CHAPTER 3

Mediterranean Experiences in Connectivity

Connectivity in regional systems of protected areas

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Introduction

The loss, the fragmentation and the degradation of natural habitats is, nowadays, the first factor in losing biodiversity. The Navarrese landscape, which in olden times was dominated by dense and uniform natural communities, has been gradually cleared out in a centuries - old process common to many Eurasian regions, ending in the formation of a mosaic of tilled fields and human settlements. In the first stage of fragmentation, an overall increase in biological diversity can be perceived, for there is a coexistence of open - space, or ecotone, species favoured by human activity, with populations from the interior or adapted to scarcely transformed environments. But the process of fragmentation and diminution of natural habitats has continued until the natural habitats have been reduced to tiny and unconnected areas, transformed into islands immersed in a matrix made up of, tilled fields, urban areas and infrastructures where the shipwrecked from the original biota still survive.

The excessive fragmentation and the destruction of natural habitats has not only reduced the area available for wildlife organisms, thus placing at risk the survival of viable populations both at a local and at a regional scale, but has also brought about the interruption of ecological processes and the alteration of natural cycles, thus threatening the dynamic balance and the self - regulation of the natural systems.

The Navarre Network of Natural Protected Areas has been gradually established by taking as starting points those small - sized sites that could be under a bigger threat or those which, being important biodiversity concentration points, were more vulnerable to human activity. The majority of them are small - sized, fragmented and isolated areas surrounded by an intensely exploited territory.

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With the exceptions of all three Natural Parks and the *Foz de Gaztelu*, *Arbayún* and *La Caída de la Negra* Natural Reserves, the average size of the remainder of natural areas, the majority of which are fluvial copses, amounts to eighty - one hectares. Many of them are affected by the channelling and defence works that prevent fluvial dynamics and the natural evolution of fluvial systems.

Ecological diversity is a common asset that must be preserved, that is materialised and distributed throughout the territory and whose components do preferably occupy the least altered spots, carrying out, whenever is still possible, essential movements to guarantee their long - term viability. Numerous ecological processes, on whose maintenance depends the conservation of biodiversity and our own very existence, at least as we know it now, are not attached to finite and specific spots in the territory but require the existence of flows and movements. Therefore, the conservation of biodiversity depends on the maintenance of a territory's natural dynamics. An essential component of the said dynamics is the connectivity between natural areas, which is only rendered possible by means of the conservation and restoration of biological corridors.

The evolution of ecological theories and, in the main, the acknowledgement of the dynamics of ecological systems and that of the processes of colonization - extinction of the species, has lead to the rethinking of this static view of nature conservation. The idea is prevailing that protection measures in restricted areas ought to be accompanied by a reflection on the reservoir function of the territory as a whole, as well as on the buffer zones and the corridors, for they are important to guarantee the coherence of the said measures (Burel and Baudry, 2002).

The Community Directives on Birds (Dir. 79/409/EEC) and Habitats (Dir. 92/43/EEC) define the European regulatory framework for the conservation of biodiversity and establish the designation of Special Protection Areas for Birds and that of Special Protection Areas (SPA) which will create a coherent ecological network consisting of natural habitats and species habitats to be called, as a whole, Natura 2000.

Even though it conceptually assumes the concept of biological corridor, the Directive does not go beyond encouraging the member states to enhance the functionality of Natura 2000 by protecting those landscape elements making the dispersal and the exchange of species possible. However, it does neither establish

nor suggest any specific planning instrument or criterion that enables the integration of ecological corridors into the natural territorial structure of the member states; accordingly, we are again taking the risk that the network becomes a new inventory of isolated natural areas subject to variable protection schemes.

The works carried out for the selection of the Natura 2000 areas have provided an incomparable occasion to review the coherence of the basic territorial structure for conservation in Navarre.

Such structure, made up of natural areas large enough to encompass the areas with the highest ecological value, surrounded by buffer zones and connected by ecological corridors, will allow us to proceed from what was a catalogue of protected areas, including the most representative natural areas, however incomplete and scarcely representative of the Navarrese biodiversity, to a system of natural protected areas having internal coherence and harmoniously integrated into the rest of the territory (Figure 1).

