zones of slight biodiversity present their own particularities. They are important too inasmuch as they exert significant influence on the more productive continua, often playing the role of demographic reserve.

Each continuum constitutes a partially independent ecological grid or a network in which animal and vegetable species are organized to form first biocenoses and then habitats according to a more or less complex mosaic that is more or less favourable to different species. **All continua taken together along with their connective corridors** constitute the visible natural infrastructure on the basis of which all biological functioning is organized in a given landscape.

This particular landscape organization is primarily informed by geological, climatic, hydrological and anthropogenic constraints. As a result, ecological networks can be seen to be the expression of biotic potential—subjected to these different constraints.

The aim of this cartographic approach is to represent this natural infrastructure synthetically and then to incorporate into that representation all the available data on the biocenoses present.

In order materially to render continua's extension zones, the different classes of terrain occupation will be brought together in such a way as to spatially situate ensembles of biotopes presenting the most closely resembling ecological conditions possible.

The approach is always the same no matter what the source of the numerical terrain occupation data about used.

When establishing the ecological network for the department of Isère, we employed data provided by Corine Land Cover (ECONAT 2001). Later, for a number of other local studies, we used more detailed SPOT Thema data. The example of "hierarchical ecological networks" presented here is taken from the recent study of the Pays de Bièvre-Valloire (ECONAT-Concept & al. 2009), which covered an area of some 850 km^2 and 58 communes.

It should be noted the distinguishing categories applied to the terrain both for the mapping and the inventories (Table 2) result from a high level of precision, a level that is necessary if we are to properly organize a naturalist database. Unless a detailed cartography of the whole study zone is available, however, not all the categories resulting from the field are applied at the general mapping level. Thus it is that a synthetic map of the regional ecological networks contained in an entire study zone necessarily retains a lower level of detail.

4.5.2 Utilisation of Land Use Databases

Different numerical databases are currently available on the market. We have successively employed GEOSTAT, Corine Land Cover and SPOT Thema, each of which presents its own advantages and drawbacks:

- **Geostat** (GS) is a biophysical terrain-occupation database covering Switzerland. It provides data on a hectare-scale grid, updated every five years since 1980. GS distinguishes 85 terrain-occupation classes, which correspond to those proposed by the CLC. The GS has been employed since 1995 for the establishment of the Swiss National Ecological Network (REN-CH).
- **Corine Land Cover** (CLC) is a European database of biophysical terrain-occupation. It is a vectorial base drawing on photo-interpreted satellite images (Landsat, SPOT, IRS, etc.) at a precision scale of 25m issued from the IMAGE2000 and IMAGE2006 projects. CLC distinguishes between 44 terrain-occupation classes. It is pertinent to numerous applications in the field of the environment and territorial planning, and has been notably used for the establishment of the Ecological Network of the Department of Isère (ECONAT 2001) and the Rhône-Alpes Regional Ecological Network (ASCONIT 2009).

These two databases are perfectly adapted to the establishment of thematic maps to the scale of 1/100,000, but, because of their lack of precision at the scale of the detailed and linear structures that play such an important role in the functioning of local ecosystems, they are not adapted to use at larger scales.

- **SPOT Thema** (ST) is a land use database with a level of precision pertinent to the scale of inter-communal problems and issues (see Box 3): applications are possible up to a scale of 1/25,000. It is a vectorial base drawing on interpreted images from SPOT satellites and enriched by the adjunction of numerous exogenous documents which allows the level of detail to be improved to a precision at 10m. The database distinguishes 29 terrain-occupation themes. It was used, for example, to establish the Pays de Bièvre-Valloire Ecological Network, and it this example that will be used here to demonstrate our methodology at a territorial scale.

The following extracts from two maps of the same study zone, one produced by CLC (Fig. 23) and the other by ST (Fig. 24), allow their relative precision to be compared.

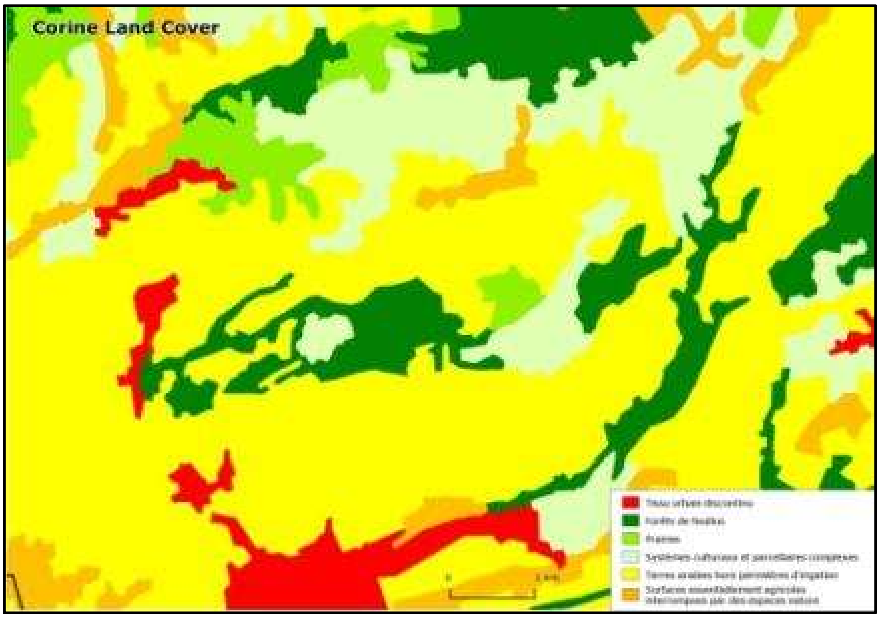


Figure 23.

Extract from a terrain-occupation map produced using numerical data from CORINE Land Cover. This base is appropriate for producing regional maps to a scale of 1/100,000 or national maps to a scale of 1/500,000.

Source : ECONAT-Concept & al. 2010

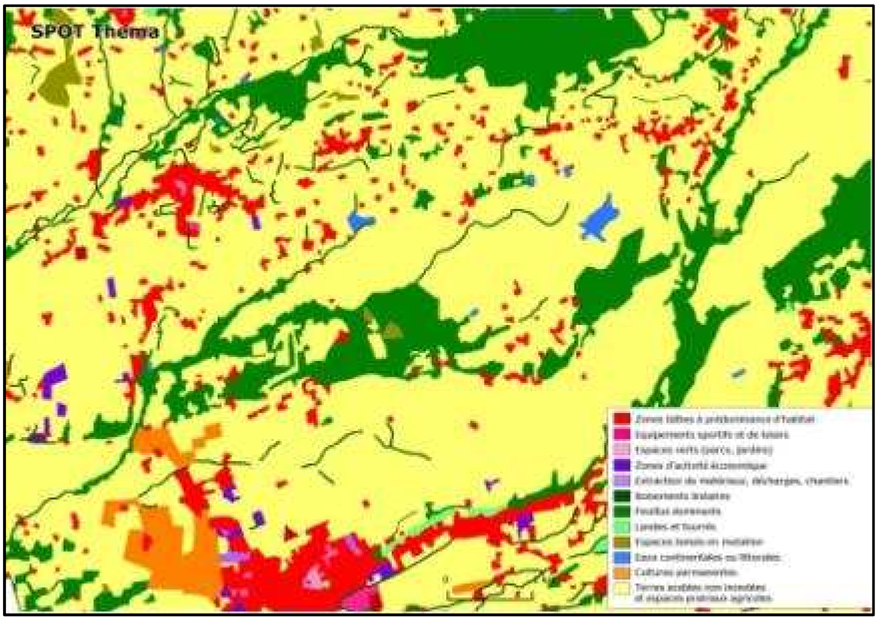


Figure 24.

Extract from a terrain-occupation map of the same study produced using numerical data from SPOT Thema. This base is appropriate for producing maps to a scale of 1/25,000.

Source : ECONAT-Concept & al. 2010

Box 6
What is SPOT Thema?

A numerical land use database

The analysis of land use produced by SPOT Thema is founded on two techniques: the semi-automatic extraction of information (image analysis) and Computer-Assisted Photo-Interpretation (CAPI). Over and above the use of SPOT data, CAPI also relies on numerous exogenous documents so that image-interpretation data may be augmented: aerial photography, topographical maps, etc..

Photo-interpretation is carried out according to the Minimal Thematic Extraction Unit (**MTEU**) principal that stipulates the selection of the minimal surface area to be represented so as to meet the needs of the greatest number of users. Thus the MTEU constitutes the surface area (expressed in square metres) smaller than which a thematic object belonging to a given class (wooded area, type of activity, etc.) cannot be considered as such. In these cases, such an object will be attributed to the largest neighbouring class (geographically) or to the one which is closest to it thematically.

Fundamental data: the products of SPOT Thema necessitate images of the type P+X (where P is a panchromatic scene and X, a multispectral one), without any cloud cover, taken between May and September (growth period) and orthorectified on the same bearing points as the BD ALTI of IGN.

The scene P+X SPOT product (a black and white panchromatic scene **P** + a four-band multispectral scene **X**i or a three-band **X**s) is developed from two simultaneously acquired images of the same geographical zone using the same SPOT instrument. The resulting image, obtained from the combination of the Xi or Xs image with the P image, has a 10m resolution.

Costs: Numerical data has to be purchased from SPOT IMAGE in Toulouse.

The average 2009 is in the region of 20 € per km^2

Utilization constraints: numerical databases are not transferable to other any users other than the direct purchaser. For details concerning utilization, contact supplier.

Some ground-cover categories, such as grassland, are not distinguished from arable cropping.

Continuum Type	CORINE LC	SPOT Thema	ST Designation	Terrain Code	Terrain Mapping Designation
Forest Continuum: Forest and open woodland	311	61	• Predominantly deciduous	611	• Beech- and oak-woods
	-	-	-	612	• Slope forests, wooded banks
	-	-	-	613	• Alder- and ash-woods
	-	-	-	614	• Acacia coppices and underwood
	312	62	• Predominantly coniferous	620	• Conifers predominant
	-	63	• Indeterminate populations	630	• Indeterminate populations
	324	64	• Mutating woodland	640	• Mutating woodland
	-	65	• Woods and hedgerows	651	• Riverine
	-	-	-	652	• Low hedges
	-	-	-	653	• Mixed hedges
	-	-	-	654	• Woody hedges
	-	-	-	655	• Scree, rock shrubs
	322	71	• Moorland, thickets, woody wasteland	711	• Blackberry bushes
	-	-		712	• Thermophilic bush thickets
	-	-	-	713	• Wet bush thickets
	-	-	-	714	• Agricultural wasteland and fallows
	222	52	-	521	• Poplar copses
	-	-	• Plantations, orchards	522	• Walnut copses
	-	-	-	523	• Plantations (various species)
	-	-	-	524	• High-trunked orchards
	-	-	-	525	• Low-trunked orchards
			-		
Aquatic and Wet Continuum Aquatic and marshy milieus	411	78	• Marshes and peat bogs	781	• Mown water-meadows and flood-meadows
	-	-	-	782	
	412	-	-	783	• Reed banks
	511	81	• Rivers and streams	811	• Peat bogs
	-	-	-	812	• Rivers (> 5m wide)
	-	-	-	813	• Streams, permanent courses
	512	82	• Continental and coastal waters	821	• Streams, temporary channels
	-	-	-	822	• Forest ponds
					• Agricultural ponds
Agricultural Continuum Agricultural and pastoral milieus whether extensive or intensive in kind*	21	51	• Arable and pastoral terrains	511	• Enclosed multi-crop-land
	-	-	-	512	• Unenclosed multi-crop-land
	-	-	-	513	• Large-scale cropping
	-	-	-	514	• Maize, tobacco & potatoes
	22	-	-	515	• Vineyards
	-	-	-	516	• Fruit-growing
	23	53	• Mown meadow-land and pasture	531	• Dry pasture
	-	-	-	532	• Wet and mesophilic pasture and meadows
Anthopogenic Milieus or "obstacles"	111	11	• Continuous urbanization	110	• Continuous urbanization
	112	12	• Discontinuous urbanization	120	• Discontinuous urbanization
	121	21	• Industrial and commercial zones	211	• Warehousing and malls
	-		-	212	• Greenhouse agriculture
	122	22	• Transport infrastructures	221	• Roads and motorways
	-	-	-	2222	• Railways
	124	-	• Airport infrastructures	23	• Airport infrastructures
	-	-	-	224	• Agricultural or forestry roads
	131	31	• Mining and mineral extraction	312	• Gravel and sandpits
	132	-	• Dumps	313	• Dumps
	-	41	• Parks and green space	410	• Parks and green space
	-	42	• Sports infrastructures	420	• Sports infrastructures
	-	90	• Free urban spaces	900	• Free urban spaces

***Tableau 2**. Organization of land use categories serving to define the extension zones that underlie different continua.*

(*) *The difference is accessed as a function of terrain declivity*

Box 7

Steps necessary to ensure comprehensive numerical land-cover data or failing that, at least, data sufficiently coherent to enable the drawing up of maps of ecological networks

Although SPOT Thema data is relatively detailed, it is not sufficiently so to enable all the continua to be properly distinguished. Grasslands and wet zones are not, for example, distinguished from arable farmland. Resorting to inventories of the areas in question or to making interpretive approximations are possible temporary solutions, which might be made up later through local analyses.

Some regions are already covered by the detailed mapping of certain NATURA 2000 habitats, which do include dry grassland and wet zones. If this is not the case, then it is possible to employ a few technical tricks that enable the sought-after habitats to be identified with a good level of probability:

- Grassland and extensively farmed agricultural land are distinguished by CORINE Land Cover. Thus, the required data can be extracted from the CLC database and then sumperimposed on the SPOT Thema data. Although they are less precise, CLC data is adequate to the definition of continua. Following on from this, one would take advantage of the process of the identification of reservoir zones, carried out obligatorily in the field, to correct the extension zones furnished by CLC;
- Grasslands can also be selected by locating all non-wooded slope zones, whether wet or dry, with regard to declivity, exposition and using a numerical terrain model;
- The use of aerial or satellite infrared photography allows dry and wet zones to be distinguished from each other easily;
- The systematic use of numerical or scanned national-scale maps enables habitat areas or lines or analytically useful landscape structures to be extracted. As this information is often out of date, however, it makes sense to facilitate on-site verification with the supplementary use of aerial or satellite photography.

In all events, it is human habitation and its corresponding infrastructures that increase the most rapidly, risking thus interference with the real presence of habitats favourable to the original continua. Any over-generous definition of original natural continua is only problematical where their potentials are incompatible with topographical conditions.

It should always be remembered that the definition of continua and their zoning invariably constitutes an iterative and progressive process and that the reality of the existing landscape status can only be ascertained by detailed field study.

4.5.3 A Continuum’s Extension Zone

Within a given ecological network, the extension zones of different continua constitute the visible basis of the landscape’s natural infrastructure: the skeleton around which the different ecological phenomena will be articulated, phenomena that frequently go unnoticed by users. Distinguishing between the various broad continuum types enables a first rough sorting of the innumerable existing habitats to be carried out. These sorted habitats will then be linked one with the other by exchange flows that are more or less substantial according to their affinities, antagonisms and relative accessibility within the landscape mosaic.

➢ Identification of Forest Continua Extension Zones

In order to obtain a practicably small number of polygons covering all the different types of wooded milieus, a grouping of the polygons of the various classes designating all the forest vegetation types identified within the study zone is carried out (Fig. 25). Only SPOT Thema data is used here (Table 3).

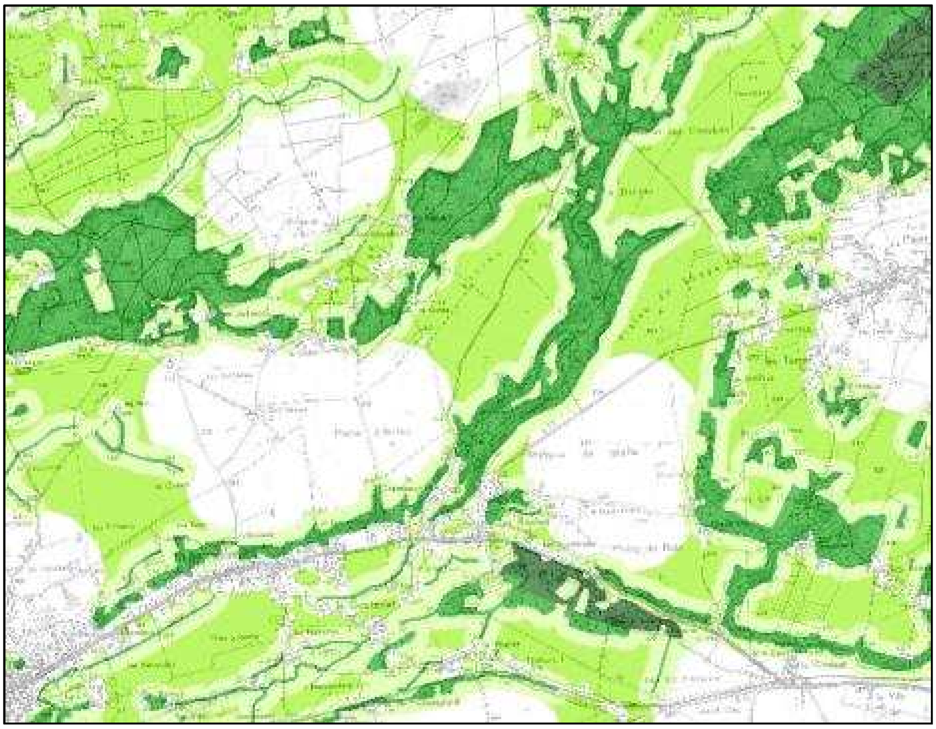


Figure 25.

Example of a forest extension zone map. The data represented concern topographical relief, constructed zones, transport infrastructures, etc., so allowing groups of wooded vegetation to be situated.

Legend:

Nodale zone
Extension zone
Ecotonal margins
Potential corridor

Source:
ECONAT-Concept & al. (2010)
Cartography AURG

➢ Identification of Aquatic and Marshy Continua Extension Zones

The practice of grouping together all aquatic milieus, including rivers and streams on the one hand, and standing water and marshy zones (including water- and flood-meadows and reed banks) on the other is usually justified both by the high level of ecological linkage within the whole hydrographical network—organised as it is into drainage basins—and by largely common ranges of species. In more localized analyses directed at specialized species groups, however, it is often useful to treat the two sub-groups separately.

The case of this continuum is particular in that both ST and CLC are insufficiently precise to be capable of distinguishing a river system in its entirety (Fig.26). This is because not all linear cartographic elements are considered by them (surface areas insignificant or null). Thus it is necessary to make up the lack by employing vectorial hydrographical network data. In our case, the IGN's Carthage database is used.

The units selected by STU are grouped together so as to produce a practicably small number of polygons of wet zone classes, both running and standing water (Table 3).

The vectorial river system network obtained by Carthage database distinguishes between permanent and intermittent channels, as well as agricultural drainage ditches and culverts. All these various elements are represented with their specific attributes maintained. The requirement then is to transform, with the help of variable buffer zones, "poly-lines" into polygons organized into three breadth categories defined by the data table (see Box 7). This new layer is overlaid upon that produced by ST to constitute the aquatic and wet milieu extension zone (Fig.27).

BOX 8

Creation of polygons from the vectors of a hydrographical network so as to define the aquatic continuum's extension zone

In reference to the GBI method (Green and Blue Infrastructures) developed by the DIREN Rhône-Alpes, an average value rounded up to the next higher unit and associated with the buffer zones around the poly-lines:

Breadth of stream according to BD Carthage:	Decided buffer width:
• 0 to 15m or default if no available data	⇨ 4m buffer on either side, thus an arbitrary breadth of 8m
• 15 to 50m	⇨ 16m buffer on either side, thus an arbitrary breadth of 32m
• Over 50m	⇨ 25m buffer on either side, thus an arbitrary breadth of 50m

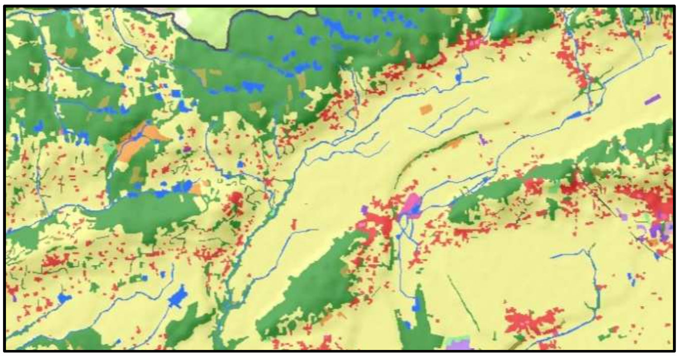


Figure 26.

Example of a raw data map of aquatic and wet continuum extension zone before the integration of SPOT Thema data with that of BD Carthage.

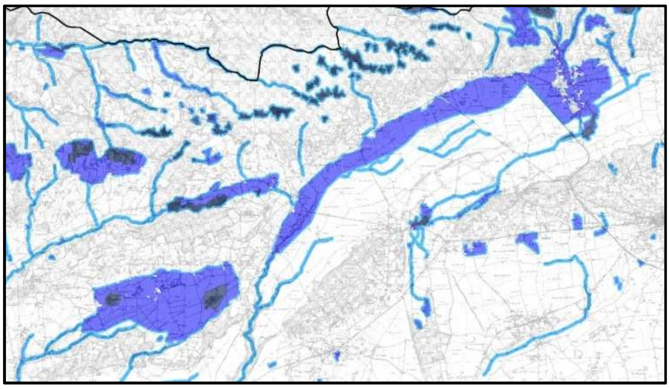


Figure 27.

Example of a map of aquatic and wet continuum extension zone after the integration of SPOT Thema data with that of BD Carthage.

Source:
ECONAT-Concept & al. (2010)
Cartography AURG

➢ Identification of Sloping Agro-Pastoral Continua Extension Zones

The absence of any terrain audit prior to analysis makes it impossible to make an *a priori* identification of extensive agricultural zones, rich in meadows and pasture and structured with hedges. Of course, a simple visual check of an aerial photograph allows this landscape type—of particular interest because of its biodiversity—to be identified. Thorough analysis, however, requires a lengthy manual digitalization of polygons which are visually identified according a particular fragmentary grid in a manner that leaves room for uncertainty about the exact types of the milieu involved (arable, lean or enriched meadowland, pasture or fallow): types that are determining for their biological value. As a first step, it is possible to dispense with this terrain mapping by proceeding rather by random sampling either by transects or by methods for the indirect detection of zones potentially favourable to this kind of terrain usage. Thus at regional or departmental scales, good descriptive probability is obtainable by using the data concerning slope orientation, declivity and altitude furnished my the numerical terrain models of national maps or via easily accessible freewares such as SRTM (Shuttle Radar Topographic Mission), created by a 2001-2002 NASA mission and which has a 90m step.

In territories of the Isère such as the Pays de Bièvre-Valloire, sloping agro-pastoral terrains have been defined as occupying all non-wooded or non-rocky spaces with a declivity greater than 15% contained within an altitude range of 500 to 1,000m. The declivity value reflects the average degree of slope above which agricultural spaces do not easily lend themselves to mechanized exploitation. Because of this, agricultural practices tend to favour a more extensive type of agro-pastoral terrain management that is more likely to shelter a richer and more varied range of species than is more intensively farmed lowland terrains. While this choice constitutes a simplification of the reality of the terrain, it does represent an approach that generally reflects practices that have in fact been observed in the field.

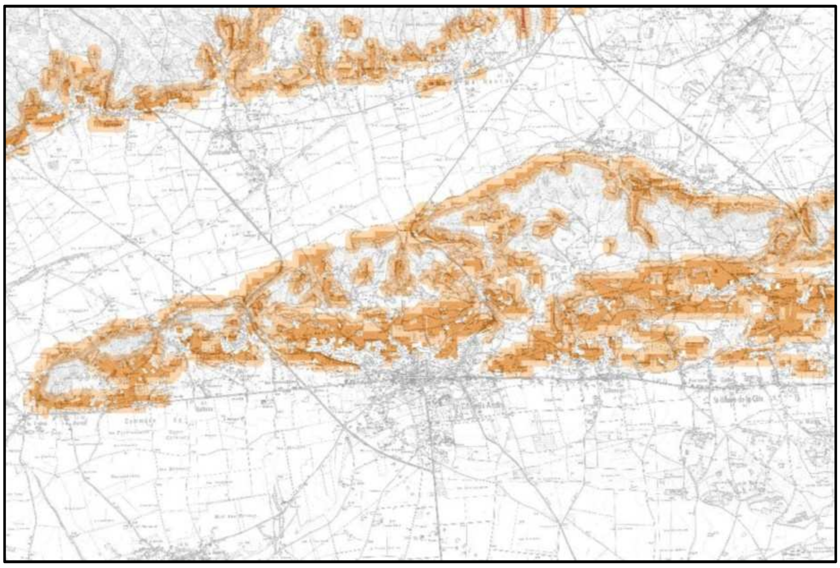


Figure 28.

Extract of a map of sloping agro-pastoral continuum extension zone.

Legend:

Nodale zone

Extension zone

Ecotonal margins

Source:
ECONAT-Concept & al. (2010)
Cartography AURG

The type of continuum brings together SPOT Thema classes of non-flooded arable land and meadows (Tab. 3). These data are then selected on terrains with 15% or more of slope (Fig.28).

The distinction between thermophilic and ombrophilic zones will be used frequently to distinguish between groups of habitats hosting partially different biocenoses. Such distinction is possible by selecting slope orientations in a numerical terrain model (NTM) applied to a grid format.

➢ Identification of Lowland Agricultural Continua Extension Zones

This continuum is the sibling of the previous one and takes account of the same ST classes, but for terrains of less than 15% of declivity. In this case, moreover, slope orientation plays no part (Fig. 29).

Biocenoses are characteristic of open zones presenting a marked steppic tendency by the presence of a number of species proper to stony, open and windy grasslands. Arable farming areas are, on the other hand, entirely artificial. It is therefore the structure of their vegetation that causes them to resemble steppes.

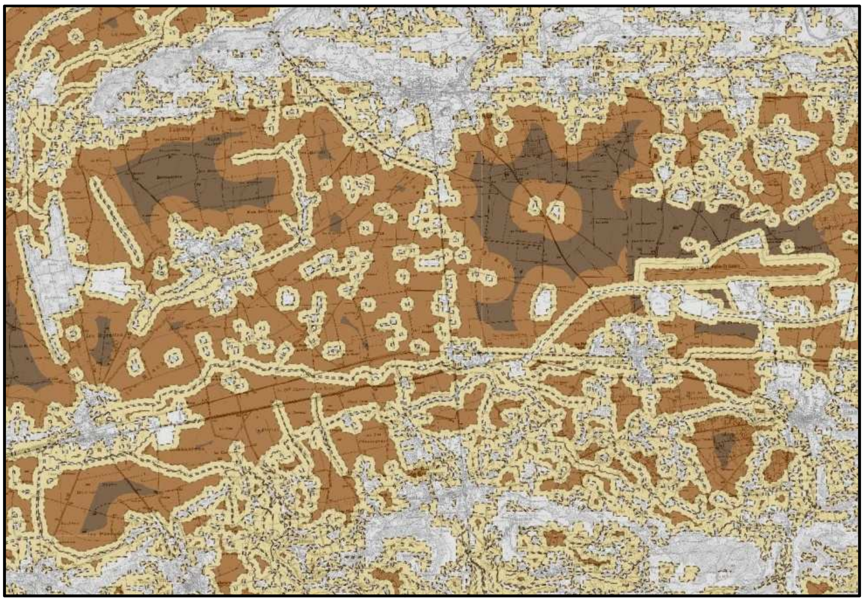


Figure 29.

Example of a map of lowland agricultural continua extension zones.

Legend:

Nodale zone
Extension zone
Ecotonal margins

Source:
ECONAT-Concept & al, (2010)
Cartography AURG

4.5.4 Integration of functional elements proper to each continuum

The designation of the extension zones of each continuum provides the structural basis for ecological networks but does not yet allow their operational dimension to be approached. For this nodal zones, complementary margins and connection corridors—which are all indispensible to the functioning of specialized networks—need to be identified too.

➢ Determining Ecotonal Margins

As a rule, defining the perimeters of continua is problematical and largely depends on qualitative factors located in their ecotonal margins and upon external disturbance factors that allow or prohibit functional interaction processes between different habitats. There are no indisputable physical frontiers, only an appreciation of the amplitude of exchange processes based on observation of particular biological activities for some indicative species.

In this way, all ecotonal margins taken together constitute a **vast anastomosed natural network of interconnections between habitats** whose functioning is indispensible to the normal working of landscape systems.

Grounding ourselves in convention, we have decided on standard widths of 50 or 100m, widths which correspond statistically to the frequentation zones of 90% of observed individuals moving outside their usual habitats during the growing period (see chapter 2.1.5). At this standard width, all surfaces connected to known obstacles and incidences relative to disturbances are automatically removed using GDS. The resulting optimized theoretical space is then employed in GDS analyses on a hectometric raster. This space also corresponds to one that is ideal for the management of forest margins and fragile buffer zones (marshes, wet meadows, ponds, etc.). In fact, it constitutes a reference width upon which it is possible to make the following analyses:

- Incidences of potential diffuse disturbances to animal movement,
- Incidences of directional disturbances due to motor vehicle traffic along roadways,
- Establishment of a management programme appropriate for limiting damage to high heritage-value spaces within this reference distance.

In reality this ideal width of ecotonal margins is modulated according to damage risks and extant spatial constraints (waterways, fencing, diverse obstacles, etc.). Starting with a spontaneous natural mode of functioning, we obtain a controlled mode in the form of more or less narrow corridors, the good quality of whose empirical implementation and management becomes more and more important if we are to guarantee normal functioning.

This detailed analysis of ecotonal margins must be carried out during a later project phase, at the same time as the study of specific natural habitats, by means of mapping and biological inventory each time a local development project allows the opportunity. At the level of the general study of potential ecological networks, we will content ourselves with broader standards (see box 8).

In terms of their graphical representation, ecotonal margins are defined in three stages:

1. Firstly, using GIS **a buffer zone around the extension zone of each of the continua** under consideration is created.
2. Then, again using GIS, the layers thus obtained (extension zones and their respective buffers) need to be separated so as to obtain the exact outline of the ecotonal margin in vectorial and polygonal form.
3. Finally, all those zones considered to constitute obstacles to animal movement are subtracted from the ecotonal margin (urban zones, transport infrastructures, etc.).

Box 9

Standard Ecotonal Margins Used to Define Potential Ecological Networks

The widths given represent an statistical approximation of the animal movements observed during the growing period (Berthoud & al. 1989)

Type of continuum	Decided buffer width
Forest continuum	100 m
Aquatic and wet continuum	50m (1)
Sloping agro-pastoral continuum	100m (2)
Lowland agricultural continuum	100m (2)

Remark 1. The aquatic milieu ecotonal buffer is added to the buffer zones established from BD Carthage's poly-lines.
Remark 2. The agricultural buffer zone is obtained a negative value extrapolated from the margins of wooded milieus.

➢ Agricultural Continuum—Specific Case

Agricultural spaces have the particularity of constituting substitution continua which shelter numerous species, and especially those usually found in steppic milieus. Thus we should consider these transformed spaces to constitute degraded steppic continua enclosed by wooded (or human-structured) spaces. Such spaces contain a 100m centrifugal ecotonal margin situated within the agricultural space and potential nodal zones which correspond to a 300 to 500m buffer zone. Thus what is obtained is an extension zone of a particular kind: while it has no apparent material existence, yet it does correspond to a functional reality (steppic space security buffer zone) (Fig. 30).

➢ Anthropogenic Continuum—Specific Case

The mapping layer constituted by anthropogenic extension zones is treated cartographically as would be a continuum in its entirety. This is due to the simple fact that these extension zones occupy such a large proportion of land surface. As a result anthropogenic continua generate numerous interactions, which most frequently take the form of disturbances and incidences of fragmentation affecting all the other continua. It should not be forgotten, moreover, that diffuse anthropogenic activities in a natural landscape often generate advantageous development opportunities for certain biocenoses linked to ecotones. This is particularly true for example in the case of maintained open spaces, the establishment of watering places, the regeneration of climacic vegetation, the building of obstacle-spanning structures, etc.. The crucial issue remains the limit fixed to anthropogenic activities and, especially, ensuring that such activities should be aimed at maintaining the natural functions of landscape.

When mapping ecological networks, it is now generally agreed that the different anthropogenic elements contained in a territory overwhelmingly generate nuisances that limit the occupation potential of space for fauna. Buffer zones corresponding to the ecological disturbances they cause have been defined around these various anthropogenic elements.

The anthropogenic extension zone is defined by the bringing together of all relevant SPOT Thema classes in the smallest practicable number of polygons that consist of all surfaces constructed, transformed or strongly subject to non-agricultural human activity (Table 3). All the linear infrastructures of transport systems, provided by IGN's BD topography, are then added to the polygons.

The anthropogenic continuum will then be defined by further adding a physical and chemical nuisance buffer zone whose minimum width is of 100m. In order to take proper account of the obstacle constituted by the lines of transport networks, the linear information layer issued from the 1999 prefectural order concerning the classification of roads with regard to sound nuisance, as well as the public thoroughfare layer from the IGN BD topography, are added. The transport network classification only takes account of roads carrying more than 5,000 vehicles a day and intercity railway lines carrying more than 50 trains a day (Table 3). At these levels of traffic, this anthropogenic extension zone is considered to be an "impassable obstacle" for the movements of species associated with other continua. The nuisance buffer zone associated with it is minimal, yet its use offers practical advantages when it comes to modelling its effects on other, more natural continua (Fig.30).

Road Category	Sound Levels in dB(A) Day/Night (Traffic Levels)	Width of Sectors Affected by Sound
1	83 / 78 (> 50,000 vhc/d)	300m
2	79 / 74 (25-50,000 vhc/d)	250m
3	73 / 68 (10-25,000 vhc/d)	100m
4	68 / 63 (5-10,000 vhc/d)	30m
5	63 / 58 (< 5,000 vhc/d)	10m

Tableau 3. *Size of Roadside Buffer Zones as a Function of Sound Levels (Est. Ministerial Order, 30 May 1996.*

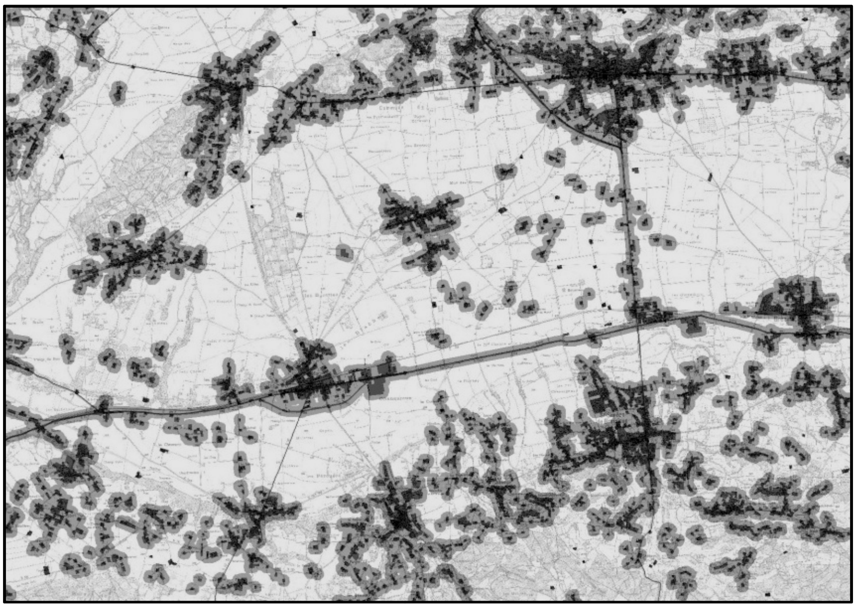


Figure 30.

Example of a map of anthropogenic continua including extension and buffer zones.

Transport infrastructures possess variable buffers depending on traffic volume.

