Connectivity and networks of natural protected areas. From the theoretical model to the practical view of management

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Introduction

The objectives of the Nature conservation policies have evolved over the last few decades by shifting from the placing of an emphasis on the protection of emblematic species or their habitats, as well as natural monumentality, towards a greater concern over the conservation of ecological processes in the landscape (Regier, 1993; Montes, 1995). Such an approach is the most appropriate to guarantee the services rendered by natural ecosystems and to deal with the undesirable effects of global change with greater assurances (Holdgate, 1996; Knuffer, 1995). The better knowledge of ecological processes in the territory, attained in the last few years, and the progress made in the field of institutional policies for the regulation of the territory and the protection of nature, make already possible a reflection aimed at the formulation of objectives concerning the creation of networks or systems of natural protected areas. In this paper we intend to analyse the scope of those policies whose purpose is to establish networks of natural protected areas in the light of current scientific knowledge. Only by starting from a free - flowing dialogue between the knowledge of ecological processes at the scales of landscape and region, and the realities of territorial management and conservation of nature, will it be possible to arrive at realistic solutions.

Many of the concepts usually utilized in this field are polysemic, and their meaning can vary depending on the context in which they are used. By way of example, the term network of natural protected areas does appear in the literature both to refer to the connection of ecological processes, and to the flow of management - related information that makes the coordinated running of a set of areas possible. Some networks have been conceived to facilitate the genetic interchange of populations, whereas the idea behind some others is to guarantee the existence of a representative sample of the variety of species and ecosystems from an ecological and regional range. In either case the knowledge and the operational instruments used for achieving its end will be different. In the following paragraphs we shall discuss some useful scientific concepts, and elsewhere in this paper the approach to the networks of natural protected areas will be dealt with according to their objectives and to the current state of the art.

The most appropriate space and time scale for the design of networks of natural protected areas, and for territorial planning at large, is that of landscape, for this is the scale used when the majority of the management and planning decisions are made. In this case, we understand by landscape the territorial mosaic made up of patches, each one of which is a differentiated ecotope. An ecotope would be the smallest homogeneous unit of landscape that could be mapped and which represents the spatial location of an ecosystem. The concepts of landscape and ecotope entail an observation scale which, generally speaking, matches up with the human intuitive / perceptive concept of landscape.

At a higher scale of analysis, the concept of eco - region is used to refer to territories occupied by the same types of ecosystems and species, and in which a characteristic combination of landscapes occurs (Forman, 1995). The region would, therefore, occupy a higher place than the landscape does in the territorial hierarchy, for it encompasses a larger territory. The eco - regional approach is being adopted by different international institutions as a framework of reference for the conservation of nature. By way of example, we can mention the biogeographical regions defined for the selection of ZECs to be included in the Natura 2000 Network, or the regionalization prior to the selection of the most representative areas carried out by the PEIN in Catalonia (Catalonia Regional Government, 1996).

The basic premise of landscape ecology is the existence of a close connection between the spatial configuration of landscape and the processes taking place within it (Forman, 1990; Wiens *et al.*, 1993). The configuration or structure of the landscape includes the nature of its elements as well as the spatial and topological properties of size, shape, frequency, neighbourhood, nearness and organizational pattern, which condition the ecological flows in the landscape. Theses flows of matter, energy and information may be due to physical factors (gravity, wind, water flows), or to the very mobility of animals and to the action of man, a uniquely efficient species in the horizontal transport of matter and energy. To understand the way landscapes work it is necessary not only to identify the flows and processes, but also to take into account the different scales of space and time in which they are given and the relations of hierarchical dependency existing between them (Klijn and de Haes, 1994; Levin, 1992; Wiens, 1989; Noss, 1990; Montes *et al.*, 1998).

Human activities have an influence over the organization of the landscape by affecting its beneficial functions. Of special importance are the reduction of natural areas, the nature and the length of the boundaries or contact lines between ecotopes and the density and the degree of spatial isolation. Linear infrastructures such as roads and urban areas, as well as those of intensive agriculture, create fragmentation, whereas ecological corridors and crossing points are structures which facilitate the permeability of the territory and reduce isolation. The structure of the landscape mosaic and its most significant variable, heterogeneity, help to explain the effects of fragmentation.

