5. CRITERIA FOR THE DESIGN OF CONSERVATION NETWORKS

The design of networks of protected areas does require an objective and repeatable process which makes it possible to know up to what extent a certain territorial configuration allows the set goals to be reached. It would involve a dynamic assessment, in which the contribution made by each part of the territory towards reaching the network's goals can be appraised.

The insufficient level of knowledge that we have of the largest part of ecological processes, together with the compelling need to deal with the conservation policies, in environments subjected to social, economic and ecological changes, makes a flexible decision - taking process indispensable. The starting point of such a process must be well - defined objectives and, by means of an uninterrupted and reliable information, the said process must enable the continuos readjustment of the planning (Holling, 1978)

To this end, it is imperative to define the goals which we intend to reach as well as to define a system of objectively verifiable indicators, allowing the establishment of an assessment procedure, both systematic and applicable to the territory as a whole.

The assessment is the process by virtue of which values are assigned to different portions of the territory. The assigning of values to the criteria is an indispensable requirement and it entails the passing of a judgement: what is better and what is worse. The values are determined by society, by its needs, expectations, preferences, etcetera. Scientific knowledge must be the source of evidences on the basis of which these values are justified.

The quantification of criteria makes possible the contrast between observers and the feeling that the subjectivity of the assessment process is being diminished, even though, in actual fact, subjectivity lies in the very choice of criteria and in the assigning of values. Having said that, the preparation of a well - defined list of criteria makes it easier to understand the goals of the conservation and the conveying thereof, provides the assessment process with methodological coherence, and the making of decisions with clearer bases (Mallarach, 1998a).

In the assessment process several elements are required (Wascher et al, 1999):

- *Criteria:* Qualitative characteristics of the landscape, properties of a portion of territory that can be used to reflect the interest of the said territory for conservation purposes. The criteria may be aesthetic, ecological, social and economic, etcetera.
- *Indicators:* Objective dimensions of the criteria, in such a way that they can be used in the assessment process. A criterion can be broken down into several different indicators. By way of example, if we use the nesting birds as an assessment criterion, the relevant indicators would be: wealth of species, diversity, etcetera.
- *Parameters or rates:* Algorithms chosen as expression of an indicator. For instance: number of bird species, Shannon diversity rate, etcetera.

The set of indicators must be so defined as to enable the assessment with different levels of detail: for the network as a whole, for each of its components and even for the ecosystems and the species.

The criteria used in the assessment of the natural heritage can be grouped into ecological (those deriving from environmental sciences and ecology, which enjoy a longer tradition), planning and management - related (factors of a social, administrative or political kind which may have an influence on the management, such as opportunity, feasibility or efficiency) and cultural (scientific, religious, educational, historic, etcetera). Some of the ecological criteria being more frequently used in the assessment of the natural heritage are described below.

5.1. Indicators based on species and ecosystems

The utilization of objective criteria in the selection of conservation areas has been the usual practice since the sixties. The ones most widely used are generally related to the value assigned to certain species or groups of species (Usher, 1986, Mallarach, 1998a) deemed to be of particular interest due to their endemicity, rarity, degree of threat they are under, representativeness, etcetera (Table 5.1).

A second group of criteria is applied to certain selected elements, be they called habitats, ecosystems, ecotopes or vegetation units. They refer to units having a clear spatial expression, generally characterized by a dominant type of vegetation or use of the ground, and for which the existence is assumed of characteristics and values of their own and different from those of the rest of elements. The criteria used for the assessment of the ecosystems are similar to those used for the species: rarity, endemicity, threat, etcetera (Table 5.1).

The representativeness criterion is based on the idea that the system of natural protected areas of a given territory must include the range or spectrum of variation of the ecosystems or environmental complexes being representative of the said territory. Since the resources available for conservation are limited, the representativeness criterion makes it possible to select areas having a sample of each representative ecosystem, thus avoiding redundancy (recurrence of protected areas having samples of the same environment) or the lack of protected areas in certain natural systems (González Bernáldez, 1988).