Source: ECONAT-Concept & al. (2010) Cartography AURG

Avenues for improvement: Ideally, the width of buffer zones should be modulated according to the intensity of disturbance caused. Such modulation could, for example, be established around residential zones as a function of their size and housing density. By the same token, it is possible to define a number of different levels of the ecological nuisance caused by the majority of anthropogenic elements—strong, average or weak—by means of detailed local analysis based on the acquisition of field data that would be comprised of a grading of various disturbances (physical and chemical pollution, maintenance by mowing, uncontrolled activities, dumping, presence of species commensal with humans, etc.). This approach, however, would be limited to local development projects whose planning required an impact study.

➢ Gravel Pits and Quarries—Specific Case

The proliferation of mineral extraction zones can play an important role in the evolution of regional biodiversity. Like all other anthropogenic milieus, the biogenous effects caused by brutally laying bare raw mineral, sand, gravel and stony materials, more often than not accompanied by the exposure of the water table, provokes the sudden appearance of pioneer biocenoses. This process, as transitory as it is spectacular, needs to be properly controlled, for the negative effects are as numerous as the positive ones. The problems that need to be addressed principally concern the creation of demographic reserves for regionally unstable species and temporary habitats for invasive non-native species.

As a primary analysis, it is better to situate mineral extraction surfaces as part of anthropogenic zones. Later, as part of a local study and exploiting detailed local mapping, the pertinence of integrating them to possible developments in other continua or existing biological corridors—whether forest, aquatic, grassland or rocky in nature—which might lack evolutionary coherence or dynamism should be examined. This should be carried out on a case-by-case basis according to the specific stage of the sites' evolution or exploitation (undergoing exploitation, at the end of exploitation or, during partial restoration of the site, when pioneer biocenoses are more or less developed).

Indeed, during the working of gravel pits, at the moment of their closing and during the partial rehabilitation phase, those pioneer biocenoses proper to gravel pits are more-or-less well developed. It can be useful to employ the colonised areas to reinforce those continua structures — aquatic, forest, grassland or riparian — that lack progressive coherence or dynamism.

4.5.5 Designating Corridors

In an eco-systemic vision of the landscape, a corridor is, by definition, always attached to one or more continua. This being so, corridors only designate spaces located outside continua, spaces that are occasionally or regularly used by representative specialized species for vital dispersive or migratory movements.

A number of approaches for designating corridors are available in cartographic methodology:

1. **By polling surveys and discussion with experts**, those landscape polygons serving as corridors can be designated consensually. These polygons are then registered manually.
2. **By specific dispersion simulations using a resistance matrix** applied to a hectometric terrain occupation grid, the most favourable connections between similar continua can be identified. This method has been applied at the level of each continuum—so as to define maps of potential ecological networks before carrying out systematic verification in the field—separately in both Switzerland and the Isère region of France.
3. Even without dispersion simulation, maps of continua are immediately utilizable as long as **successive buffers, engendering capture zones,** are integrated—capture zones which are more or less favourable depending on the function of the targeted species group (Fig. 31).

All three approaches are valid and they are perfectly complementary. So as to optimize and simplify the method, however, the third approach was chosen for use according to a precise protocol.

Two tests are successively applied to each continuum:

- A first test by dilation "swelling" / "shrinking" is carried out employing progressive buffers from 200 à 500m (see Box 10).
- A second test by dispersion applied in a grid format to the terrain occupation matrix allows the identification of an ensemble of sites potentially able to correspond functionally to biological corridors. It is indispensible at this stage to validate this role by on site verification.

For indeed, some of the foregrounded species may turn out to be no more than simple artefacts connected to GDS actions. It is necessary, moreover, to make clear exactly which are the species groups that use the space. From this, we proceed to verification by questioning naturalists and the users of the terrain, before finally proceeding to designate the areas as potential corridors.

Practise has shown that the potential corridors identified by modelling always turn out to be used in fact by highly mobile fauna: their trails being traceable in the terrain. This is the result of the combined effect of the principal of the "path of least effort and least risk", which ensures that the shortest trajectory is always the one most frequently taken. Other, less mobile, animal species tend to favour safety by straying only rarely from forest verges and other refuge zones. These species, therefore, employ ecotonal margins as dispersion corridors.

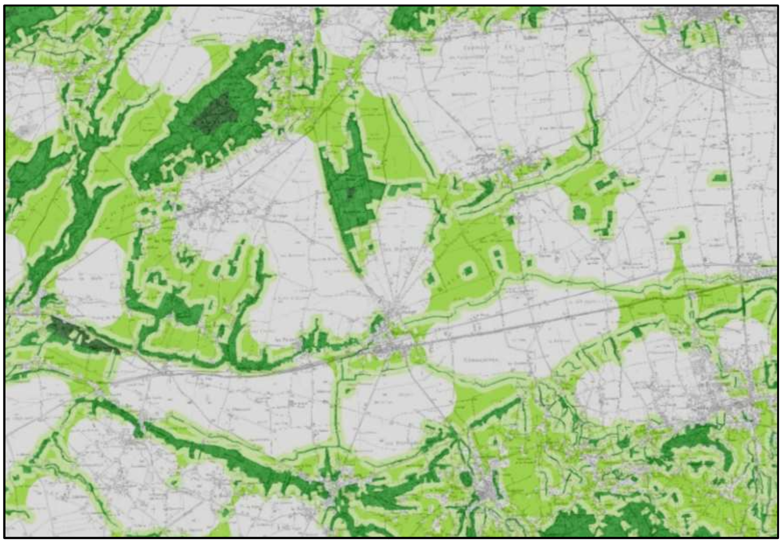


Figure 31.

Example of a map of forest continua with their potential corridors designated by swelling-shrinking.

Source:
ECONAT-Concept & al. (2010)
Cartography AURG

Practical application has shown that such corridors, identified by modelling, are indeed used by high-mobility fauna, and that it is possible to find their tracks in the field. The result of the combined effects of the principles of "least effort" and "least risk" defines the shortest route as being the one that is always the most used. Other, les mobile species, on the other hand, favour safety by rarely straying from edges and other refuge zones. This later category therefore employs ecotonal margins as dispersion corridors.

All these considerations taken together clearly demonstrate the extent to which the validation of corridor sectors can be achieved without an iterative, on-site validation phase and/or the use of expert naturalists familiar with the terrain in question, alternated with computer-based modelling refinement.

In order to be able clearly to make out the real potential of the connection spaces identified by the swelling/shrinking process, it is useful to supplement the map with terrain occupation data in a way that allows possible obstacles to faunal movement to be visualized. A map of potential conflicts may therefore be established by superimposing the synthetic map of all continua and their corridors with all of the instances of terrain occupation causing obstacles to faunal movement (buildings, fencing, canals, lighted areas, large reliefs, etc.).

Box 10

"Swelling / Shrinking" Test

The purpose of the test is to fix the perimeters of potential corridors permitting the movement of fauna between the extensions zones of a continuum. The test is carried out continuum by continuum. GDS treatment is executed in two phases starting from the initial data layer of the continuum's extension zone.

The first phase consists in "swelling" the extension zone's polygons out to a distance greater than the continuum's normal margin (between 100 and 500m according to continuum).

Using GDS, a buffer is established whose expanse should correspond to the potential of species associated with the continuum to move outside the extension zone without any particular difficulty. Such swelling allows extension zones that are initially separated to be joined together by contact. In this way, it enables potential connections to be visualized.

Continuum type	Maximum expansion fixed for swelling
Forest continua	500m
Aquatic and wet continua	100m
Sloping agro-pastoral continua	100m*
Lowland agricultural continua	100m

In the most common cases, this swelling remains within normal continua margins which do not exceed100m. As a result of the presence of certain particularly mobile species, however, this width can be increased on a case-by-case basis. In normal circumstances then, the swelling almost exclusively concerns the forest continuum, whose most mobile species (ungulates, mustelids, canidae and bats) can easily cover several hundred metres beyond cover. Such supplementary swelling is not justified for other continua as the corridors used by specialized species are **always linked to ecotonal margins.**

The second phase, known as the "regression or shrinking" phase consists in the opposite process starting from the fused boundaries of the swelling zone: the shrinking is executed employing the same values as for the swelling but with a resulting "negative" buffer.

As the example of the forest continuum illustrates (Fig. 32), this double operation allows those sectors or avenues susceptible to being used as corridors by fauna to be revealed. The resulting avenues are saved in the form of vectorial "corridor" polygons associated with each continuum. Graphically, and by definition, this corridor corresponds only to the exterior polygon of the two continuum polygons brought together by the swelling/shrinking operation.

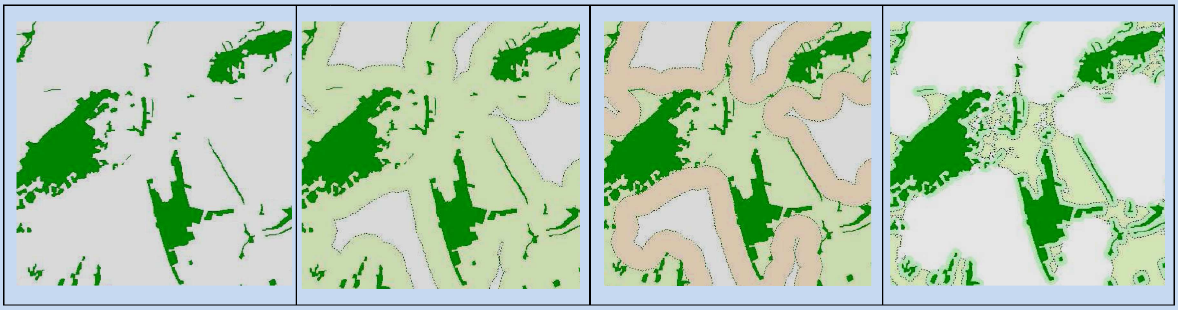


Figure 32. *Illustration of the double swelling/shrinking GIS operation allowing minimal potential corridors to be designated.*

4.5.6 Selection of Nodal Zones in a Territory

The approach developed here places a premium on a perspective centred on the heritage value of natural spaces and constitutes an important stage of the method. Thus the particularly valuable spaces that will be identified by the process will serve on the one hand as a basis to define the nodal zones of each continuum, and on the other hand, to evaluate the quality of the natural milieus contained therein (see Chapter 5.5.7).

Inasmuch as they constitute sources of dispersion, nodal zones should in theory be determined principally in terms of their functional importance rather than in terms of their heritage value. It is, moreover, true that the two concepts do not entirely overlap, as sites that are very rich from a functional perspective can be constituted by mostly "banal" animal and vegetable species. The opposite is also true: sites hosting rare and/or protected species can be relatively uninteresting from a functional point of view. Happily however, such cases are rare and, more often than not, functional and heritage significance are related.

Structuring Sites	Significant Sites
• Biotopes Protection Decree (APPB) • Natural Zone of Ecological, Faunal and Floral Interest (ZNIEFF), type 1 • Watercourses: Classification by decree L232-6 Classification by order L232-6 Classification law1919 • ENS (Vulnerable Natural Space) Departmental, intervention zone Local, intervention zone • Sites Natura 2000 (Directive Habitats) • National Nature Reserve	• Natural Zone of Ecological, Faunal and Floral Interest (ZNIEFF), type 2 • Watercourses: Classification L232-6 (propositions) • Vulnerable Natural Space (ENS) Departmental, observation zone Local, observation zone • Sites Natura 2000 (Directive Birds) • Important Zones for the Conservation of Birds (ZICO)

Table 4. *Selection classification for potential nodal zones.*

Therefore, the method applied here progresses via an approximation of a concomitance of the functional and the heritage aspects, at least to begin with. **The identification of nodal zones is thus based on the presence of sites recognized as possessing statuses of endangerment, protection, management or recognition in a heritage inventory**.

In the territorial logic of the Isère region, the spaces of the first category, or **"structuring sites"**, are often small in area and designate rare/protected/endangered species and milieus. The second category, or **"significant sites"**, contains much larger sites whose landscape and ecological roles insure the global coherence of the networking of heritage site (Table 4)

This first selection of sites constitutes a starting point from which to designate the nodal zones for the study area. The designation criteria of the sites are highly selective however and rarely take into consideration those milieus that, though relatively common, are of a high quality. So for example, the majority of woodland and grassland zones, representative of many agricultural landscapes and which host significant biodiversity, are only rarely considered among sites of particular interest. Thus in the Pays de Bièvre-Valloire study, important gaps are apparent with regard to potential priority zones concerning habitats and heritage species (Fig. 33). There is then a need to find a complementary approach so as to obtain a list of the most representative sites for the landscapes analyzed. The list should be further augmented by naturalist inventories giving rise to propositions for other potential sites based on more scientific and less administrative criteria.

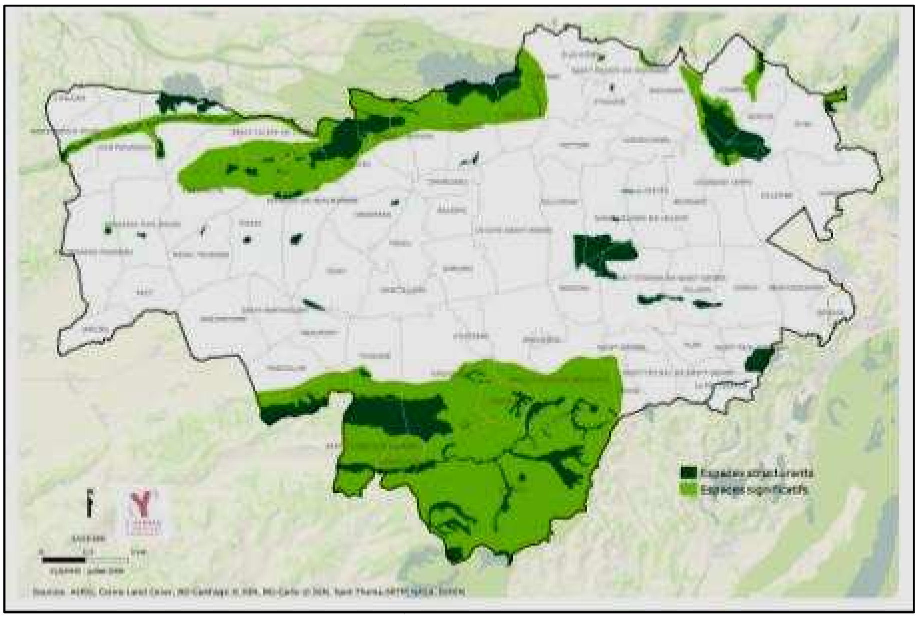


Figure 33.

Example of map of the official recognized natural spaces of particular interest of the Pays de Bièvre-Valloire.

Structuring sites (in dark green) are distinguished from significant sites (in light green).

Sources :
BD Carthage IGN ; DIREN
Cartography AURG

It is apparent that the information layer concerning structuring spaces serves principally to indicate what may be termed “natural reservoir zones”. Following the logic of ecological networks, these correspond *a priori* to nodal zones. On the other hand, the significant site category indicates rather those spaces recognized for their landscape qualities, inasmuch as they play the role of buffer zones surrounding sites of heritage value which cannot easily be considered as nodal zones.

In order to compensate for these gaps in our knowledge of real nodal zones, it would be possible to employ the qualitative criteria of “**islands of tranquillity**” continua located beyond the reach of all the principal anthropogenic disturbances. Indeed, it is logical to suppose that there is a good probability that zones of this type host potential nodal zones. The two approaches are complementary and both will be used according to analysis requirements.

It should be noted, however, that there is nothing to prevent a later procedure serving to identify—by specialist opinion or a range of recognized indicators—high ecological potential landscape zones capable of constituting consensual nodal zones.

At the level of regional or territorial analyses, the nodal zones of each continuum are defined as follows:

- The GIS layer of available structuring sites is separated into parts, each part corresponding to each extension zone of the continuum. The resulting elements are then identified as the nodal zones of the continuum. This operation is repeated for each continuum.
- Where necessary because of the absence of sufficient data concerning nodal zones, a selection based on tranquillity zones designated by negative buffers of 300 to 500m according to the particular situation in each case is effected.

➢ Forest Continuum Case

Continua of this type clearly suffer from a lack of zones of recognized heritage significance (Fig. 34). Thus in this case, the two approaches are combined:

- Wooded structuring sites often indicate particular populations, whether dry or wet, but only more rarely exploitable natural woodland.
- Complementary “tranquillity” zones designated by a 300m buffer zone allow the useful addition of potential nodal zones that are indispensible for the modelling of the functions of isolate woodland massifs.

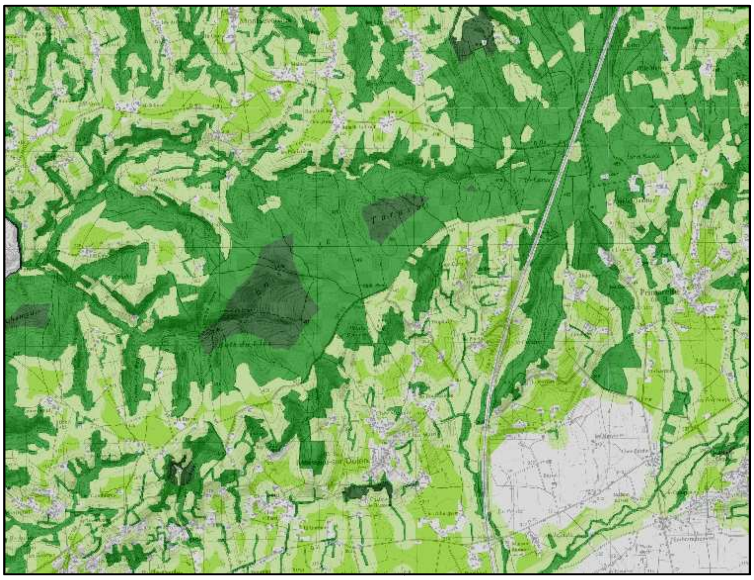


Figure 34.

Example of map of forest continua. Nodal zones recognized by classification are augmented by potential nodal zones.

Legend:

lale zone

ənsion zone

tonal margins

ential corridors

Source:
ECONAT-Concept & al. 2009
Cartography AURG

➢ Aquatic and Marshy Continuum Case

Although wet zones and standing waters are generally well protected and classified, for rivers and streams this is far less often the case. Given this state of affairs, to identify the nodal zones of this continuum properly, it is necessary to utilize the water-quality data furnished by SAGE (Water Management and Infrastructure Schema).

SAGE places inventorial data concerning hydro-biological quality on GIS via three indices:

- **NGBI (Normalized Global Biological Index)**: a punctual indicator allowing the evaluation of the hydro-biological quality of an aquatic site by means of the composition of populations of benthic invertebrates occupying various river and stream habitats. IBGN is sensitive to variations in physical-chemical water composition, and particularly to organic and chemical pollution fluctuations, but it is also sensitive to the nature of substrata (work in the river or recalibration) and to climatic events (thunderstorms, heavy flooding)
- **FGI (Faunal Group Indicators)**: a global indicator that permits the determination the quality of surface water in rivers and streams and which integrates NGBI data.
- **Classification of physical-chemical quality**: Sections of the river of stream are organized into five classes (very good, good, average, mediocre, and poor)

Combined, these three indices allow the establishment of a classification of rivers and streams by sections while indicating nodal zones, extension zones and continua (Fig. 35).

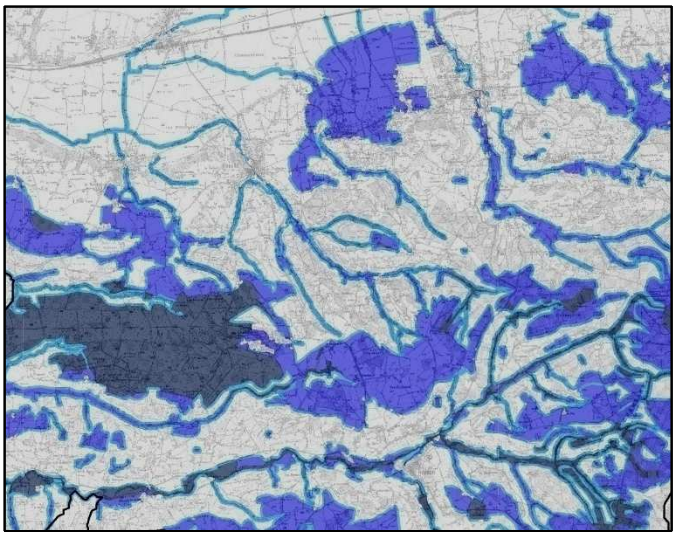


Figure 35.

Example of a map of the nodal zones of aquatic and marshy continua.

Legend:

one

n zone

margins

Source:
ECONAT-Concept & al. 2010.
Cartography AURG.

➢ Agricultural Continua Case

All too often, agricultural spaces are the “poor relations” in policies of heritage landscape evaluation. Indeed, they are rarely represented in lists of recognized spaces of natural interest. This gap then needs to be filled by indicating “islands of tranquillity” using GIS so as to identify potential nodal zones in agricultural spaces.

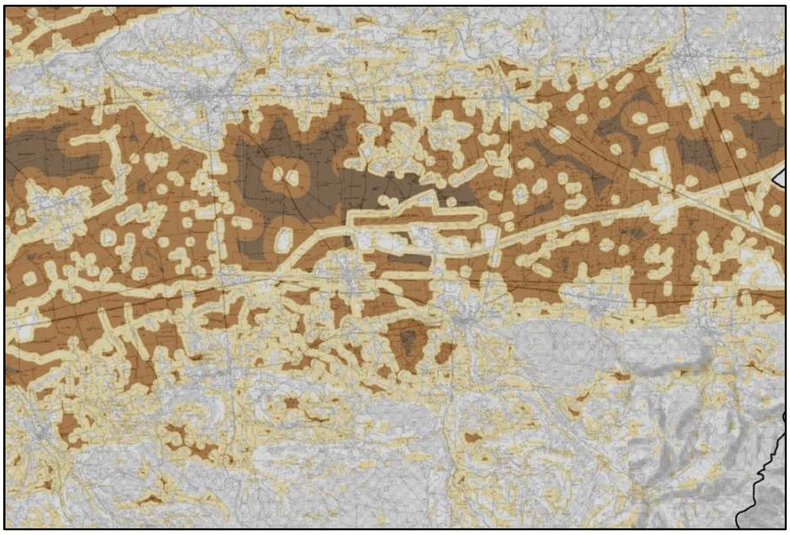


Figure 36.

Example map of agricultural nodal zones defined by a 500m negative buffer starting from the edge of forest and anthropogeni extension zones.

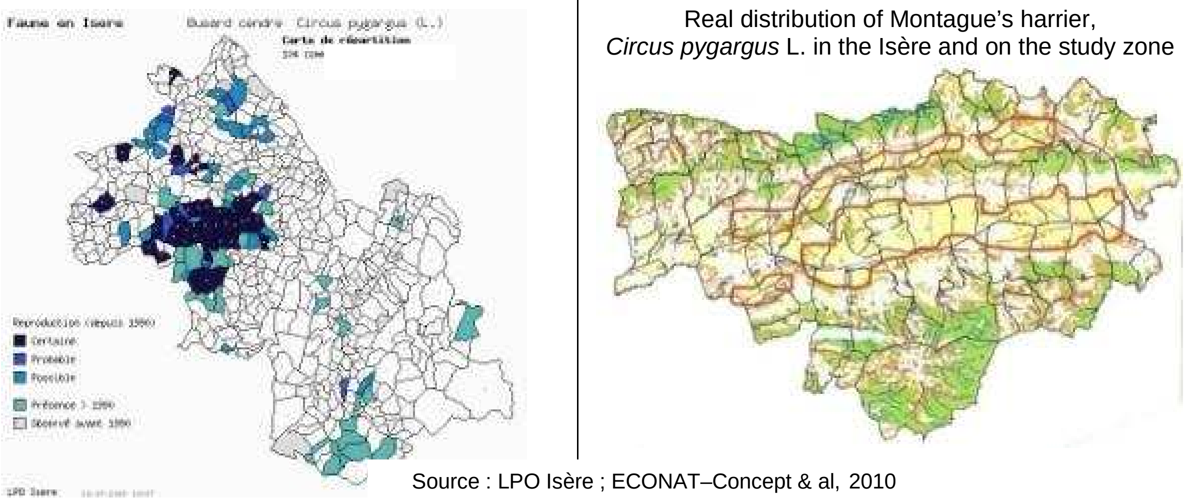
Legend:

Nodales zones
Extension zones
Ecotonal margins

Source:
ECONAT-Concept & al. 2010.
Cartography AURG.

Technically, these potential nodal zones are defined as being those sectors situated more than 300m from forest extension zones, urbanized spaces and transport infrastructures. In reality, these two buffers will isolate all the agricultural spaces contained within them (Fig. 36).

If we follow the study of the Pays de Bièvre-Valloire, the available data concerning the distribution of those sectors vital to the reproduction of the principal heritage species permit the conclusion that this approximation is satisfactory. In the study zone indeed, more than 80% of the nesting populations in the Isère of species such as the Curlew *Numenius arquata (L.)*, the Lapwing *Vannellus vanellus (L.)*, the Stone Curlew *Burhinus oedicnemus (L.)*, Montague’s Harrier *Circus pygargus (L.)* and the Northern Harrier *Circus aerogineus (L.)* are concentrated in these zones. Other studies of the distribution of the Brown Hare *Lepus europaeus (L.)*, (Pfister & al. 2002) and the Grey Partridge *Perdrix perdrix (L.)* (Jenny & al. 2002) demonstrates the same mechanisms of population concentration in agricultural surfaces away from roads and other urban disturbances.



Real distribution of Montague's harrier, *Circus pygargus* L. in the Isère and on the study zone

Source : LPO Isère ; ECONAT–Concept & al, 2010

Figure 37. *Example of naturalist data allowing the definition of heritage issues and of the importance of constant tracking of the evolution of ecological networks.*
The case of a species closely associated with the lowland agricultural continuum

➢ Improving Selection of Nodal Zones

For the nodal zones of all various continua taken together (or hearts of nature), the principal avenue of improvement consists in the promotion of the data and knowledge of naturalists specialized in given territories in order to augment information about spaces of particular natural interest. Actually, numerous spaces possessing a heritage interest that justifies their protection with regard to urbanization are not included in the grids of officially recognized sites. Some examples are: dry hill- and mountainsides, ensembles of still well preserved hedged farmland, wet zones or wooded sections of particular interest.

The process would take place in two steps:

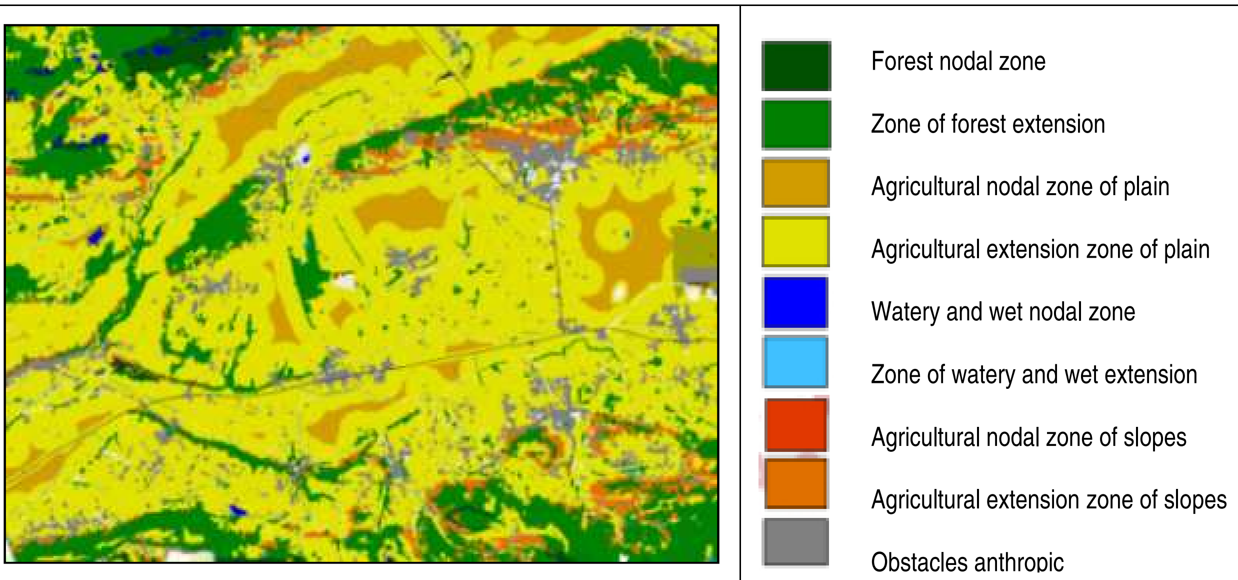
- **To begin with, a first synthetic mapping** of spaces of recognized particular interest and potential nodal zones is drawn up so as to distinguish three levels of interest: potential sites, structuring sites and significant sites.
- **In a subsequent step,** this first selection is enhanced by integrating where possible naturalist databases of flora and fauna. Each group of experts consulted will thereby augment the initial network of spaces of particular natural interest by means of a series of argued and geographically localized propositions. A synthetic map is produced for **final validation**.

A validated and consensual cartography of these "hearts of nature" has thus been created. The interest of such an undertaking is in its homogeneity and its precision. It should enable territorial protagonists (notably elected officials and technicians) to take full control of their natural heritage without being continually focused on the constraints engendered by existing legislative statutes.

At the completion of this work, certain sectors that are still insufficiently prospected will almost certainly appear. For these the level of sampling of current data is insufficient and they will need to be subjected to supplementary terrain inventories within the context of impact studies for local development projects.

➢ Summary map of different identified continua

The constitution of a synoptic map of the various ecological networks identified in a given study sector permits only a few possible avenues of exploitation beyond the provision of a visual and statistical presentation of the size of different continua and of the localization of nodal zones (Fig. 38). These raw data are difficult to interpret without the phase of hierarchical organization by specialized networks.



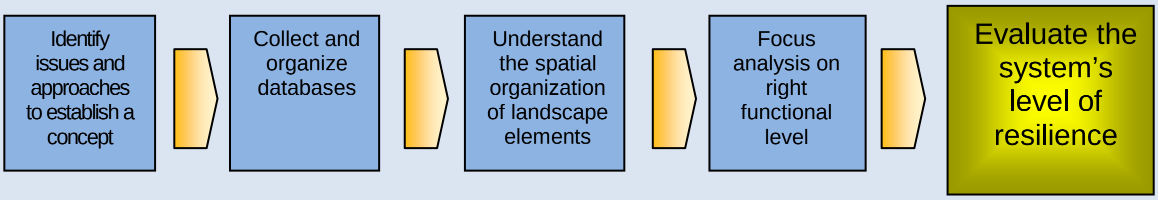
Type of continuum	Extension zone: surface in hectares	Buffer zones: surface in hectares
Forest continua	25'926 ha	18'100 ha
Aquatic and wet continua	1'047 ha	6'687 ha
Agro-pastoral and slope continua	5'949 ha	14'678 ha
Lowland agricultural continua	46'780 ha	18'023 ha

Figure 38. *Example of a map of all the extension zones of continua without their buffer zones. Surface area statistics respective to scale of studied territory.*

Source : ECONAT-Concept & al. (2010). Cartography AURG.

CHAPTER V

The Hierarchical Organization of Specialist Ecological Networks



Summary

Paradoxically, the need to evaluate the effects on the environment of plans and projects very much preceded the need to map eco-systemic networks. National and international environmental legislation have long favoured the segregation of spaces and actions, by protecting natural elements of particular interest while systematically accepting all projects judged to be environmentally compatible.

Its is only recently, with the development of a strategy for the conservation of landscape and biological diversity, and then more recently still with the Grenelle of the Environment Forum, that the concept of a more complete and equitable eco-systemic approach, based especially on the sustainability of developments, has emerged.

The method for evaluating the ecological potential of milieus is based on the weighting of multiple environmental indicators that in turn allow the factors which determine the ecological potential of a habitat, a sector or a territory to be evaluated. In this guide, the method is combined with cartographical modelling of ecological networks so as to obtain the desired hierarchical classification of the issues at stake in the model established.

The model provides a useful tool for ascertaining:

- The initial global state of each spatial entity, presented in the form of a cardinal value that subsequently allows fruitful comparisons to be made;
- The separate evaluation of the factors that determine ecological potential;
- A referential evaluation of issues at stake with regard to the foreseeable evolution of one or more environmental factors;

In the eco-systemic approach, ecosystems—taken to be the determining entities of landscape and the biosphere—constitute the final, unavoidable receiver of all environmental changes linked to the production or exploitation of natural resources. The evaluation method employed in this guide has been specially developed not only for the analysis of development projects subject to impact studies (projects such as extensions of exploitation, transport infrastructure construction and nuisance-creating activities), but also so as to be able to propose measures of integration, improvement and compatible compensation.

Within the framework of the definition of ecological networks, this tool allows the preventive identification of issues at stake and of appropriate approaches for the correct definition of programmes of management and restoration measures for ecological networks.

The overriding principle is the maintenance of the system's ecological potential: i.e. its global efficacy despite inevitable changes.

5.1 Hierarchical Evaluation of the Initial State of Ecological Networks

In an ecosystemic approach to the natural and transformed habitats present in a given landscape, parameters other than diversity and the presence of heritage species need to be understood if the systems of networked habitats which make up the landscape are to be defined in a more interactive way. The “ecological potential of milieus evaluation (EPME)” method was developed in the context of an interdisciplinary study entitled “the Swiss national research program for land use” (Berthoud & al. 1989). The method allowed the ecological value of landscape-constitutive surface elements to be calculated. Originally conceived for the manual cartography of landscape ensembles at the local scale, with the later development of Geographical Data Systems (GIS), subsequently allowed each habitat or habitat ensemble to be evaluated individually. In the present case, the method serves as the basis for the hierarchical modelling of ecological networks.

The EPME method requires the use of a raft of multifactorial ecological indicators in which each factor is characterized by a group of complementary or redundant indicators. The reliability of the evaluation is founded precisely on the built-in redundancy of the measurable or evaluable parameters in a milieu. The term “milieu” is used expressly as a generic designation of a habitat, an eco-complex of habitats, an ecological sector, a biological district or a bio-geographical region depending on the mapping scale employed. For each species studied, the method enables an **evaluation of the development potential of every functional entity** expressed according to three factorial axes — the QUALITY, the hosting CAPACITY of milieus and their FUNCTIONING — within an interactive organized system.

This multifactorial evaluation of the ecological potential of milieus is obtained by applying the following formula:

$$\boxed{\mathbf{EV = Q \times C \times F}}$$

In which:

***EV** = Ecological Value; **Q** = the weighted “Habitat Quality” factor; **C** = the weighted “Hosting Capacity”; and **F** = the weighted “Functioning” factor*

This synergetic multifactorial approach contributes to the definition of potential development hyper-volume (an ecological niche as understood by Hutchinson 1957) in which the removal of one of the factors reduces ecological value to nil. The usefulness of the method lies in the creation of a multi-criteria dilation of ecological efficacy at the level of bio-geographical processes. It is applicable to different spatial scales using the same factors, but with variable indicator groups.

The indicators employed were chosen with regard to their pertinence to the targeted evaluation of the ecological potential of a milieu. These indicators have been borrowed from other methods that sought to define the natural values of landscape spaces, such as those of SUKOPP (1978), OLSCHOWY (1978), DE BLUST (1987) and LUDER (1980).

Thus, The **QUALITY of milieus** factor uses the following indicators:

- Taxonomic diversity;
- Wealth of heritage species;
- Rarity of the site;
- Naturality or the degree of hemeroby;
- etc..

The **hosting CAPACITY of milieus** contains the following indicators:

- Surface area of milieus,
- The density or the ratio between length of perimeter and surface area;
- The diversity of vertical structures;
- The complexity of habitat mosaic;
- etc.

Possible indicators of the **FUNCTIONING of milieus** factor should represent at once the intrinsic ecological role of the milieus of the zone under consideration and the existing interactions between those milieus. Priority functions selected are as follows:

- The proportion of reproductive taxons;

- The relative portions of various consumers of food resources;
- The connectivity between similar habitats;
- The accessibility to other habitat types;
- The degree of functioning in the specialized network.
- etc..