The territorial regulation as a whole, together with infrastructure, agriculture and nature - conservation policies, exert an influence on the organization of landscape. The maintenance of environmental services in the landscape must be dealt with through all these policies; it is, however, the policy of nature conservation the one that has taken this objective most seriously. The main purpose of the natural protected areas is the conservation of nature. They perform, therefore, the function of bastions from which the environmental regulation of the whole of the territory can be undertaken.

The conservation networks and systems and the natural protected areas are, therefore, a response by the institutions to the challenge of maintaining environmental services in landscapes and regions. Their goal is to approach conservation from a more integrated standpoint, by taking on the relation between the protected areas and its surrounding territory and by searching for coherent ways of regulating the territory which are in keeping with this goal, namely the maintenance of environmental goods and services.

The study of the ecological processes and flows at the scale of landscape has been dealt with from three main perspectives: the study of the role played by certain landscape structures with regard to the dispersal of species of special interest, the analysis of the role played by the territorial mosaic with regard to the maintenance of ecological flows and, finally, the ecological integrity at the scale of landscape. In the following lines we will be reviewing the current state of the art in these three study levels, then to contrast them with the reality of territorial management and conservation of nature.

Connectivity

One of the most frequent approaches to the study of ecological flows in the landscape stems from the need to guarantee the genetic exchange between subpopulations belonging to species of special interest. It is in this context that the concept of connectivity arises: the capability the territory has to permit the flow of a species among resource patches (Taylor *et al.*, 1993). It is, therefore, a property of the territory for a species or a set of similar species from the point of view of their ecological requirements and their dispersal capability.

For the study of connectivity mathematical models have been developed, both theoretical and applied to the solution of specific problems. The models simulate the flows or movements which take place in the landscape (individual movements, metapopulation dynamics, etc.), either in continuous (e.g.: Gardner *et al.*, 1989; Johnson *et al.*, 1992; Wiens *et al.*, 1993) or in discrete time (e.g.: Hanski, 1994). In certain cases (e.g.: Fahrig and Merriam, 1985; Henein and Merriam, 1990; Anderson and Danielson, 1997), the simulation models lose part of their value for not being spatially explicit.

Many studies are focused on one single type of habitat or of landscape element -binary maps with two categories: habitat and non habitat. However, it is possible to integrate the different types of elements without losing the information concerning the functionality of each one of them, thanks to the use of the Geographical Information Systems in the preparation of the simulation models (Baker, 1989; With and Crist, 1995; Gustafson and Gardner, 1996; Childress *et al.*, 1996; With, 1997). It is even possible to use in the models simultaneously different variables; for instance, a soil map and a vegetation map (O'Neill *et al.*, 1992).

By considering the different fragments of habitat, it is possible to make appraisals of the probabilities of occupation, extinction and colonization of the said fragments (e.g.: Opdam, 1990; Wiens *et al.*, 1993; Ims, 1995; etc.). For that purpose it is necessary to introduce into the simulation models the data concerning the size and isolation of these fragments (e.g.: distance to the nearest neighbour), together with other descriptive features of the spatial structure or the quality of the habitat found in these fragments (e.g.: Verboom *et al.*, 1991; Vos and Stumpel, 1995; Clergeau and Burel, 1997; etc.). In these models, data concerning the processes involved (growth rates, emigration, etc.) are usually related to the different fragments as well (Wiens *et al.*, 1993; Hanski, 1994).

The dispersal or connectivity models, already incorporated into the commercial Geographical Information Systems, provide cost distance maps which represent the effort required or the difficulty involved for a species to reach each point of the territory from the points of origin. By taking these connectivity maps as starting points, it is possible to work out the minimal - cost routes between the points of origin (Figure 1).



Figure 1. Model of connectivity between forestal habitats located in the Natura 2000 sites of the Region of Madrid.