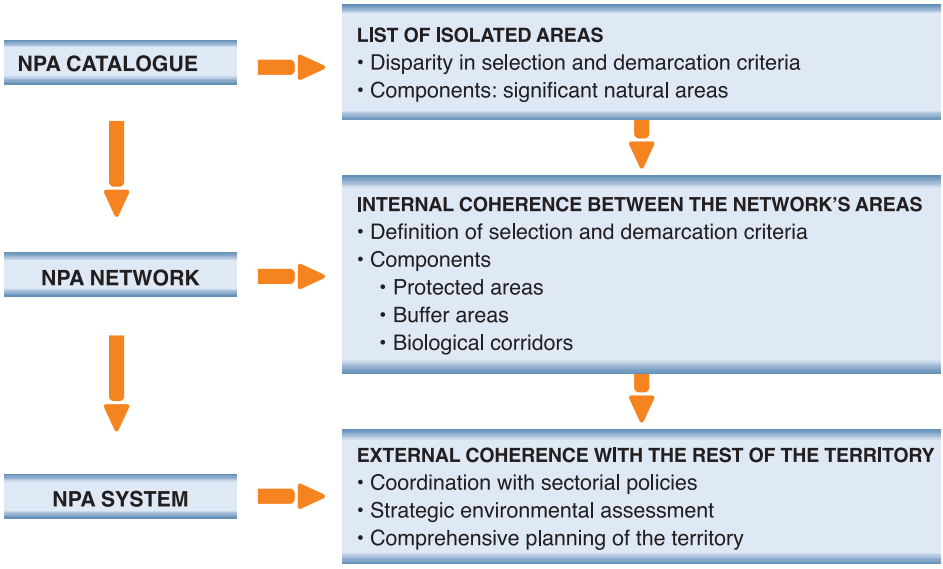


Figure 1. Evolution towards networks and systems of natural protected areas

This paper is stating, firstly, how a network of biological corridors, as structural components of a regional system of protected areas, has been defined (García, 1998). Secondly, examples are provided of some works concerning the definition of faunistic corridors.

Brief description of the methodology

The purpose of this paper is that of identifying, by means of the analysis of georeferenced information and orthoimages, the landscape structures that may play an important part in the designing of biological corridors. Landscape units are specially suitable to analyse the ecological integrity of an exploited territory at a regional scale, where it is important to interrelate the biological components and the processes in which they play a part along with human activities.

There are numerous studies in which significant characteristics or attributes of landscape elements have been defined when it comes to establishing valuations concerning the ecological quality of an area. Some of those most frequently used have been the biological diversity, the heterogeneity of habitats, the degree of naturalness, the rarity, the structure of the landscape and the vegetation communities, the use of the land, the vulnerability to man -made perturbations, the maturity of an ecosystem, the size, the shape, the connection value, the affinity, the fragmentation, etc.

For the use of these attributes in the ecological assessment of the territory it is necessary to have indication variables or descriptors which are easily mensurable: road density, use intensity and variety, relation between interior / ecotone / open eco - space species, slope, accessibility, isolation, ecotone length, permanence of the biomass in the ecosystem, etc.

The usefulness of either attribute depends on its efficiency in reflecting what we want to measure, on its availability or on whether calculations can be easily made at the scale of the work and for the whole of the geographical scope of action, as well as on its independence from the selected scale. It is, thus, frequent, to have to reject excellent descriptors due to their not being applicable in a systematic manner to the territory as a whole, for being quite difficult to obtain or for being highly sensitive to the change in the scales in which we operate, which reduces their value as indicators.

The systematic and homogeneous application of these attributes to a large territory requires the use of a GIS, in which calculation automatisms can be established and through which a large volume of information can be managed, it being possible to perform statistical treatments of information and to reflect the results on a cartographical base.

The selection of attributes makes it possible to define new themes to be dealt with. Once a specific weight has been established for each one of the new layers and for the classes existing in each of them, a multi - criterion analysis has been applied. The result obtained is a landscape's structural permeability map characterized by a weft of enclosures whose respective suitability as connecting elements or, in other words, for favouring the movements of a species or the ecosystemic flows, is different.

The results have been contrasted with orthophotoimages on a scale of 1:25.000 of locations of which there is a good field knowledge.

The superimposition of this net upon the Navarrese Network of Natural Areas (RENA) and the application of new criteria that make it possible to identify the linear elements that run between the areas in this network following a natural direction, enables us to obtain the network of potential biological corridors which is the aim of this study. In this manner a first image is obtained of Navarre's natural sustainable system with its three basic components: core areas, nodes and biological corridors (Figure 2).

The scale used in this work has been that of 1:25.000, with which it is possible to achieve an acceptable level of resolution in works at a landscape and regional scale, even to the point of enabling the definition of spots of the different types of habitats with an extension greater than one hectare.

Smaller elements of the landscape, such as untilled margins or hedgerows, are excluded. However, these microelements of the landscape do perform an important connection and refuge function, above all, in intensive -use areas and in the case of multi - habitat[1] species, and must be identified in local - scale studies. For actions intended for the establishment of corridors at a local scale it is necessary to adopt more precise scales (1:10.000 and 1:5.000) or other scales fitting in with the grain of each species in the case of faunistic corridors[2].

[1] A multi-habitat species is that which exploits in a complementary manner different habitats throughout its life cycle
[2] The concept of grain of a species refers to its mobility and, therefore, to the extension of its territory.

