3. LANDSCAPE FRAGMENTATION AS THE MAIN THREAT TO THE INTEGRITY OF THE OPERATION OF THE LANDSCAPE

The loss of habitat and the fragmentation are deemed to be the main threats affecting biological diversity (Harris, 1984; Wilson, 1988; Saunders and Hobbs, 1991; Alverson et al, 1994; McCullough, 1996; Pickett et al, 1997; Fielder and Kareiva, 1998). Conservationists, planners and ecologists refer to the loss of habitat and to the isolation of habitats by using the term “fragmentation” (Collinge, 1996).

The fragmentation of habitats has been studied since the sixties on the basis of two theoretical foundations: the bio - geographical island theory (MacArthur and Wilson, 1967) and the metapopulation theory (Levins, 1969). The island theory does study the influence of isolation (distance between fragments or habitats) and the size of the fragments in the richness and composition of species, considering colonization and extinction as fundamental processes. The term “metapopulation” was introduced by Levins (1969) to describe populations consisting of subpopulations, and places emphasis on the concept of connectivity and on the exchange between populations which are apart from each other in terms of space (Hanski, 1999). This concept has been used in models concerned with the management and with the conservation of threatened species (Simberloff, 1997).

In this context, it is assumed that fragmentation is always associated with the negative effects deriving from human actions which entail a deep modification of the territory, which modification translates into an important loss of natural habitats, into the decrease and even into the extinction of species.

The main causes of fragmentation are the expansion of urban development, the industrialization processes, the intensive agriculture and forestry and the expansion of road and railway infrastructures. The extension of the road and railway networks is one of the main causes of fragmentation, less because of the loss of net area than due to the interruption of the operation of the territory as a whole.

In this chapter we shall review the main consequences of the fragmentation for the territory's structure ad, accordingly, for the operation of the ecosystems and the dynamics of the species, by examining those aspects being specially relevant to the devising of ecological networks of natural protected areas.

3.1. Fragmented landscapes: their structure and degrees of alteration

Fragmentation is a continuous and dynamic process, whose effects on the structure of the landscape can be described by means of rates such as the percentage of natural habitat, the number of fragments, etcetera. As Hobbs and Wilson (1998) suggest, we could distinguish a continuous gradient with four levels of landscape alteration: intact, dotted or veined, fragmented and relict (Fig. 3.1). As the loss of habitat area increases, the connectivity diminishes and the edge effect becomes more pronounced.

The fragmentation processes bring about a diminution of vegetal covers, leaving the original vegetation from a certain area reduced to small fragments, isolated from one another, and immersed in a more or less altered matrix.

The matrix is the prevailing area in the landscape, being, on the other hand, an important portion of the territory which is often left without protection. The matrix's characteristics do vary depending on the degree and the use which man makes of it. The landscape matrix provides habitats in small spatial scales, for organisms which do not require very large territories, but which need individual structures which are scattered through the matrix; such is the case of species living in dead trees, stone walls, hedgerows, boundaries, rocks, etcetera. These elements of the matrix play an important role in areas which have been subjected to structural fragmentation, where these simple structures play the role of habitat, resource and refuge. The preservation of the matrix's biological diversity can be fostered either through the conservation of these types of elements or through less intensive treatment or exploitation.

The matrix can increase the functionality of the fragments by acting as a buffer area, in addition to contributing connectivity to the landscape and fostering it among the fragments. The functionality of fragments is closely linked with their size and their shape, as we shall see below.

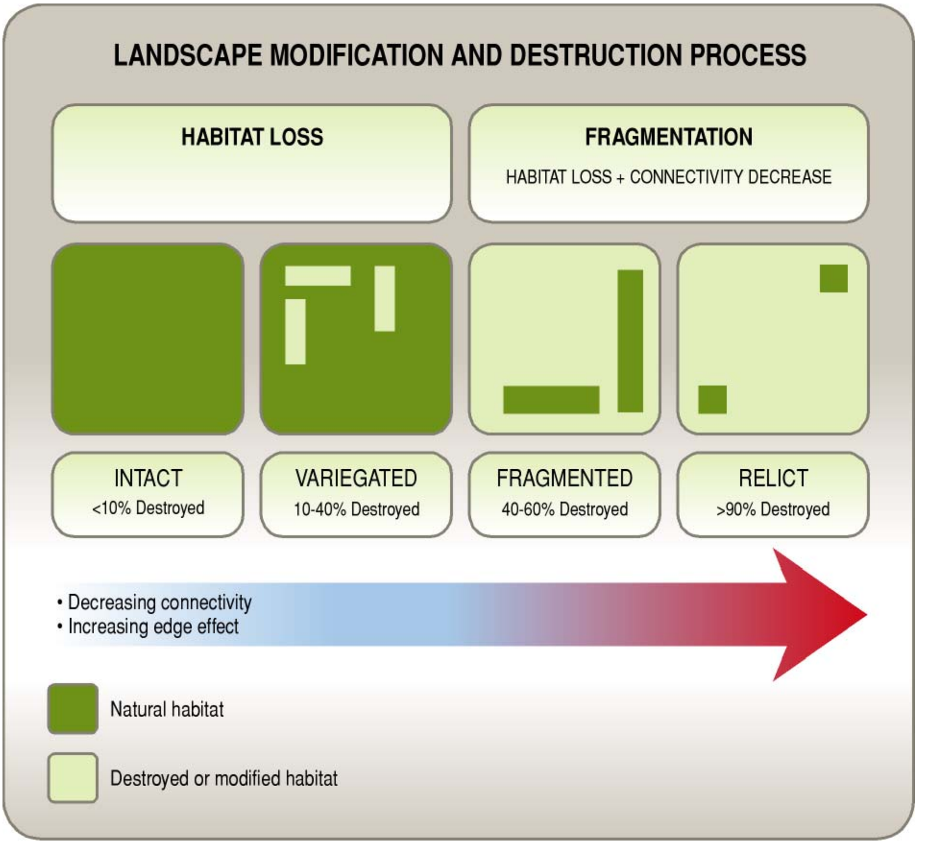

Figure 3.1. Degrees of landscape alteration. Four degrees of landscape alteration are shown. Starting from the intact natural habitat, which gradually loses habitat area and increases the edge effect, as well as the isolation of fragments, while the connectivity is reduced. Modified from Hobbs and Wilson (1998).