These basic indicators may be complemented by others depending on requirements. To achieve a reliable evaluation, on should, if possible, attempt to weight at least three of the factorial indicators mentioned or seek out other indicators in order to achieve the desired level of redundancy.

In the context of a supra-local or regional study, the separate analysis of each and every habitat is impossible. In such case, indicators should be applicable to sites, to landscape compartments or to continua (landscape mosaics). Usable data is relatively patchy and very general, as it is situated at the scale of the general cartography of continua or that of the typology of landscape spaces readable from satellite imagery or that provided by local-scale naturalist inventories (habitat sampling). It is necessary therefore to proceed by the crosschecking, simulation and extrapolation of data so as to obtain a coherent ecosystemic picture at the overall scale. This picture may, however, remain temporarily imprecise with regard to local detail.

All stages of an ecosystemic evaluation procedure should always be carried out within the same continuum. It must allow comparison between the results for different territories or regions. The condition for achieving this being the use of the same indicators, weighting scales and multifactorial calculation mode.

The aggregation of evaluation data originating from a number of continua of different types should be avoided, as their basic indicators are not comparable. It is, however, possible to establish a summary mapping which localizes sectors presenting priority issues, but which does not allow conclusions to be drawn about, for example, cumulated ecosystemic values.

5.1.1 Evaluation of the QUALITY Factor

Each milieu possesses its own intrinsic characteristics dependent on its natural state (naturality) and on the portion of initial biocenosis present on its available surface. This portion is positively influenced by the existence of a constant flow of propagules that temporarily and randomly enrich this initial biocenosis. By the same token, external disturbances caused by neighbouring milieus (anthropogenic milieus producing physical and/or chemical nuisances—noise, smells, pollutants, light, etc.) will have a negative impact on the final biocenosis.

This qualitative description can therefore be carried out:

- At the level of the final result of the biodiversity present, by distinguishing species vulnerable to disturbance and which are thus present only in particularly tranquil areas of high ecological quality, as well as those, more common, tolerant species (biodiversities α and β).
- At the global level of specialized networks, by attributing a potential naturality gradient to the different cartographical elements of the specialized ecological network: very high biodiversity zone; central high naturality zone; average naturality extension zone; poor naturality ecotonal marginal zone; and very poor naturality corridors.

The combination of the two approaches, with accompanying adjustments to attributed zoning, gives pertinent results. One should note that transformed milieus, or even completely anthropogenic ones, can also be treated by the same criteria, as built up anthropogenic zones have their range of commensal and allopatric species too.

Among the four basic indicators of the QUALITY factor—faunal and floral diversity, rarity of biotope, wealth of rare species and the naturality of the milieu—only two are actually used for the weighting of the factor at the level of territorial analysis, for which there does not exist a sufficiently detailed mapping of habitats beyond that of global terrain occupation categories.

- The first indicator (Q1), known as the “heritage interest indicator”, gives a summary expression of biological diversity and natural heritage interest of a milieu. It is in this case transcribed to terrain occupation units.
- The second indicator (Q2), known as the “naturality indicator”, expresses the relative “naturalness” of a milieu. It is here transcribed to the internal zoning of the continuum that the unity of terrain

occupation belongs to. It should be noted that the closer to the “heart” of the continuum a milieu belongs, the greater its degree of naturality.

The **naturalness of a milieu**—its “natural” character—translates the level of pressure exerted by human activity on that milieu. Thus, generally speaking, the lesser these pressures, the greater the naturalness of a type of habitat and the greater its biological potential, particularly with regard to its characteristic species.

The values of the two **indices (Q1) and (Q2) are evaluated in the same way as all other indices on a scale of five classes**.

➢ The Index of Biological Richness and Heritage Significance

The evaluation of the **Q1 indicator** is based on terrain studies carried out by naturalists and by the analysis of inventory data furnished by habitat samplings that aim at producing a good level of landscape representativeness (Table 5). Unfortunately, the initial natural milieus used for terrain studies had to be produced synthetically as SPOT Thema data is not at all discriminatory enough.

This synthesis poses difficulties concerning the simplification choices required at the level of the general vision of ecological networks in a landscape sector. The wealth of terrain inventories is not sufficiently reflected in the final result (Table 6). Ideally, on the one hand, the initial terrain occupation database should be enriched with field data based on photo-interpretation techniques and, on the other hand, more filed inventories ought to be gathered so as to increase their reliability as references, particularly in comparison with other sections of the study.

Box 11

Taking Account of Human Activities Favourable or Unfavourable to Landscape Continua

When it comes to analysing the ecological networks in a landscape, grasping all the details of the incidences of human activity on the use of space in each habitat is not easy. On the other hand, it is possible to localize with relative certitude those zones that are subject to the probable influence of various types of disturbance likely to alter the quality and functioning of the most vulnerable habitats. **A superposition of continua networks along with the zones of disturbance using GIS will provide potential conflict zones.**

Following this in the analysis, the type of habitat and its position in a specific network will allow us to identify the issues at stake precisely—as long as the analysis is pushed so far as to obtain a potential ecological value for the ensemble of the elements in the landscape mosaic. This stage of the identification of issues at stake allows research to be directed where necessary towards the discovery of solutions aimed at improving the local situation. It can also serve to justify the implementation of compensatory measures.

This depth of research is not always possible at the outset as it is rarely possible at the scale of 250km^2 (insufficient time and budget). Yet this more detailed mapping and inventorial work is common for the majority of protected zones, whether it be with regard to management goals documents for protected sites (DOCOB) or to the analyses of Regional Natural Parks (RNP), or in a number of recent motorway projects.

		FLORA				FAUNA					GLOBAL	
N°	Type	Taxons	Avg.	Herit	Class	Taxons	Avg.	Niche	Herit	Class	Bonus	Class
	OPEN SPACES											
521	Mixed Farming with Hedg	242	87	2	V	35	8	18	10	V	3	V
522	Mixed Farming without H	165	65	0	III	18	5	9	5	II	1	III
523	Large-Scale Cropping	154	35	2	III	18	3	6	6	II	2	III
531	Dry Grassland	200	50	4	IV	27	5	20	5	III	2	V
532	Mesophilic Grassland	157	38	4	III	26	4	16	7	III	3	IV
781	Wet Grassland	189	36	2	III	27	4	15	8	III	3	IV
	FALLOW AND SCRUB											
655	Scree	55	18	0	I	1	1	1	0	I	0	I
312	Quarries and Gravelpits	153	39	0	III	31	7	20	12	IV	3	V
664	Agricultural Fallow	143	26	0	II	25	7		8	III	2	IV
661	Thermophilic Fallow	140	31	1	II	31	8	15	4	IV	1	IV
662	Scrub Fallow	221	52	7	IV	33	8	26	5	IV	3	V
652	Low Hedgerows	136	29	5	II	29	7	23	6	IV	3	IV
653	Mixed Hedgerows	56	18	0	I	21	7	8	5	III	1	III
654	Wooded hedgerows	122	27	2	II	31	9	31	4	IV	1	IV
	FRUIT FARMING											
672	Walnut Groves	97	24	1	II	25	7	12	3	III	1	III
541	High-Truncked Orchard	81	25	2	I	17	4	6	2	II	1	II
543	Fruit Bushes	83	41	1	I	1	1	1	0	I	0	I
	DRY FOREST											
611	Forest	110	32	4	II	32	10	28	1	IV	1	IV
612	Wooded Slooes	128	31	2	II	33	11	22	1	IV	0	IV
614	Accacia Coppices	95	32	2	I	20	5	0	0	III	0	III
	WET FORESTS											
613	Alder and Ash Woods	154	37	6	III	28	10	21	1	IV	2	IV
651	Riparian	128	33	1	II	29	7	18	0	IV	0	III
	WET ZONES											
782	Reed Beds	33	10	4	I	15	5	6	2	II	1	I
812	Watercourses	107	26	0	II	5	1	1	0	I	0	I
813	Wet Ditches	80	19	0	I	9	2	5	2	I	0	I
821	Forest Ponds	58	14	3	I	16	5	5	1	II	1	II
822	Aricultural Ponds	133	47	3	II	21	6	9	2	III	0	III

Diversity class calculated as a maximum % floral or faunal value

I	1 to 20 %
II	21 to 40 %
III	41 to 60 %
IV	61 to 80 %
V	81 to 100 %

Heritage species bonus

0 = nil
1 = low
2 = average
3 = high

Table 5: *The attribution of classes of biological and heritage diversity based on 200 naturalist inventories organized by sampling on sites within the research zone chosen for their representativeness.*

Source: ECONAT & al. 2009.

Although this lack of definition is frustrating, however, it is not too great a problem inasmuch as the desired aims of the analysis of ecological network is to highlight the issues at stake and the points of friction and to develop appropriate management programmes. Detailed local inventory data will always be useful when it comes to resolving local problems.

Terrain Code	Terrain Categories	Econat Score	ST05 Code	Spot Thema Categories	Consensus-based Score
Aquatic and Wetland Continua					
781	Water Meadows	4	78	Marshes and Peatbogs	5
782	Reed Beds	1			
821	Forest Ponds	2	82	Standing Water	4
822	Agricultural Ponds	3			
812	Rivers and Streams	1	81	Watercourses	2
Forest Continua					
611	Beech and Oak Woods	4	61	Forest – Predominantly Broadle	4
612	Sloping Forest	4			
613	Alder and Ash Woods	4			
	Not Inventoried		62	Forest – Predominantly Conifer	2
	Not Inventoried		63	Forest – Indeterminate Types	3
614	Accacia Coppices	3	64	Forest – Mutating Types	4
651	Riparian Woodlands	3	65	Forest – Linear Types	4
652	Low Hedgerows	4			
653	Mixed Hedgerows	3			
654	Wooded Hedgerows	4			
	Not Inventoried		71	Moorland and Copses	5
Sloping Agro.Pastoral Continua (Slope > 15 %)					
521	Mixed Farming with Hedgero	5	51	Arable and Grassland - Slope >	4
522	Mixed Farming without Hedge	3			
531	Dry Grassland	5			
532	Mesophilic Grassland	4			
541	Orchards - High Trunks	2	52	Permanent Arable	2
542	Orchards - Low Trunks	2			
Lowland Agricultural Continua (Slope < 15 %)					
541	Orchards - High Trunks	3	52	Permanent Arable	2
542	Orchards - Low Trunks	2			
543	Small Fruit	1			
523	Large-Scale Arable	3	51	Arable and Grassland	3
	Not Inventoried		24	Airports-Grassland	5
Anthropogenic Built-Up Continua (Obstacles)					
	Not Inventoried		11	Urban Spaces - Built-up Areas	2
	Not Inventoried		12	Urban Spaces - Infrastructures	1
	Not Inventoried		21	Urban Spaces - Industrial Zone	1
	Not Inventoried		22	Urban Spaces - Roads	1
Anthropogenic Non-Built Continua					
312	Quarries and Gravelpits	5	31	Quarries and Gravelpits	4
	Not Inventoried	2	41	Green Spaces	2
	Not Inventoried	1	42	Sports Areas and Infrastructure	1
	Not Inventoried	2	90	Free Urban Spaces	2

Table 6: *Correspondence table for qualitatively weighted values of the indicator of biological and heritage diversity (Q1) by milieu obtained on the Pays Bièvre-Valloire research zone.*

Source: ECONAT-Concept & al (2010)

➢ Naturalness Indicator

The naturalness indicator (Q2) expresses the relative level of naturalness residual in a milieu. It is here transcribed to the internal zoning of the continuum to which belongs the unit of terrain occupation—considering that the more a milieu is part of the "heart" of the continuum, the greater its degree of preserved naturalness.

The **naturalness of a milieu**, or its degree of hemeroby, translates the amount of pressure exercised by human activity on a milieu. Thus it is generally speaking that the lower such pressures, the greater the level of naturalness of a milieu and the greater its biological potential—particularly with regard to its characteristic species. As a result, the classification of the different zones adopted can be used to constitute the ecological network, which is the product of a global appreciation of naturalness (Fig. 39) as follows:

- Nodal zones: naturalness 5
- Extension zones: naturalness 4
- Continuum margins: naturalness 3
- Corridors: naturalness 2

The naturalness value of 1 is reserved for non-functioning zones located outside the network.

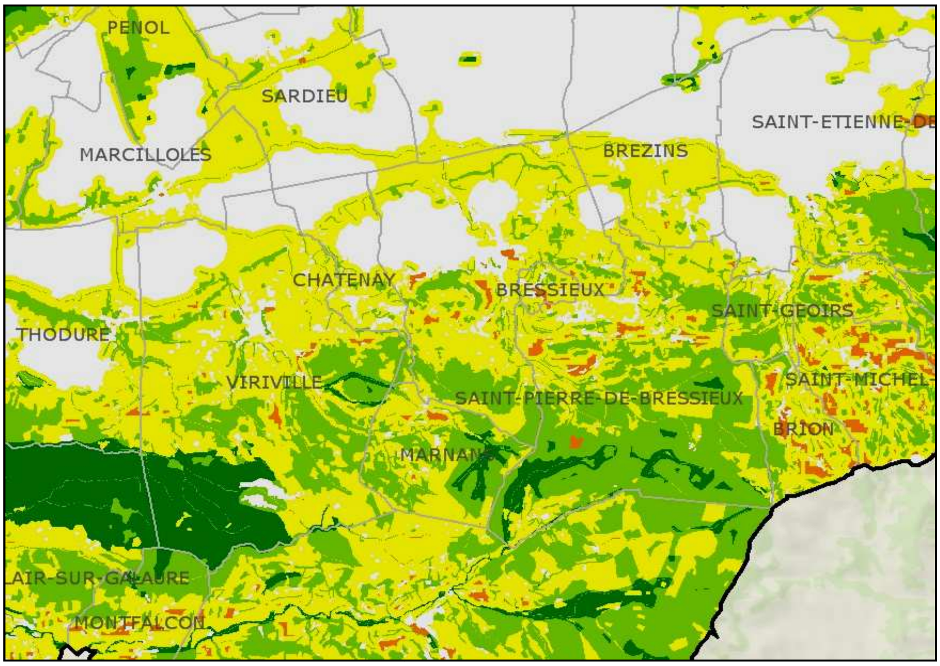


Figure 39.

Example of forest continua weighted according to the QUALITY factor using the two indices Q1 and Q2

Legend :

1 very high
2 high
3 moderate
4 low
5 very low

Source: ECONAT-Concept & al. 2010. Cartography AURG

At the local scale this indicator needs to be improved by ascertaining the degree of naturalness for every habitat (object of mapping).

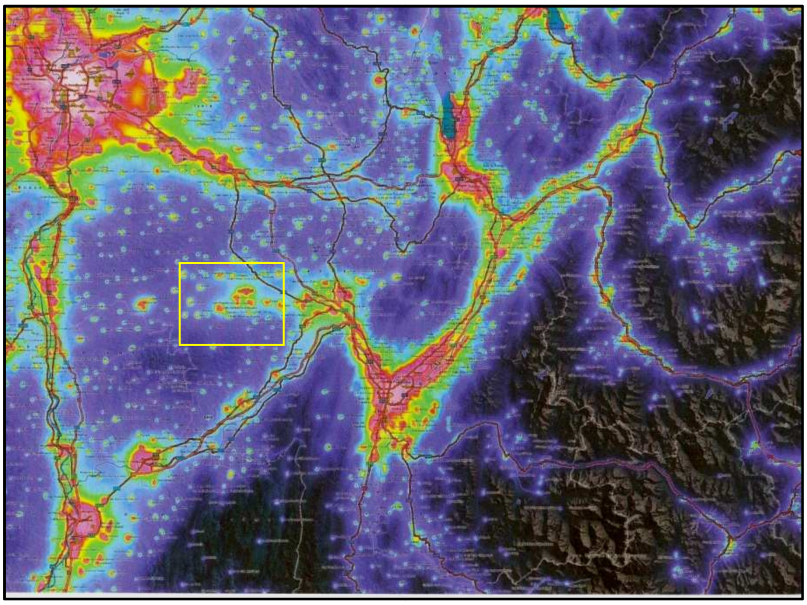


Figure 40.

Extract from satellite image of light pollution over the Isère region.

Simplified scale
White: = <15 stars visible
Red: 80-150 stars visible
Yellow: 250-500 stars visible
Cyan: 1000-1500 stars visible
Black: >3000 stars visible

The zone of study is framed

Source: © F. Tapissier ; http://avex.org.free.fr

At the regional or departmental scale, an **areal indicator of anthropogenic disturbance**, in the form of a hectare-grid land register, can be used, for example by calculating the relationship between the surface area of zones of cumulated anthropogenic incidence and that of unaffected zones. This indicator, however, needs to be translated to a unit of a type of terrain occupation (forest, agriculture, natural milieu, etc.), not to an administrative area, such as a commune, that is not eco-systemically pertinent.

Another surface indicator of perturbation can be obtained at the same scale, which can be added to the survey of anthropogenic impacts already mentioned, namely that of the sources of light pollution established by the analysis of the night sky (Fig.40).

5.1.2 Evaluation of the factor of CAPACITY

The normal evaluation of the factor of hosting CAPACITY is chiefly based on three different indicators: surface area, structural complexity and the wealth of structuring elements.

- **The surface always constitutes an indicator pertinent to the methods application at all scales:** the larger the surface, the more favourable it is to those species typical of the relevant milieu and, as a result, the more the specific diversity of the milieu is potentially rich. A value of the factor of CAPACITY, structured in five classes, is attributed to each of the polygons that constitute the continuum. Surface areas are calculated in km^2.
- **Structural complexity** is usually established by calculating the ratio between the surface area of an object and the longer of its perimeter — two parameters calculate automatically by GIS. The fact is that the ability of a functional habitat core to present a good capacity for flora and fauna depends not only on its surface area but also on its shape: the more the form approaches that of a circle, the greater its compactness and thus the greater will be its biological potentialities. Conversely, a linear habitat will possess a very low, not to say non-existent, compactness.
- **The wealth of structuring elements** has never yet been used in the analysis of ecological networks. This wealth is of particular usefulness where the method of analysis exploits detailed land-occupation data, which is absolutely the case with SPOT Thema.

In the evaluation of the factor of CAPACITY, it is also possible to employ a **circularity index** as described by Miller (1953) and taken up by Gravelius (2002). In this case, as was suggested in the study of the ecological potentialities of the regional territory of the Pas-de-Calais (Biotopes GREET, 2002), it makes sense to directly combine the surface effect with the polygon effect by calculating a **compactness indicator**.

Such a compactness indicator is equivalent to the required weighting for the factor of CAPACITY. Thus in this indicator, the value associated with the surface area remains the most SIGnificant element but it is weighted according to the compactness of the object in question. From a biological perspective, a large but fragmented natural space is more valuable than a tiny though compact one.

Calculation of the circularity indicator (I_{ci}): $[\, I_{ci} = 12{,}57\ A/P^2 \,]$ Where:

A = the area of the object in question and
P = the perimeter.

Calculation of the compactness indicator (I_{co}): $[\, I_{co} = 12{,}57\ A^2/P^2 \ X\ A \,]$ Thus:

circularity indicator x surface area of the object

This indicator is calculated for all SPOT Thema polygons, including nodal zones, extension zones and buffer zones. A reclassification of the distribution of surface values into five categories is carried out using the GRASS software. The results thus attributed to all polygons are then transformed into a raster format with a 10 m pixel so as to permit the calculation of the final ecological value, pixel by pixel (Fig. 41).

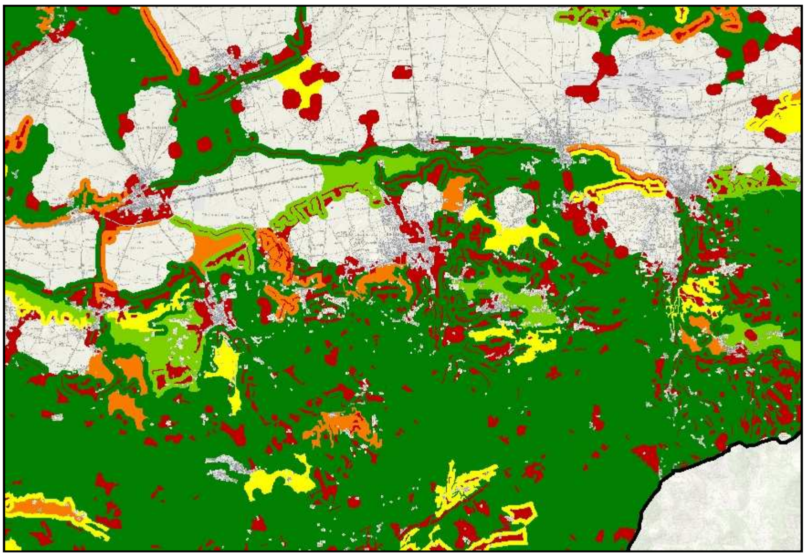


Figure 41.

Example of the presentation of the results of the capacity indicator calculated for an agricultural continuum.

Source: ECONAT –Concept & al. 2010 Cartography AURG.

5.1.3 Evaluation of the factor of FUNCTIONALITY

The initial method, developed for the most part to be used in terrain surveys, comprises a number of synthetic indicators based on a global appreciation of the ecological functions observed at the level of habitats. The evaluation, however, of these indicators — such as refuge possibilities, reproduction of representative species, availability of food, exchange flows with adjacent milieus, etc. — are not adapted to the requirements of study at the scale of a large territory. Other indicators, therefore, based mainly on GIS analysis, need to be found.

For this reason, we have preferred two indicators of the functionality of ecological networks that can be ascertained from the GIS data produced by our approach:

- ⇨ **Continuum polyvalence (F1)**;
- ⇨ **Level of species connectivity (F2)**.

These two indicators are gauged on a five-point scale. After which **the global FUNCTIONS factor is obtained from the average of F1 and F2**.

➢ F1 Indicator: Continuum polyvalence

- ➢ **The F1 indicator: continuum polyvalence** is understood in terms of the number of continuums superposed at a given spatial point. It is considered that the greater the number of superpositions at a given site, the more its level of functionality is favourable. This approach is corroborated and confirmed by the naturalist inventories produced during the Bièvre-Valloire study (ECONAT & al, 2009), which show that significant differences in the specific global wealth and frequency of nesting birds in a given habitat as a function of the number of continuum margins that influence the habitat. (Fig. 42).

The method consists in carrying out a preliminary assembly and then fusion of the polygons that constitute each continuum so as to obtain a single layer for each continuum: comprising nodal zones, extension zones, buffer zones and corridors.

GDS counting calculates the number of overlaps at each spatial point. As this number is by definition at least one (a single continuum) and not more than four (superposition in a few rare places liminal to all four continua), a classification of values from one to four is therefore established. The resulting layer is then rasterized in the same way as previously.

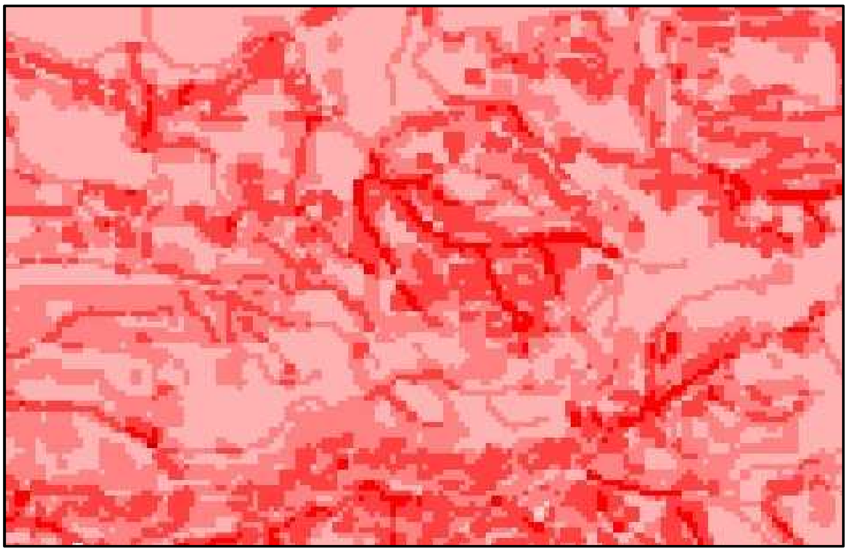
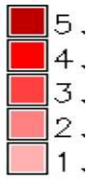


Figure 42.

Example of a polyvalence map obtained by the superposition of continua.



Source:
ECONAT-Concept & al. (2010).
Cartography AURG

➢ F2 Indicator: the level of spatial connectivity

Connectivity in ecological networks consists in a number of complementary approaches:

- The **potential of the natural infrastructure** in a given landscape.
- The **potential specific connectivity calculated by user group,** using the known dispersion parameters of species such as their locomotive capabilities, their ecological needs with regard to vital space and food resources and the social behaviours determining their spatial distribution.
- The **actual specific connectivity obtained by direct observation** of identifiable individuals (distinctive markings, tagged telemetry, transponders, etc.) allowing their movements to be monitored ever extended periods so as to determine the extent of their seasonal living spaces.

It should be noted that each of these three approaches corresponds to an incremental data level that corresponds to a rising gradient of our perceptions of the functional complexity of network systems. These data levels also correspond to very different levels of the amount of effort required to obtain them.

Within the context of this model of successive levels of data, it would be wrong and illusory to attempt to analyse the connectivity of an ensemble of habitat networks — so as to define, for example, the survival chances of a given population of a threatened species — without applying the modelized constraints to the other data levels. Thus, dispersion models for heritage species that are based solely on resistance factors attributed to terrain occupation categories will be critically biased if one fails to take account:

- The **constraints of network organization** as defined by the modelization of specialized continua, which implies:
- By the modelization of specialized continua, which in turn implies large-scale data capture concerning dispersion flows in relation to those virtual spatial constituted by buffer zones and corridors.
- **Population constraints**. These are cognate with the social behaviours of learning and impregnation. They should be ascertained solely through detailed field observation. Very often they reduce a species' dispersion opportunities.

To put another way, **a theoretical dispersion — calculated from source zones using only the resistance gradients attributed to different milieu types — will be completely biased given that a species' dispersion is never a chance effect.**

At the analysis level of the potential ecological network of a region or a study zone covering several hundred km^2, only the **potential connectivity of the ecological network** would be used in the modelizing phase.

It is possible that the calculation of potential specific connectivity could be applicable in a second phase at the validation stage, by taking a few characteristic species to be representative of "utilizing" species.

This indicator is connected to the spatial distribution of the values resulting from those dispersion tests that gauge the level of connectivity between the extension zones of each continuum. The resulting layer is already in raster format with a 10 m pixel.

The value distribution will then be subjected to a reclassification in five value classes.

➢ Carrying out a standard dispersion test

- **Objectives and Principles:**

- To simulate the potential movements of fauna starting from nodal zones and integrating the resistance factor of these movements caused by the nature of the milieus crossed.
- The principle of the test is based on a prior modelization of the landscape in question, employing the idea of movement cost (or friction value) for relevant animal species according to the landscape elements crossed.
- The result of the test allows the propagule rating of connectivity sectors starting from nodal zones to be established.

From an IT perspective, this test constitutes a modelization based on a “lowest cost” method. Viewed in this way, connectivity is understood as the degree to which spaces (defined in terms of terrain occupation data) facilitate or hinder the movements between nodal and extension zones of a given species or population.

On the basis of territorial data (here, the land use layer of SPOT Thema), the floral landscape is modelized as a grid in which each cell contains a datum about terrain utilization. The resulting mapping of friction constitutes the basis of a landscape modelization that allows the dispersion of a hypothetical individual starting from a chosen source location to be displayed.

Friction values for each of SPOT Thema’s land use classes are established on the basis of expert opinion according to **two criteria:**

1. The degree of ecological affinity of a group of species indicative of the milieu in question (this is the chief criterion).
2. The degree of difficulty involved in crossing an area and of a given route for the species present in a milieu, taking account of the risks encountered and the stress produced.

This second criterion is included by means of the pre-selection of surface areas within the specific network.

The establishment of this test requires a number of stages and methodological precautions if it is to be efficient.

Stage 1: Definition of the resistance matrix

This is established to begin with by following the logic imposed by the direct observation carried out in the field. A resistance (or friction) coefficient is attributed to each terrain occupation class — SPOT Thema or others — according to the type of continuum in which it is situated. This coefficient expresses the relative ease with which a specialized guild is able to move through the milieu in question. The resistance values adopted (Table 7) correspond to the following logic:

- The “0” resistance value only applies to the continuum’s nodal zone,
- The “5” value applies to all attractive milieus within the extension zone,
- The “30” value applies to accessible milieus within buffer zones and corridors,

  The “100” applies to all positively unattractive milieus or to identified obstacles within the network.

Spot Thema Categories	Code ST05	Wooded Continuum	Aquatic and Wetland Continuum	Semi-Open Milieus Continuum	Agro-Pastoral Slope Continuum	Flatland Agricultural Continuum
Marshes and Peatbogs	**78**	5	0	30	5	5
Standing Water	**82**	30	0	100	100	100
Watercourses	**81**	5	0	5	5	5
Forests - Predominantly Broadleaf	**61**	0	30	30	30	30
Forests - Predominantly Coniferous	**62**	0	30	30	30	30
Forests - Indeterminate Type	**63**	0	30	30	30	30
Forests - Mutating Types	**64**	0	30	30	30	30
Forests - Linear Types	**65**	0	5	5	5	5
Lawns and Steppes	**73**	30	100	5	0	30
Moorland and Copses	**71**	0	30	0	5	100
Permanent Arable - Slope > 15%	**52**	5	30	30	0	30
Arable and Grassland - Slope > 15%	**51**	5	30	30	0	30
Permanent Arable - Slope < 15%	**52**	5	30	30	30	0
Arable and Grassland - Slope < 15%	**51**	5	30	30	30	0
Urban Areas - Built-up Zones	**11**	100	100	100	100	100
Urban Areas - Urban Infrastructures	**12**	100	100	100	100	100
Urban Areas - Industrial Zones	**21**	100	100	100	100	100
Urban Areas - Road Infrasructures	**22**	100	100	100	100	100
Quarrying and Gravelpits	**31**	30	5	5	30	5
Green Spaces	**41**	30	30	30	30	30
Sports Areas and Infrastructures	**42**	30	100	30	30	30
Free Urban Spaces	**90**	30	100	30	30	30

Table 7.
Resistance values attributed the elements of each continuum type.

Source: ECONAT (2001)

These values are based on the empirical observation of faunal movements within study areas in the Swiss-Plateau region (ECONAT, 1998). They are calculated on the basis of a 100 x 100 m landscape grid (grid per hectare). They will serve to calculate the movement cost.

By a GIS table-combination process, the values are accorded to all SPOT Thema polygons (Table 7). Once rendered cartographically, this initial treatment allows the visualization of the theoretical level of the territory's connectivity for each faunal group associated with a particular continuum Fig. 43).

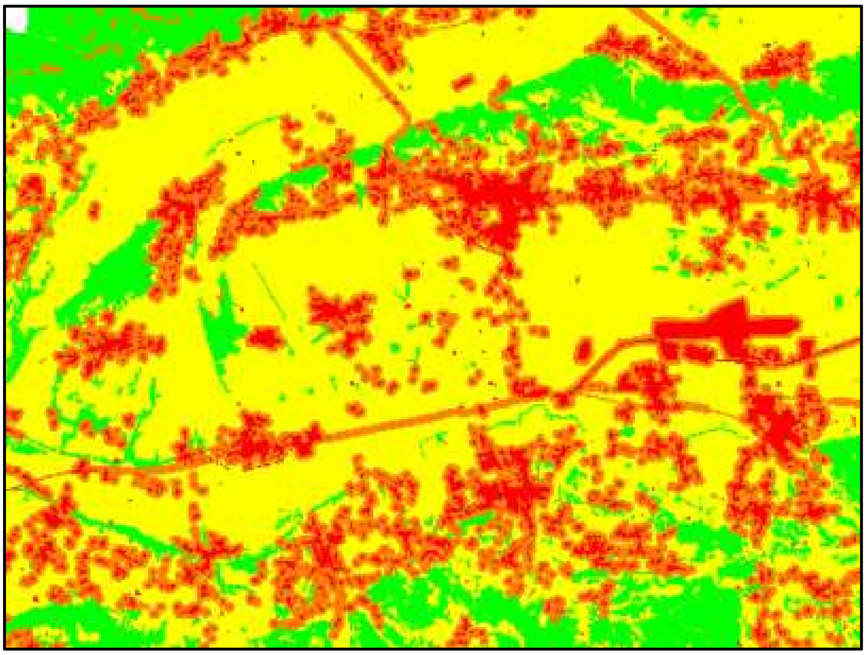


Figure 43.

Example forest continuum weighted for the incidence of resistance.

resistance scale:
Dark green = very low
Green = low
Yellow = moderate
Orange = high
Red = very high

Source:
ECONAT-Concept & al. 2009
Cartography AURG

Stage 2. Creation of a layer for the "impassable" or "disturbed" elements

In every continuum there exist numerous overlap zones with other continua. The first thing that needs to be done is to integrate any effects generated by the anthropomorphic continuum, and also to consider whether disturbance gradients need to be accounted for in the model.

In any event, before computer testing can be launched, all sectors judged to be impassable to any natural faunal species need to be eliminated whatever the continuum under consideration. Such spaces are constituted by urban spaces and large-scale road and rail infrastructures. All such spaces are defined and then removed from the test zone. They will subsequently be reintroduced and classified as impassable zones whatever the continuum under consideration. The effective result of this procedure is the creation of an "obstacle" layer at the level of terrain use.

Modelling of natural obstacles can be improved by the **integration of two further criteria:**

- **Declivity**: the steeper the slope, the greater resistance of the milieu: to the point where it eventually becomes "impassable". The use of an TNM (Terrain Numerical Model) allows zones of high declivity to be outlined. In the **case of cliffs and rock faces**, this effectively amounts to introducing a new data layer serving to locate these linear elements, elements that are poorly identified by SPOT Thema. These natural obstacles can also be added to the inventory of conflict points by manually creating the appropriate polygons (they are so included in the inventory of conflict points for the Isère Valley).
- **Disturbance gradients**, whose measurement models allow discrete bands to be fixed (e.g. noise, dust, gas, light, etc.)

Stage 3: Treatment of buffer zones surrounding anthropomorphic elements

In order when modelling connectivity to properly take the disturbance effects on fauna of anthropomorphic elements into account, we have added a resistance level to the initial class attributed to the milieu in question. This resistance level represents the qualitative deterioration of the milieu.

In concrete terms this can be understood in the following terms:

1. That a milieu (or terrain occupation type) considered as "structuring" (coefficient 0) would become "attractive" (coefficient 5);
2. That an "attractive" milieu (coefficient 5) would become "little frequented" (coefficient 30);
3. That a "little frequented" milieu (coefficient 30) would become "repellent" (coefficient 100).

Stage 4: the test itself

The test is carried out using a grid-type processing software such as GRID, IDRISI or GRASS. For the territorial study in the Department of the Isère, for example, the raster module of GRASS (Geographic Resources Analysis Support System) was employed.

By a process of trial and error, we finally settled on a pixilation scale of **10 m by 10 m cells**, despite the fact that the cells of the initial model are of a dimension of 100 m by 100 m (1 ha), this being the detail level for departmental and regional maps. The module scale finally decided upon allows the cumulative cost of moving from one cell to another to be calculated by averaging the difference between the resistance of the starting cell with that of the destination cell.

Where **R** is the resistance coefficient of a polygon i,

the software's calculation is:

$$\mathbf{(R1 + R2)/2 + (R2 + R3)/2 + \ldots}$$

A value gradient is obtained. This then needs to be distributed in classes of connectivity, factoring knowledge of the terrain in so as to obtain thresholds that are realistic (Fig.44).