Two are the main meanings of the representativeness criterion (Mallarach, 1998a):

- *Inclusive representativeness:* is typical what characterizes a certain place in a unique or peculiar way.
- *Typical representativeness:* what is common is typical of a place. In a specific territory, typical characteristics are those being predominant in the greatest part of its surface.

The application of this criterion presupposes an integrated classification of the territory allowing the identification of such environmental units as characterise it, preferably in a hierarchical way, so that the representativeness criterion can be applied in a gradual manner, from the broadest levels to the most specific in the hierarchy of natural systems. For instance, the Plan of Catalonian Areas of Natural Interest (Catalonia Regional Government, 1996) does establish in the first place a hierarchical ecological regionalization according to six natural regions which, in turn, are divided into sub - regions. At a later stage, those areas are selected containing samples of the natural communities being representative of each region or sub - region.

Naturalness refers to the degree of difference of natural conditions, or to put it in other words, to the absence of human alteration. This definition gives rise to the difficulty of defining which are the natural conditions, a task which often cannot be dealt with in view of the difficulty (or even the impossibility) of finding in this planet places void of human intervention. In the final analysis, also an ideal landscape void of human intervention would be made up of a mosaic of formations with different degrees of maturity: the community having reached the climax would coexist with others, either pioneering or immature, as a result of natural disturbances such as fires, pressure by herbivores, etcetera.

An approach to the quantification of naturalness usually consists in assessing the degree of human intervention in the ecosystems in existence in the area under study, in an ordinal scale ranging from those ecosystems where human intervention is greatest (e.g. intensive cultivation), to the intermediate ones (e.g. extensive cultivation, pasture lands, thickets) to those showing the lowest degree of intervention (e.g. non exploited forests).

The stability or persistence of the ecosystems can be an indicator of the degree of maturity, as a reflection of naturalness. The most mature, non exploited ecosystems keep low rates of mass renovation, slow flows which delay the circulation of matter and energy, by keeping them in the ecosystem for as long as possible. Primary productivity can be used as an indicator and it can be estimated from certain instances of thematic cartography (Atauri et al 2000, Atauri and de Lucio, 2000).

Table 5.1. Examples of biological-type criteria based on species and ecosystems.

CRITERIA	*SPECIES*	*ECOSYSTEMS*
Endemicity	Regionally or nationally endemic species	Endemic communities or associations
Rarity	Rare species	Rare communities or associations
Peripheral species	Species at the edge of their distribution area	Habitats at the edge of their distribution area
Threat	Threatened species and those in danger of extinction (according to international criteria such as those of IUCN)	Threatened habitats (e.g. habitats and vegetal communities protected by the Habitat Directive 92/43/EEC)
Special interest elements	“Key” species (e.g. species being in a central position in the trophic networks)	“Key”habitats and ecosystems
Representativeness	Species representative of the biogeographical unit	The most representative ecosystem is deemed to be the most typical, the most abundant in each biogeographical unit.
Naturalness	Autochthonous,non exotic,species	Ecosystems having been hardly altered by man
Stability , persistence	Species having reached the climax, belonging to the most advanced stages of the ecological succession	Mature ecosystems, with a low rate of biomass renovation

To apply on the territory the indicators based on the species, it is possible to use parameters such as the value of the presence / absence of the species, the size of the populations, the total wealth of species, the wealth of certain groups, the diversity of species, etcetera (Table 5.2.). each indicator is calculated for each group of species about which there is information (birds, reptiles, amphibians, lepidoptera or vascular plants). In certain cases it is advisable to use indicators concerning specific species which are deemed to be key or of special interest, with a view to assessing whether the conservation network gives enough protection to the populations, the habitat or the species’ distribution area.

Likewise, the indicators being based on ecosystems can be applied with parameters such as the presence of certain ecosystems, their area, the wealth and diversity, etcetera (Table 5.2.). In order to assess up to what extent the most valuable ecosystems are sufficiently protected within an area or within the whole network it is necessary to analyse which percentage of their area is included in the area or in the network. In the Habitat Directive (92/43/EEC) the area criterion is included for each one of the types of habitat protected by the said Directive, and the application is suggested of the relevant indicators and parameters. For instance, the indicator "relative area" refers to the part of the natural area covered by the type of habitat relative to the overall area covered by this type of habitat in the whole of the territory under consideration.