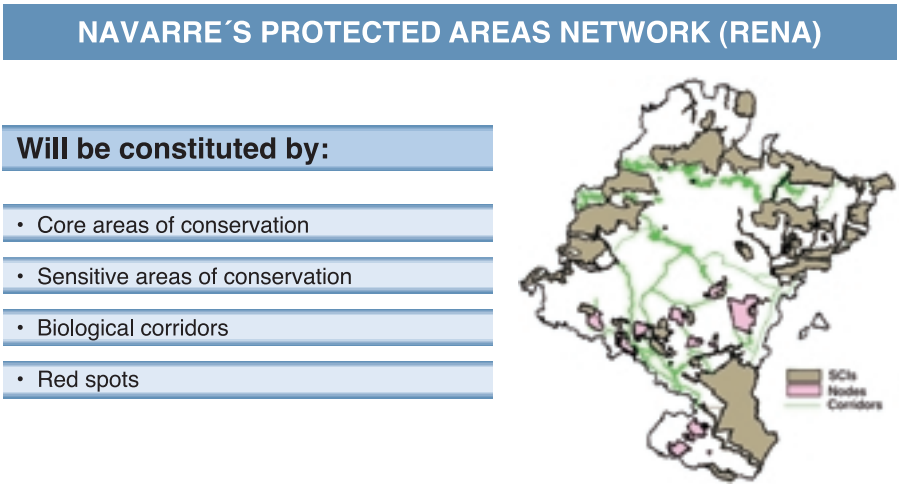


Figure 2. Navarre's natural sustainable system image

Preparation of the suitability map as connector

The criteria selected for the assessment of the suitability of the territory, which are stated below, make it possible to envisage the following analysis variables: Land uses, vegetation types, habitat heterogeneity, slope, orientation, size and shape of each spot, natural and man - made isolation, fragmentation, presence of habitats of community interest, density of infrastructures and land ownership.

As it has already been expounded, a specific weight has been attached to each one of the maps, as well as a value to each class within each map. These are combined at a later stage by means of an algorithm, which makes it possible to obtain a new structural permeability map of the territory with closed enclosures, distributed among the following categories according to its greater or smaller degree of suitability as connectors: A: High Suitability; B: Intermediate Suitability; C: Low Suitability; D: Unsuitable

The thematic coverages generated are described below.

Heterogeneity Map

Spatial heterogeneity is a measure of landscape diversity (number of elements and spots) and complexity (distribution or relative position). It can be quantified by using the number of types of neighbours in a plot and by means of their degree of interspersion. The latter refers to the amount of contacts between different plots and provides us with an average of the degree of fractioning of the territory or the number of ecotones. In conclusion, this is about identifying the number of different types of land uses adjacent to a point and the number of fragments of each type and, to some extent, the number of ecotones. It is admitted that, with the exception of the case of the forestal systems, heterogeneity entails a factor that increases the value of a territory with regard to its suitability as junction or corridor.

Numerous heterogeneity indexes have been developed: the number or the density of types of land use and the number of spots with different land use, the number of land uses existing along the diagonals of a grid, the total length of ecotones or the Shannon index; all of them referred to a grid as a superficial calculation unit. The complexity or sensitivity of these indexes to the scale of the work is variable.

In this occasion, in order to obtain the heterogeneity map we have proceeded to carry out a reclassification of the crop and exploitation map by resorting to class aggregation. Thus, a map is achieved showing categories with different man - action gradient. Later, the intermediate class has been subjected to a neighbour analysis by using, to that end, the unfinished map, without aggregations, defining a 10 x 10 pixel weft which amounts to 100 x 100 m^2. This treatment enables the reclassification of the said class into three different ones depending on whether they have only one use, two or more than two uses. These three intermediate categories have been contrasted with the map of Plot Concentration Zones (1992) downgrading to the next diversity class those concentrated zones, except in the case of monocultures, in which the value of the class has been maintained; those zones having a fallow rate above 30% have been upgraded to the next class; with the exception of those enclosures having more than two uses, whose class value is being maintained. Finally, the class of enclosures having a single use has been collated with the map of natural habitats, increasing the value of the class if the use was inventoried within any of the thicket typologies.

The final result is a five class map:

Class 1: irrigated crops, urban nuclei, buildings and infrastructures.
Class 2: unirrigated monocultures and exotic afforestations.
Class 3: two different uses and afforestations using Aleppo pine.
Class 4: more than three different uses. Landscape in mosaic.
Class 5: mature associations of natural vegetation.

Extension

Although the idea is not exempt from controversy, it is admitted that the larger the size of the spot the bigger its specific wealth will be, and so will the viability of the subpopulations.

The distance that separates the spots determines the exchanges of individuals and the movements. On the other hand, fragmentation is a phenomenon that can be perceived in a widely different manner depending on the species, as it is the case with the degree of permeability of the barriers. In much the same way, the functional distance between two habitat spots bears relation to the Euclidean distance between the same spots and the hostility of the territory separating them, which is also variable depending on the species. However, in this study it is assumed that the spots separated by a distance shorter than two hundred and fifty meters, a distance that can be cleared by the majority of species, unless impermeable barriers exist, make up a single functional spot.

According to the species three different classes are assigned:

A. Areas larger than one thousand hectares.
B. Between two hundred and one thousand hectares.
C. Areas smaller than two hundred hectares.

Isolation rate

The objective is to select the areas being favourable to species from the interior and having low perturbation levels, as well as those which, their extension being equal, have a smaller contact surface or perimeter (ecotone) with

the adjacent habitats. It is therefore an attribute that takes into account the "size" and "shape" variables of a spot.

Some authors suggest that the isolation rate be calculated as the area located farther away from a road than a given distance. However, this indicator hardly provides any new information with regard to the previously calculated artificiality rate, and, highly interesting though it is to analyse the effects deriving from some human activities, it is insufficient to assess the effects of natural fragmentation or those deriving from the changes in the use of the territory.