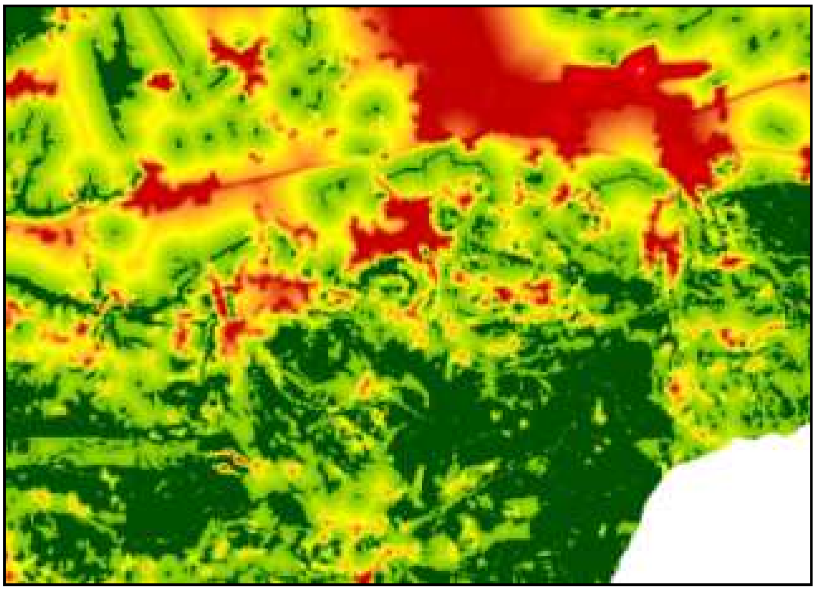


Figure 44.
Example of a standard dispersion test applied to a forest species potentially present in reservoir zones.

The result provides the (F2) connectivity indicator

750 very low
500 moderate
250 very high
0

Source : ECONAT & al. (2010)
Cartography AURG

The average of the indicators of versatility (F1) and connectivity (F2) enables the weighting of the FUNCTIONS factor and the drawing up of a summary map of each continuum type (Fig. 45)

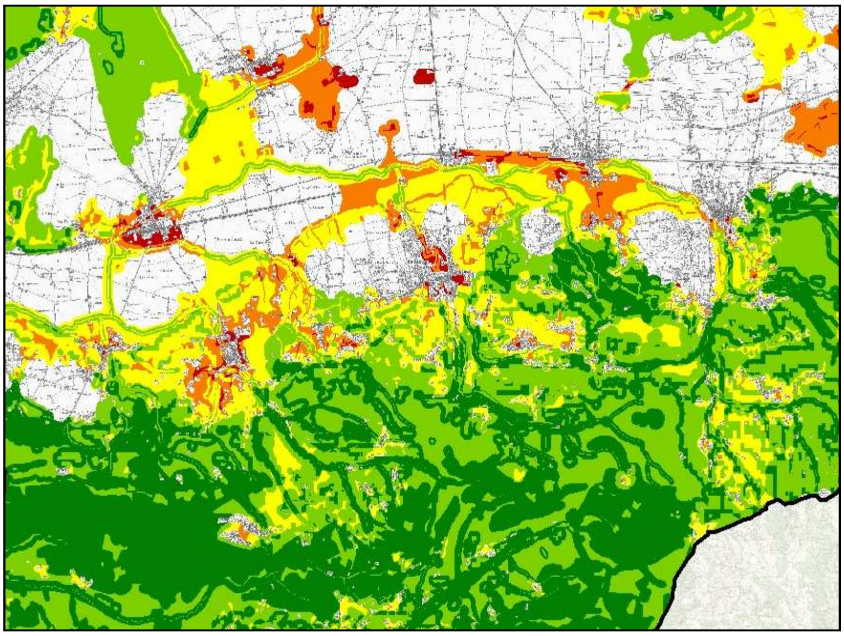


Figure 45.

Example of forest continua weighted by the FUNCTIONS factor by combining the indicators F1 and F2

5 very high
4 high
3 moderate
2 low
1 very low

Source :
ECONAT-Concept & al. (2010)
Cartography AURG

➢ Approaches for the improvement of local approaches

It this stage of the analysis, it is now possible to integrate **known crossing points** with the obstacle layer and to further factor in coefficients of low resistance. The following precautions do, however, need to be taken:

- The data employed must be the product of inventories that have properly considered the real usability for fauna, by employing qualitative and quantitative criteria concerning the diversity and representativeness of species for the zone in question. Existing contact zones bridging transport infrastructures are numerous; few however are considered to be genuinely favourable (viaducts, covered ditches, tunnels, animal crossings). Other faunal crossing dispositions, such as hydraulic works, need to be subject to serious analysis and approval by specialists before they can be considered functional for fauna. A continuously updated database of transport-network conflict points and crossing infrastructures already exists for the Department of the Isère (ECONAT & EVINRUDE, 2007).

- The incremental scaling within the “obstacle” layer of a functional crossing point for fauna needs to be of a minimum of one pixel equalling a single unit of the chosen grid scale (10m or 100m). If this is not the case, the dispersion test will not work.

The modelling of ecological disturbances associated with anthropomorphic elements can be further refined by the introduction of the notion of the intensity of disturbance: such intensity depends on the one hand on the size of the urban zone (the widths of buffer zones are differentiated as a function of the size of the disturbance), and on the other hand on the distance away from this zone: disturbance diminishes the further the distance and could be classified, for example, in three categories (strong, average, weak). This task would require that before it is accomplished a more nuanced classification of urban spaces than that possible with SPOT Thema should be carried out. Such an approach is very promising but would take a long time to prepare appropriately for a large area. It is, on the other hand, perfectly applicable for local analyses within the context of development impact studies.

5.1.4 Global ecological value by continuum

The ecological value is calculated using the VEPM method (Berthoud et al, 1989). This is applied in a raster format with the GRASS software[3], pixel by pixel, at an areal precision of 10m. The ecological value is obtained with the following formula:

$$\mathbf{Ve = Q \times C \times F}$$

where **Q** corresponds to the weighted factor QUALITY, **C** to CAPACITY and **F** to FUNCTIONS.

Using an evaluation scale of 5 points for each factor, which corresponds to the precision level of the data employed, we chose a map of ecological values which are also organized into five classes as a function of the probability of the scores:

From 77 to 125 points:	very high ecological value
From 51 to 76 points:	fairly high ecological value
From 30 to 50 points:	average ecological value
From 9 to 29 points:	low ecological value
From 1 to 8 points:	very low ecological value

The study of the natural heritage of the Bièvre-Valloire territory (ECONAT-Concept & al, 2010) provides a good example of the spatial hierarchization of eco-landscapes by ecological potential (Fig. 46 to 50).

The results of this hierarchization process by continuum affords:

- A synoptic view of the development and efficiency of each specialized network.
- The ability to identify those polygons of particular interest given their ecological potential (high or low), about which it would be necessary to check the validity of available data: protection status, naturalist reference indexes, along with the appropriate management measures for their conservation or restoration as needs may be.

Although this global hierarchical classification is, of course, still only sketchy, given the imprecision of the indices applied, yet it does offer a satisfactory overview the general functioning of the specialized network at the territorial scale. The potential ecological value attributed to each continuum can serve as a reference for a given temporal horizon (e.g. the initial 2007 state of the aquatic and wetland network for the Bièvre-Valloire territory).

The principle governing the approach plainly gives rise to the idea that the next logical step would be to draw up a map consolidating all the ecological networks of a territory so as to obtain a global document containing all the natural landscape elements needing priority conservation. Such a thematic map would, moreover, be easily obtained by the simple addition of the defined potential values for each ecological network. It would, however, not in fact be ecologically pertinent insofar as it would agglomerate incompatible values and would in no way give rise to zones with new priorities (Fig.44).

[3] Other raster GIS like GRID or IDRISIS are available on the market

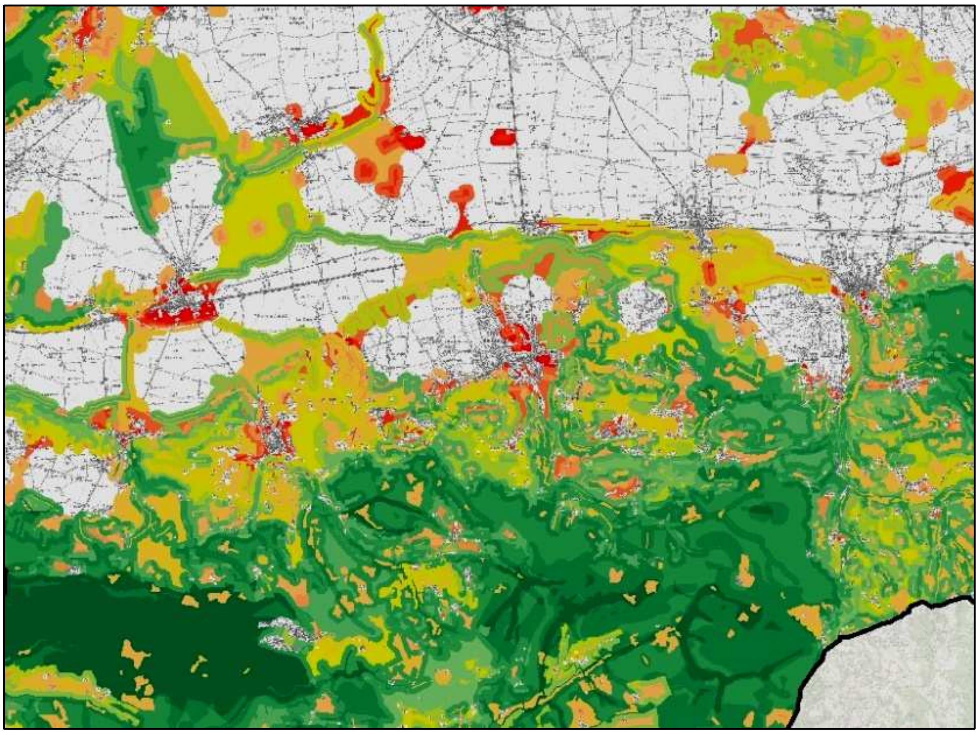


Figure 46.

Forest network categorized hierarchically in terms of its ecological potential.

Echelle :

125 — Very high
75 — Moderate
50
30 — Very low
9
2

Source :
ECONAT-Concept & al. (2010)
Cartography AURG

. *Remark: In order to illustrate the stages of hierarchization leading to the summarizing map of high ecological potential zones, the extracts presented here always involve the same landscape area.*

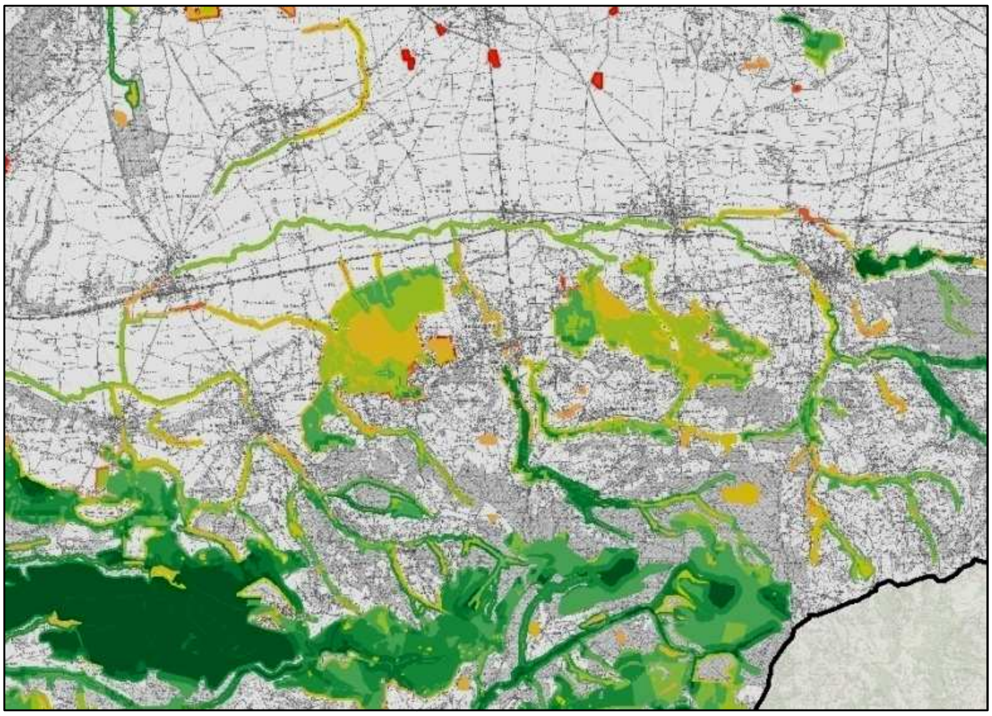


Figure 47.

Aquatic and palustrine network categorized hierarchically in terms of its ecological potential.

Echelle :

125 — Very high
75 — Moderate
50
30 — Very low
9
2

Source :
ECONAT-Concept & al. (2010)
Cartography AURG

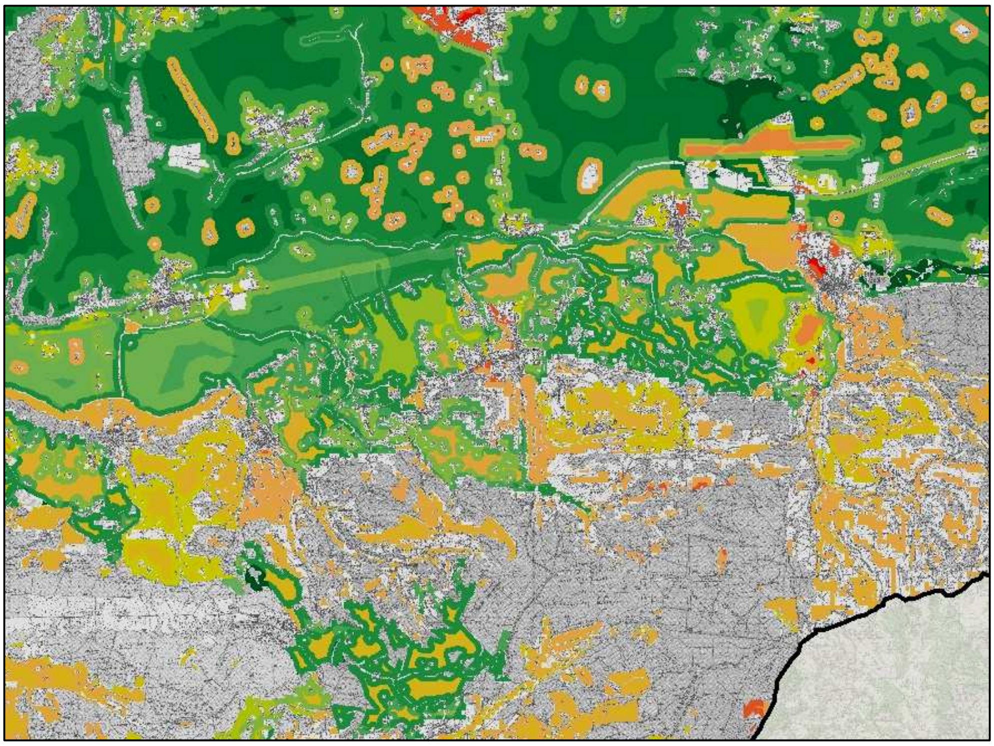
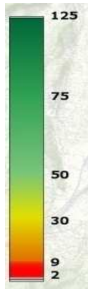


Figure 48.

Lowland agricultural network categorized hierarchically in terms of its ecological potential.

Echelle :



Very high

Moderate

Very low

Source :
ECONAT et al. (2010)
Cartographie AURG

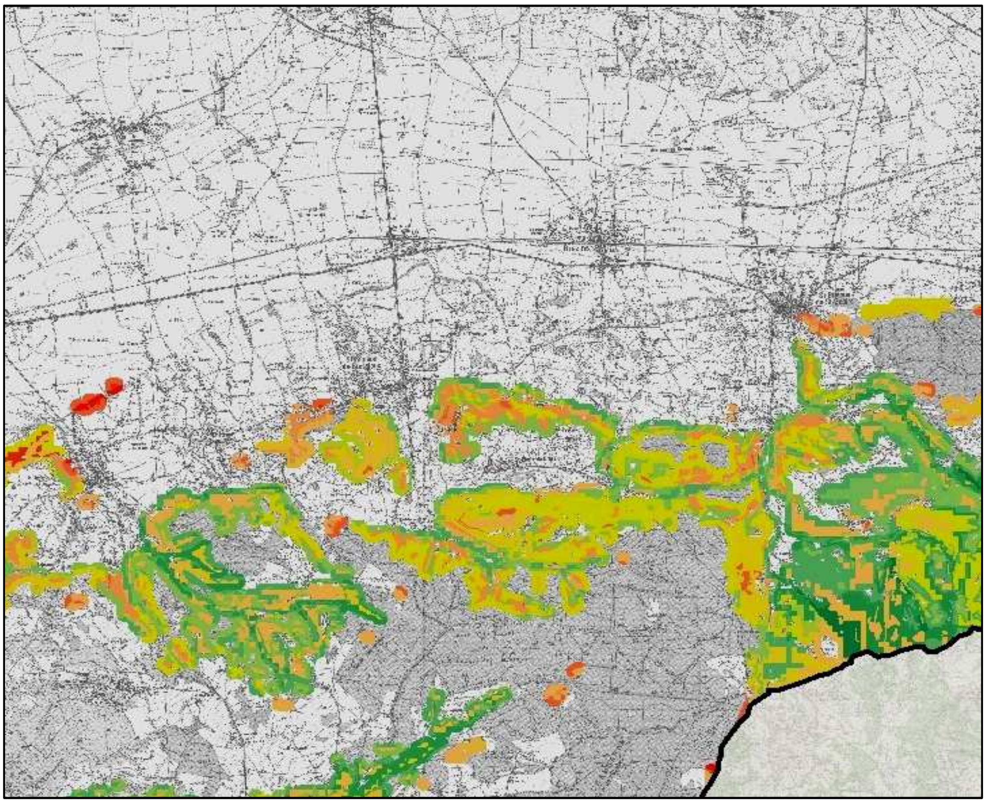
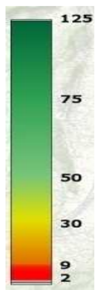


Figure 49.

Sloping agricultural network categorized hierarchically in terms of its ecological potential.

Echelle



Very high

Moderate

Very low

Source :
ECONAT et al. (2010)
Cartographie AURG

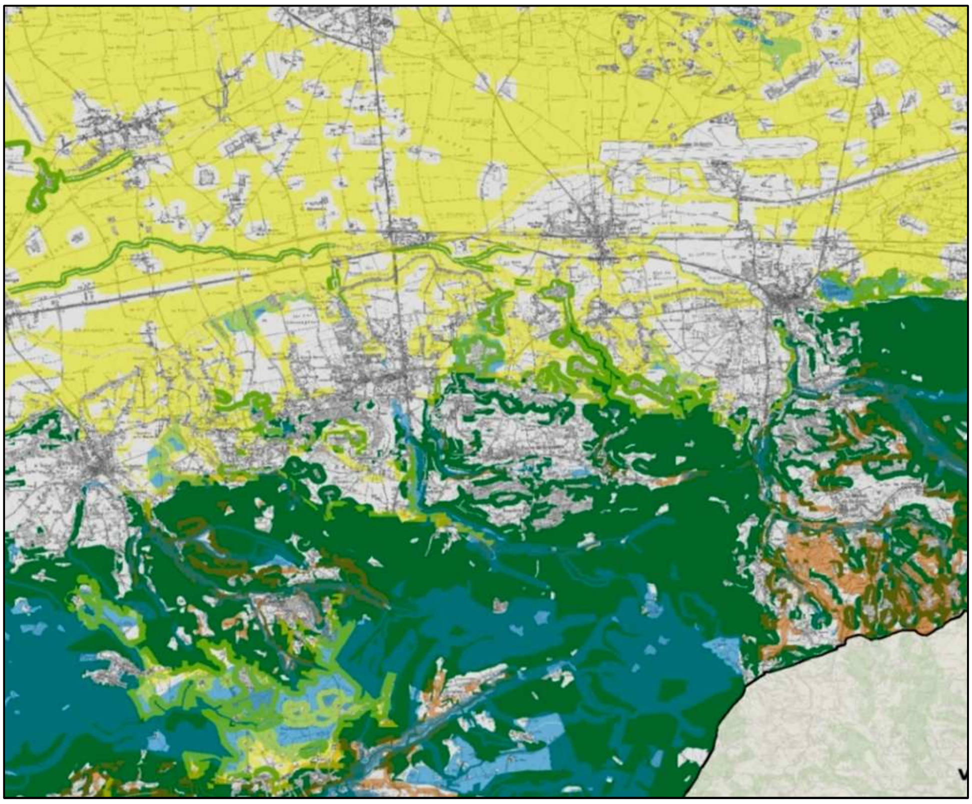


Figure 50.

Synoptic map of zones of high ecological potential at the territorial scale.

Zones underlying superimposition appear by transparency.

Légende :

Values from 4 to 5

Espaces agro-pastoraux

Espaces agricoles

Espaces aquatiques

Espaces forestiers

It is, on the other hand, possible to establish a synoptic thematic map by presenting, for example, all high ecological potential zones (Fig.50). In this case, the localization of priority zones is of more importance than the values attributed to continua.

Thus, the selected priority zones in each continuum are attributed an identifying colour such as, for example, green for forest zones, blue for aquatic zones, brown for agricultural zones and yellow for thermophilic zones. This, purely informative, map would allow the visualization of those zones presenting of particular interest with regard to the protection of the natural environment and for which statutory protection would probably be necessary.

The most pertinent applications devolving from the mapping of ecological value by continuum are as follows:

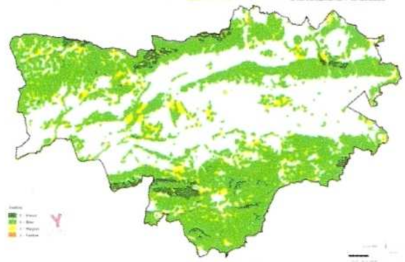
- The selection at the local scale of those zones of particular significance with a view to their coordinated management (DOCOB, PLU, local development action plans). Planning can be effectively targeted on those network spaces and parameters liable to improvement.
- The systematic appraisal at the territorial scale of all identifiable conflict zones by the superposition of anthropomorphic zones, for these zones are now described in terms: of their location within the network, of the surface areas concerned, of disturbances to ecological functioning and of the degree of conflict.

The display of coherent and efficient eco-systemic ensembles (those whose ecological potential is high) **allows the gradual replacement of the limited notion of the protection of given sites with that of the protection of ecological networks.**

ANALYSE DU CONTINUUM FORESTIER EN BIEVRE-VALLOIRE

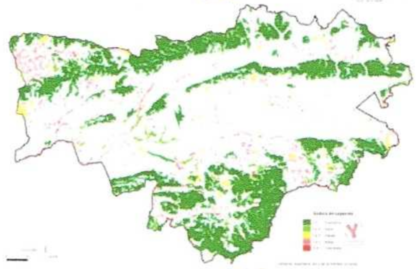
Carte 1
Développement des continuums

Zone nodale : 3 546 ha
Zones d'extension : 25 926 ha
Zones complémentaires: 18 100 ha
Corridors : 4 896 ha
Surface totale : 48 922 ha



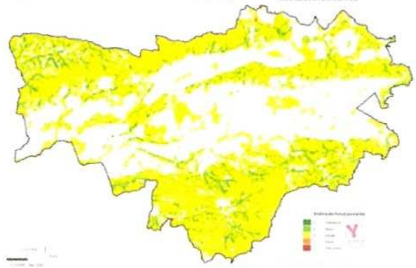
Carte 2
Indice du facteur QUALITE

Surfaces de valeur 5 : 3 213 ha (0,56 %)
Surfaces de valeur 4 : 40 618 ha (83,02 %)
Surfaces de valeur 3 : 4 816 ha (9,85%)
Surfaces de valeur 2 : 275 ha (0,56 %)
Surfaces de valeur 1 : 0 ha (0%)



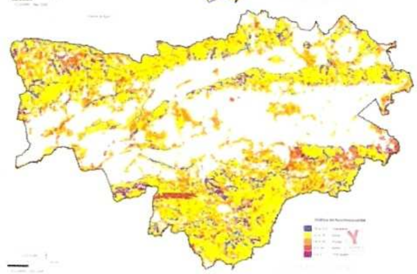
Carte 3
Indice du facteur CAPACITE

Surfaces de valeur 5 : 21 814 ha (84,1 %)
Surfaces de valeur 4 : 803 ha (3,1 %)
Surfaces de valeur 3 : 1224 ha (4,7%)
Surfaces de valeur 2 : 678 ha (2,6 %)
Surfaces de valeur 1 : 1407 ha (5,5 %)



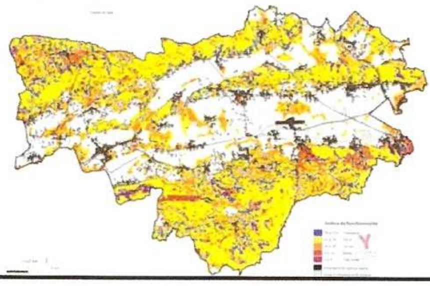
Carte 4
Indice du facteur FONCTIONS

Surfaces de valeur 5 : 730 ha (1,5%)
Surfaces de valeur 4 : 6 732 ha (13,76 %)
Surfaces de valeur 3 : 41 074 ha (84%)
Surfaces de valeur 2 : 368 ha (0,7 %)
Surfaces de valeur 1 : 18 ha (0,04 %)



Carte 5
Valeur écologique potentielle

Surfaces de valeur 5 : 730 ha (1,5%)
Surfaces de valeur 4 : 6 732 ha (13,76 %)
Surfaces de valeur 3 : 41 074 ha (84%)
Surfaces de valeur 2 : 368 ha (0,7 %)
Surfaces de valeur 1 : 18 ha (0,04 %)



Carte 6
Atteintes écologiques
Surfaces de valeur 5 : 730 ha (1,5%)
Surfaces de valeur 4 : 6 732 ha (13,76 %)
Surfaces de valeur 3 : 41 074 ha (84%)
Surfaces de valeur 2 : 368 ha (0,7 %)
Surfaces de valeur 1 : 18 ha (0,04 %)
Surface totale avec incidences anthropiques : 7 264 ha

Figure 51. *Summary of data available on GIS for each hierarchical network. Example of forest continua in the Pays de Bièvre-Valloire.*

5.2 Use of the data produced by hierarchical ecological networks

The advantages accruing from the evaluation of ecological potential from spatial data of networks of habitat continua are numerous. The resulting maps supply not only an overview of the natural infrastructure but also an understanding of how it operates as an interactive system. This thus allows us to pass from the management of circumscribed habitat zones to that of networks of habitats thanks to the availability of a modelizing tool serving to create action scenarios tailored to each specialized network. This makes it theoretically possible to visualize the effects of a given management strategy or specific infrastructure in the model.

It is, however, absolutely obvious that **this tool can only be as effective as the quality of primary data** it depends on. If the precision of the cartographical data is weak and the naturalist inventories insufficient or not up to date, this analytical tool will not be up to the task of generating long-term management approaches.

5.2.1 Analysis of the specific conflict points of each specialized network

A map of points of conflict (disturbance) or dysfunction can be easily established at the level of each specialized network. It can be achieved by means of the simple superimposition onto the network map of zones lastingly disturbed or modified by human activities not compatible with the with quality and normal functioning of the milieus in question.

Permanent obstacles — natural or artificial — have already been removed from the synthesizing layer of the specialized network. It still remains, however, to locate those zones invalidated by any disturbance having a significant effect on the quality or functioning of network elements (Fig. 52). This task can be easily executed by displaying all altered zones using GIS:

- Those zones depreciated by anthropogenic activities are positioned beneath the various buffer zones of the “artificial obstacle” layer.
- Zones affected by the presence of natural continua little compatible with their own characteristics (e.g. a forest zone containing a thermophilic zone) are taken into account within the general ecological model, notably in the multi-functioning of buffer zones. However, newly installed plantation elements can very well be accounted for in the form of new layers containing their incidence zones within the natural network. Good examples would be a plantation of poplars in a wetland zone, or reforestation on dry prairies, etc.
-

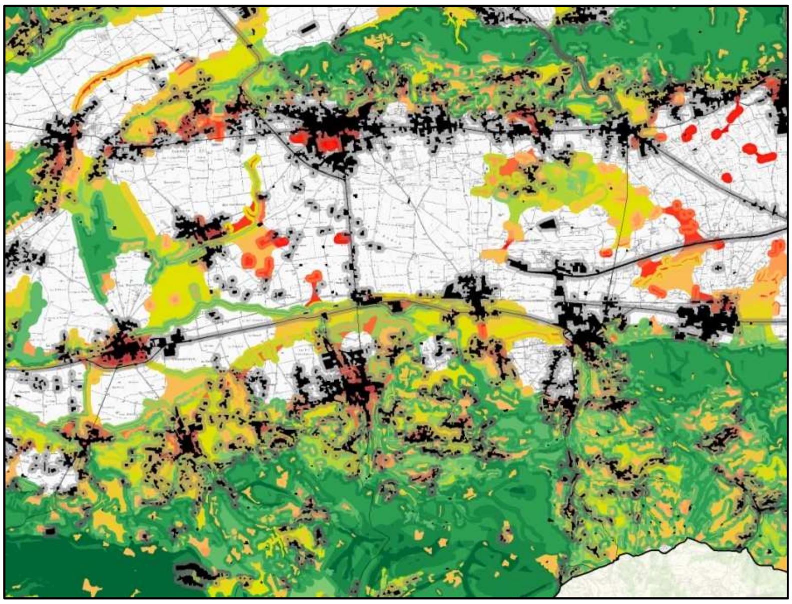


Figure 52.

Example of forest continua hierarchically organized with superimposed conflict zones.

Legend:

Source :
ECONAT-Concept & al. (2010)
Cartography AURG

If we accept that the overall ecological network occupies virtually all non-urbanized space, it becomes plain that the identification of conflict zones is more pertinent when carried out at the level of each specialized network whose ecological potential has been organized hierarchically. In this way and using GIS, the scale of the issues pertaining to each given space, along with the parameters that have generated its ecological value (indicators of value, of capacity and of function) can be ascertained.

At this level of analysis, this process of ascertaining issues simultaneously produces appropriate avenues for improving the situation where necessary (infrastructure or management measures allowing the improvement of the given milieu's quality, capacity and/or functioning).

Issue analysis can be reduced to four summary situation types:

⇨ **Case 1.** A continuum is progressively encroached and fragmented by urbanization and disturbance activities. In the following example of a forest continuum (Fig. 53), a proliferation of urban clearings progressively causes larger, joined-up areas. This constitutes the first stage in a more significant fragmentation with a notable weakening of the continuum. This incidence of the fragmentation process can be said to be serious where it affects nodal zones or zones that are highly functional for fauna.

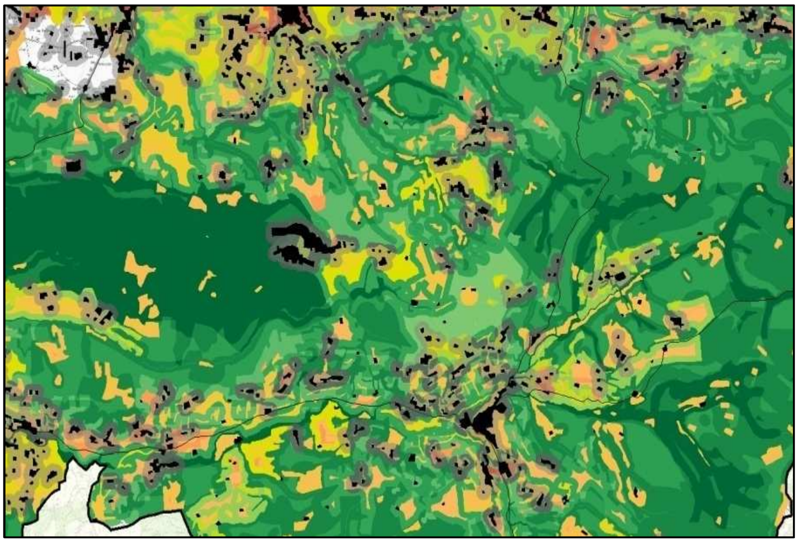
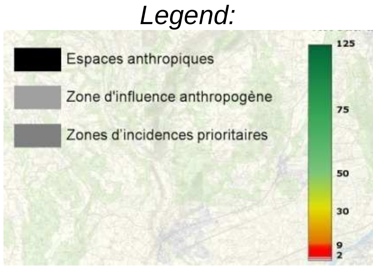


Figure 53.

Progressive fragmentation of a forest continuum caused by building and agricultural or leisure activities.

Legend:



Source : ECONAT-Concept & al. (2010)
Cartography AURG

⇨ **Case 2.** A continuum is bisected by a high-flow transport infrastructure and by localized urbanization (Fig. 52). The bisection of the forest, emphasized by the existence of security fencing and by a large disturbance zone, results in complete fragmentation. If the two resulting continuum parts constitute significant extension zones — both in terms of surface area and quality (presence of nodal zones on either side of the barrier), the effect of the bisection can be reduced by the construction of crossing infrastructures appropriate to the species present.

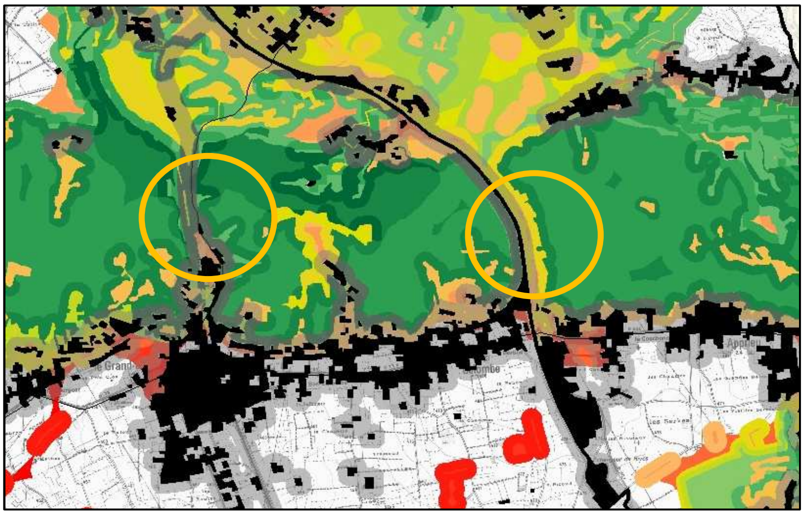


Figure 54.

Disturbance of continua caused by transport infrastructures and urbanization.

Source :
ECONAT-Concept & al. (2010)
Cartography AURG

⇨ **Case 3.** The forest and aquatic corridors of regional importance which cross the plain of Bièvre are being subjected to fragmentation by urbanization and transport infrastructures (Fig. 53). Taking account of their importance to the regional ecological network as a whole by means of a hierarchical classification in forward urban planning, key corridors should be maintained in terms of their location, quality and coherence or, where necessary, restored so as to allow them reclaim their original functions.

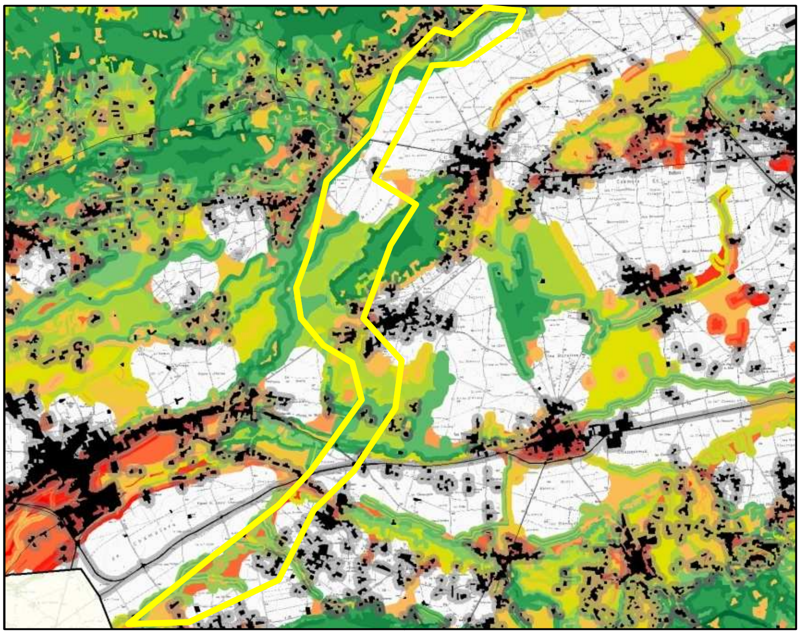


Figure 55.