Table 5.2. Indicators for the selection of conservation areas on the basis of species and ecosystems

	SPECIES	*ECOSYSTEMS*
Presence	Presence of each species	Presence of each ecosystem
Abundance	Number of members of the species, surface of the distribution area (%)	Surface (%)
Wealth	Wealth of species,diversity	Wealth and diversity

5.2. Indicators of landscape structure and function

The rapid evolution of the Geographical Information Systems (GIS) has given rise to an important change in the type of descriptors of the structure and the operation of the landscape that can be found in the subject's literature and that can be used for the assessment of conservation networks (Gulinck et al, 2001). From the nineteen nineties on, tests started to be performed of rates applicable at a landscape scale, which make it possible to assess in an indirect way the functionality of the landscape, up to what extent the different components of the landscape remain unaltered and the flows and processes characterising it (O'Neill et al, 1988; Turner et al, 1991; Jones et al, 1997).

The repercussion of measures related to territorial planning or management on the ecological integrity of the network can be studied with different types of spatially explicit simulation models (with GIS). The possibility has to be highlighted of generating virtual scenarios according to different conservation and management objectives, applicable in the preparation of monitoring and control programmes.

The indicators concerning the structure and the operation of the landscape are closely related to the indicators based on species and ecosystems (Table 5.3).

Some landscape indicators, such as, for instance, the fragmentation, can be applied to a specific species (fragmentation of populations or their distribution area), to a type of habitat (e.g. woodland fragmentation) or to a network of protected areas.

5.2.1. Surface

The justification of the surface criterion is based on the premise that the number of species is greater in larger areas. In principle, large protected areas would be preferable to the small ones for they would sustain bigger populations and the extinction rates would be smaller (Diamond, 1975). Besides, it is considered that a minimum viable habitat does exist, a minimum surface below which it is not possible to guarantee the survival of certain species.

As a rule, international conservation strategies and most of the national ones refer to the need to conserve large enough areas so that they can sustain the diversity of characteristics, species and genes of the natural systems. In addition to the total surface of the protected areas, the already mentioned surface indicators can be used, with regard to species (percentage of the total surface of the distribution area) and habitats (percentage of the habitat's total surface).

Table 5.3. Examples of landscape - related ecological indicators usable in the design and assessment of conservation networks.

INDICATORS	***PARAMETERS***
Surface / Size	Overall surface of the protected area Surface of area patches / Overall surface
Fragmentation	Number of isolated areas (network fragments) Surface of each fragment, average size of fragments Distance which separates the fragments
Shape	Surface / perimeter Elongation (maximal length / surface) Tortuousness of the perimeter (perimeter / maximal length)
Heterogeneity	Number of ground uses and types of vegetation Diversity of ground uses
Connectivity	Length of barriers (roads and railway / square kilometre) Number of connections among the elements of the network
Integrity / Disturbance	Building surface Surface occupied by cities and villages,infrastructures,industries,etcetera Distance from urban areas,roads,etcetera

5.2.2. Fragmentation

It refers to the number of elements making up the conservation network. A conservation network consisting of many small - sized areas, isolated and lacking in spatial continuity will have a high degree of fragmentation. Conversely, a little fragmented network will consist of a small number of large interconnected areas, so that they do not constitute isolated fragments. The basic measurements used to quantify fragmentation are the number of fragments, their size and the distance separating them from one another.

An excessive fragmentation of the ecosystems can reduce the fitness of an habitat for certain species, for there are no large enough fragments to sustain stable populations (Usher, 1987). However, a larger number of reserves can provide other kind of advantages (greater resistance to local disturbances and extinctions, greater genetic variability, etcetera) (Higgs and Usher, 1980). The selection of many large - sized areas is not always possible due to the limited resources available for conservation purposes. The discussion about the advantages and disadvantages of many small reserves as against a few large ones has given rise to a scientific debate with an open conclusion, for each one of the strategies has advantages and disadvantages which must be assessed in each case (Forman, 1995).