This is the reason why the procedure explained below has been followed in the calculation of the isolated areas:

The road network map has been superimposed upon the heterogeneity map, thus generating some buffer areas around the said roads. Simultaneously, a two hundred - meters buffer has been created from the perimeter of each enclosure towards the interior. Such a measure favourably selects the rounded - shaped areas as against the elongated ones having the same size, where the ratio of isolated extension to the perimeter is smaller, and where the "boundary effect" creates less important effects.

Human development map

Its purpose is that of detecting scarcely developed areas concerning which there is currently no expectation of development. The density of the road network can be a valid indicator of artificiality or degree of humanisation and transformation of the territory. Firstly, the survival conditions of the wildlife are better in areas with no roads or with low accessibility. Taking no account of other created effects, the road network has a threefold direct effect on wildlife: the elimination of natural habitats, the creation of barriers that hamper movement and the increase in accessibility and penetration by man and by general or foreign species.

In addition, road density is not only an indicator of movements but also, in general, of human activity. Because of that many planners do recommend to begin the design of regional networks of protected areas by mapping areas being scarcely developed and having a low road density.

Three classes have been defined according to road - density intervals:

A: areas whose road density is smaller than 0,5 Km./Km^2
B: areas with a road density between 0,5 and 1 Km./Km^2
C: areas whose road density is higher than 1 Km./Km^2

Anfractuosity or roughness of the ground

It is obtained by taking the orientation and the clinometrical maps as a starting point, the latter taking into account the variable *slope*. It provides a measurement of the unevenness of the ground by classifying it as flat, rolling, rough and very rough.

The combined value of the slope and the changes in orientation of the ground provides a value for the accessibility and exploitation difficulties of an area, the roughest areas being the same as those in which the said difficulties have favoured their conservation and the existence of low perturbation levels.

Had the *slope* variable been taken exclusively into consideration, the low hypsometry areas would have been discriminated against, in favour of mountain areas. In the areas having a high anfractuosity level and located in the medium and low zones of Navarre, the number of territorial units for certain key species is higher than that for flat zones. This criterion makes it possible, therefore, to consider the relief and physiography conditions that favour conservation by selecting areas less subjected to anthropical transformation.

Land ownership

It tries to assign a decreasing specific weight depending on whether the ownership of the land belongs to:

A. The Public Domain and the Government of Navarre.
B. Local Bodies and Associations thereof.
C. Few owners of large private farms.
D. Many owners of small farms.

This is a socio - economic criterion having a great repercussion on the maintenance and restoration possibilities of a corridor, for the management is simplified if the land is publicly owned or if, being public land, the ownership is scarcely fragmented, which makes it easier to reach agreements.

Analysis of the structural permeability map of Navarre

The insularity of natural or semi - natural areas in Navarre is more accentuated in the Pamplona Basin, the Medium Zone and the Ribera region, since the adjacent areas are usually farms which occasionally have high intensification ratios in the use of the land. Such is the case of the reticular and scattered structure of copses and wetlands associated with intermediate and low stretches of the main fluvial courses or with the endorheic basins. In the rivers, the best copses have been left isolated from fluvial dynamics, and the corrections of the river bed as well as the diversions of the flow due to canalisations, defence works, inefficient irrigation and small power stations, are causing a fall in the alluvial water table and symptoms of senectitude and deterioration are beginning to be perceived in the river - bank vegetation, even in protected areas, which brings to light that the protection model of specific and isolated areas has failed. Waterwheels and non - permeable dams prevent the movements of the aquatic species. In short, the lateral and longitudinal connectivity of the hydrological systems is seriously damaged.

In Central and Southern Navarre the agrarian and forested Mediterranean landscape and the pseudo - steppe areas predominate. Both areas can currently boast the dubious honour of containing the most threatened habitats in Navarre; the former, due to the abandonment of tilled and grazing lands; the latter, as a result of agrarian intensification. The acknowledgment of landscape heterogeneity in ecological systems has raised the question of the definition of *climax*, which up to then had been deemed to be a state of equilibrium. The concept of spot dynamics has given rise to the notion of *metaclimax*: a set of succession subsystems being out - of - step among them, but being equally needed for the operation of the system at the scale of landscape (Blondel, 1986). The maintenance of a pattern of man - made perturbations is responsible for the *dynamic and unstable equilibrium* that exists in the mosaic of spots in a different succession stage and with a characteristic distribution pattern that guarantees the coexistence, at the scale of landscape, of a large number of species.

Thus, within the context of the Mediterranean forest, where, in a strict sense, there are no specialized interior species, but multi - habitat species, functional connectivity does not depend as much on the existence of linear structures but, rather, on that of a mosaic created by the alternation of crops, grazing lands, boundaries and tended groves, and by their positions relative to each other. In other words, by their distribution pattern. In this way, it is possible to see how the big unbroken spots of holm - oak grove in the *Estella* region have less diversity than the heterogeneous and fragmented mosaics found in *Leoz* or *Ujue*. The area covered with holm - oak grove, gall - oak grove and thicket has been expanded at the expense of a simplification of the mosaic.

The same can be said about the Mediterranean cereal pseudo - steppe, being the more heterogeneous and biologically diverse the greater the fallow ratio is, and where there has been no concentration of plots. The highest - value spots coincide with those excluded from the Navarre Canal's irrigation project and are included like islands in the matrix of future irrigation lands. A comparison between the extension of these spots and the 1986 map shows that the said spots have been reduced as a result of the introduction of vast trickle -irrigation embowered vineyards and other small irrigated crops which, incomprehensibly, have been introduced in the areas excluded from agrarian intensification by the very impact survey carried out by the Canal.