The interruption of a number of regionally important corridors (aquatic, forest and ecotonal) by urbanization and transport necessitates the introduction of a protected and managed corridor (in yellow).

ropic space

ropic influence

ity incidences

Source :
ECONAT-Concept & al. (2010)
Cartography AURG

⇨ **Case 4.** Disturbance to aquatic and forest buffer zones caused by light pollution, pollutants and domestic animals are common in dispersed urban areas (Fig. 54). Such conflict zones usually constitute demographic sinks for faunal species that move through them (intense predation, injury caused by maintenance machinery and roadkill). The limitation of such disturbance requires the introduction of management regulations in planning provisions. The higher the classification level of natural structures, the more severe will be the necessary constraints.

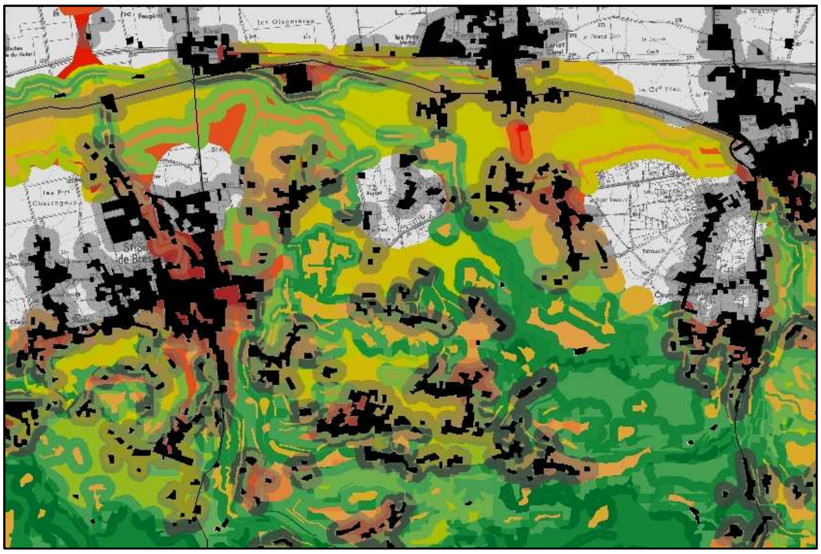


Figure 56.

Disturbance and destruction of aquatic and forest buffer zones in dispersed urban areas can be controlled by good use of relevant data and the elaboration of management regulations.

ropic spaces

ropic influence

ity incidences

Source :
ECONAT-Concept & al. (2010)
Cartography AURG

5.2.2 Validation of ecological networks by existing naturalist data and complementary inventories

A good grasp of the richness of the natural commonwealth is always of scientific interest. Databases allow us to make concrete arguments about the necessity of protecting or managing those spaces of strategic importance to the maintenance of local or regional biodiversity. And such data will in any event be useful when it comes to raising the ecological consciousness of landowners and managers.

More often than not, collected data takes the form of species lists established by commune. More rarely, the lists are organized by habitat type or locality. Such lists are all the more valuable inasmuch as they represent the sum and synthesis of many years of patient observation. Unfortunately, however, they are almost targeted on a given area of which the habitats and localization are precisely known. In these conditions, it is practically impossible to establish a cartographical synthesis of the data, unless one is fortunate enough to be acquainted with the naturalists who collected the data in the first place and that these are inclined to reveal the jealously guarded secret of the location of their observation sites.

In the best cases, it is sometimes possible to benefit from the existence of properly geo-referenced and dated databases that are rich enough to allow a complete overview of a given region. The mapping of the Swiss National Ecological Network (Berthoud & al. 2004) relied on the very comprehensive faunal and floral databases of the Swiss Centre for Faunal Cartography in Neuchâtel. This data proved very useful in the identification of nodal zones and in defining the real extent of the extension zones of those natural zones that were the most emblematic in the protection of the natural environment — such as wetlands, peat bogs, dry grasslands and alluvial zones — when it came to establishing the provisional network. On the other hand, the same data has proved very inadequate when considering less prestigious milieus such as forest or agricultural zones. Their principle fault, however, is that they reveal a highly significant analytical bias at the level of the distribution of zones studied. Indeed what is obtained is a patchwork distribution of data according to that essentially reflects the distribution of observers and the relative accessibility of sites. In the final analysis, data of this type turned out to be most useful at the final validation stage of the ecological networks of each canton, in which it served to verify the coherence of the proposed cartographical model with respect to the available data. It is, moreover, interesting to note that the discovery of potentially interesting but as yet undocumented zones was the object of intense prospection during the years that followed. Thus the databases mainly served to enable *a posteriori* validation of network maps, whereas the initial goal was the availability of basic data.

In an eco-systemic approach, **the gathering of naturalist data must be organized** in such a way as to meet the following research objectives:

- To produce data for a certain number of referenced sites, which are selected so as to representative of the study zone. The selection should be organized with regard to a typology of the milieus comprising all extant natural and transformed milieus.
- The **position within the ecological network** must allow not only the relative diversity of the functional zones of the continuum to be calibrated, but also the role of the evaluation factors of the milieus present in the sampling site — such as their naturality, surface area or eco-systemic functions.
- Reference inventories must, if possible, assemble data that is comparable at the level of the bio-indicator groups employed. These inventories must at the very least contain data gathered about birds and flora, and should where possible aim to cover all vertebrates, insect groups such as Lepidoptera, Orthoptera and Odonata, as well as higher species of flora. In reality, the choice of groups studied depends on the type of specialist available in the study zone. The most important thing however is **to dispose of a database that is homogenous.**
- Inventories should not be only qualitative (list of species); they should be **quantitative too** (number of individuals and of breeding pairs). They should, moreover and if possible, indicate the **biological status** of the observed species.

The cost in time and money of obtaining reference data is always high. It takes easily to eight to ten times longer than producing the provisional cartography of the ecological networks of the study zone. As a result, it is essential that the organizational constraints pertinent to sampling inventories, even if it is the case that naturalists, left to their own devices, prefer exploring at will any sites that seem the most interesting. For the priorities in this case are reversed:

To acquire a proper understanding of ecological networks and their functioning, data collected in areas supposed to void of biological interest is just as interesting as data originating in highly diversified zones. This former class of data constitutes a integral part of any initial appreciation of a study zone.

In the context of the cartography of ecological networks, naturalist databases produced by sampling organized in terms of geo-referenced habitats constitute the only means by which one may be able to dispose not only of points of comparison with inventories taken in different territories, but also be able to make comparisons with the situation pertaining several years into the future, while taking intervening changes to the landscape into account. A given site can appear to have remained intact, especially if it has protected status, and yet still in fact have been progressively losing species if the environment has been changing. Databases focusing on heritage sites allow changes (e.g. the impoverishment of biodiversity) only to be ascertained, without producing any verifiable explanation.

Some databases referring to benchmark habitats are beginning to be established. Since 2000, the Swiss authorities, for example, have initiated a programme enabling the tracking of biodiversity by means of sampling plots distributed over the whole country. A less ambitious naturalist database, yet one still standardized on the basis of a handful of simple and reliable indicator groups, would merit development as a complement to the development of ecological networks and other ecological grids.

5.2.3 Identifying species significant to ecological networks

The principle of establishing guilds of indicator species for ecological networks has been proposed for several years now, notably in Switzerland in at several different stages in the process of elaborating a national ecological network. In this way, Berthoud (1998) used simple but reliable indicator groups to distinguish the fundamental zonal ecological organization of the various continua in the structuring of terrain mapping of networks at the cantonal scale (Fig. 57). The same guilds were employed to establish the departmental network for the Isère (ECONAT, 2000).

For the subsequent stages of the analysis, more precise data, based on a selection of species whose ecological value indicative for habitats has already been ascertained by scientific study, were employed to create the guilds appropriate to designating each continuum and sub-continuum. The species contained in guild are used directly on mapping in the form of codes indicating the sub-continuum (Fig. 56). Thus in this case too, indicator species are employed *a posteriori* to validate provisional mappings of ecological networks.

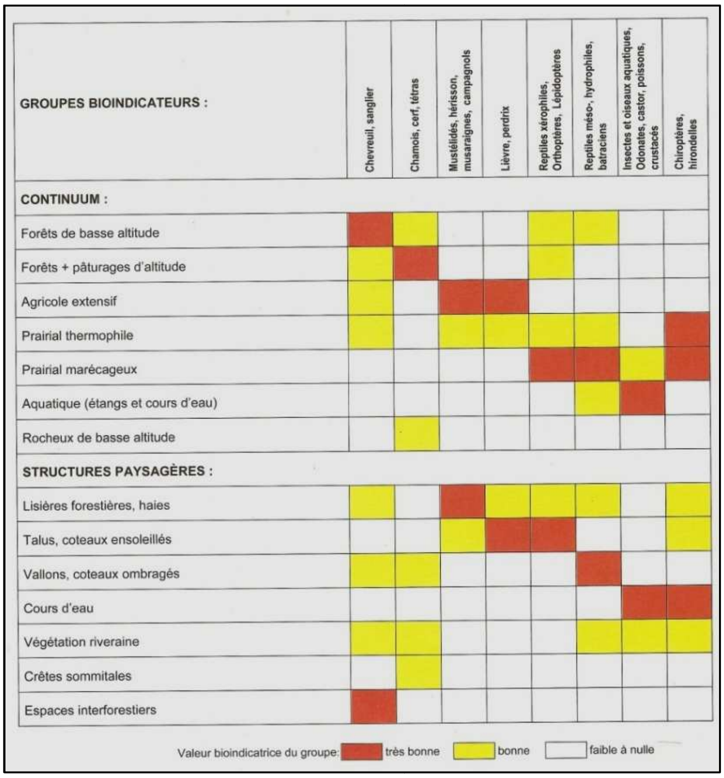


Figure 57.

Bio-indicative value of several faunal groups in the analysis of the different elements constituting a regional ecological network.

These ordinary species and guild of species allow the quick elaboration of provisional specialist networks.

Source: Berthoud (1998)

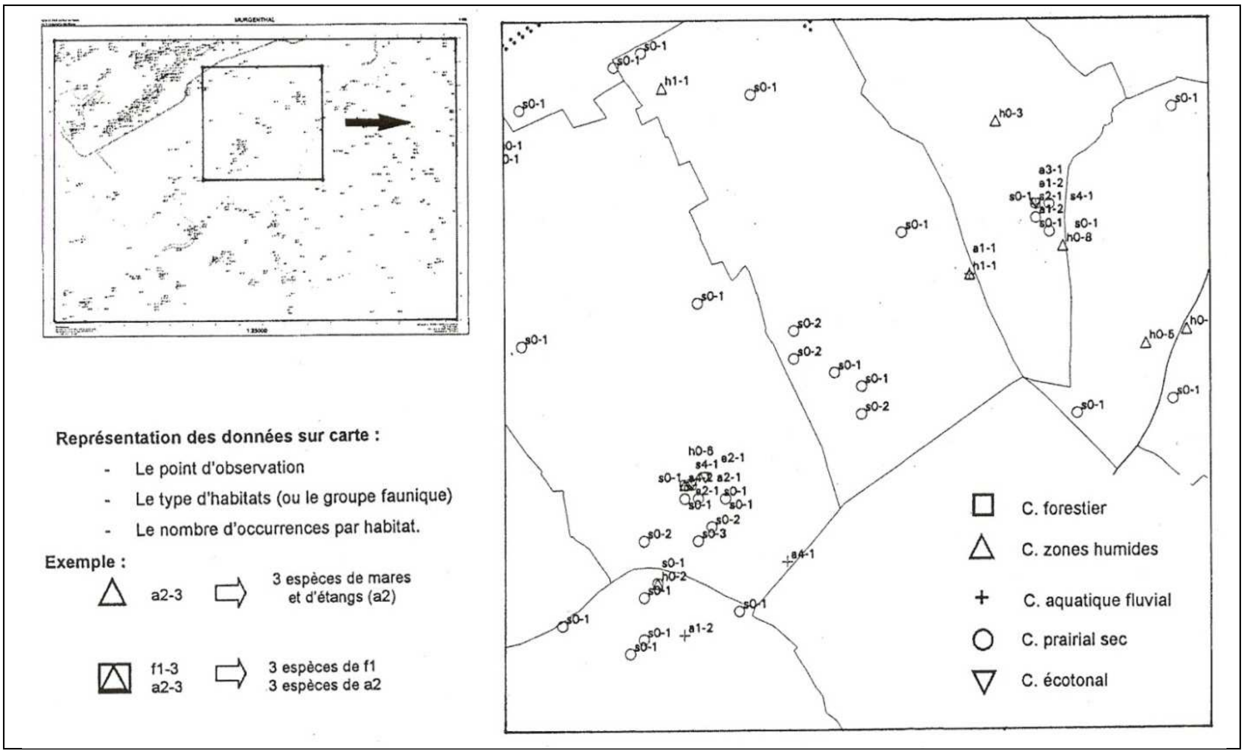


Figure 58. *Example of a map at 1/25'000 figuring the guilds available in national databases (CSCF) to access REN maps.*

Source: Berthoud & al. (2004)

In the Guide 2 Green and Blue Line, "National approaches for the preservation and restoration of ecological continuities", appendix III plans a list of determining species GBL at the regional scale. Without going into too much detail concerning known provisional lists, it is — after more than ten years of cartographical practice in the ecological networks of Switzerland and the department of the Isère — necessary to point out that, though the approach is certainly interesting from a scientific point of view, it is difficult to apply practically for a number of reasons:

- The species mentioned are either too rare or too little understood in terms of the real populations to be useful as indicator species;
- The generally very limited nature of their distribution is not usable for the designation of so widely spread a network;
- The length time it takes to precisely describe the present living spaces of eligible species is too great to allow the correct ecological grid scale pertinent to the species in question to be quickly ascertained.

The application of the principles of an eco-systemic approach consists first and foremost in the adoption of an approach that is both global and coherent with regard to ecological networks and the landscape and which is only secondarily concerned with verifying the presence of specialized, rare species serving as indicators of the system's quality.

The policy of benchmark species (or umbrella species), a policy which works well with regard to a politics of environmental protection, is of limited value in terms of applied ecology:

It is not rare and threatened benchmark species that determine the hosting capacity and the functioning of an ecological network. Rather it is the existence of a widely spread and functional network that can potentially enable the presence of such species. With regard to eco-systemic efficiency, general diversity and biomass are more easily analysed than the random presence of rare species.

To summarize: refined by the lessons of repetition in application, the cartographical approach to a hierarchically organized ecological network can quickly provide an effective tool for the visualization of the functioning of landscape constituents. Multi-factorial weighting of these constituent elements allows the hierarchical organization of what is at stake ecologically, in terms of ecological dysfunctions and potential. Qualitative tracking based on the presence of benchmark species habitats comes only next to complement the eco-systemic evaluation of the network's elements, by furnishing reference indicators (surface area, habitat type, list of species and population size).

5.2.4 Reinforcing the approach with specific dispersion tests

The ecological networks approach based on a faunal model has been the object of numerous scientific studies over the last few years. Theoretically, it would suffice to know the dispersion capacity of a given area and to couple this parameter with the friction values of each type of habitat crossed to be able, using GDS, to create a model of a potential dispersion area spreading concentrically from, for example, a known point of reproduction. In this case, constraints on movement are summarized in the following three values:

- **Crossability,** which expresses the possible barrier effect of certain obstacles (roads, forests, watercourses, etc.);
- **Friction,** which expresses positive or negative effects on faunal movement;
- **Influence distance,** which characterizes the range of attraction or repulsion exercised by objects in the territory.

These "species" models are useful to form hypotheses about the propagation of a studied species. They do, however, necessarily imply the subsequent statistical verification in the field, by means of the marking of individuals followed by tracking by telemetry or trapping and re-trapping. As a result, the validation of these models is always time consuming and applies, of course, only to particular cases of the spatial organization of habitats. With the multiplication of research studies, one might hope in the end to be able to dispose of a sufficiently wide range of specific models to allow the reliable testing of study zones of limited size. Developing approaches of this type is of interest for sectors for which detailed mapping of habitats and relatively comprehensive biological indexes exist: sectors such as Regional Natural Parks or in the context of charting the management mission statements for the NATURA 2000 sites.

Defining ecological networks species by species, however, requires scientific precise and verified data concerning the locomotive behaviour of each species. This data is now beginning to be available, but is still far from being sufficient to cover in a representative way all the species using landscapes transformed by human activity.

The species by species approach coupled with dispersion models can, therefore, only be pertinent if used as a complement to an *a priori* definition of ecological networks. For, though such techniques are attractive inasmuch as they allow access to data immediately applicable to the protection of a target species, they exploit only distribution data for a given time, and are, therefore, unable to identify the ensemble of natural structures potentially favourable to the long-term development of a population. There exists, moreover, an inevitable choice that must be made with respect to the ecological preference parameters of a given species: should one study living spaces potentially favourable to the reproduction of a known population, or should one rather study spaces susceptible to serve as new colonizable habitats?

In the first case, habitually examined using dispersion models, the aim is define **living spaces pertinent to the definition of nodal zones in a biological network**. This particular phase of the annual cycle is at once both demanding of the quality of the specific biotope and circumscribed by particular criteria for the spatial distribution of habitats — proximity or direct connection with highly variable complementary habitats: forest and grassland milieus; dry and wet zones; rock or grassland. In this case, what exists is a range of juxtaposed complementary habitats articulated around a given reproductive strategy, inasmuch as the majority of species are polytopic during the mating season.

In the second case, much more rarely studied using dispersion models, the aim is to define **functional spaces conducive to pre-adult dispersion in an ecological network**. This dispersion phase — of variable but relatively long duration (often several years) in a species life cycle — is relatively less demanding in terms of habitat quality but implies a more limited choice of refuge milieus. As a result, what is defined is a selection habitat continua complemented by corridors.

In the Isère, an interesting application of the eco-systemic approach using "species" models was developed the associative practice OGE in the context of an impact study for a projected motorway bisecting a NATURA 2000 site in the Isle Crémieu. Cartographical data for the REDI departmental ecological network was complemented by detailed samplings of habitats distributed along the route of the proposed motorway. Starting from know reproduction sites, possible dispersion models for a number of heritage species (European pond turtle, crested newt, mercure azure, grassland Orthoptera) were tested according to number of possible scenarios (Fig. 48). The results perfectly highlighted the fragmentation risks to species populations. The analysis, however, has not unfortunately been repeated as a future projection taking account not only of the motorway, but also of potential installed faunal permeability infrastructures — which would, by comparison with the initial state of the site, have shown the scale of effects on the relative heritage species.

This combined approach of “habitat networks” and “specific dispersion models” constitutes a possible judicious application for relatively large sites (200 km^2) that are well inventoried and mapped.

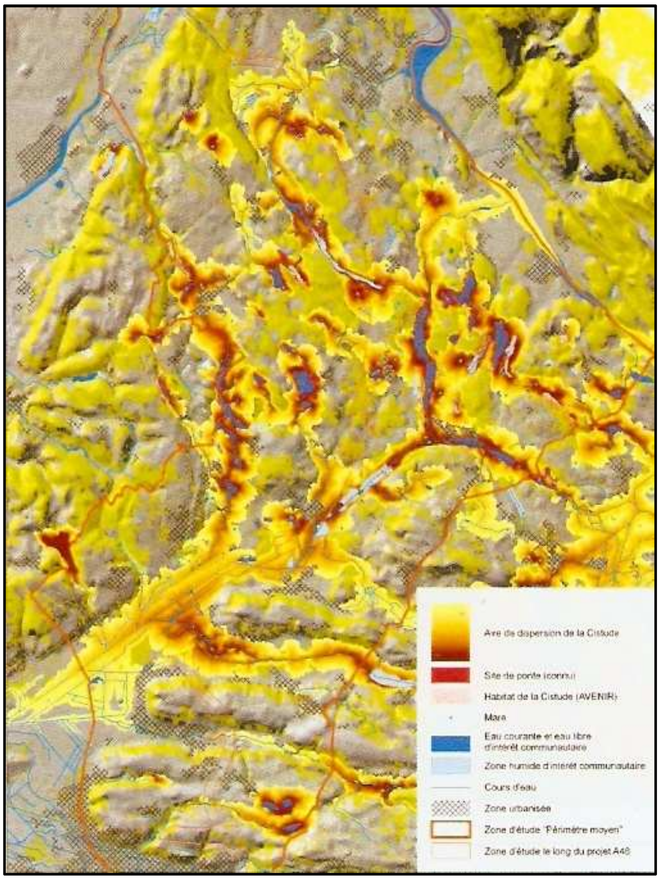


Figure 59.

Potential ecological continuities for the European pond turtle in the Isle Crémieu in the Isère

The sites occupied by the species were furnished by AVENIR (2003). Hypotheses on migration capabilities are as follows:

- *Dispersion capacity is based on a maximum displacement of 1000 m overland and 10 km in watercourses*
- *Relative migration costs are: 1/5 in forest, 1/2 in open country (agriculture or meadows), 1/500 in urban milieus*
- *Should the turtle reach a pond, the allocation of residual energy is doubled*
- *All above values are modified by slope declivity and exposure, with a preference for warm southerly expositions*

Source: OGE, 2007

In other words, available data more often than not concerns benchmark species studied in favourable, not to say ideal, milieus. Only far more rarely does it address borderline situations concerning disturbed and fragmented habitats, which unfortunately constituent the majority of our low-altitude landscapes. Studies carried out by the radio tracking of mammals, for example, furnish numerous examples of exceptional migrations over long distances of animals during dispersion phases. Such exceptional movements, statistically improbable as they are, nonetheless constitute the principal vector of new colonizations.

A more global approach, applied by groups of species possessing the same migratory capabilities and the same ecological affinities, would come down to the application of the ecological network method: simpler and quicker when it comes to defining the available natural infrastructure in a given landscape. In consequence, it is recommended that the task be carried out in two phases:

- As a prelude, establish the cartography of the ensemble of existing ecological networks in the study zone;
- Then, firstly, undertake a standard dispersion test to isolate and identify functional networks and well-connected habitat reservoirs;
- And secondly, test the validity of the identified networks by applying to them specific dispersion models for a selection of benchmark species, whose biotic potential in the available network one would want to verify.

These combined and progressive applications are regularly practised in transport infrastructure project studies so as to locally verify the level of connectivity between sub-populations enabled by the installation of crossing infrastructures.

CHAPTER VI

Local and Regional Applications

Summary

The fundamental study for the departmental ecological network in the Isère in France (REDI) served as a common thread for a number of different studies for local and regional applications elsewhere.

The departmental cartography of the principal landscape continua, drawn up to a scale of 1/25,000, with the aim of subsequently producing synthesis map to a scale of 1/100,000, provided the initial vision of a global diagram of the spatial organization of the natural heritage of the Isère, in terms of natural entities, but also in terms of interactions and potential connectivities. This first document notably defined the ecological characteristics of the various districts involved through the description the development of the dominant natural infrastructures, while at the same time underlining the flagrant dysfunctions generated by invasive urbanization and by the rapid expansion of transport infrastructures. A few of the priority issues extracted from a first inventory that described over 350 conflict points identified during the study were then made the objects of a long-term action programme. The recognition of a generalized fragmentation of the landscape encouraged the following actions:

- *The establishment of a strategic policy of remedy based on the construction of faunal crossing infrastructures;*
- *The integration of biological corridors in planning documents;*
- *Encouraging planners and site managers to remedy conflict situations for which they are responsible;*
- *For every development project, the obligation to respect the constraints pertinent to the maintenance of ecological networks.*

This policy of ecological coherence with regard to the utilization of departmental territory has enabled the realization of a number of studies re-employing the principles developed for the REDI at different scales.

These local applications necessitated the development of more finely calibrated methods adapted to local circumstances, and especially enabled the application of the principles of the "evaluation of ecological potential of milieus method" established by BERTHOUD (1989), which is complementary to the ecological networks method. This method allows, on the one hand, the hierarchically structuring of the elements of networks and, on the other hand, a tracking tool based on numerous indicators.

The various work stages are illustrated here by a series of examples, which permit the cartographical and analytical techniques applied to each situation to be precisely described. Today, this accumulation of practical experiences allows a whole range of simplified and optimized procedures — with regard to the definition of ecological networks, to the evaluation of the natural system and to the impacts of human activities — to be proposed.

By retroaction and starting from these applied experiences, it has now become possible to offer an updated version of the REDI tool that integrates new usage briefs involving territorial and local applications. The application originally intended for the alpine pilot zone in the Isère has thus been rendered far easier.

6.1 The Departmental Ecological Network of the Isère

The study of the departmental ecological network of the Isère (REDI) began in 1999 following an order from the General Council of the Isère to the ECONAT consultancy as a result a presentation of cartographical methods and applications under way throughout the territory of Switzerland.

The idea was to establish, at the departmental scale, a synthetic system of analysis of landscape functioning that would enable natural issues at stake to be understood and a coordinated programme of sustainable natural protection actions to be planned.

A provisional cartography to a scale of 1/25,000 was established so as to define the principal continua of the vegetation characteristic of landscapes in the Isère. This was carried out on the basis only of the information contained in the CORINE land cover database and on algorithms employed in Switzerland for the definition of continua. A considerable amount of fieldwork, carried out over a period of ten months, was necessary to calibrate and manually correct, map by map, the assemblies of land occupation continua so as to obtain coherent continua. This verification work provided the opportunity to map and list the various obstacles contained in the territory and to define the principal issues for the future management of natural spaces.

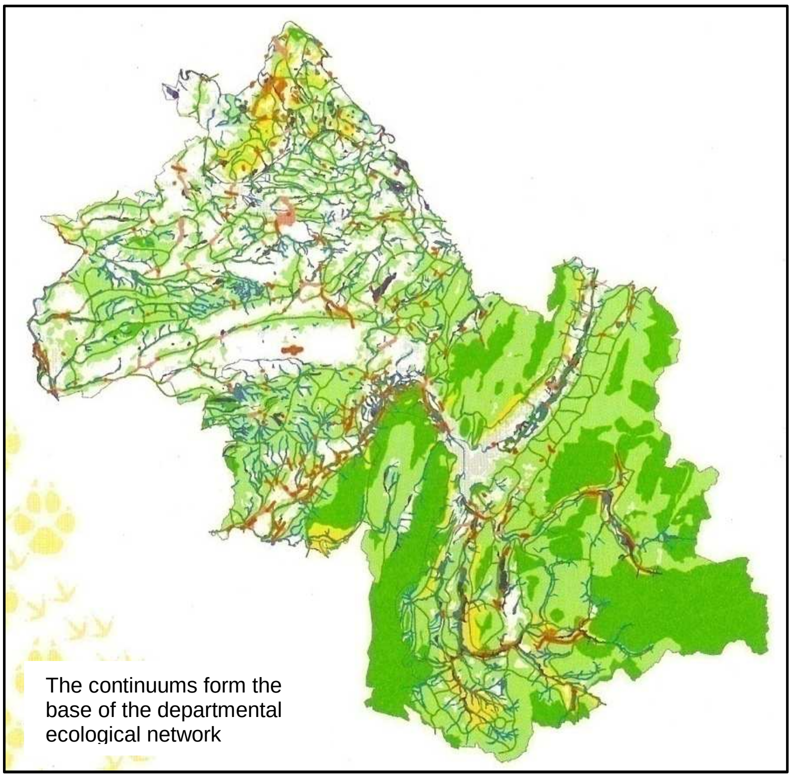


Figure 60.

Map of globalized ecological networks in the department of the Isère.

Legend:

Forest continuum
Forest nodal zones
Continuum of wetlands
Wetlands nodal zones
Thermophilous continuum
Thermophilous nodal zones
Points of conflict with fauna
Corridor with fauna

Source: ECONAT (2001)

The final report of the REDI project, accompanied by four maps to a scale of 1/100’000 was delivered to the General Council in 2001.

The aim of the relatively rapid and summary cartography — in comparison with methods practised presently — was to furnish a synoptic vision, to the scale of 1/100’000, of the interconnectivity of large landscape spaces (Fig.60) and to situate the zones of priority issues at the departmental scale (Fig. 61).

In addition to the methods and the statistical data produced by the cartography, the report presented a list of 320 points considered critical for the functioning of ecological networks accompanied by a hierarchical listing of the problems based entirely on their localization in the networks and the degree of the impacts observed.

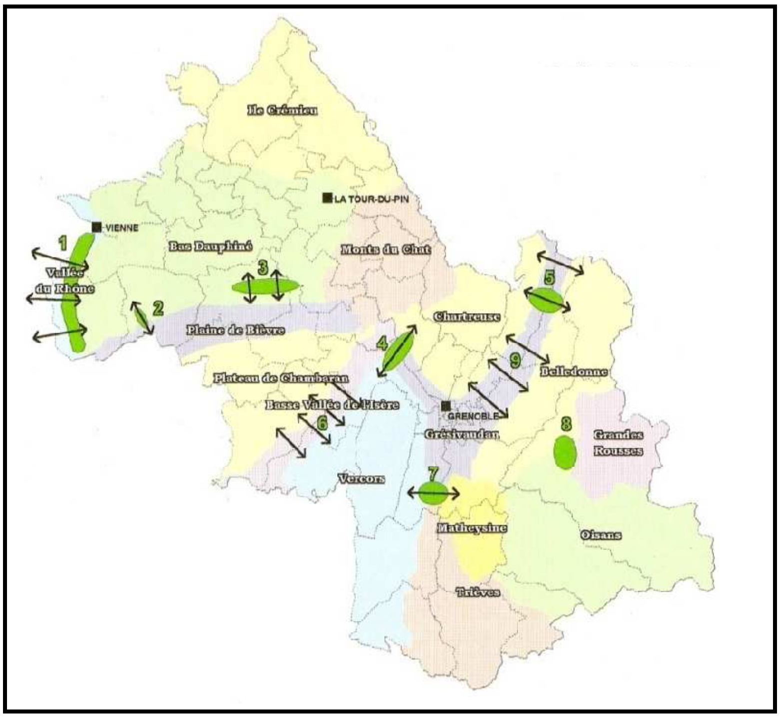


Figure 61.

Identification of the principal issues concerning the maintenance of biological corridors in the Isère

Legend:

Zone of re-establishment of exchanges between the compartment landscape

Axes of connection to be maintained or develop

Source: ECONAT (2001)

The identification of the issues involved results at once from the interpretation of the general REDI map, from the superimposition of identified conflict points and from the global understanding of the terrain. The hierarchy is produced in this case only by logical reasoning based on the following criteria:

- What are the large natural ensembles susceptible to functioning as reservoir zones?
- Which of them is sufficiently connected or is rather isolated by urbanization and transport routes?
- Where are the most useful connections situated: those allowing the improvement or the conservation of the functions of biological exchange between reservoir zones?

Figure 62. *General public brochure presenting the results of the REDI study (2002).*

At this stage in the development of databases concerned with the REDI, the choice of priority sites is not easily determined given the relative imprecision of the data, which does not allow a real hierarchy, based on the ecological potential of the chosen areas, to be produced.

Thus, a tracking of the efficacy of the steps undertaken or a study of corridor route variants are impossible because of the lack of data on the size of habitats, on their relative quality and, especially, the diversity of their species and finally on the real development potential of their populations.

The analytical and management tool for natural spaces has only been developed progressively following a number of local applications.

The publication of an information brochure for the general public entitled, "Taking Account of Biological Corridors" following the final REDI report (Fig.62), provided the opportunity to publicize the essential points raised by the technical report, but also to spread the principals of a new policy for the management of natural spaces, based as much on the protection of natural elements of particular interest as on the management of ordinary elements and completed by the notion of interconnects vital for populations.

The 2009 publication by the General Council of the Isère of an updated inventory of conflict points (Fig. 63) constitutes a wake-up call about the consequences of traffic dangerous to fauna (or about zones where collisions are a particular hazard) that is intended to foster a programme of the gathering of information indispensible for the management of the general problem of landscape fragmentation. This "conflict points" database should progressively bring about consideration of and dialogue about ways to improve the situation within the context of current financial and technical constraints.

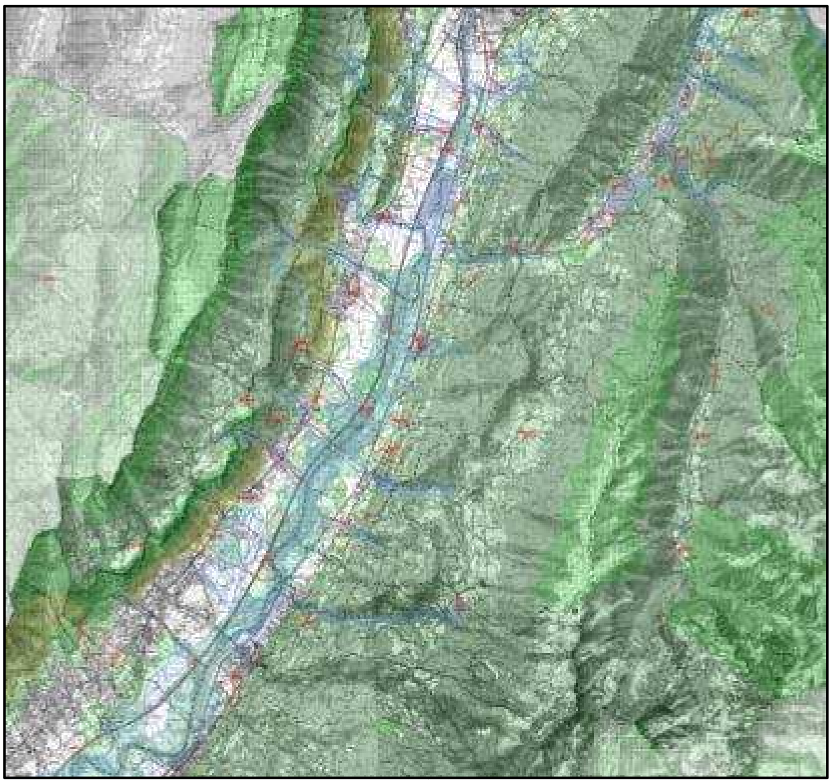


Figure 63.

Extract form the departmental map of conflict points in the Grésivaudan territory.

Source: REDI (2009)
General Council of Isère

The map of the exterior connections of the ecological network (Fig. 64) also constitutes a first approach allowing the expression of interactivity issues regarding the corridors and continua situated along the departmental boundary. In the absence of any data external to the department of the Isère, the presentation of the different force lines in the development of the department's ecological networks — which would take the form of factorial axes — constitutes on of the possible ways in which the data collected by the REDI study might be presented. This extreme diagrammatical simplification of continuum resultants (corridor axes) and their interconnections is part of the progressive iterative process of the establishment of networks at the regional or national scale. Sooner or later, these extrapolated axes will need to be confirmed by analyses undertaken in neighbouring territories. They may well be completed or modified once these analyses of external connections have been carried out. This way of proceeding conforms to the approach adopted for the establishment of Swiss faunal corridors (Holzgang et al. 2001) and for the Swiss National Ecological Network (Berthoud & al. 2004).

The REDI approach along with its cartographical methodology has been adopted *in-toto* as the basis for **empirical applications at the scale of the entire Rhône-Alpes region**. The results of this project to map the regions ecological networks have been published in CD form (Région-Rhône-Alpes, 2009). The document in question contains an atlas of global maps, a description of the methods and approaches employed, as well as a guide serving to reproduce this regional cartography locally at the appropriate scale. The guide notably provides a detailed account of the technical bases and tricks available for the creation of local mapping as well as guides to available financial support.