- A Map of resistance (displacement effort) for a standard forestal species, acquired from the vegetation and land use map according to existing bibliography on forestal species.
- B Map of effort distances considering Manzanares as the starting point. The minimum effort routes to both Lozoya and South-East (white lines) are shown over the map of Natura 2000 sites.

It is shown the importance of natura 2000 sites in enhancing the connectivity from Monte de El Pardo to the North (Manzanares, Lozoya) and to the South-East (Manzanares, Jarama-Henares, South-East). The minimum effort route between Manzanares and South-East mainly coincide with the river Jarama.

The values of friction or resistance to the movement represent the cost or the difficulty which for a species entails the movement though places outside its habitat, understanding by habitat the ecotope which the species uses as feeding, refuge and breeding ground. For a species living in the woodlands, forestal ecotopes favour the movement, whereas open spaces put up resistance to the dispersal.

A unique case of connectivity is the one related to the connection between complementary territories having a specific function in the life cycle of a species; for instance, migratory routes for birds with stopover points, valleys and mountains and seasonal cycle, etc.

The main artificial causes of the loss of connectivity are the development of linear infrastructures and the reduction of the extension of the habitats as a result of the exploitation of the ecosystems, and the use of the ground for other activities. The fragmentation into small patches of the originally larger ecosystems brings with it population isolation problems which may lead to the gradual vanishing away of the species, starting with the smaller fragments.

The identification of critical isolation and fragmentation thresholds for the species and the search for solutions to guarantee connectivity are the most relevant tasks in those territories undergoing strong transformation processes. When the goal of keeping large extensions of ecosystems in good state is no longer attainable, the most appropriate formula may consist in looking for the optimal layout of the residual fragments, by striving to achieve their linkage.

Barriers may be brought into existence by the natural operation and structure of the landscape, as it happens in the case of mountain alignments and large rivers, or by human influence due, in the main, to road infrastructures, urban development, intensive agriculture and deforestation. Barriers bring about the interruption of ecological flows as a result of the breach of the habitat's continuity.

Likewise, certain landscape elements may provide connectivity by having smaller friction values than those of the surrounding matrix. Such elements are usually considered as corridors, for they effect the acceleration of the flows running through them, and they are generally related to the movement of species, even though these elements may also play a part in the control of other flows such as those of water, nutrients, etc (Burel *et al.*, 1993). Linear elements such as hedgerows, river banks or walls quite often play an essential role in the maintenance of connectivity for certain species in landscapes in which a hostile matrix predominates, which is the reason why their preservation or restoration may be one of the first actions that guarantee connectivity between protected areas (Figure 2).

Connectivity has been a field of frequent interaction between landscape ecology and conservation biology, for the models and the results make it possible to lay down landscape management recommendations being beneficial to specific species. These models have a direct application to the design of ecological networks and corridors (Bielsa, 1996; Pearson *et al.*, 1996; Brown and Veitch, 1995; Bennet, 1999).

Permeability

A second level of analysis, much less frequently found in the scientific literature, consists in taking into consideration not only certain species and their habitats, but the landscape mosaic as a whole, with the variety of elements that it contains and the different species that make use of them.

For some authors landscape connectivity is a general terms into which the concepts of corridor and barrier are integrated, and which indicates how the ecological flows respond to the structure of the landscape (Noss, 1993; Forman, 1995). Although it is frequently used as a synonym of connectivity, we shall be reserving the term *permeability* for a more general property of the landscape related to the maintenance of the connectivity for each and every organism that inhabits it. A landscape is permeable when the dispersal of species throughout the different ecotopes is guaranteed. This concept may also include the maintenance of the flows by avoiding perturbations. This relation depends on the physical or structural aspects of the landscape, as much as it does on the characteristic of the ecological flow and on the very size, behaviour and mobility of the animals (Taylor *et al.*, 1993).



Figure 2. The role of lineal elements in connectivity. Through these figures the landscape connectivity for a forestal species in the South part of the Guadiamar basin (SW Spain) is studied. A simulation of connectivity changes after applying three restoration measures is performed: cattle road revegetation; riverside vegetation restoration and small landscape elements restoration. Connectivity patterns are different for each analysed assumption, defining different dispersion routes between the selected areas. The length of the minimum effort route between the source areas A and B and the accumulated resistance across the route are useful parameters for the quantitative evaluation of differences among assumptions.