5.2.3. Shape

The indicators concerning the shape of the landscape units are gradually gaining importance as the relation between the shape of the patches of the landscape and their operation is being known, it is therefore possible to assign different values to the different shapes. As a rule, those areas with a smaller edge effect, and in which there is a higher ratio of interior habitat, far from the disturbances that may arise as a result of the vicinity to other patches, are preferable (Forman, 1995).

In order to measure the geometrical shape of the patches, different indexes can be used. The most simple index to define the shape is the relation between the surface and the perimeter. In principle, it can be said that areas having a low surface / perimeter ratio are to be preferred, for in such areas the edge effect is reduced and, along with it, so is the influence of external disturbances, and the interior habitat ratio is increased. Thus, circular - shape areas would be preferable to those having an elongated shape.

5.2.4. Heterogeneity

Landscape heterogeneity, in particular with regard to the variety of extensive uses coexisting with unaltered vegetation patches, enables a high diversity of species values and a better functionality of the ecological processes. Heterogeneous landscapes have, in principle, a greater aptness to operate as buffer or corridor areas between sections of large, well - preserved habitats. Heterogeneity can be measured as the wealth of ground uses and types of vegetation which coexist within a UTM grid or within a landscape unit.

5.2.5. Connectivity

Connectivity is the feature of the landscape which makes the flow of materials and individuals between different ecosystems, communities, species or populations possible. In the case of the species and the populations the connectivity encompasses both the daily or seasonal movements and the dispersal movements by the youngsters, the migrations or the movements intended to escape disturbances.

The connectivity of a network of protected areas is an indication of the extent to which this network allows the flow of species and populations. If we think of protected areas as node points of this network, and of the corridors as links, it is possible to establish an index that measures which proportion of all possible connections is being maintained by the network. The closer the value gets to the maximum, the greater the network's connectivity (Forman and Godron, 1986).

Connectivity is very closely related to the landscape's linear structures, which is why those indicators linked with the importance of linear and bank corridors within the network's general connectivity have enormous significance; by way of example: the number of areas connected by means of bank corridors or the number of areas connected by means of linear corridors.

Also relevant are the indicators of the length or rivers and banks, hedgerows and other linear elements included in the network. These indicators can be quantified in different ways: in proportion to the total number of rivers within the territory, by the type or the category of rivers and banks, drawing a distinction between the stretches included in the network running through some protected area and those running through non protected areas.

Connectivity can also be assessed by means of spatially explicit models, in which, on the basis of the information on the habitat requirements of certain species, selected as a result of their relevance or representativeness, it is possible to simulate the most likely routes between specified points (e.g. the areas included in the network) and to detect the main corridors and barriers, as well as to model the repercussion on the connectivity of different management alternatives (restoration of banks, fauna crossings or the building of infrastructures).

5.2.6. Ecological integrity

As a way to solve the difficulty of defining naturalness and to overcome assessments based on the diversity of species, the integrity criterion is starting to gain relevance. The ecological integrity refers to the presence within a system of all the elements belonging to it as well as to the operation of processes at the appropriate scales (Angenmeier and Karr, 1994). However, no agreement has been reached concerning the quantification of this integrity criterion, and a large variety of indicators have been put forward, which vary widely depending on the standpoint from which the problem is being dealt with (Noss, 2000).

The greater or lesser intensity of the man - made perturbation may be an indicator of the naturalness of the landscape. The built area or that occupied by infrastructures is the clearest parameter, but the distance from urban areas, roads, industries, etcetera is used as an indirect indicator of the man - made pressure on the territory. The areas being close to large communication infrastructures, to large population centres, may, in principle, be subjected to a greater degree of disturbance due to the direct influence of man (touristical or leisure-related use, dumping, light or sound contamination, etcetera).