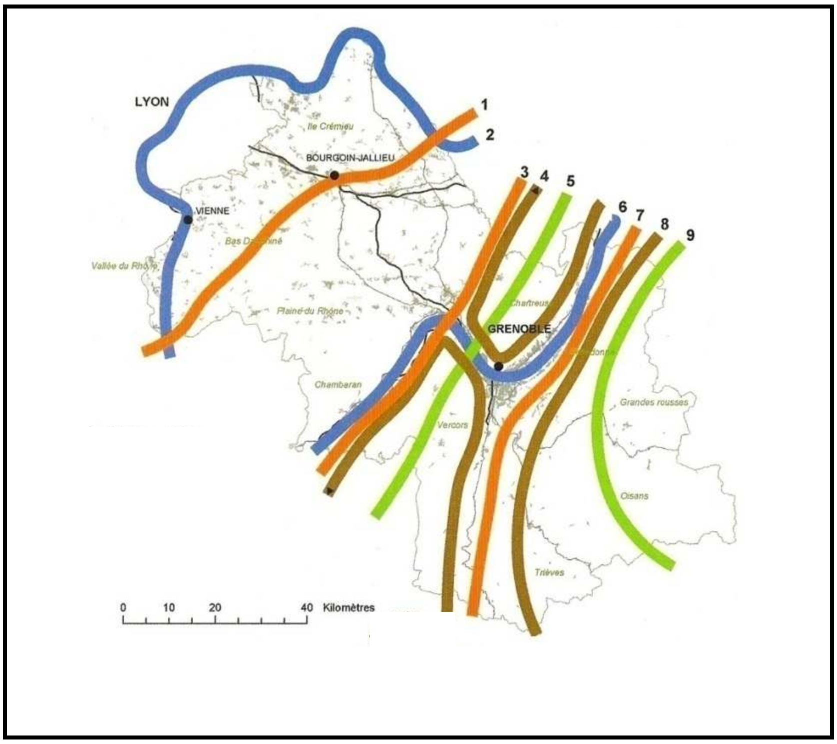


Figure 64.

International-, national- and regional-scale connections of the Isère ecological network.

Legend:

Corridor air fauna (birds, insects)

Corridor fauna watery and semi-watery.

Terrestrial corridor, fauna of edges in low altitude.

Forest corridor large fauna in altitude

Source: ECONAT (2001)

6.2 The Permeability of the AREA Motorway Network in the Isère

The AREA motorway network was for the most part constructed between 1970 and 1980, during which process little attention was given to the problem of faunal transit across the routes created. The rare possibly passage points for fauna have been systematically restructured to allow the secondary circulation of service, agricultural or forestry vehicles, or even for the stocking of building materials. For this reason, form its outset of the REDI project, the AREA motorway company was interested in the potential advantages of a new cartography of faunal circulation that would allow a better understanding and management of the problem of repeated collisions with large animals, despite the generalized presence of protection fencing, with a view to instigating a remedial programme if possible.

In consequence, AREA mandated the ECONAT consultancy to carry out an audit of the permeability of its motorway network in the department of the Isère and to suggest possible improvements (Fig. 65).

The analytical approach covered all 440 km constituted by the A41, A43, A48, A49 and A51 motorways.

The study was carried out by cross-referencing the REDI mapping with daily collision data collated by the maintenance centres. All transit infrastructures of whatever type (hydraulic, technical piping, overpasses and underpasses for road and rail traffic) built across the motorway routes were systematically visited, which enabled the verification of their possible use by fauna (by means of ground tracking, trapping and polling of managers).

A linear check of protection fencing also allowed the discovery of certain conceptual errors and weak points.

A complete report was drawn up on the basis of current situation maps of each motorway section (ECONAT 2002). It provides:

- Detailed situation maps to a scale of 1/25’000 along accident data and crossing infrastructures classed according to their relative permeability (Fig. 65);
- A descriptive technical card for each infrastructure that recapitulates: its size, its priority function, any further observation concerning fauna, and a indicative permeability factor produced by the combination of the presence of continua or corridors, the potential for faunal utilization and accessibility;

- Diagrams and photographs enabling a better understanding of the state of the site at the time of the visit.

A summary table for each motorway sector enables a visual appreciation of the situation in each case and of the possibilities for remedial measures.

The results were verified and validated by the maintenance centres, whose task it will be to undertake the creation of all structures involving the daily management of motorway assets. The largest resulting projects, such as the construction of faunal passageways, are undertaken as part of local projects to reinforce and manage biological corridors (see the Cluse de Voreppe and Grésivaudan corridors projects).

All resulting documents were made available to the Environmental Service of the General Council of the Isère, so as to facilitate coordination with the implementation of REDI management programmes.

AREA systematically involved itself in all project studies and in the construction of works aimed at improving the unhindered circulation of fauna across its infrastructures.

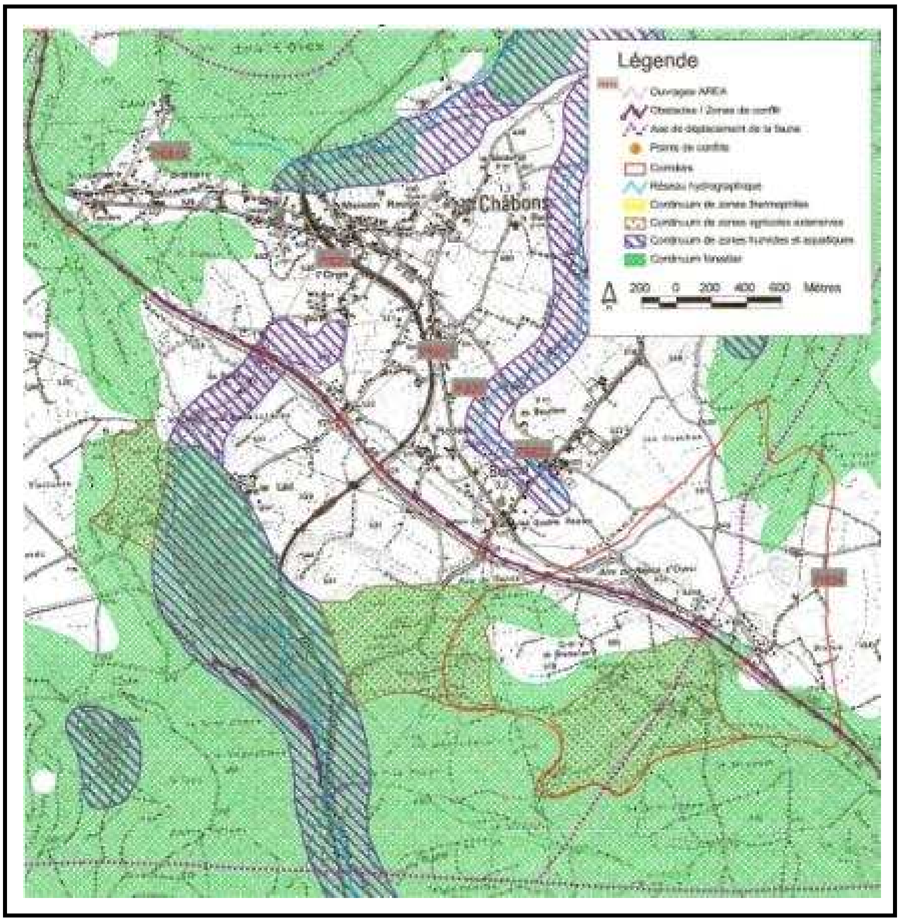


Figure 65.

Extract from the map of faunal permeability issues along the length of AREA motorway routes in the Isère.

Example the A48 Bizonnes – Colombes sector.

Source: ECONAT (2002)

6.3 The Grésivaudan Biological Corridors.

The four mountain massifs of the Vercors, the Chartreuse, Belledonne and the Bauges tend to be isolated because of the highly developed artificialization of the Grésivaudan Valley. Its particular topography creates a juxtaposition between urban spaces and areas of particular natural interest, thus drawing part of the wild fauna down into the bottom of the valley.

This territory imposed itself as a priority in the context of the European project for the protection of corridors (period 2008-2014).

Following the publication of the REDI report in 2001, the General Council of the Isère was in possession of a large part of all information concerning both the organization of the various ecological networks and the situation of the characteristic corridors present in the Grésivaudan Valley. The urban planning agency for the Grenoble region (AURG), whose responsibility it is to manage the development of urbanization, was interested in the possibility of integrating the principal ecological and landscape constraints sketched by the REDI report as effectively as possible into the future utilization of the area (Fig. 66). Its task was rendered all the easier by the approval in 2000 of the overall plan for the Grenoble region, which set out the principle of maintaining green-breaks and introduced the concept of ecological corridors.

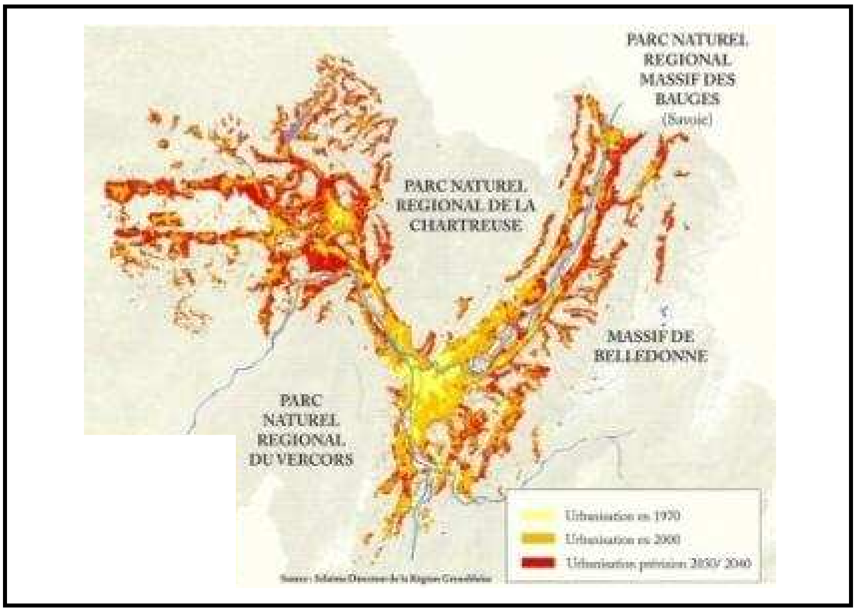


Figure 66.

Provisional urban development zones in the Grenoble region.

The overall regional plan issued a strong signal about the worsening of landscape fragmentation. It is the eleventh hour for the integration of constraints aimed at maintaining natural connections.

Source:
Overall plan for the Grenoble region (2000)

Between 2004 and 2006, the AURG tasked itself with the plot-by-plot definition of the longitudinal and transversal corridors indispensible to the maintenance of faunal circulation in the valley and with setting up steering committees necessary for the effective project implementation.

At the same time Mixed Unions of the Isère Hydraulic Basins project (SYMBHI) was initiated to to restructure the bed of the River Isère along with its alluvial corridor.

Once all the relevant issues, remedial measures and project partners had been identified, the "**Biological Corridors of the Grésivaudan, Paths of Life for the Alpine Region**" project was presented to the EU so as to take advantage of available FEDER funds (Fig. 67).

Figure 67.

The Grésivaudan Valley FEDER Project.

Thanks to the support of multiple partners, the project will enable installation of numerous structures necessary to the restoration of biological corridors.

Source: AURG (2008)

Approved on 27 March 2008, the project represents a budget of 9 million euros over a six-year period. It involves the participation of six financial partners:

- The Rhône-Alpes Region
- The European Regional Development Find
- The general Council of the Isère
- The AREA
- The Rhône-Mediterranean-Corsica Water Agency
- The Isère-Drac-Romanche Departmental Association

6.4 The Voreppe Gap Corridor

The Cluse de Voreppe (Voreppe Gap) corridor is part of the larger Grésivaudan corridors project. It does, however, pose some problems that are specific to it alone, problems associated with the multitude of obstacles that already exist, the rapid development of industrial zones encouraged by the presence of numerous transport infrastructures concentrated in the valley bottom.

This section in particular was then from early on the object of a draft project for the reconstitution of an important biological corridor linking the Vercors and Chartreuse massifs. The pre-existence of the corridor needed to be verified before the selection of a favourable route for the reconstitution.

Stage by stage, the steps leading to the resolution of the various problems encountered were as follows:

- **Problem 1: Is the reestablishment of a corridor justified today?**

  Answers:

  - Faunal circulation was extensive up to 1980. Traffic accidents involving large animal species are still seen every year (notably roe deer, wild boar and chamois);
  - Numerous small animals are being constantly run over on the entire road network in the sector;
  - The interpretation of REDI maps highlights this dysfunctional bottleneck between two important regional-scale reservoir zones.

- **Problem 2: How should one route variant by chosen for the corridor?**

  Answers:

  - By the combination of data on non-built, more-or-less natural spaces (Fig. 68) and on the movement capabilities of the various faunal groups present in the sector (Fig. 69). Installations are necessary to meet the needs of different species;
  - The choice is in the final analysis decided by a consensual decision of the technical committee. It is arrived at by calculating an indicator of the potential functioning of the initial state combined with a cost estimation for necessary installations.

- **Problem 3: What are the species implicated in the reconstituted corridor?**

  Answers:

  - Targeted species are those characteristic of the continua linked by the corridors — either forest species from the mountain massifs or thermophilic species from the bottom of the foothill slopes. For the most they are ungulates such as chamois, roe deer and wild boar, all of which are abundant in the region, as well as red deer, lynx and wolf, whose populations are expanding.
  - The continuum consisting of wet and alluvial zones is here located on a perpendicular axis to the corridor that needs to be reconstituted. The crossroads must therefore integrate two types of corridor without crating any obstacles for either. This will be achieved by the installation of mixed, open, wooded structures arranged in mosaic.

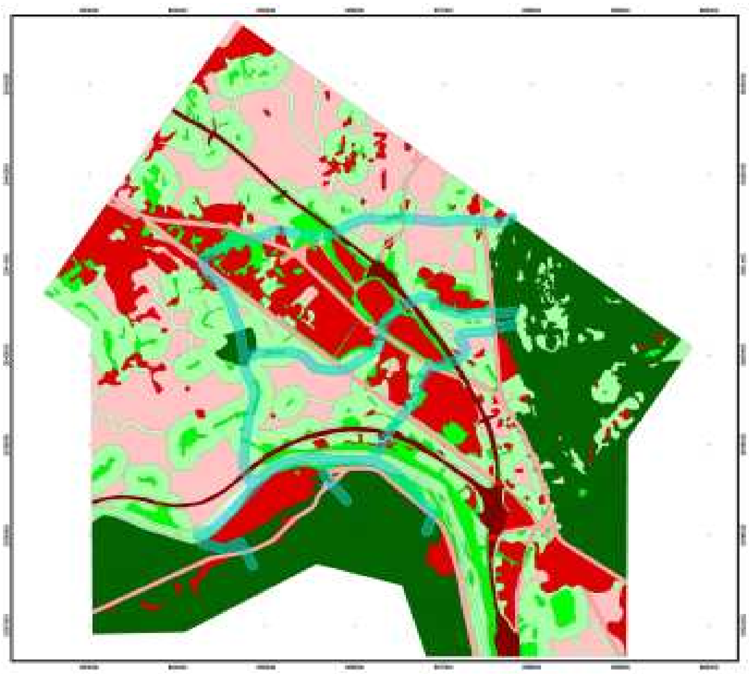
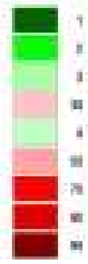


Figure 68.

Resistance factors of landscape elements applied to the movements of forest fauna.

Legend:
Resistance value as a %



Source: ECONAT (2003)

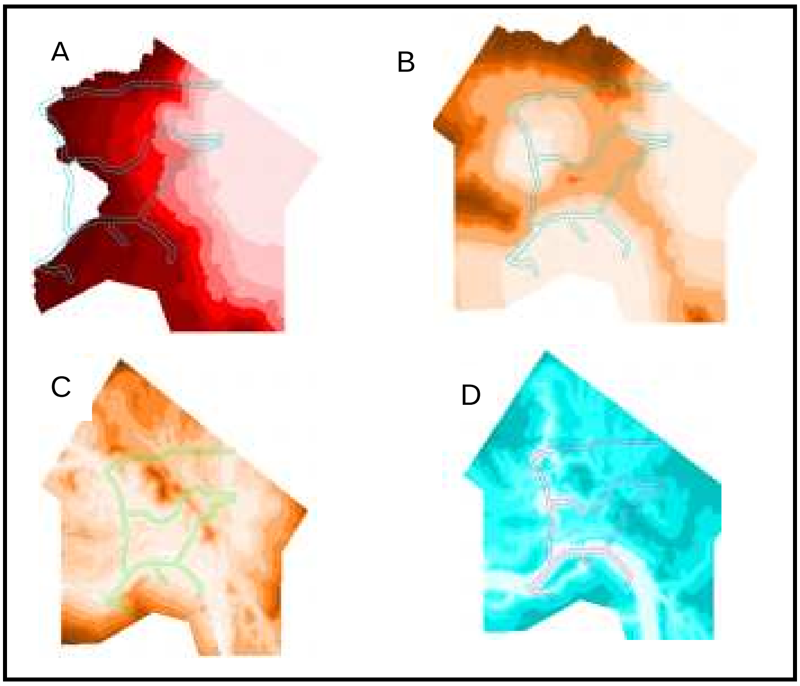


Figure 69.

Dispersion tests on four specialized networks of the Voreppe gap.

Source zones:

A) Chartreuse forests.
B) All forests
C) Dry thermophilic habitats
D) Wet habitats

The dispersion gradient is illustrated by colour intensity.

Source: ECONAT (2003)

- **Problem 4: How should the ability to cross the various obstacles identified on the corridor route be re-established?**

  Answers:

  - Significant installations of underpass and overpass types need to be constructed successively on the national road (1 underpass) and the two motorways (two overpasses, of which one is already built).
  - Departmental roads and the railway are to be bridged by means of route-side integration systems (faunal detectors with alarm signals for drivers, coupled with protective fencing).
  - This succession of constructed passageways will create certain slowing of the corridor's normal functioning. Quality relay zones in the form of semi-open thickets will ensure the necessary tranquillity for coherent functioning.

- As dispersion tests have demonstrated (Fig. 69), the corridor to be reconstituted must be clearly “signposted” and cleared of all obstacles so as to become attractive for all targeted fauna. Failing this, dispersion over the whole extent of industrial, urban and agricultural zones will continue as in the initial situation.

- **Problem 5: How should the long-term tracking of the corridor’s efficacy be organized?**

  Answers:

  - The tracking of the global efficacy of the corridor is part of the project remit given scale of the initial investment. Tracking installation by installation is necessary, but should not be envisaged without a global perspective of the functioning of the elements of the interconnected ecological networks.
  - A complete local monitoring model for a corridor must at the very least contain a complete evaluation of the ecological potential — calculated according to the VEPM method and using a raft of appropriate indicators — of nodal and extension zones and corridors.
  - A detailed GIS modelling should install all the elements necessary for a complete application of the hierarchically organized ecological networks method, including all measurable or evaluable factorial indicators. This modelling may, however, be limited to the predefined ensemble of two reservoir zones and the installed corridor, without taking all the local and regional networks into account (the observation of the development dynamics of just two reservoir zones is sufficient to gauge the exterior evolutive context).

Box 12

Follow Up on Biological Corridors

In a long-term installation and management phase of local-scale ecological networks, the availability of tracking tools focussed on particular landscape zones can be required, as can the ability to temporarily target financial resources on priority actions. When this is the case, there is a danger that the overall perspective of the ecosystemic functioning of the landscape as a whole can be lost. For this reason, while a focus on the management of corridors is a possible option, it should never be allowed to hide the global objectives of the general ecological network.

➢ Understanding the functional entity of a biological corridor

A corridor is, by definition, a spatial entity that allows groups of natural or artificial habitats hosting populations of animal and vegetable species to be connected. These species will be of interest because of the size of their populations or because of the presence of rare and threatened species. A corridor must function just as well for vegetation species as for animal ones — the time scale, however, being different. It needs to be understood, moreover, that many seeds rely on animals for their transportation. When this transportation is reduced to a corridor, it is often rendered unpredictable by the presence of obstacles or the interjection of disturbances, whether natural or artificial, which make the genetic or social exchanges which guarantee the long-term survival of populations possible.

There is no need to reconstitute the relevant species’ long-term habitats in a corridor in a corridor. All that is required is that minimal conditions allowing the exchanges necessary for the conservation of populations in reservoir zones be maintained.

Thus, for the rational ecological management of a corridor to be achieved, it is necessary to understand both its internal context — such as the structuring of its vegetation and any possible disturbances of its functioning — and its external context — such as the nature of the reservoir zones that feed the corridor during dispersion phases or that of seasonal migrations. Other elements of the ecological networks that might interfere with the initial corridor (hydrographical networks, alluvial forests, agricultural areas, thermophilic ecotones, etc.) need to be taken into account.

(Box: cont.)

➢ Evaluation of corridor exchange flows

Generally speaking the frequentation of the corridor will be:
- Proportional to the populations of the two source zones it connects;
- Inversely proportional to the distance covered;
- Representative of the species diversity present in the source zones;
- A function of the quality of the "signposting" structures;
- A function of the capacity of the refuge habitats distributed along its length.

This frequentation is organized according to two complementary dispersion modes:
- If it conforms to the "ecotonal" type, then the regular presence of elements of the originating habitats, or of elements homologous to the original, is necessary;
- If it conforms to the "long distance" type — the sought for habitats being far away but findable by direct sighting or by odour tracking or by memorized trial and error — then it occurs by the "staging post" principle.

This the resulting flows can vary along a continuum described by two poles:
- Where the dispersion is primarily ecotonal, they occur massively over short distances and involve a wide variety of species;
- Where long-distance dispersion predominates, they are random, unpredictable and rapid and involve only few highly mobile species.

In both cases, pendular migratory behaviour is only produced as the result of trial and error in a stable context that allows the repetition of movements.

Generally speaking, each of the two dispersion types is employed by different groups of animals to those employing the other. The two types can, however, take place together, being practised only by certain species or certain individuals depending on the physiological state (stress) or because of a risky choice due to inexperience. The result of all this is that each corridor possesses its own specificities, which implies different installation and management strategies.

➢ Choice of useful evaluation criteria and indicators for periodical tracking

To structure and manage a space for a particular group of species associated with a given corridor without realizing that a risk was being run of disturbing other species not dependent on said corridor would be regrettable. So, for example, thermophilic species can be blocked by the development of wooded vegetation favourable to forest continuum species.

The criteria useful for the good management of corridors concern aspects both internal and external to the site:

- The internal criteria are those employed to evaluate a corridors ecological potential;
- The external criteria are those which guarantee the maintenance of environmental constraints within their known and ecologically acceptable parameters.

In a long-term management phase of local-scale ecological networks (the case with the north Grésivaudan territory), an environmental indicator grid would be used (Appendix 2).

6.5 The Pays de Bièvre-Valloire Natural Heritage Study

A first study began in 2005 with the naturalist inventories carried out by the "FRAPNA – CORA – GENTIANA – Gère Vivante" work group in the western part of the Bièvre-Valloire territory. It targeted open milieu located in the western sector of the extension to the overall plan for the Grenoble urban region. This study was the subject of a first report (FRAPNA – Isère Natural Heritage Network, 2005).

The elaboration of these inventories were continued in 2007 in the context of a complementary study carried out by the same team supported by geographers seconded from the AURG and by an operation manager from the ECONAT consultancy. The goal in this case was to carry out a new campaign of naturalist samplings in the as-yet non-prospected eastern sector. The research orientation this time, however, was directed at the implementation of naturalist samplings within a detailed mapping of ecological networks such as those originally furnished by the REDI.

This collaboration allowed a more complex approach to be tested on a study zone that was relatively large for the Isère. This complex approach, however, allowed more ecologically coherent results to be obtained.

The cartographical approach applied in this study differs somewhat form that used to establish the REN-CH and the REDI, but it has enabled the development of an automated mapping process and, especially, an attempt to apply evaluation techniques based on recent naturalist data. For once, it ought to be possible to base the "hierarchically organized ecological networks" approach not only on unverified, out-of-date, pre-existent data but, if possible, on data collected specifically to inform the cartographical analysis. The approach is not entirely without precedent inasmuch as we have been practicing it for over twenty year in the context of a dozen large transport-infrastructure projects subject to impact studies in both Switzerland and France. Nevertheless, in all these cases, the collection of naturalist data by sampling was set up specifically to inform sites directly affected project footprints. In the case of the Bièvre-Valloire project, on the other hand, sampling should involve a whole, relatively diversified and large landscape ensemble whose natural infrastructure (the ecological network) covers the entirety of the landscape.

The approach and the results obtained have already been widely commented in previous chapters. It is not then very useful to describe the whole process again here. It does, however, seem of interest to outline the approach's advantages and limitations, which came to light during the study.

- **Point 1. Utilization of SPOT Thema numerical data for land use**

The acquisition of a SPOT Thema database — more detailed that CORINE Land Cover — enabled a level of precision analysis compatible with a 1/25,000 mapping scale. Nevertheless, the database still needed the addition — with the minimum of handling — of the essential linear data not accounted for in land use categories (see Chap.4.5.2).

Advantages: The identification of continua is relatively easy and the definition of boundaries is more than precise enough to identify the extension zones, buffer zones and corridors associated with each continuum ST. Validation by sampling or by transect are necessary and can be combined with naturalist samplings.

Disadvantages: The definition of vegetation types is still insufficient, particularly for grasslands and crops. A more detailed analysis of plant cover, obtained by site visits and manual mapping, is indispensible if specialized networks are to be obtained; this adds to the cost. Generally speaking, the approach is possible at a local scale as long as relevant issues have already been identified for particular thematics (e.g. rich dry grassland rich in orchids or butterflies). SPOT Thema data need to be bought from the SPOT satellite image provider and are subject to usage restrictions. Data is available only for the direct acquirer and are transmissible to any partners except in the form of analyses results (transformed data without the database).

- **Point 2. Choice of a GIS software**

The use of a Geographical Information System is indispensible for the management of data produced by ecological networks. Many such softwares are available on the market, but some are better adapted to data treatment than others. At the beginning, for the establishment of REN-CH and REDI, the ARC-INFO programme was employed exclusively, which allowed us to manage the large data mass of collected information at the national scale efficiently, and particularly, enabled the automatic seizure manually scanned data. Later, the more convivial ARC-VIEW was progressively preferred. In the case of the most recent analyses, the MAPinfo software has been adopted. Although its treatment performance is lower, it

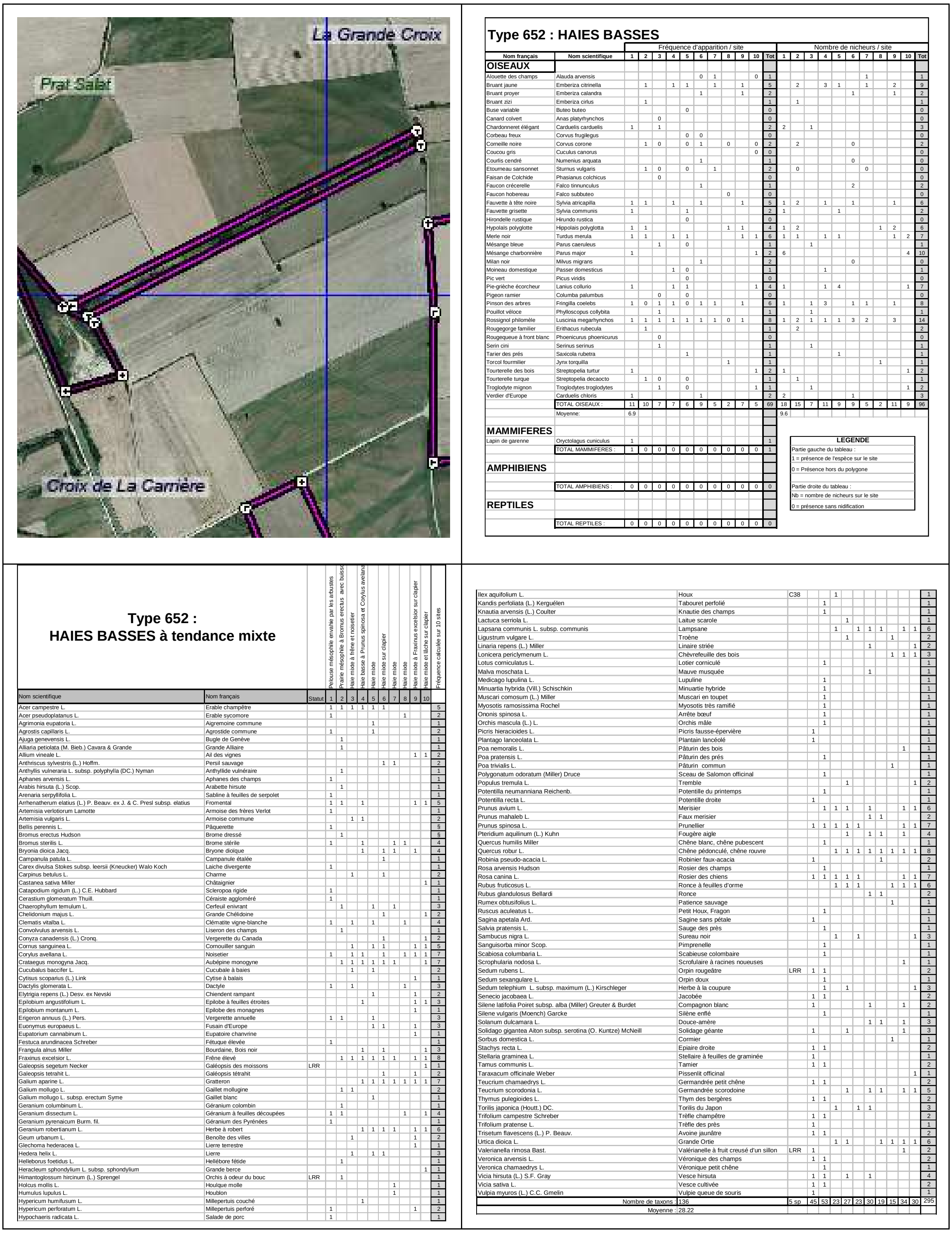


Figure 70. *Example of the structuring of naturalist reference data in the context of an ecological network study. Data is geo-referenced at the scale of the inventoried habitat. Floral and faunal data for similar habitats are grouped in comparative tables.*

Source: ECONAT-Concept & al (2010)

is cheaper and simpler to use day-to-day. On the Pays Bièvre-Valloire study, MAPinfo was employed exclusively and data capture procedures were automated as far as possible.

Advantages: The various softwares available are nowadays to all intents and purposes equivalent in their ability to manage simple data. The MAPInfo programme presents the not inconsiderable advantage of being commonly used by consultancies, thus allowing data transfer to more complex systems.

Disadvantages: The enrichment or correction of vectorial data — to enter the outlines of new particular sites for example — significantly increases treatment time with MAPInfo.

- **Point 3. Utilization of naturalist inventories**

The collection of recent and reliable naturalist data in indispensible for the establishment of a coherent management of natural heritage.

The organization of naturalist inventories must be strictly orientated towards sampling representative of all the characteristic milieus present in a landscape (Fig. 70). Otherwise the resulting data is only very partially usable.

Advantages: data collected by representative sampling can serve as a reference for non-prospected sites in the territory, natural district or region. Progressively, a reference database can be made available to other studies. A choice of representative sites made prior to site visits obliges naturalists from different specialisms (flora, birds, mammals, insects, etc.) to work in the same places. Data will thus be complementary even if it is not exhaustive.

Disadvantages: Budgets available for carrying out inventories are almost invariably too limited to enable the creation of completely representative inventories right away. Choices therefore must obligatorily be made, leaving out anthropogenic or little frequented milieus, even though these too have their particularities and ecological issues. It is of course always possible, however, to return in later more local studies to those milieus that were left out the first time.

- **Point 4. Inventory data formatted for an ecosystemic approach**

The application of the “hierarchically organized ecological network” method is restrictive for the collection and treatment of data, as the aim is to extract the most information possible from the inventory data. In an ecosystemic approach, **useful information must be associated with a habitat, an eco-complex or a sector**, defined by ecological criteria rather than ecologically arbitrary limits such as the boundaries of a plot, a commune or according to some areal measurement scale (ha or km^2).

Data must be associated with measurable ecological factors so as to be able to deduct possible correlations. As naturalist information is always expensive to gather, it must be as complete and profitable as possible for the analysis of the territory in question.

Naturalist data must also be geo-referenced and exhaustive; or at least representative the spatial entity under consideration. And it must propose a diagnosis of the biological status of the inventoried taxons. Atlas-type data on floral and faunal distribution are unfortunately of no practical utility except to locate the probabilities of encountering a given taxon at a given point.

Advantages: The observational data are usable for global comparative analyses of habitats or for analyses of specialized ecological networks.

Disadvantages: The data-capture forms for traditional atlas-style databases must be reformatted so as to be multifunctional.

- **Point 5. Cartographical data management**

The management of cartographical land use data must be carried out by a competent team also capable of exploiting the data and, particularly, the evaluations of the ecological potentials necessary to the hierarchical organization of ecological networks.

The formatting and subsequent analysis of data requires both the skills of a geographer trained on GIS and of a naturalist conversant with ecosystemic modelling. A sustained collaboration in the context of an interdisciplinary team is required to establish a real competence in the field of ecological network management and analysis.

Advantages: Functioning in interdisciplinary groups creates a veritable transfer of competencies that is indispensible to the long-term management and development of data and models. The robustness of the cartographical model is reinforced.

Disadvantages: work processes are slowed by the multiple iterations implicit in this mode of functioning, but it is indispensible to the real acquisition of competencies.

Box 13

Guidelines for the Collection of Usable Naturalist Data in the Cartography of Hierarchically Organized Ecological Networks

- **Habitat typology in the study zone**:
  - A habitat corresponds to topological and vegetation structures associated with the same ecological factor (soil, water, wooded structure, open structure, etc.);
  - Draw up an exhaustive list of all natural and artificial habitat types present in the study zone in provision of the establishment of a complete cartography and a representative sampling of the habitats present;
  - If necessary, habitat sub-classes will be defined, having been noted during site visits.
- **Selection of sampling sites:**
  - Every habitat type should be subject to a number of samplings sufficient to describe its principal biological characteristics: list and abundance of species and utilization mode of the site throughout the year. Access to the site during favourable periods should be forward-planned and possible owner authorizations obtained;
  - If certain sites cannot be inventoried because of accessibility or cost issues, it is anthropogenic sites that will be left to one side and analysed globally.
- **Selection of taxonomic groups**:
  - One should seek to establish a list of encountered species belonging to those taxonomic groups that are easily treated — but which comprises, at the very least, all higher flora, all vertebrates and a selection of ecological indicator invertebrates (Odonata, Lepidoptera, Orthoptera and Coleoptera). The latter groups are usually selected with regard to the specialisms of the experts available within the work group. Birds are often favoured in naturalist inventories, but they do not in fact constitute the best indicators for a small habitat. There are, in the other hand, good indicators for habitat complexes;
  - Species' behaviours constitute as important a datum as the recognition of their presence. It is therefore necessary to allow enough observation time and to be able to interpret the behaviour observed.
- **Inventory organisation**:
  - Inventories often necessitate long visit routes. It is preferable that sampling sites should be grouped according to logical circuits and transects.
  - The visits required to observe the presence of species should generally be spread over a number of different daily and seasonal periods so as to spot different species. Each specialist should define the appropriate frequency and optimal timing of his visits.

(Box, cont.)

– Inventories are coordinated in such a way that every specialist visits the same sites as his colleagues so as to collect the most data possible on the chosen habitat type;

– Negative data, such as the absence of interesting species, also constitutes information valuable for the global analysis. Searching outside the predefined site is pointless;

Naturalist inventories represent a sizable investment in comparison with the rest of the study. It is then necessary that collected data should be as usable as possible by respecting the following points:

– Data must be reliable. This guaranteed by employing experienced specialists for its collection;

– Data must be homogenous, by ensuring a uniform repartition of the prospection effort over the whole of the selected sites;

– Fortuitous observations, outside designated sites, are not without usefulness of course, but they must be recorded separately on *ad-hoc* sheets;

– Collected data must inform the hosting and development capacity of the site.