Since the number of species having a presence in a territory can be very large, landscape permeability cannot be taken as the sum of the connectivity values for each one of the said species. Some species are quite demanding with regard to habitat requirements, and studying the requirements that have to be met to enable their mobility at the scale of landscape could make sense (extension of the favourable habitat, size of the patches, distance from one to the next, existence of corridors, etc.). However, the greatest part of the species make a multiple use of the landscape by using different patches at different scales of time and space, which provides them with different capabilities at different stages of their life cycle. The distribution of species is not steady, but it constantly varies in time and space (Smallwood et al., 1998). Many species can use a certain type of habitat during the summer and a different one during the winter, to breed or to feed themselves, or they can even use different habitats in daytime and at night (Law and Dickman, 1998). Furthermore, it has been pointed out that the more general species, widely distributed over the landscape and which make a multiple use of its resources, ought to be the subject matter of conservation too, since, in addition to contributing to general diversity they may have a greater capability to respond to uncertainties (climatic change, changes in the use of the land) than rare, threatened or relict species do (Holdgate, 1996).

Despite the importance of environmental heterogeneity and that of the multiple use of the landscape by the species, very little importance has been attached to the role of landscape mosaics with regard to permeability. It is none the less obvious that the conservation of flows of species within the landscape cannot be restricted to just one or to a few of them, but it is necessary to tend towards the maintenance of the possibility of dispersal throughout the landscape of the whole set of species that inhabit it.

In this regard, certain forms of heterogeneity facilitate the dispersal and the movement of the species. The heterogeneity of the landscape is very closely linked to the distribution of biodiversity (Kerr and Packer, 1997; Pino *et al.*, 2000). Thus, in Mediterranean landscapes it has been found out that the wealth of species is associated with a greater landscape heterogeneity (Figure 3). As a rule, the greater the heterogeneity of the landscape, the greater the diversity of species, for the coexistence of different types of lands use entails a greater wealth of habitats and enables the coexistence of groups of species that exploit different niches, which results in a greater global diversity (Farina, 1995, 1997; Atauri and de Lucio, 2001).



Figure 3. Relationship between landscape heterogeneity and bird species richness in the region of Madrid. Landscape heterogeneity, as the number of different land uses within a landscape (in this case plots of 10x10 Km²) is directly related with the species richness. This relationship is more important when considering species groups holding higher dispersion capabilities, such as birds. Meanwhile when considering other groups such as amphibious and reptilians is more important the presence of certain habitat types. A higher heterogeneity favours a higher resources availability, that may be used by a higher number of species, as well as increases the number of ecotone species.

This is the reason why semi - natural heterogeneous landscapes may play a crucial role as connection and buffer zones between far - away natural areas (Pino *et al.*, 2000). Landscapes being managed, but maintaining a mosaic of patches with different states of ecological maturity, in which plots more intensively managed are interspersed with patches of natural vegetation, can guarantee the diffusion of a wide range if species through them. This type of permeability, based less on the existence of corridors than on a landscape mosaic making the different ecological flows possible, can be achieved under certain conditions in heterogeneous landscapes, such as the Mediterranean agricultural ones.

On the one hand we must not forget that heterogeneity is also related to fragmentation. A very high degree of heterogeneity, with many different types of land use, may result in the fact that patch sizes be far too small, which may lead to a high degree of fragmentation, which means that the increase in diversity linked to the heterogeneity has, in general, a maximum value, above which it can diminish (Edenius and Sjölberg, 1997; Santos and Tellería, 1997).