5.3. Effect of the spatial scale on the definition of indicators

There are very few studies which provide us with methods for the selection of work scales, or which facilitate the use of tools to quantify the effects of the changes in scale. This shortage becomes specially important in the case of the landscape's linear elements, due to their great dependence on the analysis scale.

The scale, be it spatial or temporal, does include two main concepts: resolution and extent. The resolution or grain size is the minimal spatial or temporal analysis unit, whereas the extent is the space or temporal interval covered by a study.

Resolution and extent are quite useful concepts in ecology, but it is necessary to distinguish these components of the scale pertaining to our observation from the characteristics belonging to the different organization levels of the ecosystems, or from the different units and processes that they consist of (Allen and Hoekstra, 1992). To correctly study an organization system or level, as well as its relevant units and processes, we must use an extent that makes it possible to observe the organization level in its entirety, and a resolution allowing us to distinguish each one of the different units or components of the system.

The representation of landscape structures and ecological processes is inherently linked with the analysis scale. Such a dependence shows the need to incorporate the effects of the changes in scale into the landscape's ecological research (Turner et al, 1989 y 1991). In the study of the landscape structure, the resolution or size of the grain is the spatial unit having the smallest recognisable size in a map, which must be several times smaller than the size of the elements of interest (e.g. fragments of types or cover or linear elements) (O'Neill et al, 1996). In raster format, the size of the grain is the pixel size, and in vectorial format, the size of the grain is determined by the size of the smallest polygon existing in the map. In the case of linear elements, a linear resolution in vectorial format can also be considered, depending on the length of the minimal recognisable unit being classified as one type or the other of linear elements.

The extent is a very important scale component in order to assess the necessary prospection efforts, and also to establish a comparison between different studies. As a rule, the extent of a study is defined on the basis of administrative determining factors. However, the extent must depend on the processes or species to be studied as well as on the regional or local character of the ecological flows under consideration. By way of example, in Andalusia the regional movements of the fauna (which require a large extent) are determined by the altitude gradients and by the arrangement of mountain systems and their vegetation levels, and local movements (small extent) depend on a variable weft of factors (food sources, refuges, wet areas, wooded areas, etcetera).

It is often necessary, in addition to the resolution and the extent, to define an intermediate scale. The analysis and the assessment of portions of the territory or sub - areas inside the area being studied, is a quite common technique in landscape ecology, which makes it possible to describe the spatial arrangement or the variation in the value of the indicators inside the area being studied. The dimensions of these sub - samples or special analysis units are a basic component of the scale (O'Neill et al, 1996). The sub - samples are usually square (e.g.. UTM grids), but they can also fit with municipalities, regions, biogeographical units, protected areas, etcetera. The size of the sub - samples is related to the extent, and all confusion must be avoided with the resolution or size of the grain, for inside a sub - sample abundance date can be gathered (e.g. in pixels) whereas a pixel is the minimal recognisable spatial unit. The 10 x 10 km UTM grids, for instance, can be used as study areas (extent) or as sub - samples in the study of the structure of the landscape (e.g. Múgica et al, 1996a), but at the same time, these grids constitute the minimal spatial unit (size of pixel) of the distribution maps of many species on which there is no information at a greater resolution.

5.3.1. Effects of the scale on the recognition of linear elements and on the application of landscape connectivity indicators

The criteria used for the design of a conservation network must be translated into indicating measurements. Such indicators are generally obtained from geographical information available at a certain resolution scale. The effect of the scale can be very important in certain cases, for instance in the measurements obtained from the landscape connectivity models. It can be expected that the use of low - resolution scales have a great influence on the landscape connectivity indicators, due, in the first place, to the disappearance of those landscape elements having smaller dimensions. For instance, in a Northern Belgium area it has been observed that the connectivity values diminish when the resolution level is reduced (Fig. 5.1). Optimal resolution can be achieved with a pixel size smaller than 10 x 10 metres, it being necessary to use high - quality aerial photography (Adriaensen et al, 2001).