Data is then at once:

- Qualitative: species lists distinguishing their regional status (common, rare protected species, etc.);
- Quantitative: number of observed individuals or pairs or appreciation of abundance;
- Functional: biological status on the site (reproduction, feeding, sheltering, etc.), behaviour and development dynamics.

Collected data must should be able to serve as a reference in local or regional databases, and to this end should be presented in a standard format.

➢ **Point 6. Process of validation by the active participation of users**

The use of cartographical modelling methods is complex. The logic of the approach needs to be understood by all the various contributors to and users of the results it produces if they are to be understood and accepted. There is little point in investing large amounts of time and money to obtain complicated results if the tool provided by the mapping of ecological networks remains unused. Nor will the applied solutions proposed have much effect if the method of analysis and the logic of results that justify those solutions are not understood.

Advantages: Both the problems and their solutions are made explicit in advance as issues that need to be addressed before any misunderstood diagnosis is made or any misunderstood application measures are taken.

Disadvantages: The whole process of work, information and justification requires more time than just the work needed investigate and analyse the situation.

6.6 The Ecological Networks in the PLU of the Commune of Saint-Martin d'Uriage.

The commune covers some 3650 ha, spread between 320 and 2,200 m in altitude in the Belledonne Massif, 15 km east of Grenoble.

The territory of the commune is roughly divided into four large spaces:

- An extensive forest massif occupying the higher altitude zones;
- An urban and peri-urban zone of about 400 ha;
- Another urban zone developed in the middle of the agricultural zone in the piedmont;
- A mixed zone of forest and pasture above the piedmont.

Local economic activities are centred on the thermal baths and the communal casino, but the traditional rural activities and forestry still maintain local importance. Agricultural activities are developing, even if usable surfaces tend to be diminishing in favour of urbanization.

The population of the commune is 5,200 souls spread through fifteen hamlets and served by 80 km of communal roads.

in 2003, a number of disputes concerned with environmental issues caused the communal authorities to revise its PLU. Several studies were carried out with the aim of better understanding the commune's natural heritage:

- The goal of a first study was to establish a management plan of the Sensitive Natural Space (ENS) constituted by the Seiglières peat bog located in the forest zone;
- A study serving to "identify the ecological networks on the communal territory of Saint-Martin d'Uriage" was carried out in 2005, by the "ECONAT-CORA-FRAPNA-Gentiana" work group;
- A further study concerning an inventory of trees and hedges of special interest was carried out at the same time by DRYADES association.

Cartographical results and inventories were delivered to the consultancy tasked with producing a planning document establishing the definitive criteria with which to fix the boundaries of corridors and draw up a hierarchical table of them. One notable aim was to pass from the map of the ensemble of ecological networks at a scale of 1/25'000 to a map on the cadastral base at 1/5'000 used for establishing the definitive zoning of the PLU.

The commune's reasoning is worth examining:

The publication of REDI in 2001 inspired the commune to think about its runaway urbanization in the context of ecological networks that appeared to be well developed over its territory, but whose problematics were difficult to grasp. According to the initial REDI cartography, the entire territory apart from built-up areas was part of a vast forest continuum over which a thermophilic grassland continuum was partially superimposed. The commune's problems were principally concerned with the progressive fragmentation of agricultural surfaces by dispersed building which tended to cluster on the banks of streams in natural hazard zones.

The cartography of the ecological networks in the commune revealed four characteristic continuum types:

- The general forest continuum divided into four sub-networks: alpine moorland, arolla pine forest, subalpine forest, mixed conifer – beech groves with fir – oak and beech wood;
- The arable farming continuum, divided into intensive and extensive zones;
- The aquatic and paludal continuum, containing torrents, wet zones and some ponds;
- The grassland continuum, consisting of thermophilic meadows and permanent mesophilic meadows.

Each continuum contained nodal zones identified in the field by floral and faunal sampling (Fig. 71).

The communal territorial planning issues only concerned:

- Maintaining the "biological corridors", which in cartographical terms consists in ecotonal zones bordering forest edges and river banks;

- The protection of “nature cores”, identified by the Protected Natural Spaces status already attributed to them (ENS, NATURA 2000 sites) and in complementary nodal zones to be possibly designated by our own inventories.

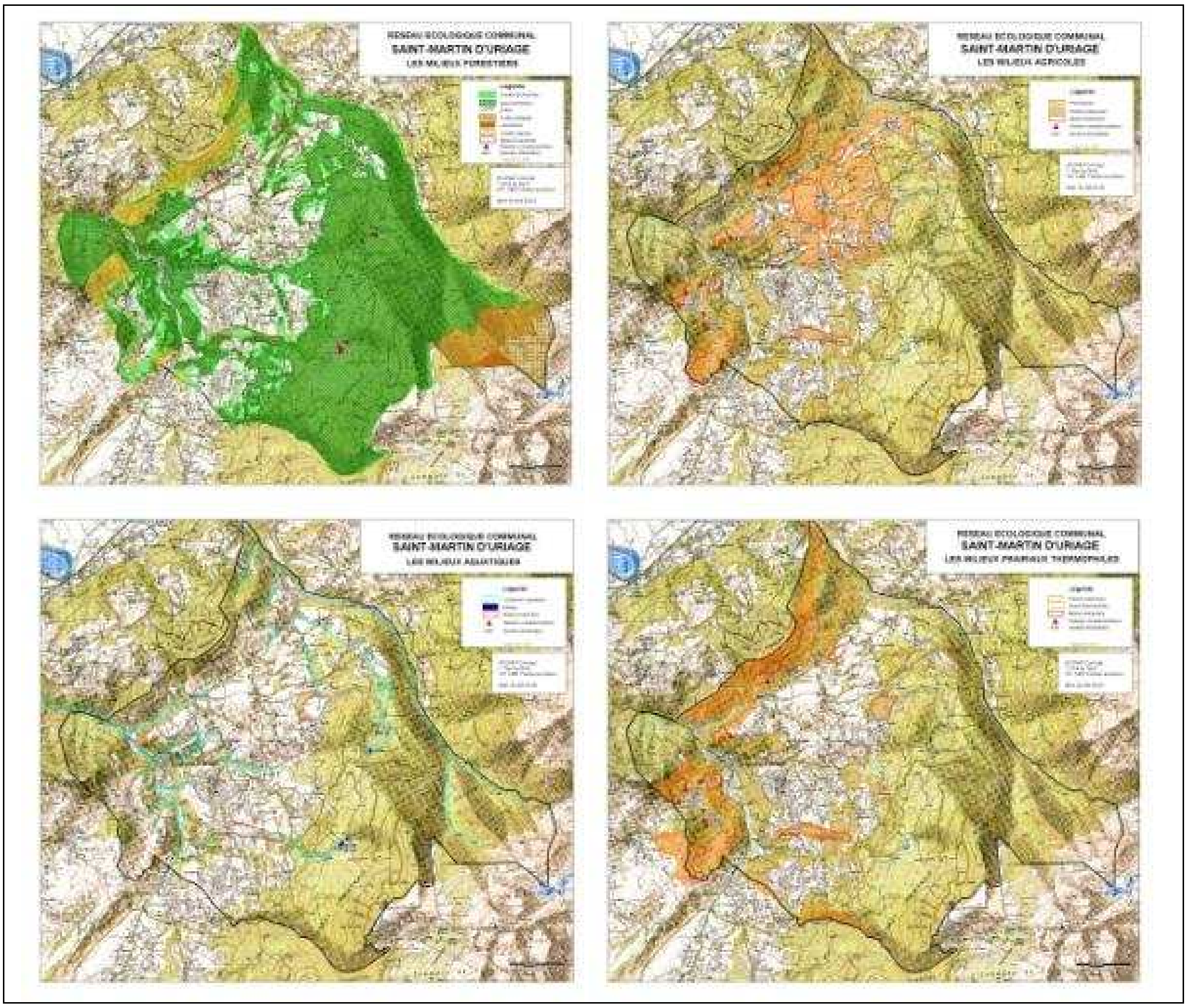


Figure 71 *Manual cartography of the four principal continua characteristic of the commune of Saint Martin d’Uriage.*

Source: ECONAT-Concept (2006)

In this situation, the criterion of versatility of the various zones, and especially those close to edges, was the only ranking tool used to designate priority spaces to be integrated to the local urbanism plan (PLU).

The abundance of species and the size and frequentation of corridors have been the subject of numerous committee discussions, but their principles are not doubted.
Spaces recognized as corridors are accounted for in different way depending on the basic character of the zones crossed. For example:

- Corridors in natural zones are identified by the zonal code, “**Nco**”;
- In agricultural zones, biological corridors keep their agricultural status, but with added constraints concerning the use of pesticides and the installation of fences;
- Corridors in building zones with restrictions concerning natural hazards (avalanches and alteration of watercourses) reinforce the building and fencing interdictions.

In order to conserve the communal ecological continuities and corridors, 40 hectares were re-zoned in the 2008 PLU.

Box 13

Local Applications of the Hierarchically Organized Ecological Networks Method

One of the approach's priority goals is the ability to apply ecological mapping to local planning or management actions, while at the same time ensuring ecological coherence at supra-local and regional scales.

In such cases, mapping scales habitually applied will range from 1/25,000 to 1/1,000.

The prior definition of a study or reference zone allows the establishment of this coherence. Such a global vision should always strive towards gaining an overall picture of the biological organizational level above that of the project in question (see Chapter 3.2).

In this way, the establishment or management of an ensemble of habitats (or even of a single habitat or habitat fraction) should always seek to frame the action envisaged by integrating it into the relevant ecological sector. In turn, this sector should be framed within the context of the natural district to which the habitat ensemble belongs.

This perspective of interlocking bio-organizational levels constitutes the best means by which interconnection mechanisms may be taken into account — and thus also interactions between those habitats that are conducive to the maintenance and development of biodiversity.

Practically speaking, the research for a local project would always begin with a cartographical definition of the ecological sectors generated by the anthropogenic fragmentation of the landscape.

Priority actions for the restoration of ecological potential result logically from this analysis:

- □ The conservation of existing natural heritage through the management of areas of particular interest;
- □ The re-establishment of indispensible interconnections between neighbouring ecological sectors.

CHAPTER VII

Future Perspectives

Summary

The overall aim of the ECONNECT is the establishment of a network of protected spaces across the entire Alpine region and within the international framework of the Alpine Convention. The goals of this methodological guide are to present the methodological bases of the "ecological networks" tool that has, over the last ten or more years, been developed over a number of practical application projects in Switzerland and France, and by this to facilitate a transfer of knowledge and know-how concerning the networking of protected areas as a first, necessary step towards the setting up of pilot projects throughout the alpine region.

Ecosystemic modelling of the landscape by the application of the hierarchically organized ecological networks method is at once flexible and demanding. Flexible because it enable the rapid acquisition of a provisional and progressive picture of existing networks based on available numerical data. Even where it is incomplete, naturalist data are added to reinforce the first local and regional models.

Its progressiveness is owed to the way it can integrate more detailed research from field cartography, which is also reinforced by new naturalist audits. This new data allows the improvement of initial models by the introduction of supplementary criteria.

The system is also demanding because its underlying philosophy and its organizational structures both aim at an optimal ecological coherence in its approach to landscape. "Administrative" models of the interconnects between protected spaces, such as that proposed by the pan-European ecological network concept are not totally realistic with regard to their network diagrams because the priorities of such approaches are capable of guaranteeing the efficacy of the network systems established.

The ecological coherence intended by the Habitats directive (art. 10) should not thought of as a means of catching up, employed merely to complete networks of protected areas. On the contrary, it ought to be a condition sine qua non *of the definition of ecological networks. It is not the anthropogenic (administrative) vision of what* can *be protected that ought to take precedence. Rather it is the ecosystemic vision of biological interrelations in landscape that should define where the management and protection of landscape elements are* necessary. *An analysis of the example of the Isère will allow us to highlight some approach options.*

7.1 Applications in the Alpine Region

The international ECONNECT project aims to establish an ecological network covering the whole Alpine region. The approach is, nevertheless, articulated first and foremost on the setting up of networks of protected areas whose final goal is the long-term protection all biodiversity present in the Alps. It is therefore essential that we obtain a coherent ecological approach to this wonderful reservoir of biodiversity by asking the right questions. The recently published summary report, "Overview of the Most Important Instruments Concerning Ecological Networks in the Alps" (CIPRA alpMedia, 2009) affords us an opportunity to reframe the various approaches practised.

➢ What are the ecological specificities of the Alpine region?

In the various regions of the Alps, as with all mountain ranges, it is the orography, geology and climate that generate the diversity of habitats and, as a result, biological richness. These three parameters combine to create a characteristic organization of habitats by horizontal altitude bands of vegetation types and be the presence of numerous natural infrastructures in the form of ridges, ravines, valleys and bluffs. From all this results an extraordinary mosaic of habitats whose biocenoses are subjected to powerful natural dynamics characterized by inter-habitat exchanges structured for the most part by the presence of innumerable ecotonal margins.

In this very specific context, the habitats of mountain zones are incorporated in multiple networks, complexified by numerous structures and natural obstacles. As a result, Alpine habitats are organized in hyper-functional ecological networks generated by natural spatial fragmentation.

Biological corridors appear, as they do everywhere, in accompaniment to the development of ground occupation by human activities and constructions. In mountain zones, however, agro-pastoral activities, residential building and transport infrastructures are all concentrated in valley bottoms and along some accessible slopes and plateaux. Corridors are then also created by local human-natural conficts engendered by ecologically inappropriate ground occupation.

In the perspective of the management of natural spaces in mountain zones, **even more than in other landscapes, what is needed is an understanding of how ecological networks function before we can begin to imagine constituting connection corridors between protected spaces**.

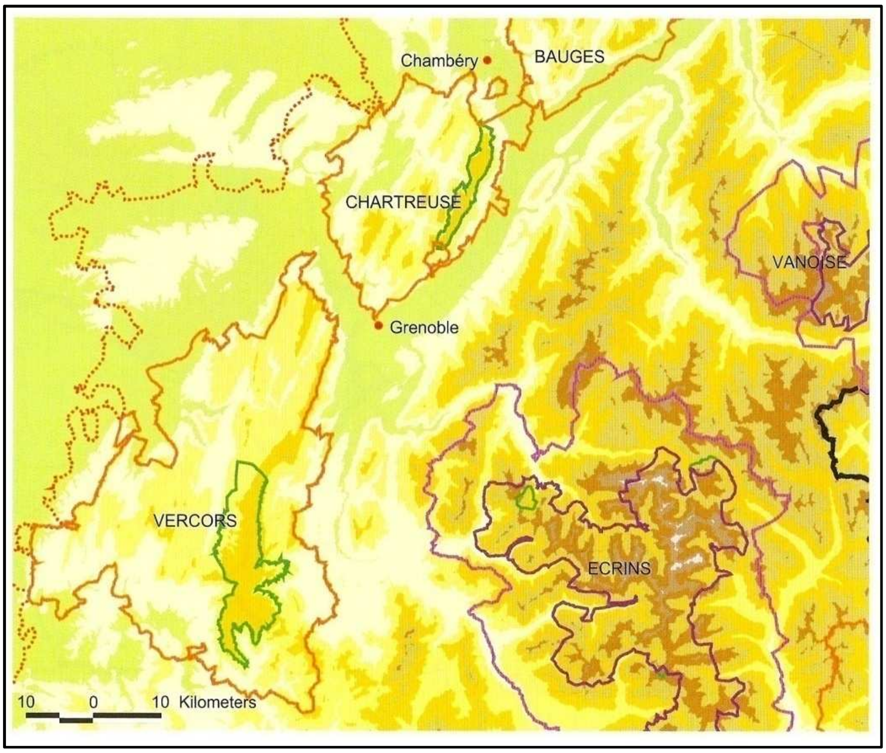


Figure 72.

Altitude bands in the Isère region, with the distribution of protected species.

Légende
Perimeter of Alpine Convention
National borders
National park
Peripheral zone of the national park
Parc naturel régional
Natural reserve
Citv

Etages altitudinaux
4000 - 4500m
3500 - 4000m
3000 - 3500m
2500 - 3000m
2000 - 2500m
1500 - 2000m
1000 - 1500m
500 - 1000m
0 - 500m

Source: Réseau Alpin des Espaces Protégés (2004)

The most important question is: question should the protected areas be connected, or should the existing corridors rather remain interconnected?

The mountainous part of the Isère was chosen as one of the eight exemplary zones in which to study the principles of the trans-frontier ecological network of the Alpine region in application.

The analysis of this zone — formed around the Vercors, Chartreuse, Bauges Massif regional natural parks and the Ecrins national parks — provides a very representative example of the ECONNECT project approach in action. The zones cover an area of 3'250 km^2, 1450 km^2 of which constitute protected areas. The simple distribution analysis of surface areas contained in the altitudinal bands, along with that of the protected spaces (Fig. 72) allows a better understanding of the problematical difference between the installation of a network of protected areas and the cartography of ecological networks. A good level of complementarity exists with regard to the similarities between the mid-altitude habitats of the Chartreuse, the Vercors and the Bauges. The direct proximity of the three massifs allows the probability that propagule exchanges between them are possible. The valley bottoms, on the other hand, are affected by a very high level of urbanization, particularly in the areas of Chambery and Grenoble, creating a virtually impassable barrier (cf. chap.6.3). If the direct connection desired to reconnect the three massifs is not reconstituted, absolutely no means of contact between will be possible.

The situation of the extant ecological networks linking the Ecrin, Belledonne and Vanoise massifs is different. The overwhelming majority of the habitats are associated with the lower slopes and the piedmont, situated outside any protected areas. The circulation of propagules in this case involve numerous and diffuse flows. The creation of corridors here is not really justified inasmuch as it would be practically impossible to define spatially limited connection spaces that would be attractive and efficacious for flora and fauna. In a case such as this, only a global management of the ecological networks already in place is necessary. The constraints governing than management are then concerned with any modulation in possible disturbances. Crossing from one side of the Maurienne valley, especially with the presence of both motorway and high-speed rail line, has been facilitated by the installation of a number of faunal crossing-ways, which conform to current practice as far their efficiency goes. It will, however, probably become necessary to install access corridors leading to the crossing-ways, so that fauna can avoid the disturbances caused by human activities and building.

One should also note the weak representativeness of the low-altitude habitats located in the Vanois and Ecrins parks. In order to obtain and maintain an adequate level of long-term connectivity over the whole zone chosen as an example, precisely defining the status of all the territories outside the parks on the piedmonts — notably those of the Vanoise and Belledonne massifs — would be necessary.

Figure 73.

A diagram serving as a justification of the problematics of the Grésivaudan corridors identified in the context of networks of protected Alpine spaces networks initiative.

Source: FEDER Project.
Conseil général de l'Isère (2008)

The diagram resuming the zone's problematics with regard to corridors that need to be established between the four parks underlines the strategic role played by this part of the Isère territory, as well as the need to restore the Grésivaudan corridors (Fig. 73). It should be remembered, however, that before understanding, managing and justifying the implantation of biological corridors, the first essential step is to produce a precise and complete definition of the zone's ecological networks.

Often in a "hierarchically organized ecological network-type" approach, an administratively designated protected area only corresponds very imperfectly to the nodal zones of the different continua present in a given territory. Generally speaking, what is observed is that even though certain habitats — agro-pastoral, watercourses with their alluvial zones or thermophilic grassland piedmonts — may form interesting continua, they are not included inside the park area for purely administrative reasons. This environmental envelope surrounding a protected area can be progressively annexed by the park's peripheral zones (buffer zones), but these surface areas remain, more often than not, limited only to the buffer spaces necessary to guarantee the tranquillity of the park's central zones and are not large enough, therefore, to cover all the extension zones, let alone possible corridors, along which spontaneous dispersion from nodal zones could take place.

A complete cartography of ecological networks should serve to enable the whole of the potential developments of the various extant continua in a sector to be re-centred. The management choices, installation projects and possible priorities for strategic corridors will logically be obtained by a general cartographical tool for ecological networks.

To summarize, in any development strategy for protected spaces in the Alpine ecological network, the mistake to be avoided absolutely would be to adopt a too constraining perspective by considering this network to be no more than an association of interconnected protected spaces. For this would wrongly imply that only part of the Alpine region is concerned by the problem. The overall aim is not merely to create a network of protected spaces, but rather to conserve a veritable functional ecological network comprising enough protected spaces to guarantee the development of the most vulnerable species.

7.2 Critical Analysis of the Basic Models for Establishing Ecological Networks

The recent global report published by CIPRA alpmedia (2009) provides an opportunity to focus attention on the different approaches to ecological networks — such as those proposed by the EU or that developed in this present guide.

Point 1. Global or selective approach to ecological networks?

The ecological networks principle based on the ecological interconnection of habitats has never been contested as a whole. Only the formulation of its objectives can give cause for confusion:

1. To follow up the practical applications of the 92/43/CEE Habitats Directive — which initiated the Natura 2000 programme — in a series of habitats and for a series of priority species eligible for protection, the ecological networks definition logic — employed in the context of the pan-European ecological network — aimed to develop a system priority habitats organized in networks cover all of Europe. This **selective approach** is of a piece with the traditional concepts of natural protection that seek to protect those species and spaces deemed "of particular interest". Despite its many significant successes, the approach has demonstrated its limitations, inasmuch as it has proved unable to halt the erosion of biodiversity in the world;
2. Today, taking account of habitat interconnection and of ecosystemic dynamics at work in the landscape offers new perspectives for nature conservation. As opposed to the traditional one, this new approach necessitates **non-selective approaches and a global management of the complexity of interactions**. With this in mind, the approach seeks to understand and to mange "ordinary" species and spaces, so as to re-locate those of "particular interest" in their real environmental context.

Point 2. What ecological network model?

The ecological network model proposed by BENNETT (1998), in the context of the implementation of the pan-European ecological network, illustrates the theoretical approach to the basic elements to be used in the constitution of a network according to the CEE vision (Fig. 74). Once transferred to the field, unfortunately, the model proved too reductive to enable a realistic definition of functional ecological networks:

1. The nodal zone only rarely coincides with a protected area because numerous complementary vital zones are not usually included within the original protected perimeter;
2. The notion of the buffer zone needs to be modified so as to be defined as an extension or propagation zone. The protection of a central zone in a park certainly requires a buffer zone capable of allowing possible disturbances in the totally protected zone to be controlled. From the biological perspective, propagules originating in the central zone will disperse over a much larger area contained in favourable habitat continua.
3. The three corridor types are not necessarily appropriate when the issue concerns connection elements extending over several kilometres. In such cases, corridors must be of a certain size in order to be functional, and when this is indeed the case, they can extend over surface areas as large, or even

larger, that the protected area. In the reality of the field, what is being dealt with is a landscape matrix that is itself organized in ecological networks according to well-established rules of functioning. These ecological networks notably contain various types of specialized networks of which some are to a greater or lesser degree versatile. Thus the choice of a “biological corridor” cannot be an administrative one.

Or, to put it another way: **Nature always decides.**

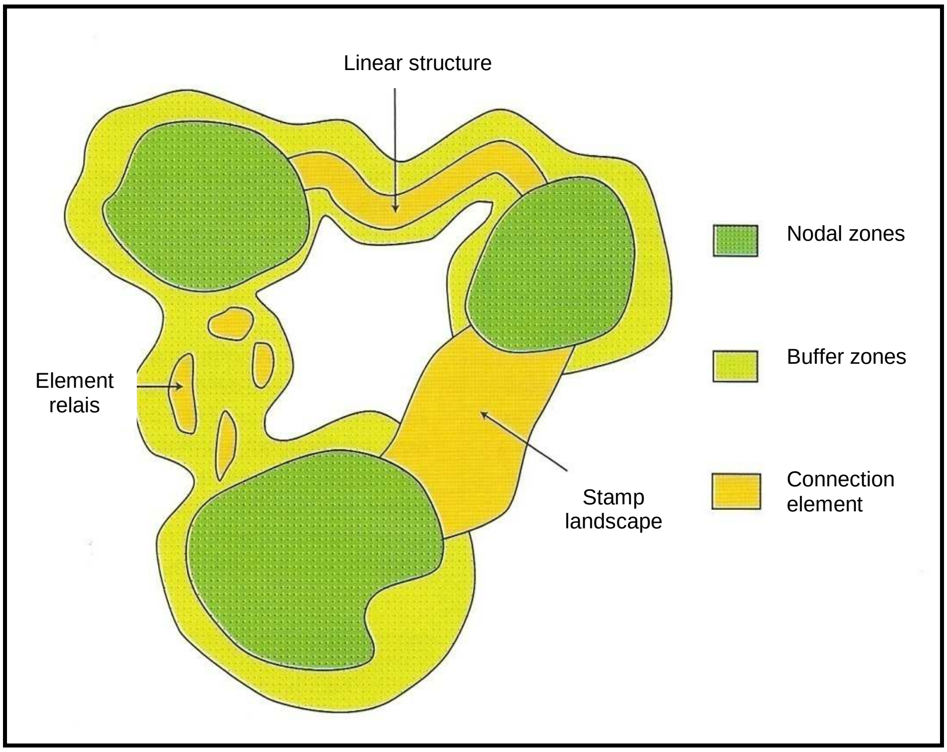


Figure 74.

Elements of an ecological network according to the selective approach based on interconnected protected species, such as that intended by the EU.

Source: BENNETT (1993)

Following on from the previous remarks, re-establishment of local habitat networks model (Fig. 75) should be interpreted as follows:

Situations illustrated in figure 72:

1. ***Previous situation:***
   The landscape is composed of a multitude of elements connected each to the other and forming a coherent whole
2. ***Current situation:***
   The landscape is fragmented; each landscape element is isolated from the others by extensive farming areas
3. ***Intermediate stage:***
   Central zones isolated each from the other are widened, and become relay biotopes

Commentary regarding applications of the ecological networks model:

- It does not illustrate the nodal zones of a particular habitat, but rather fragmented forest biotopes
- The buffer tones represent the ecotonal margins of the forest continuum. Biotopes extended by functional edges can play the role of complementary extension zones in a system functioning by meta-population
- Relay biotopes of the forest type (hedges and isolated trees in agricultural areas) can be included in a corridor of the ecotonal forest type

4. ***Future situation:***
Existing ecological corridors connecting isolated landscape elements are revitalized or re-created. Agriculture becomes more extensive. Thus central zones and relay biotopes can be interconnected

- Once the location of the forest corridors has been decided, by consultation with farmers, less intensive farming methods are introduced in the designated areas. Meta-population functioning of the forest biotopes is thus ensured.

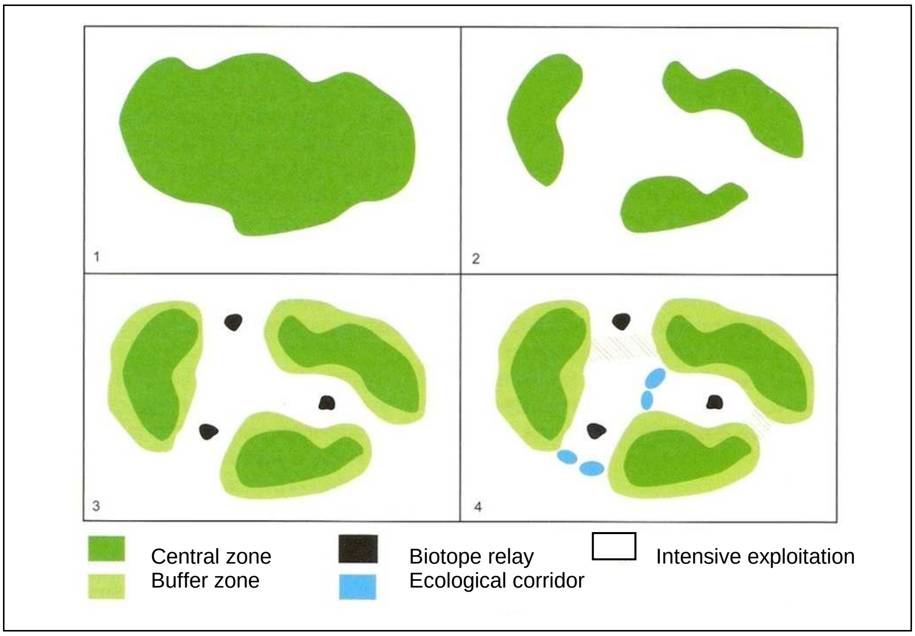


Figure 75. *Stages in the restoration of local habitat networks.*

Source: CIPRA alpMedia (2009)

The demonstration of the establishment of networks as illustrated in the CIPRA alpMedia report (Fig. 76) remains highly theoretical. All that are figured in the illustration is the administrative boundaries and those in which are applied measures that are necessarily coherent with the presence of ecological networks. The selection of priority zones for application strategies of the types “protected landscapes”, “linear liaison elements (= corridors)” and “ the application of agro-environmental measures” must correspond to the restrictive criteria defined by the presence of ecological networks. It is only possible connect habitats which share ecological affinities that either the same or complementary for the life cycles of their species. It is for this reason that it is the definition of specialist ecological networks which must always serve as the basic outline of administrative networks.

It is true that the majority of parks and nature reserves in the Alpine region for the most part protect ensembles of habitats at mid and high altitudes. Even in this situation, however, the biological interests of the species protected therein is generated by the combination of various closely interlocked continua, which depend on or which feed into other lower altitude continua.

In consequence, it is necessary to complement the present consensual but over administrative approach with an approach based on more ecosystemic criteria.

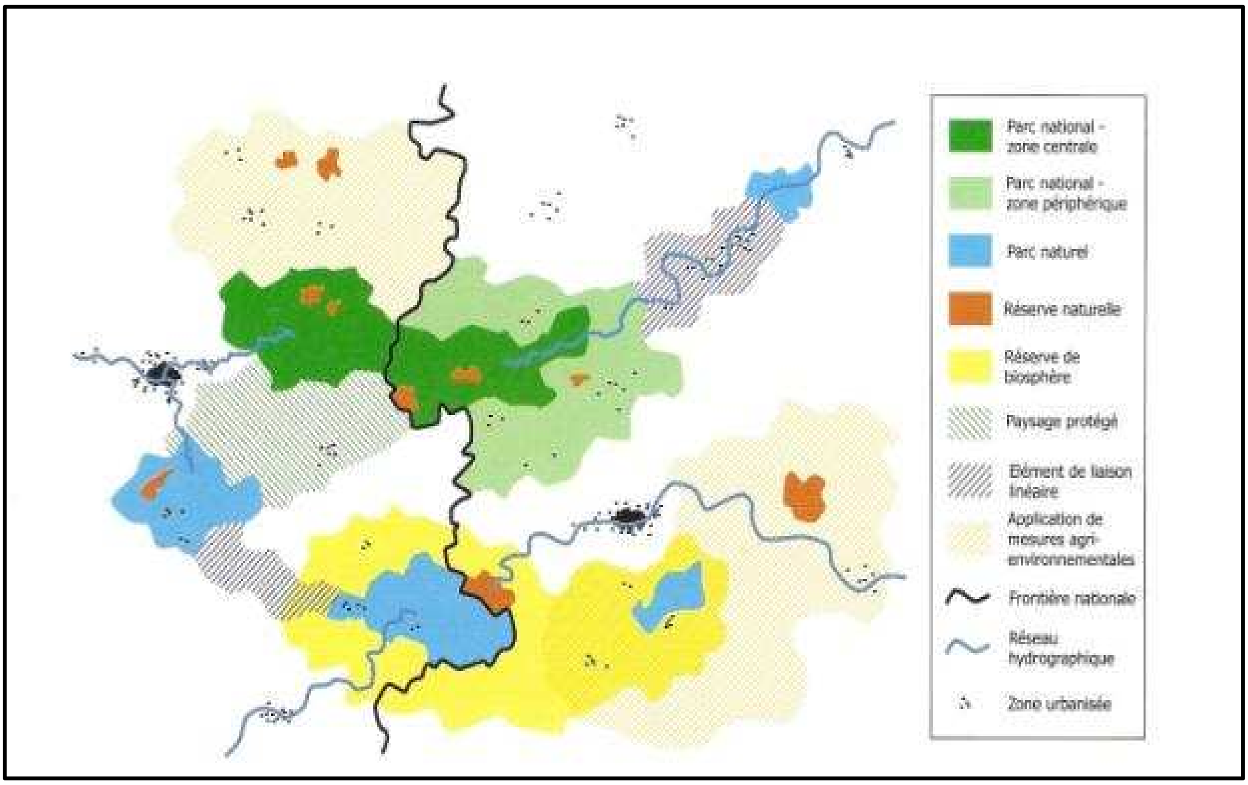


Figure 76.

Installation of a cross-border network of protected areas

Source: CIPRA alpMedia (2009)

7.3 Elaboration Stages of a Network of Protected Areas Using an Ecosystemic Approach

The following stages are explained in detail in Chapter 4 and 5. They are summarized here so as to reframe the approach.

Stage 1. Identification of determinant landscape groups

In the Alpine region, the following nine types of generic landscape groups at least need to be considered:

- Low altitude forest continuum;
- High altitude forest continuum,
- Moor and copse continuum;
- Grassland, steppe and high-altitude pasture continuum;
- Rocky continuum;
- Nival continuum;
- River and lake continuum;
- Xeric and mesophilic grassland continuum;
- Anthropogenic continuum.

Continua of other types can be added depending on regional specificities.

Stage 2. Choice of a land use database

The European Corine Land cover (CLC) database has practically imposed itself as the standard. More detailed cartographical data also presents a possible choice, however, as long as an initial correspondenc table on CLC has been established first.

Stage 3. Definition of the extension zones for each basic continuum

These zones are obtained by the aggregation of the different ground occupation categories (see chapter 4.5.2).

Stage 4. Distinguishing the floral sub-groups

The use of a numerical terrain model (NTM) enables slope expositions (north-facing or south-facing) to be distinguished. This allows the spatial modelling of vegetation sub-groups, taking account at the very least of altitude bands (Fig. 77). Distinguishing the sub-groups of vegetation in this way is chiefly of use for the organization of faunal and floral inventories. It can very well, however, be carried out at a later stage.

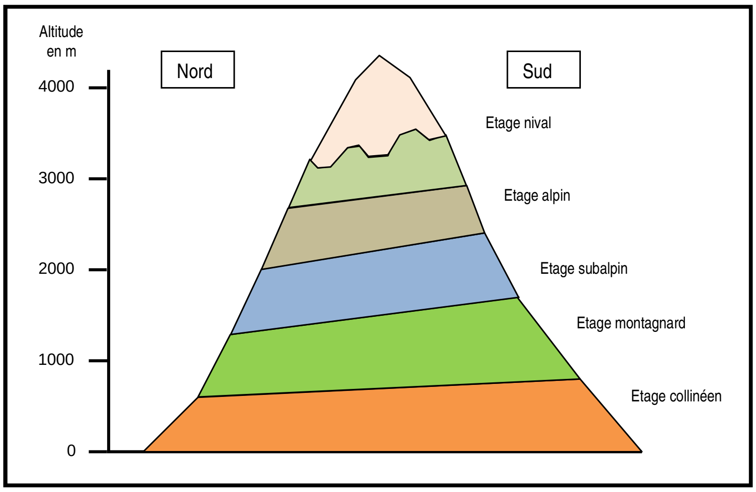


Figure 77.

Correspondence of vegetation bands in the Alps according to Ozenda (1985). Each band possesses its own species guild, even though all bands are constantly associated with each other

Stage 5. Cartographical addition of ecotonal margins (buffer zones) for each continuum

(See Chapter 4.5.4).

Stage 6. Designation of the corridors proper to each continuum

(See Chapter 4.5.5).

Stage 7. Selection of nodal zones for each continuum

(See chapter 4.5.6).

Stage 8. Evaluation continua quality.

The evaluation of the QUALITY factor requires the setting up of a table of biological diversities and of the relative heritage value of each habitat concerned with the relevant continua (Indicator Q1). Following this, the levels of naturality (Q2) furnishes by GIS need to be integrated (see Chapter 5.1.1).

Stage 9. Evaluation of capacity in each continuum

GIS can calculate an indicator of density directly by combining the surface area of each polygon with its structure (see Chapter 5.1.2).