Landscape heterogeneity is also related to the pattern perturbations such as fire, whose advance is hampered in landscapes made up of patches of different types of vegetation. The nutrient and material cycles may be slowed down in heterogeneous agrarian landscapes, in which patches having different degrees of maturity coexist. In the patches made up of mature ecosystems, nutrient cycles are slowed down, the runoff is controlled and, therefore, so are the flows of materials and the hydrological ones. For their part, exploited systems are characterized by a greater rate of renewal, by faster nutrient and material cycles and, occasionally, by a worse control of hydrological cycles. An appropriate distribution of patches creating mosaics of different types of land use, with a presence of patches of mature ecosystems having a low renovation rate next to exploited plots, favours the accumulation of biomass and the formation of soil, the retention of nutrients and the control of the runoff, as well as the movement of species through the landscape, thus guaranteeing connectivity between far - away populations.

Stability, integrity, health

A more integrative level of analysis in the study of flows within the landscape concerns the maintenance of ecological integrity. By ecological integrity we understand the capability of an ecosystem to perpetuate its function over time by following its natural way of evolving, and the capability to recover after experiencing a perturbation (Brown *et al.*, 2000). Integrity entails a greater strength (the system's overall capability to process matter and energy), a better organization or efficiency in the transfer and degradation of energy, and the capability to withstand perturbations (Westra *et al.*, 2000). A more unimpaired ecosystem would be capable of getting more useful performance out of solar energy than other less unimpaired one in its same location (Ulanowicz, 2000). Maximal integrity excludes human activities that use up energy and disorganize the ecosystem. Ecological integrity is a state of reference which points out the optimal state for the assessment of the ecosystems.

As a precedent we can mention the concept of "ecological stability", which has been in use since the eighties to provide a base for the design of conservation networks in Slovakia. Stability is defined as a dynamic capability the ecosystems have to maintain themselves and to renew the system's functioning conditions (in particular, vital conditions of the biological components of the systems) – specially by means of self - regulation mechanisms – after perturbations. It is expressed as the resilience, the persistence, the resistance to and the flexibility of ecosystems concerning perturbations, be they originated by man and / or by nature (Miklos, 1992, 1996) and it is directly linked to the aforementioned integrity concept.

In the case of those territories having undergone transformation as a result of human activity, maximal integrity is nor feasible. The most appropriate objective consists in maintaining the necessary integrity to keep the ecosystems healthy. The health of one ecosystem is the capability it has to support its structure and function over time against external stress (Costanza, 1992). It is, therefore, a threshold below which not only there is a drastic reduction in goods and services provided and rendered by the natural function of these ecosystems, but their very existence is being threatened.

The most adequate way of analysing the properties of integrity and health is the integrative approach provided by landscape ecology. Ecological integrity, as related to landscapes or regions, encompasses the representation of the whole range of native species and ecological functions with their natural variability, regardless of the local state of an ecosystem at a given moment in time. The space and time scales used reveal spatial patterns and processes impossible to perceive at detailed scales. For them to be studied it is necessary to look for indicators making possible the description and the diagnosis of the landscape's ecological condition, as well as an early warning system concerning it (Smallwood *et al.*, 1998), by following a hierarchical approach, from the regional scales to the detail of specific habitats or populations (Noss, 1995). Such indicators must provide an idea of the progress or regression of each territory and region towards or away from a better integration of human activities into natural ecological processes and vice versa (Table 1). Table 1. Some state indicators and landscape trends according to O'Neill et al. (1994).

INTEGRITY AND BIOTIC DIVERSITY

Number of pixels that change the status. Loose of corridors between patches. Length of natural patches borders. Area/perimeter relationships. Plots size distribution. Fragmentation and isolation.

HIDROGRAPHIC BASIN INTEGRITY

Changes in the agricultural and conurbation/ woodlands surface relationships. Universal equation of soil depletion at the scale of hidrographic basin. Vegetation distribution in relation to slopes and watercourses. Land uses arrangement.

LANDSCAPE STABILITY

Probabilities of disturbance dispersion (percolation theory).

Probability of disturbance occurrence.

Tendencies in land uses changes.

Indicators of economic activities changes, as for instance road network. Un-sustainable land use surface.