The ploughing up and the elimination of boundaries, uncultivated plots and terrace boundaries, favoured by an undesirable application of the plot concentration procedure, are creating an alarming uniformity and the disappearance of the characteristic mosaic landscape. The problems stemming from the very design of the plot - concentration schemes, as well as the actions subsequently undertaken in the new plots by the farmers, are affecting the whole of Navarre and probably are the most serious environmental problem faced by rural areas.

In the case of the beech - tree groves in Atlantic and Mountainous Navarre, in spite of the lack of large natural designated areas, there is a certain continuity favoured by the existence of an unbroken expanse of wooded land and by a large network of Public Utility Woodlands. In these areas the problem would not be the fragmentation, the size or the distance from one adequate forestal spot to the next, but a model of forestry exploitation which has contributed to the existence of mono - specific masses of timber - yielding species, with straight shafts, few old trees, dead wood, clearings and underwood or other shrub - like species.

This not the case of the Atlantic oak woods at the bottom of valleys. The massive ploughing up carried out in the past and the drainage of floodable ground, intensified in the eighties in order to increase the area of fodder grasslands, greatly reduced their extension and increased the degree of fragmentation of the wooded masses. The intensification, the destruction of hedgerows and the elimination of alder groves likewise affected the territorial connectivity and, presumably, the countryside species.

On the other hand, the high density of roads, rural paths and forestal tracks increases the levels of perturbation and nuisance to the wild fauna deriving from accessibility by man to its natural habitats. The enlargement of the urbanized area and the proliferation of infrastructures has given rise to the reduction and fragmentation of the natural - habitat area, specially in the Pamplona basin. In parallel with these events, natural linear structures that used to enable the flow of biological components and ecological processes between the fragmented spots have been gradually lost or degraded.

In spite of it all and taking account of the stated differences concerning zones, Navarre still retains a functional network of ecological corridors made up of the river network, which still keeps in operation its connection capability in many stretches, the mountain alignments and a rural landscape consisting of a mosaic of pasture, crops and wooded spots. To which it must be added the remainder of the natural vegetation, that in the shape of hedgerows and thickets is still preserved in some areas, and the artificial network of cattle ways.

Selection of biological corridors

The ecological corridor network has been created by taking the structural permeability map and that of the natural priority conservation areas as starting points. When it comes to establishing corridors and selecting the spots to be integrated into them, we must pay attention not only to the permeability of each spot, but also to their relative position to each other and to the main conservation nuclei, by trying to identify the best possible alignments and the possibility of establishing a redundant structure. It must be said that the enhancement of the connectivity was one of the criteria used in the selection of priority conservation nuclei, as shown by the chain of areas and natural reserves that erstwhile were laying along the river courses, and which in the new proposal has been replaced

with long stretches that include the river bed, the banks and the frequently flooded areas. In this way, the network of natural areas is itself delineating large axes which are strengthened by the complementary network of ecological corridors.

To define the said network the fact has been taken into account that there are landscape and natural structures showing a clear directionality between nodes and nuclei, and that they can enhance the corridor's "unbrokenness". Such is the case of rivers and mountain ranges. The cattle routes, being a cattle - related infrastructure of human origin, have an important ecological value, be it as a result of their direct significance to the dispersal, or due to the recovery of the public domain as a natural habitat or as a support for recreational activities linked to the natural environment and capable of offering alternatives that make it possible to reduce human pressure on more vulnerable areas.

Both rivers and cattle routes run on public domain land, which reduces the introduction costs and facilitates the future management of the corridor. In the majority of cases, the degree of intrusion on the cattle routes has been such that they no longer can be recognised on the ground. Something similar happens with the river banks, which have been reduced to just the margins of the river bed.

However, the establishment of a coherent natural structure must be a long - term objective, which occasionally will entail the taking of decisions bearing the future in mind. Which is why in the current definition of potential corridors any capitulation and resignation attitude in the face of such intrusions must be avoided. That involves the selection not only of those linear structures which currently still maintain a certain degree of connectivity, but those that, potentially, may and must recover it.

To rivers, cattle routes and mountain ranges, the reticular structures that have been identified in the preceding process must be added.

By virtue of what has been stated, to obtain the layout of the biological corridors the following maps have been superimposed:

- Sites of Importance to the Community and conservation - sensitive areas (RENA).
- Structural permeability of the territory, previously obtained.
- Hydrological network including the main river courses and the main and secondary tributaries.

- Inventory of habitats belonging to the Natura 2000 Network.
- Cattle way network.
- Hypsometric areas.

The node and scale outlines are established in accordance with their demarcation in the suitability map. The layout of the corridors linking them to each other and to the nuclei has a fixed width of one kilometre in corridors, in the case of landscape structures. A variable width has been established for rivers since there is no demarcation, apart from exceptional stretches, a buffer area has been defined in each bank to demarcate them, being five meters wide in the irrigation channels; twenty - five meters wide in the upper courses; fifty meters wide in the intermediate or in the very narrow stretches and one hundred meters wide in the lower stretches of the main river courses. This latest width corresponds to the policing area established by the Water Act currently in force. For the cattle routes the width has been established as assigned to them according to their individual category.