Stage 10. Evaluation of the level of functioning in each continuum

The evaluation of the FUNCTION factor is carried out in three successive stages:

- The versatility indicator is furnished by GIS;
- The calculation of potential connectivity is also furnished by GIS;
- The integration of obstacles and disturbance zones can either be carried out automatically on GIS, or it can be achieved by sampling in the field.

Stage 11. Evaluation of ecological potential, which will allow hierarchical continua to be obtained

(See chapter 5.1.4).

Stage 12. Dispersion tests in networks

The representative species can be used to test the mapping of ecological networks. Using at least one known species (documented localized reproduction zones and dispersion capacity) is desirable.

Stage 13. Analysis of protected areas

Once all cartographical documents and previous stages have been assembled, an objective audit of the situation on each protected site — addressing the following questions — is necessary:

- Are the nodal zones of each continuum totally or adequately contained within the protected perimeter?
- Is it necessary to define new, complementary extension zones?
- Is it possible to select priority connection zones?

The answer to this last question is far from straightforward, because we find that in numerous cases the landscape matrix in its entirety plays the role of connection space. Thus there would be no reason to select a given, limited zone, which would run the long-term risk of constraining interconnection between protected spaces.

By the same token, the *a priori* choice of fluvial corridors is not necessarily appropriate for high-altitude protected areas.

To summarize, the global landscape context and the ensemble of ecological networks to which a protected area belongs must be taken into account before any long-term protection strategy is defined.

7.4 The Expansion of Large Fauna

Without going into detail here about the question of the cohabitation of agro-pastoral activities and large mammals, which is a reality in the Alpine region, the problematics of the dispersion of large predators is often in the news. It is then only normal to pose the question as to the degree to which the setting up of corridors between protected areas, or the recognition of ecological networks, will contribute to the increased dispersion of these species.

All of the French Alps, including the Isère, have, over the last twenty years years, experienced the re-apparition of the lynx, *Lynx lynx*, originating in populations in the Swiss Jura, as well as that of the wolf, *Canis lupus*, coming from Italian populations and which penetrated the Mercantour national park in about 1980 and has since re-colonized the Vercors, Chartreuse, Vanoise and Bauges parks

These examples of successful recolonization by large mammals have not been aided by the setting up of ecological networks for the simple reason that no reconnection strategy was in place during the time these expansions occurred. It is, however, true that the well-documented tracking of the dispersion of these two species has allowed the validity of the first ecological network models — elaborated during the same period — to be verified. With hindsight, it is possible to affirm that the simple reading of the maps of ecological networks allows us to reliably predict the probable dispersion of these species, along with their current and future expansion areas. The proposed ecological network models, as well as the parameters concerning migration capacities and territorial behaviour, are now sufficiently well understood for them to be used to obtain a synoptic picture of the potential living spaces of these species.

Thus, the establishment of the cartography of ecological networks, as with the restoration of corridors or the reinforcement of protected areas, improving actions for the global management of the Alpine region and of large fauna, inasmuch as the GIS models and tools set up in this context must efficiently support the conservation of ecologically strategic natural spaces over the long-term.

There is therefore no causal relationship between the reappearance of these large mammals and the, still modest, establishment of biological corridors.

CHAPTER VIII

Conclusions

The ecosystemic approach to landscape is now unavoidable if one wants to understand and manage biodiversity in a global context, but at the scale of a department or a region. Each habitat, and in consequence each of their biocenoses, is the result of numerous, often complex interactions that are difficult to grasp without a global environmental perspective.

The understanding of the problems of the conservation of an endangered species or habitat within a given landscape can only be reached by gaining knowledge of the different ecological parameters that act to favour the presence of a particular biological community.

For a long time, the traditional approach to natural conservation has been to turn certain habitat ensembles into sanctuaries. The approach appears (on the basis of criteria that are often only visual) to work well enough to protect those spaces from external anthropogenic impacts. Unfortunately, this simplifying approach is not, in the medium term, particularly helpful for very large, little transformed territories. Even if the policy has locally allowed to maintenance of a good number of endangered species, in the long term, it will prove unable to control the global reduction in biodiversity.

Current strategies for biodiversity all agree that a larger ecosystemic vision is needs to be promoted. This system would use spatial models — organized in habitat networks — to take account of the relative interconnection of all natural and transformed habitats. Such habitat networks act like highly functional and productive natural cores, interlinked by less favourable spaces that serve as corridors of biological exchange.

This strategic vision is still too diagrammatic to be considered completely satisfying, for it remains selective inasmuch as it ignores the vast landscape matrix composed of spaces transformed by human activity, and whose presence exerts great influence on the islands of preserved nature.

The Econnect project — whose goal is the creation of a network of protected spaces and the improvement of general ecological connectivity in the Alpine region — intends to initiate an international collaboration by means of the sharing of experience in the elaboration of ecological networks whose purpose is the better management of protected spaces, notably by ensuring their connectivity. The project provides the opportunity to present the methodological bases of a cartographical tool named “hierarchically organized ecological networks”. This tool has been under development for over ten years through a number of practical applications in Isère and Switzerland.

The present methodological guide furnishes, for the first time, a synthesis of these local and regional applications. All of these applications have always sought to accompany the ecological transformation of landscapes caused by transport, construction and urban planning development projects, whose ecological impacts could otherwise have significantly threatened the functioning of the natural ecosystems.

The causes of these landscape transformations are well understood:

- Replacement of natural spaces by built up areas, or their transformation by agricultural production or resource exploitation;
- Fragmentation by transport infrastructures;
- Deterioration caused by emissions (various pollutants).

These progressive transformation mechanisms reveal a number of measurable impacts on original natural habitats:

- Edge effects;
- Modification of dispersion flow distribution;
- Alteration of species’ fitness;
- Invasion by exogenous species.

The cartographical approach that allows the identification of homologous habitat networks, which form continua and which are complexified by ecological zoning, is based on a pragmatic application to the whole landscape of the “networked protected areas” concept intended by the 1995 pan-European strategy for the conservation of biological and landscape diversity. Such networked protected areas contain particular biocenoses — some of which merit protection — but also areas of biological perdition in the form of “demographical sinks”, whose effects are far from insignificant on the global balance of the biodiversity in a landscape.

Such modelling of habitats as a whole organized in interconnected networks also provides a number of perspectives:

- It provides a global picture of the amplitude of the different natural infrastructures present in a given landscape;
- It allows the examination of the synergies and antagonisms which are necessarily created in the interfaces between continua;
- It also furnishes a realistic picture of the ecological footprint of the multiple anthropogenic impacts exerted on functional networks, thus facilitating the implementation of integration and conservation (where necessary) measures that are genuinely appropriate to the foreseeable impacts caused by such projects.

Once modelized, these negative impacts highlight a number of secondary survival or decline mechanisms perceptible at the level of species populations:

- The ability of certain species to function in meta-populations;
- The capacity for dispersion and passive emigration that is possible for other species;
- The appearance of tertiary biocenoses, consisting for the most part of invasive exogenous species.

These transformation mechanisms are important for our landscapes because they introduce the ideas of the coherence and ecological resilience of habitats:

- To what extent can our landscapes and their characteristic biocenoses assimilate all these transformations?

One thing is certain: it would be better to provide the natural environment with the best possible chances to adapt to the new conditions created by anthropogenic change and to withstand rapidly insetting climate change.

Thanks to the current utilization of geographical information systems, the basic cartographical method for ecological networks has become an efficient analysis and management tool for ecological networks — supported by a second method known as the “evaluation of the ecological potential of milieus” method (Berthoud & al, 1989). This latter approach uses available and measurable describers of habitats to establish a “dashboard” for ecological networks that allows an understanding of the level of efficacy of the habitats in question in all points in the landscape by comparison with other landscape elements.

From this, a landscape a “hierarchically organized ecological networks” model of landscape which allows spatial management to be properly oriented:

- By preserving priority spaces;
- By reinforcing strategically weakened zones;
- By reconstituting the ecological coherence of existing networks in significantly transformed landscapes.

The elaboration stages proper to this analytical tool for ecological networks are presented and illustrated by numerous examples of applications at different scales. After more than ten years of such applications, the approach has now been optimized by the utilization of precise numerical data and of high-performance analytical softwares that guarantee rapid results for large territories.

The various stages of the undertaking constitute a part of the elaboration process by means of the progressive iterations of the “top-down, bottom-up” type. This ensures both a successful validation process and a progressive improvement in the quality of results thanks to the acquisition of new data.

Preparatory stages consist of the establishment of a provisional cartographical model of the various specialized networks that are considered characteristic of the landscape in question, so as to arrive at a provisional general evaluation of the ecological potential of milieus, based only on numerical ground occupation data et on standard appreciations of their functionality.

These results are then validated by experts and refined by on-site verification in the context of local applications.

Possible landscape transformation scenarios for areas impacted by human projects, as well as dispersion test for key species, whose local distribution is known, can thus be analyzed with the proposed tool.

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Glossary

Buffer Zone	Space situated around nodal zones or corridors to protect them from the negative influences of their surroundings. A certain level of human activity inside buffer zones is implicitly allowed—or even encouraged where there is question of maintaining the traditional exploitation of milieus.
Continuum	An ensemble of milieus favourable to a particular ecological group and composed of a number of continuous elements (without physical interruption), including the marginal zones belonging to other continua or which are merely accessible for temporary activity. As a result a continuum contains: – One or more nodal zones; – Extension zones of a lower quality than nodal zones but which correspond to the same generic type of milieu. – Complementary margins that are partially or temporarily used by fauna characteristic of the continuum but which are of another typology of milieu. This external envelope serves an important role as a feeding and displacement zone for all of the fauna characteristic of the continuum. The use of this complementary margin depends on animals' ability to move away from boundary or refuge zones. Such continuum margins are very versatile. They notably serve as corridors for numerous generalist species, but also for some specialist species during their dispersion phase. The systematic designation of continua organized into specific, more or less independent networks was originally posited as part of the elaboration process that led to the SNEN. Five elementary continuum types are distinguished and their combination forms the national ecological network.
Continuum Marginal Zones	The ecotonal margins of a continuum (continuum buffer zones) are constituted of the various habitats of the landscape matrix that have not been designated as habitats belonging to the continuum. Nevertheless, this particular space plays an important ecological role by serving as dispersion corridors, food resource, and zone of social interaction. As a space where important biological phenomena take place, its boundaries are virtual. A margin is often no more than a few metres wide but, from a cartographical point of view, a uniform margin of 100m is employed so as to render them visible on synthetic maps. The functional width will be objectively ascertained by a detailed local analysis of field observations.
Continua Polyvalence	Given that a continuum is constituted by a number of ecologically similar and complementary habitats useful to its functioning, an ensemble of different types of continua necessarily creates overlap zones known as "polyvalence zones". These multifunctional zones allow contact between a number of different biocenoses, which locally causes a potential increase in biodiversity, but which especially allows the appearance of zones ecologically important for the reproduction or survival of certain species.
Connectedness	A parameter of the function of landscape that quantitatively measures the processes by which sub-populations of organisms are linked together in a functional demographic unit. A landscape sector's degree of connectivity is obtained by measuring the distance covered during the dispersion of a hypothetical animal. This animal moves through a landscape—transposed onto hectometric grid and offering more or less resistance depending on the milieu—from a starting place within a nodal zone.

Connection Network	Quality of the links between the mapped elements in a landscape's spatial structure.
Convention on Biological Diversity (CBD)	An international treaty adopted at the Rio de Janeiro Earth Summit in 1992. The convention has three goals: conservation of biological diversity; the sustainable use of these elements and the just and equitable sharing of the fruits of the exploitation of genetic resources. To date, it has been ratified by 189 countries. The signatories publish regular reports on conformity to CBD goals. The 2004 conference notably defined the principles of the eco-systemic approach that serves as the basis to this guide.
Corridor	A functional link between ecosystems or between different the different habitats of a species. Not only do corridors produce a favourable genetic effect, but also one that is advantageous to the species itself and to other interactions at the level of the population. Corridors are often classified in three types according to their specificity: linked to a linear structure; linked to the presence of refuge-islands ("stepping stones") or linked to the landscape matrix. Corridor terminology, which is strongly contradictory and variable, is employed in a variety of contexts (Bucek & al. 1996; Bennett 1999). ***Synonyms***: Habitat corridor, dispersion corridor, movement corridor, faunal corridor, ecological or biological corridor, bio-corridor, landscape link, green flow, etc.
Development Zone	Zone situated outside a network or partially isolated which would be capable of functioning as an extension zone if a nodal zone were to be established artificially or by appropriate management. A development zone can also remain as a refuge zone within the context of corridors.
Dispersion Effects	By fragmentation we usually refer to modifications of specific dispersion strategies within the fragments of an initial landscape: 1. In residual areas, colonization may compensate continual losses due to the local decline or extinction of populations. The more fragmented a landscape, the greater the average distance between habitat fragments will be. This will have the effect of reducing the level of recolonization in recently abandoned areas and will engender lower population densities in occupied areas. This, considerably reduced, level of dispersion can lead a high regional risk of extinction. The risk can, however, be significantly reduced by networks of corridors. 2. It should also be noted that—according to the theory of islands (MacArthur and Wilson 1967; Brown and Kodric-Brown 1977)—dispersion is greater in the vicinity of larger areas as these constitute the biggest "targets" and thus facilitate their recolonization following extinction. 3. Most species disperse themselves during their life cycle. Non-fragmented habitats are often composed of a mosaic of heterogeneous landscape elements that differ from each other both qualitatively and quantitatively. When dispersion is disturbed by fragmentation, species are no longer able to exploit this spatio-temporal variability of habitats in an optimal manner by "re-establishing the average" through particular local conditions. Fragmentation thus disturbs one of the essential mechanisms for the spatial stabilization of populations.
Ecological Network(s)	Habitats and their biocenoses are spatially distributed in available space according to the climatic and edaphic factors suitable to their development. In the life cycles of species, dispersion phases for surplus population always exist. These allow species to find new habitats and to swop genes. Such dispersion periods force individuals (propagules) to adventure into spaces which, though less advantageous, still temporarily offer sufficient survival conditions to carry out sometimes considerable migrations. The ensemble of regular and temporary habitats favourable to population development need to be organized into networks of accessible space that are termed "specialized ecological networks".

Ecological Sector	The definition of an ecological sector in a landscape corresponds to the account taken of the fragmentation mechanisms of landscapes: mechanisms due to human activities such as urbanization, the construction of transport infrastructures and the modalities of the intensive exploitation of natural resources. In a moderately transformed landscape, the ecological functioning of populations develops according to the discontinuous steps of propagule exchange flows. Thus, the following spatio-temporal steps are usually distinguished: the biotope, the natural district, the bio-geographical region and the biome. The ecological sector is artificially inserted into this succession of steps, usually between the biotope and the natural district. The ecological sector therefore creates a new ecological entity which needs to achieve a new equilibrium of functional autonomy, without which biocenoses would disappear. The question that then asserts itself is this: is the identified ecological sector sufficiently large and intact to insure the continued survival of the biocenoses it contains?
Eco-systemic Approach to Landscape	An ensemble of procedures for the analysis of habitats, biocenoses, and interactions in the landscape. The eco-systemic approach is based on the logic of an eco-systemic organization that comprises the evaluation of the incidences of anthropogenic actions that produce transformations in the landscapes. Landscape management according to an eco-systemic approach was defined at the conference of signatories of the Kuala Lumpur Convention on Biological Diversity of February 2004 (see Box 1). The "hierarchical ecological network", along with its associated procedures respects the principles agreed entirely.
Edge Effect	A further effect, distinct from spatial flows, appears because frontier zones often possess characteristics proper to the physical boundaries between habitats. Boundaries can also play an important role in the ecological dynamics of a fragmented habitat. One might suppose that boundaries are sharply defined. In fact there often exist large gradients of the degree of transformation of the original habitat—called edge effects—which are significantly appreciated by species present in habitat fragments. The complexity of the physical structure of boundaries has a strong effect on the degree to which fragments are penetrated by elements of the surrounding matrix. Thus, analyses of the landscape context constitute an indispensable and crucial step towards a better understanding of the way in which the fragmentation of habitats affects ecological communities and of how ecological networks are organized. As a corollary of boundary effects, an effect of the organization of flows can also be observed. This creates a highly significant increase in the probability of contacts with a given species when one is in the vicinity of a boundary between habitats or that of a physical obstacle. This major phenomenon of functional modification of landscape is used in the informing logic of organized systems (Atlan 1974; Berdoulay & Phipps 1985). The mechanism is largely exploited by predators for hunting, but it also constitutes the origin of numerous dispersion corridors in transformed landscapes.
Extension Zone	The ensemble of natural or transformed habitats that are attached to the same continuum. With respect to computer mapping, the extension zone results from the agglomeration of terrain occupation categories chosen to form a continuum. It is implicitly axiomatic that an extension zone is complementary to one or more nodal zones.

Hierarchical Ecological Networks **(HEN Method)**	Ecological networks can be mapped by the analysis of the distribution of conditions favourable to the development to one or more species possessing the same ecological affinities so as to define potential continua. By knowing the migration capacity of species, particularly outside their usual habitats, ensembles of organized habitats structured in specialized networks can be selected. For practical reasons groups of species (guilds) are defined using roughly analogous habitats, which allow the description of a landscape. In fact, however, each species has its own network of habitats which overlaps with other sufficiently similar networks that they can be grouped together in easily identifiable generic continua. The use of various criteria to characterize ecological tendencies (factorial axes) allows the importance of three factors—essential for the definition of the ecological potential for the development of a habitat or a complex of habitats—to be evaluated. These factors are: QUALITY, CAPACITY and FUNCTION. The method known as the “ecological potential value of milieus”, described by Berthoud & al. (1989), allows the evaluation and thus the hierarchical organization of all the elements of an ecological network. The “hierarchical ecological network” method uses this latter method in a GIS assisted mapping of the natural and transformed habitats of a landscape in order to produce an evolutive eco-systemic model of landscapes. It is intended to serve as a tool for the selection of complementary sectors useful for the definition of protected habitat networks and as a tool for the analysis of the impacts of all planning projects (urbanization, transport infrastructures, modifications to spatial management, etc.).
Heterogeneous Landscape Effects	Habitat fragments should not be considered as islands, but rather as constituting the elements of a type of habitat incorporated within various ensembles of alternative habitats. Given that social organization is modified and that individuals disperse asymmetrically within heterogeneous landscapes, habitat fragments and the surrounding landscape matrix necessarily constitute connected factors. In this case, the consequences for exchange flows between separate habitats are as follows: 1. In the source-reserve relationship, for example, abundance in a reserve habitat mostly reflects the productivity of the source habitats. For highly productive habitats are likely to export food, materials and organization toward less productive habitats. When compared to specialist species, generalist species can persist in greater abundance in every habitat type that they use as they are advantaged by local temporal variability of resources or of the abundance of predators. During their dispersion through less advantageous habitats, generalist species usually lose fewer individuals. This last effect has been notably and convincingly documented for a wide variety of taxa within the biological dynamics of the fragmentation of the central Amazonian rain forest (Gascon & al. 1999). 2. An invasion of “exotic” species is always observed following the fragmentation of habitats. Harrison & Bruna (1999) proved, for example, that natural ensembles of small habitat areas are enriched by the “overflow” from neighbouring communities, while simultaneously losing a few specialist species that are present in the large areas of primary habitat. Thus, forest bird species are more vulnerable in small fragments because of the influx of predatory generalist species originating in the surrounding matrix (Fahrig & Merriam 1994).
Individual or Species’ Fitness	English word meaning « physical training ». About living organisms, “fitness” is to be understood as an ensemble of physical or genetical capacities that might enhance an individual or a species’ adaptability to environmental changes.

Guild	This designates a group of ecologically close animal species occupying the same habitat, whose available resources they exploit together. The notion of the **key-guild** is concerned with a group of species selected for their emblematic value of being able to illustrate the issues of ecological networks. Thus, numerous insects serve as bio-indicators of habitat quality, while ungulates and birds serve as indicators to characterize network functions.
K and r Strategies	Concerns species possessing different reproductive strategies to maintain their population level. A **K strategy** species is generally a large species that reproduces little and prefers stable ecosystems. The strategy is based on the survival of adults. An **r strategy** evolutive is generally a small species that reproduces rapidly and prefers recent, rapidly evolving habitats. The strategy is based on rapid reproduction and a large number of individuals.
Landscape Approach by Protected Areas	The protected spaces approach to landscape is the result of an administrative perspective on the management of natural heritage that is founded on a selection of habitats and species considered of particular interest because of their rarity, the risk of their disappearance and/or their biological richness. This restrictive approach was the one adopted as the basis of the European strategy for the development of a pan-European ecological network. By virtue of the principle of respect for ecological coherence and resilience, stipulated by articles 3 and 10 of the Habitats Directive, its follows logically that networks of this type are dependent on the eco-systemic habitat networks to which they belong.
Landscape Matrix	General term used to designate an ensemble of varied habitats without any distinct dominant type that would otherwise allow particular continua to be evoked. In the selection by protected species approach, notably adopted for the pan-European network, the majority of ordinary landscape elements are included in the landscape matrix. In this context, some corridors can very well function by exploiting the landscape matrix. The term is not used in the hierarchical ecological networks method as all spaces are attached to one or more continua.
Meta-population	A population, occupying an ensemble of more or less dispersed habitats, which is constituted by a number of sub-populations that die out or locally recolonize favourable habitats.
Modes of Migration	A number of different types of migration mode are recognized and need to be taken account of in an ecological network: a) **Ground migration,** passive for flora (zoochore dissemination), active and passive for fauna, among which three migratory modes, functioning at different scales, are usually distinguished: – A mode proper to fauna whose mobility is strictly limited to contiguous habitats situated along forest margins, hedges, banks, roadsides and riverbanks (case of small mammals and numerous insects). – A mode proper to slow-moving fauna and which use undergrowth and advantageous structures for short displacements allowing them to reach various vital milieus (case of batrachians, reptiles, certain mammals and numerous insects). – A mode proper to fast-moving fauna that often move out of cover over long distances, but which always make the best use of existing refuge structures. b) **Aquatic migration**: numerous aquatic or amphibian species, but also the involuntary transport of floral and ground faunal species caused by falling into running water or by surface runoff during rains. Thus, regional hydrographical

	networks are predetermined to play a role of natural dispersion infrastructure for species, and thus that of biological corridors. This essential role of watercourses, in all landscapes transformed by human activity within ecological networks, alone justifies the maintenance of **areas of liberty sufficient** to the development of natural watercourses flanked by their natural vegetation. c) **Aerial migration**: proper to birds, bats and numerous arthropods. It necessitates the existence of visual reference points and/or staging posts allowing rest and feeding. These species, therefore, make full use of network structures that are defined *a priori* with regard to their use by ground fauna. They can, however, reach isolated sites more easily through the air without any other connection. Although apparently different to ground or aquatic networks, an aerial network in fact possesses numerous similarities in terms of obstacles and/or guiding threads present in the landscape. Thus, for actively migrating species, the shortest distance between habitats is often what defines the best route, as numerous isolated ground or aquatic zones usually remain accessible to aerially migrating species. These isolated zones (dormitories, rest sites, reproduction or feeding sites) occupy a special place in ecological networks inasmuch as they sometimes serve an important function even though they are often disconnected (ex-continuum from a cartographical perspective) from other complementary habitats. Nor should it be forgotten that windborne passive transport plays a very significant role for numerous insects as well as the seeds of certain plants. Although this dispersion mode is regulated by different rules (wind currents, prevailing winds) that are linked to local and regional climates, it nevertheless constitutes predictable network systems susceptible to modelling. Thus, the creation of a forest break or a roadway will significantly change local aerial migrations of numerous arthropods.
Nodal Zone	The sector of a continuum in which species or their principal ecosystems are present and where their vital conditions are all united for the development of the biocenoses characteristic of the continuum. ***Synonyms:*** Reservoir zone; source zone; core sector; bio-centre (IUCN 1996); high biodiversity zone; biodiversity core; “hot spot”; heart of nature;
Potential Ecological Value of Milieus (Method)	The method, described by Berthoud & al. (1989), serves to define the impacts of modification caused by a project resulting in qualitative and quantitative alterations of natural habitats in a given landscape. The method uses a range of measurable criteria that permit the evaluation of the importance of the three factors (QUALITY, CAPACITY and FUNCTIONS) determining the ecological value of milieus, which consist of ensembles of network-organized habitats. This value is obtained by the equation VE = Q x C x F, as these factors are connected and cannot be null. This mode of evaluation is just as applicable to a habitat as to an eco-complex of habitats or to a sector. It is used in the mapping of the hierarchical ecological networks method in order to differentiate the various elements belonging to a network.
Propagules	Elements of a biocenosis (faunal and floral) subject to dispersion mechanisms.
Refuge Habitat	A natural or artificial space offering a temporary hosting structure for migrating fauna. These are often constituted by residual microhabitats located in biological corridors. ***Synonyms:*** refuge islands, relay biotopes (“stepping stones”). ***Examples:*** spinneys and copses, ponds, grassy banks within intensive agricultural zones.
Sector Effects	1. The fundamental effect of fragmentation is to reduce the coherent spatial entity of a given habitat into numerous sectors. Inevitably, this causes a reduction in its biological diversity.

	2. Given that each portion of a landscape is constituted by an ensemble of habitats, any reduction in the surface area of a sector almost always leads to a reduction in the habitat diversity initially present in the landscape. In the smallest fragments, some habitats can become rare or even disappear altogether. This transformation not only affects specialized species (often rare), but certain more generalized species too. This is particularly true for batrachians whose ponds have disappeared from the original sector. In the case of species whose density is fixed by the area of their territory, any reduction in the size of the sector implies a reduction in the population. Reduction in population size increases the risk of extinction even where the environment is favourable to the degree that the species would normally be able to persist in it.
Specific Interaction and Food Chain Effects	An ecological theory of fragmentation concerns the dynamics of food chains and multi-specific interactions. It is banal to observe that interactions exist between all the species incorporated in a network and that, further, these interactions can cause significant overflow effects on the whole dynamics of a community or a food chain.
Spatio-Temporal Evolution (level of)	Specific composition changes in the structure and functioning of the eco-systems that characterize natural and semi-natural milieus according to changes in ecological parameters. These milieu dynamics are not progressive but advance rather by natural or artificial steps. In this way, we are able to distinguish the biotope, the eco-complex, the natural district and the biome as constituting the natural steps of evolution. The ecological sector on the other hand is an artificial step created by the fragmentation of the landscape due to urbanization, transport infrastructure construction and the intensive utilization of natural resources. Spatio-temporal evolution steps are regulated by the parameters of available stock and the spatial distribution of species, which will take more or less time to establish themselves depending on the accessibility of the various compartments in a landscape.
Stenoky	(From the Greek *sten*: narrow) The qualification of living organisms with very low tolerance to fluctuations in vital environmental factors. Because of this specialization, their survival is dependent on a small number of particular habitats. Antonym: euroky, qualifying species with a high tolerance to variation in ecological factors.
“Top-Down Bottom-Up” Approach	A working procedure that allows the drawing up of a consensually agreed document or map concerning the use or planning of a given territory. The procedure is both iterative and progressive, inasmuch as the principles, intentions and objectives of a given project are described so as to be subject to public negotiation. Ideas and propositions can come just as well from above—through an instigator in a central administration—as from below—as a result of the reactions of local protagonists familiar with the particular context of a given terrain.
Ecotonal Network	The ensemble of continuum buffer zones used by a large number of ubiquitous species. Without going so far as to speak of a veritable network of boundary habitats, there does exist a large number of species which take advantage of all the different types of ecotonal buffer zones to increase their populations. This is the case for numerous species of small mammals, mustelidae, hedgehogs, the majority of reptiles and innumerable invertebrates. In a highly fragmented landscape with a varied mosaic of habitats, ecotonal networks are dominated by a very small number of specialized species. In fact, the ecotonal network constitutes an ensemble of natural corridors available to the majority of species originating in all types of continua. **The appropriate management of all ecotones constitutes a strategic issue for the maintenance of habitat connectivity.**

	The significant development of ecotonal buffer zones is a subsidiary mechanism of the fragmentation of natural habitats. This fragmentation first generates an enrichment of biodiversity, but later causes degeneration towards a reductive standardization of the landscape if fragmentation is too severe.

APPENDIX

List of appendix

1. **Table of distances to propagule edges for some milieus.**
2. **Tracking Chart for Ecological Indicators in a Corridor**

APPENDIX 1

Table of distances to propagule edges for some milieus

	Forêts de feuillus						Prairies mésophiles						Zones humides						Cours d'eau					
Groupe faune :	0-5 m	5-10 m	10-20 m	20-50 m	50-100 m	Total	0-5 m	5-10 m	10-20 m	20-50 m	50-100 m	Total	0-5 m	5-10 m	10-20 m	20-50 m	50-100 m	Total	0-5 m	5-10 m	10-20 m	20-50 m	50-100 m	Total
Ongulés	34	45	40	37	12	168	2	3	3	5	1	14	4	5	2	3	0	14	3	3	2	0	0	8
Carnivores	99	124	99	35	11	368	28	33	24	14	13	112	11	12	5	3	0	31	27	6	2	1	0	36
Petits mustélidés	44	47	29	5	2	127	22	19	3	2	1	47	7	5	2	0	2	16	39	13	4	0	0	56
Rongeurs	1226	1223	662	21	13	3145	1115	545	134	14	7	1815	235	157	67	14	3	476	361	171	12	0	2	546
Hérisson européen	9	7	1	0	1	18	7	0	1	0	0	8	10	2	1	1	0	14	5	4	2	0	1	12
Ecureuil roux	41	10	3	0	0	54	0	0	0	0	0	0	0	0	0	0	0	0	13	4	2	0	0	19
Coléoptères	733	311	12	0	0	1056	387	210	124	81	33	835	227	194	84	37	2	544	214	106	23	3	0	346
Orthoptères	423	137	111	5	0	676	2226	1127	936	29	7	4325	470	315	67	14	3	869	112	63	3	1	0	179
Lépidoptères	274	74	17	3	1	369	303	211	97	53	11	675	165	64	12	11	0	252	97	64	12	3	1	177
Odonates	4	11	7	3	0	25	1	0	2	0	0	3	423	295	33	11	3	765	212	113	33	7	3	368
Arachnides	8457	4125	113	2	0	12697	4236	3352	956	74	7	8625	4705	3326	1130	117	32	9310	2124	1934	524	14	1	4597
TOTAL	11344	6114	1094	111	40	18703	8327	5500	2280	272	80	16459	6257	4375	1403	211	45	12291	3207	2481	619	29	8	6344
% de contacts	60.6	32.7	5.8	0.6	0.2	100	50.6	33.4	13.8	1.6	0.5	100	50.9	35.6	11.4	1.7	0.3	100	50.5	39.1	9.7	0.4	0.1	100

Observations in the Limpachtal on the Swiss Plateau, from April to September 1988

(21 weeks of research).

Recording of contacts obtained over four milieu types: broadleaf forest, mesophilic grassland, wet zones and watercourses.

- By periodical trapping using micro-mammal traps set once a week for twenty-four hours;
- By permanent Barber traps (pots buried at transects perpendicular to arable farming edges;
- By direct observation of animal tracks or individuals carried out once a week.

The unploughed buffer zones of the studied milieus — varying in breadth from 4 to 6 m — is occupied by a nitrophile herbaceous fallow. It has not been subjected to systematic trapping.

The edge is defined by the first ploughed furrows.

List of species in dispersion or hunting:

Ungulates: roe deer and wild boar.

Carnivores: fox and badger.

Small mustelidae: stoat, weasel, polecat, stone marten, pine marten.

Rodents: bank vole, field vole, vole agrestre, field mouse.

Coleoptera: ground beetles

Orthoptera: 14 species

Lepidoptera: 27 species

Odonata: 7 species

Arachnids: 189 species

Global results: propagule distribution curves are very homogenous (see Fig. 12, Chap. 2.2.3). More than 90% of contacts are obtained in the first 10 metres of the edge.

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APPENDIX 2

Tracking Chart for Ecological Indicators in a Corridor

Date of biological audit: …………… Communes involved………………………..
Corridor designation: ……………… Designation of connected zones: ………………
General location: see plan ……………………………

	Nature of the indicator:	Initial state score	Current state score
	• **Determining indicators of QUALITY (Q)**		
Q1	Level of permanent anthropogenic disturbance		
Q2	Level of occasional anthropogenic disturbance		
Q3	Frequency of maintenance or exploitation work		
Q4	Part of corridor under controlled management		
Q5	Hierarchical level in regional network		
Q6	Quality of spatial management		
Q7	Degree of implementation of planned eco-infrastructures		
Q8	Diversity of continua in source zones		
Q9	…		
	Average value for QUALITY factor		
	• **Determining indicators of HOSTING CAPACITY (C)**		
C1	Compactedness / corridor area ratio		
C2	Breadth variability and average		
C3	Wealth of structuring elements		
C4	Abundance of refuge habitats		
C5	Pertinence of refuge habitats with regard to obligatory passages		
C6	Permeability of obligatory passages		
C7	…		
	Average value for CAPACITY factor		
	• **Determining indicators of FUNCTIONALITY (F)**		
F1	Average indicator of resistance to movement		
F2	Average level of standard connectivity		
F3	Frequentation level by corridor species		
F4	Efficacy of obligatory passages		
F5	Roadkill reduction		
F6	Extent to which determining species are taken into account		
F7	…		
	Average value for FUNCTIONALITY factor		
	Transitory ecological value of corridor (Q x C x F)		
	• **Indicators of external context:** (Each indicator has an intrinsic value inasmuch as it contributes to the value of the corridor).		
E1	Potential diversity of source zone A		
E2	Potential diversity of source zone B		
E1	Maintenance of continua ascertained by comparison		
E2	Stabilisation of anthropogenic disturbances		
E3	Increase in built-up areas		
E4	Confirmation of protected status in PLU		
E5	Acceptance level		
E6	Threat from projects		
E7	…		

Indicator	Reference and explanatory documents
Q1	Proximity and nature of disturbances. List and distance by case.
Q2	Regular or occasional disturbance by walkers, various users, domestic animals, etc.. List and intensity by case
Q3	Agricultural or landscape maintenance: mowing, planting, harvesting, treatment, pruning
Q4	Part of managed area / total corridor area
Q5	Level of scale: 1 = local; 2 = departmental; 3 = regional; 4 = national; 5 = international. Multiplied by 2 to obtain values out of 10 points
Q6	Level of satisfaction with regard to goals
Q7	Percentage of infrastructures implemented / planned whole
Q8	Diversity of continua in 2 source zones according to GDS data
Q9	Addition of possible indicators relevant to particular cases
C1	Data furnished by GDS
C2	Data furnished by GDS
C3	Appreciation according to reference model still to be decided
C4	Appreciation according to reference model still to be decided
C5	Appreciation of the development refuge zones in the vicinity of faunal passages
C6	Lists of passages and appreciation of their relative pertinence to species
C7	Addition of possible indicators relevant to particular cases
F1	Value data by land-cover type furnished by GDS
F2	Connectivity data calculated by GDS
F3	Audit of observations by faunal group
F4	Lists of passages and estimated efficiency by group
F5	Percentage reduction or increase in relation to initial
F6	Tendency according to the established initial state
F7	Addition of possible indicators relevant to particular cases
E1	Lists of species groups and estimated population sizes zone A
E2	Lists of species groups and estimated population sizes zone B
E3	Land-cover statistics furnished by GDS
E4	Inscription with appropriate caption in PLU / SCOT
E5	Acceptance by population
E6	Known current or planned projects
E7	Addition of possible indicators relevant to particular cases

Rules to ensure a pertinent evaluation:

- Always employ the same evaluation scale for indicators. A scale of ten is advised so as to maintain a good level of precision;
- Do not forget that only elements proper to corridors are being evaluated (corridor users). The appearance of irrelevant species originating in the landscape matrix is possible but does not constitute an improvement in the corridor’s functioning;
- Periodic and sophisticated tracking of species (photographic traps, video tracking, etc.) on faunal paths is useless if information is not also obtained concerning the general evolution of species activities, or the development of their population, both in reservoir zones and the corridor;
- Multifactorial evaluation as proposed here constitutes a long-term data collection and exploitation method that is at once efficient and demanding.