Other interesting approach consists in the modelling of ecological processes depending on the structure of the landscape. The most frequent models study erosion, hydrological dynamics or the dispersal of nutrients and polluting agents. With regard to the integrity and diversity of the landscape, for instance, the relation that exists between the landscape's organization patterns and the maintenance of intact biological communities is well known. Fragmentation and connectivity are measurable properties related to integrity. The capability to take in, to retain, to store and to purify water from a basin is closely linked to the pattern of land uses and to the types of cover. The sustainability and stability of the landscapes have also been related to the landscape pattern.

Taking region and landscape scales into consideration, the concepts of integrity and health must be based on the complementariness of functions among the different elements of the mosaic. The set of natural protected areas must be organised in the shape of a network or system so that it contributes to guarantee the ecological health of the territory as a whole. Within this mosaic, we shall be distinguishing the functions of the strictly protected natural areas, whose purpose will be that of guaranteeing the greatest ecological integrity, from the functions of other areas devoted to agriculture, cattle - breeding and forestry - related activities, whose purpose can be the maintenance of the ecosystem's health by meeting certain sustainability requirements (Goodland and Pimentel, 2000), and from certain intensive agricultural, urban and mining - related uses, etc, which will not be capable on their own of meeting the sustainability requirements, and which, only within the context of landscapes, are capable of assimilating this stress and will be feasible or admissible. The final purpose is that of guaranteeing the operation of basic ecological processes in the territory as a whole (Noss, 2000). The goal of a nature conservation network is to contribute to this general purpose of the territory. The success achieved by the protected areas should be gradually assessed in this context.

From theory to practice

The gradual maturing of the nature protection systems (Gómez Limón *et al.*, 2000; Carey *et al.*, 2000) and the verification that conservation based on the declaration of isolated areas is just not possible (Franklin, 1993), have given rise to the fact that in a growing number of countries the idea of establishing conservation networks is beginning to be taken into consideration.

The greatest part of the networks of protected areas currently in existence are no more than administrative coordination networks. The definition of goals for the set of areas managed by the same body, and their management following unified criteria, is, in itself, a huge progress in management but does not permit us to speak about real ecological networks.

We could speak about ecological networks when, in addition to this institutional coordination, there are links between protected areas (often known as core areas) consisting of territorial elements that facilitate the continuity of ecological processes (corridors). The application of the concepts of landscape ecology to the design and implementation of conservation networks has been slow due, to a great extent, to the scarcity of scientific knowledge directly applicable to the management, although it is beginning to yield results. In the European context, the first approach to the implementation of conservation networks stems from the EECONET initiative, an ecological network at a Pan - European scale which is articulated by means of three well - defined types of elements: core areas, corridors and buffer areas (Bennett, 1991). The best examples of areas developed by taking this model as a starting point are to be found in the northern European countries; specially, in The Netherlands and in Belgium (Hawkins and Selman, 2002; Múgica *et al.*, 2002).

This type of networks stems from the contributions made by French and Belgian landscape ecologists about the theory of corridors and connectivity in the landscape. In them, the habitat requirements of certain representative species (focal species) are used as a basis in the design of corridor networks linking favourable habitat areas. They are networks in which a somewhat reductionist view of the flows in the landscape prevails, which generally is aimed at guaranteeing connectivity for specific species. These networks preferentially consider the properties of the linear elements of the landscape within the maintenance of key ecological functions, among which a focal importance is attached to the dispersal of species.

It is not by chance that this type of networks have developed in countries heavily influenced by the action of man, in which the restoration of landscape and the creation of linear vegetation corridors linking small patches of natural vegetation immersed in an agricultural and urban matrix, have a predominant value.

Within the scope of the European Union, the Natura 2000 Network must also be mentioned, for it includes the concept of network coherence, although it does not define specific elements intended for the linkage of areas.