The precise demarcation of the width and the redundant structures at a reduced scale must be assigned in the definition work at a local scale, following the methodology applied to the demarcation of the Sites of Importance to the Community on a scale of 1:5.000.

In short, the criteria chosen to assess the suitability of the territory as a biological corridor make it possible to envisage the following analysis variables: land uses, presence of habitats of interest to the community, similarity of the habitats to be connected, size (selection of well preserved areas smaller than two hundred hectares and not included in the previous phases), hypsometry, land ownership, linearity and natural directionality. Other criteria of interest, such as the connectivity rate, calculated as the opposite of the number of interruptions - barriers or as the number of connections, will have to be applied at a local scale or in faunistic corridors, for the perception of a barrier is different depending on the species.

Faunistic corridors at a local scale

The utilization of the landscape scale is useful in planning and regulating the territory. In this way it is possible to foresee how is regional connectivity to be affected by large projects for the conversion of unirrigated into irrigated land, or

the isolation or barrier effect that can be created by large infrastructures. It is likewise possible to identify big connection axes between the main ecosystems that can be defined within a territory at a regional scale, as it happens in the case of the beech - tree groves, the oak forests, the Mediterranean woodland or the pseudo - steppe agrarian systems.

But these works at a landscape scale must be given concrete form with others at a local scale in which the resolution of the information handled be more precise and the socio - economic aspects affecting the establishment, the maintenance and the management of the corridor can be approached with sufficient detail (Figure 3).

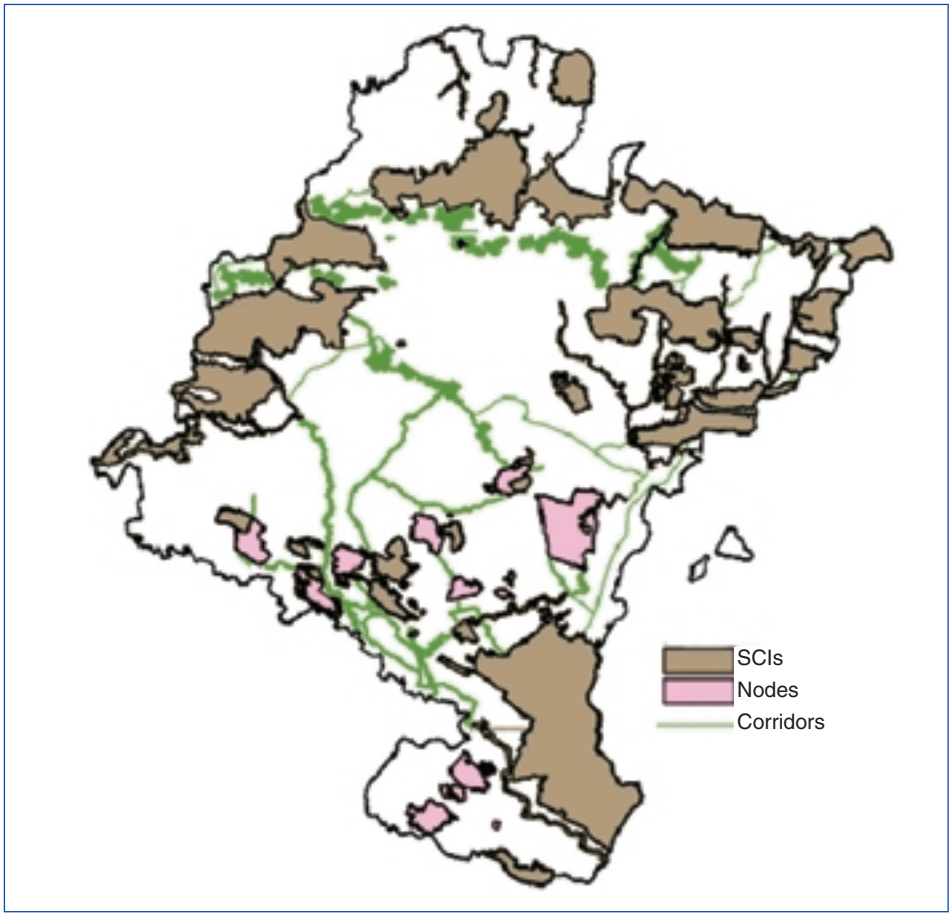
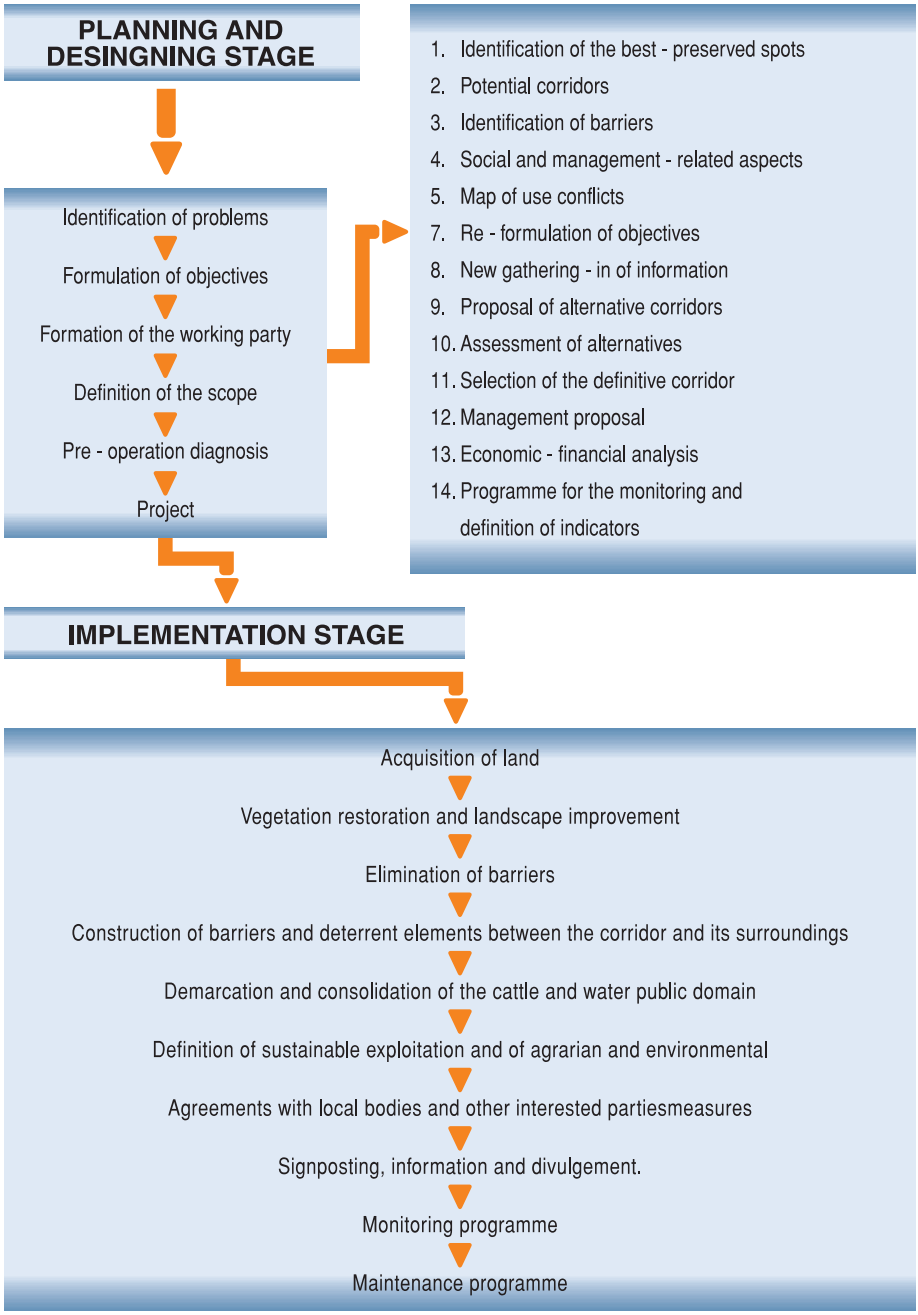