The analysis of information sources of different scales makes it possible to distinguish different elements of the landscape. Depending on the scale, some types of elements tend to be underestimated whereas others are overestimated, not only because of each type of the element's own characteristics, but also because of the sensitivity of sensors, the subjectivity of the researcher, or due to other characteristics of the sources of information and to the way they are treated (maps, satellite images or aerial photographs). The use of sources of information of a little detailed scale can result in an overestimation of the agricultural and urban areas and in an underestimation of the surface of lakes and wetlands.

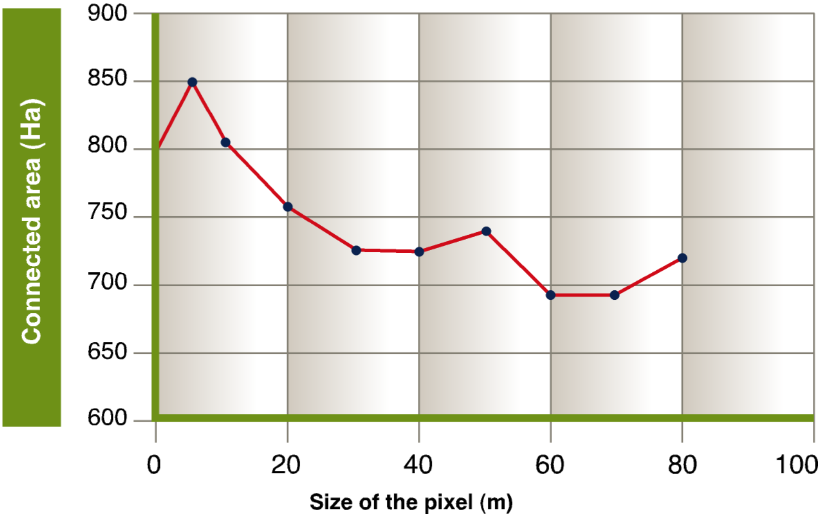

Figure 5.1. Example of the effect of the resolution on the measurements of landscape connectivity. For the red squirrel (Sciurus vulgaris), the connectivity in the central region of Flanders (Belgium) becomes smaller as the size of the pixel is increased (the resolution diminishes). In this case, the connectivity is expressed as the connected area within the dispersal range from the central core area. Source: Sastre Olmos *et al.*, 2001.

To study the linear elements of the landscape and to define ecological conservation corridors a very fine size of grain is needed, but the extent of the areas under study generally restricts the use of high - resolution scales. There are few studies that use information sources at different scales in the case of the landscape's linear elements, even if the spatial resolution is a decisive factor in the study of linear elements. The effects of the scale on the spatial structure of the linear elements are different in different regions and in different types of linear elements (Sastre Olmos, 1999). Landscape elements such as river courses, hedgerows, roads, etcetera, are better detected by using greater - detail sources, their density and spatial distribution being increased on the basis of their dimensions and physical structure (Sastre and De Lucio, 1998).

Besides the resolution scale, there are other factors which can have an influence on the connectivity measurements and which must be taken into account when applying the models. For instance, the methods used in the preparation of the cartographical sources used do determine the type of landscape elements being represented in the map. The small - sized landscape elements, such as isolated trees or vegetation lines, may be very important for the dispersal of forest species in fragmented landscapes, and, accordingly, the information on these elements must be included in the connectivity models. For the assignment of friction or crossing - resistance values, the definition of the classes in the map and the perception of the landscape by the experts must coincide with their mental image in relation to the biological species under investigation. The existence must be taken into account of small - sized landscape elements (below the size of a pixel) which disappear and become incorporated into other categories (Sastre Olmos *et al.*, 2001).

For the definition of a nature conservation network to be coherent it may be necessary to study the structure of the landscape and the connectivity at different scales, both with regard to resolution and to extent. For the selection of the network's core areas it is advisable to analyse the whole of the territory (very large - extent scale), something which hinders the use of high - resolution information sources. However, at later stages such as the delimitation of buffer zones and ecological corridors, the extent being analysed can be reduced to the territory of a core area or to the space between two core areas, which should allow the development of analyses at more detailed resolution scales.