Networks based on the connection of protected areas through corridors have also been developed in the USA, although in this case a more important role is attached to the multifunctional character of the corridors. Their role in recreation, in hydrological control, their visual value and the control of pollution are specifically taken into consideration (Hawkins and Selman, 2002). The best known example is the Florida ecological network (*Greenways*). The network approximately encompasses half the total extension of the State, having more than half its connection network in protected areas or in Public - Ownership waters (Hoctor *et al.*, 1999). The eastern European countries, starting from a scientific knowledge more focused on physical geography and with a long planning tradition behind them, have developed conservation networks by taking as a starting point more integrational concepts such as ecological stability (Miklos, 1992; 1996). The theoretical foundation was developed in the academic institutions of Brno and Bratislava (Ruzika *et al.*, 1983; Miklós, 1989), and it was incorporated into the environmental legislation of the Czech and the Slovak republics from 1989 onwards (Múgica *et al.*, 2002).

This approach attaches greater importance to the maintenance of environmental goods and services, as well as to biodiversity and the beauty of the scenery. However, the reality of a landscape severely damaged by intensive agriculture and heavy industry prevails in the final design of the networks, which acknowledges a sharp difference between natural and artificial areas, and which maintains the already mentioned division into core areas (biocentres) and corridors (bio - corridors) (Hawkins and Selman, 2002).

The multiple use that the species make of the landscape and the connection between the greatest part of ecological processes and the heterogeneity of the landscape, make it advisable to adopt an approach which integrates human activities into strict conservation. Preferential attention must be paid to the conservation of the landscape mosaic, rather than to certain components thereof; and such an approach must integrate protected areas into the planning and the regulation of the territory.

Even though it is at an incipient stage of development, the Central American Biological Corridor can be shown as an example of biological network based on the properties of the landscape mosaic and on heterogeneity of uses, rather than on specific elements such as linear corridors. It is a regional cooperation instrument approved at the highest political level, whose purpose it is that of contributing to the conservation of biological diversity and, in parallel to it, those of fighting poverty and generating economic growth alternatives. It tries to achieve the interconnected territorial regulation, in the shape of a network, of the hundreds of protected areas existing in the large region laying between Mexico and Panama, in parallel to the integration of the social and economic activities of the local population and the maintenance of environmental services (Múgica *et al.*, 2002).

The most advanced step in the design of conservation networks would be taken when the criterion would not only be that of maintaining connectivity for certain species, but also the maintenance of landscape integrity. This should be achieved by means of the conservation of landscape configurations guaranteeing the maintenance of the whole set of ecological flows and functions, which are responsible for the environmental goods and services provided and rendered by landscapes to society. The great theoretical and practical difficulties entailed by the implementation of this type of approach mean that today the examples of networks based on these concepts be nothing more than theoretical or academic trials (e.g.: Smallwood *et al.*, 1998, Atauri *et al.*, 2000), although the concept of ecological integrity is being gradually incorporated into technical and political documents on the environment (Council of Europe, 1996; Stanners and Bourdeau, 1995).

In Spain there are several examples of administrative coordination networks, among which we would like to highlight the National Park Network, which has a Directing Plan (RD 1803/99, enacted on November the 26th), or the Catalonia Special Plan for Areas of Natural Interest (PEIN), which is an example of integration of protected areas into the rest of the instruments for territorial, sectorial and urban - development planning. It likewise includes the need to integrate agrarian and traditional sustainable activities and the diffusion of environmentally proper practices with a view to contributing to rural improvement and to avoiding rural depopulation (Catalonia Regional Government, 1996; Pintó and Vila, 1998).

With regard to ecological networks having functional connections between areas, there are still few experiences, although there are some interesting initiatives. Among them, we find the legal backing for the protection of linear structures in Extremadura, where Act 8/1998 for the preservation of nature and natural areas, does establish that ecological corridors and biodiversity are concepts to be protected.

The case of Navarre illustrates the integration of the system of protected areas into a Biodiversity Conservation Strategy (Navarrese Government, 2001). In it, great importance has been attached to protected areas as a vital element to guarantee the *in situ* conservation of biological diversity. The elements making up the network are nuclei or priority areas for the conservation, peripheral protection areas, conservation - sensitive nodes or areas, biological corridors

linking conservation areas to red points, small - sized and isolated relevant natural elements left outside the network, but important for the maintenance of ecological processes (García - Fernández Velilla, 2001).