Figure 3. Definition of corridors at a local scale

DEFINITION OF CORRIDORS AT A LOCAL SCALE (Algorithmic model)



When it comes to establishing the faunistic corridors account must be taken of the ecological requirements of the species for which it is desired to connect appropriate habitats. Since it is not always possible to carry out an species - by - species analysis that encompasses all those that must be the subject matter of conservation programmes, there is a tendency towards the definition of functional groups. The importance of a correct selection of these groups is vital; many connectivity studies define a "typical species" by using some requirements so general and sketchy that the results are hardly believable when one thinks of any particular species.

On the other hand, our knowledge of the vital requirements of many species and their movements are so scarce that it is indispensable to compare it with the "field truth" and to establish monitoring programmes. In short, it is obvious that the more specific the objectives of a corridor and the better adapted its characteristics to these objectives are, the more effective it becomes.

In the specific management plans for Natura 2000 locations which are being prepared in Navarre, certain connectivity problems for different species or habitats have been dealt with. Some of the cases so studied are briefly stated below.

Study case 1. The medium - sized beak (Dendrocopus medius)

Situation:

Its peninsular population has been reduced to isolated and far - away subpopulations (three are known in Navarre). It only has a presence in oak forests, which, in Navarre, is the type of forest whose potential area has been reduced to the greatest extent, and the one which is most fragmented.

Requirements:

Strictly forestal. It needs spots with a minimal extension of ten hectares to consolidate territories, and between thirty and forty hectares to establish a viable population. Its numbers are significantly reduced below the one hundred hectare mark, the advisable size amounting at least to three hundred hectares.

Movements:

The minimal movement distance verified between forestal spots is nine kilometres. To cover it, interspersed hedgerows and thickets are required.

Measures:

1. Mapping of the potential area of hygromorphic oak forest.
2. Identification and selection of owners' plots and plots intended for restoration.
3. Promotion of hedgerow and thicket restoration projects within the framework of the offer of incentives for forestry and afforestation of agricultural land.

Study case 2. The agile frog (Rana dalmatina)

Situation:

This species is closely linked to the floodable oak forests at the bottom of the valleys. These oak forests have been replaced to a great extent with fodder grasslands and their land has been drained, which has brought about the rarefaction of the species which, as it is the case with its habitat, is highly fragmented. Nowadays it only has a presence in some nuclei in Navarre and in the Basque Country.