The Strategy of the Andalusian Network of Protected Areas, currently in process of preparation, will mean the creation of a functional and interconnected weft between protected natural areas, and their integration into the rest of the territory through coordination by using different planning tools (Múgica *et al.*, 2002).

Considerations concerning the design of conservation networks in the Mediterranean area

Starting from the previously stated considerations, we can put forward some questions affecting the Mediterranean region in a particular way, and which should be taken into account in the development of conservation networks.

Firstly, it is necessary to take into account the restriction created by the Mediterranean climate. The scarcity of hydrological resources and their irregular distribution over time and space, together with the mountainous nature of the largest part of the Mediterranean region, bring about that the environmental gradients and the vectorial flows be highly significant. Soils, scarcely developed and located in steep slopes, are very sensitive to erosion when natural vegetation is altered and the soil becomes exposed to drying - up and to torrential rains. The appropriate representation of the environmental gradients must be one of the goals of the conservation network.

The environmental conditions typical of the Mediterranean region favour the development of sclerophyllous vegetation (leafy evergreen trees and thickets having small, thick and rough leaves), and limit the agricultural and forestal productivity. This type of vegetal formations are characterised by their slow growth and by their recovery following perturbations.

Human activity is inherent in Mediterranean landscapes. The fire and the pressure exerted by grazing, in conjunction with drought, have conditioned the development of Mediterranean landscapes during the Quaternary. After the Neolithic revolution, with the transformation of agriculture and the substitution of the majority of wild ungulates for domestic animals, the speed of landscape evolution did greatly increase. The richest forests located in the fertile plains were either cleared out or cut down for cultivation, and, at a later stage, with the development of dense rural populations, every tillable slope was cleared out or terraced up, and the remaining sclerophyllous forests and thickets were periodically put to the torch and cut down. The natural landscape, densely wooded, was finally transformed into a landscape both more open and culturally richer. Natural vegetation was restricted to the most inaccessible mountain spots. Semi - natural vegetal communities, modified by human activity, were interspersed in non tillable slopes and in the boundaries of tilled fields. The balance kept by man has turned the Mediterranean vegetal into a dynamic mosaic of innumerable variants in different states of ecological maturity. The preservation of these mosaics must be included into the list of objectives of the conservation network.

In the Mediterranean, diverse traditional systems have been developed for the exploitation of natural resources (farm, olive grove - vineyard, cereal steppe, etc.), adapted to the different existing environmental conditions. These systems take up large stretches of land in the territory and match up with different types of agrarian, forestal and pastoral landscapes being very heterogeneous in space (fine grain) and in time (seasonality). They have a markedly extensive character, with low productivity in the short term, but making it possible to profit from a large variety of products and services by means of the manifold use of the different eco - spots (pasture, firewood, fruits, etc.). The maintenance of human compatible uses must be included as one more of the objectives of the conservation network.

As a result of this combination of ecological heterogeneity and man - made alteration, a diverse semi - natural and highly attractive landscape has developed; one being capable of encompassing a large biological diversity together with an ample variety of crops and uses (Naveh and Lieberman, 1984; González Bernáldez, 1991, 1992).

This type of landscapes, which require uninterrupted action, may play a very important role in the conservation networks, acting as connection and / or buffer areas around the best preserved areas.

The intensification, depopulation and agrarian abandonment processes in conjunction with an accelerated urban expansion and the pressure exerted by

tourism are marking a trend towards the loss of heterogeneity in the landscape, in general, towards the breach of the previous dynamic agrarian and pastoral balance kept by man, which has made such a great contribution to biological diversity, to productivity, to stability and to the attractive scenery of these semi - natural landscapes (Stanners and Bourdeau, 1995; Washer *et al.*, 1999; Sastre and Guillén, 2001; Jongman, 2002).

This fact, the speed and extent of these changes and their often irreversible nature, determine the urgency of conservation measures in the Mediterranean region. The measures to be taken must take into account the specific conditions of the Mediterranean region, with its environmental restrictions and opportunities, and must entail a support for the maintenance of traditional extensive systems, by developing strategies for each one of them.

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