Ecological requirements:

Weft made up of small wetland patches close to each other and near to clearings in floodable oak forests, hedgerows and gallery vegetation, with a shady herbaceous strip next to the hedgerows.

Movements:

Metamorphosed individuals start their movements at random from the point of emergence in the ponds until they reach small clearings in the forest (100 - 200 m^2) where they find food. Between tree - less plots they move through

hedgerows and through the gallery vegetation of the small river courses, hunting in the herbaceous strip being closest to the hedgerow. The usual verified distance covered in their movements hovers between fifty and three hundred meters, the maximal being five hundred meters.

Measures:

1. Demarcation of the Natura 2000 area following the bottom valleys in alignment with the potential connection strip between the fragmented nuclei.
2. Marking of metamorphosed individuals and monitoring of their movements.
3. Inventory of the ponds still existing and which have been drained.
4. Preparation of restoration guidelines and restoration of thirty ponds over the next six years, preferably selecting the ones favouring the future connection between current residual nuclei.
5. Translocation of lays to the new pools and monitoring of the subpopulations.
6. Restoration of the hedgerow network between the ponds.
7. Maintenance of an unmowed herbaceous strip by the hedgerows, compensating the cattle farmers for the loss of fodder value, in order to favour the movement and feeding of the frogs.
8. Design of agro -environmental measures to prevent the drainage and the intensification of floodable plots.

Study case 3. The Mediterranean woodland

Situation:

Maximal diversity occurs with the mosaic of crops, grazing land and thickets of Mediterranean *Quercus* species. The flora and fauna from this habitat are in the early stages of evolution. Predators reach their maximum in these mosaics of covered or wooded areas where there is an abundance of typical preys. Forestal avifauna is characteristic of Euro - Siberian forests which adapts to Mediterranean conditions. However, this old mosaic is vanishing away. Tilled land is being abandoned and crops and grazing lands are being covered with thicket. The population of rabbits and other preys is diminishing and, along with them, predators are doing likewise.

Movements:

The species are multi - habitat; they feed in open spaces and breed and move under the protection provided by hedgerows, boundaries and thickets.

Measures:

1. Location of stockyards and active shepherds.
2. Selection of abandoned tilled lands laying close to the stockyards.
3. Irregular clearing of plots.
4. Sowing by using a select mixture of seeds.
5. Erection of stone heaps as landmarks and translocation of rabbits.
6. Entering into agreements with cattle -breeders for the maintenance of the cattle load and rotation.
7. Construction of fences and ponds for the cattle and the wild fauna.

Study case 4. The river Arga

Situation:

The last stretch of the river *Arga* corresponds to a Mediterranean river with a meandering course, with typical swellings that renovate the riparian ecosystems and frequently modify the river's course. However, over the past decades the river - bed was channelled, a small power station was built at the head of this particular stretch and agricultural or forestry crops replaced and surrounded the riparian vegetation which has been reduced to some meanders and to old, abandoned river - beds. The detraction of water by the power station and by the tilled lands is quite important.

Lateral and longitudinal connectivity:

The channelling of the river - bed increases the speed of the water and favours the erosion of the river - bed as well as the fast evacuation. Thus, the height of the river - bed has been lowered by several meters and the old, abandoned river - beds have been left isolated from fluvial dynamics it being difficult to re - connect them. The alluvial water -table has diminished and, having no regeneration flow, the residual riparian forests, which were once designated as

natural reserves have gradually evolved into mature stages, the whole of the hydric system being simplified and the wooded masses being deteriorated. The river - bed has been fixed and the processes of erosion and sediment mobility have been deeply altered. Lateral connectivity between the river - bed and the associated riparian systems has disappeared as has the alternation of fast - flowing and slow - flowing waters. On the other hand, the morphology of the river - bed and banks has been modified and the spawning points and the movements of aquatic organisms have decreased. In many points the strip of riparian vegetation has completely disappeared, has been reduced to a minimum or has been replaced with poplar groves with cloned species.

Measures:

1. Demarcation of the floodable zone.
2. Planification of uses being compatible with floodability, and analysis of costs and profits.
3. Agreements with owners.
4. Restoration of an unbroken strip of riparian vegetation.
5. Reconversion of certain intensive crops into integrated produce; of these, into ecological ones; of these into poplar grove and of these into copse.
6. Elimination of mounds and defence works to favour the floodability of copses and lateral connectivity.
7. Elimination or permeabilization of obstacles to favour the movements by the aquatic fauna and longitudinal connectivity.
8. Simulation of swelling flow in abandoned branches by means of irrigation ditches.
9. Acquisition of land.
10. Enlargement of the floodable area and, in the long term, facilitation of the lateral movements of the river - bed.

References

García, S., 1998. *Estudio para la constitución de una red de corredores biológicos.* Dirección General de Medio Ambiente. Gobierno de Navarra.

Burel, F. and Baudry, J., 2002. *Ecología y paisaje; conceptos, métodos y aplicaciones*. Ediciones Mundi-Prensa, 353 p.

Blondel, J., 1986. *Biogéographie évolutive*. Masson, París.