According to the percolation theories (O'Neill et al, 1992; With and Crist, 1995; With, 1997) natural systems with less than 60% of natural habitat begin to have problems deriving from the diminution of the habitat area. Nature conservation policies must ask themselves which is the loss of habitat threshold that can be accepted.

In the Mediterranean ecosystems, the processes of humanization of the territory, such as the growing of thickets, the conversion into pasture land or the practice of intensive agriculture, have given rise to heterogeneous landscapes which, occasionally, are home to higher levels of diversity than equivalent systems are without any type of management (González Bernáldez, 1991, Pineda and Montalvo, 1995). In such cases, neither the threshold of loss of habitats, nor the threshold of break - up of the ecosystems' horizontal patterns have been reached (hydro-geological flows, processes of accumulation, transport and sedimentation, etcetera) which mean a real fragmentation of the territory. We would be at a stage similar to the "dotted or veined" landscape phase in the diagram suggested by Hobbs and Wilson (1998).

Different management measures are suggested for each level of landscape alteration. In deeply transformed landscapes a relevant role is played by small landscape structures which are scattered throughout the matrix, such as linear elements (hedgerows, boundaries or stone walls) or singular plant groups, rocks, etcetera (Fig. 3.2). These elements of landscape are not usually taken into account in the planning process; however, they are of great interest for the conservation of the biodiversity associated with rural landscapes (Pino et al, 2000).

In little transformed landscapes, where the loss of vegetal cover is below 40%, the effects of this alteration will affect species having very special habitat requirements. Measures aiming at the preservation of connectivity and functionality of these systems will be channelled into the conservation of the matrix, the protection of well - preserved fragments and the keeping of those areas acting as links among different fragments.

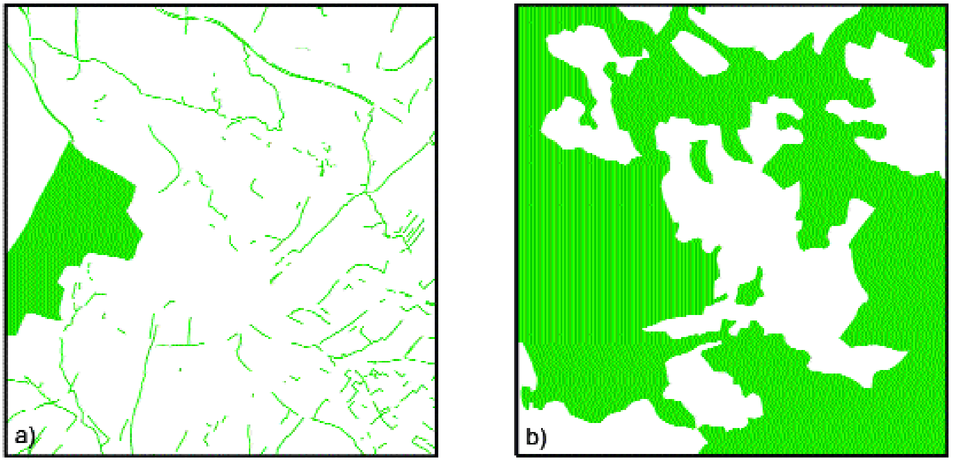

Figure 3.2. Different degrees of landscape alteration taken from the Guadiamar river basin (Seville - Huelva). a) Maximal alteration of the landscape. Small linear structures remain which play an important role concerning the connectivity of this landscape. b) Intermediate degree of alteration. Large patches of natural vegetation remain.

3.2. Main effects of the fragmentation on the operation of natural systems

Fragmentation, understanding by it a dynamic process by virtue of which a certain habitat is gradually being reduced to fragments or islands of smaller size, more or less interconnected within a matrix of habitats being different from the original one, entails certain spatial effects which can be summarised in three (Forman, 1995):

- Decrease of the habitat's area. All fragmentation processes are associated with a loss of the natural covers in favour of human uses of the territory (urban development, industry, infrastructures, agriculture, etcetera).
- Reduction in the size of the fragments, due to the division of more or less large areas into smaller - sized fragments.
- Isolation of fragments in the landscape, as a result of the intense destruction of the natural areas which, in turn, increases the distance separating habitat fragments from one another. The isolation can be measured through the rates calculating the distance to the nearest fragment. This effect has an important functional component, for the matrix or altered area can be more or les permeable depending on the species.

As a rule, the processes being more deeply affected by the effects of landscape fragmentation are those which depend on transmission vectors in the landscape. The scattering of seeds, the pollination of plants, the predator - prey relations, the dispersal of parasites and epidemics are examples of fragile ecological processes due to its relying on animal vectors which, in turn, have their movement through the landscape limited.

These effects do threaten the survival on the affected organisms in three different ways (Santos et al, 2002**,** Atmar and Patterson, 1993, Lawton, 1993, Hanski, 1998):

- When the availability of habitat area diminishes, a net loss occurs of the size of the populations living in it.
- The reduction of the fragments results in an increase in the perimeter - area ratio, which increases the permeability of fragments for the purposes of peripheral habitats.

- The isolation of fragments and, therefore, the increase in the distance separating them, makes the exchange of individuals difficult, which in numerous occasions is associated with the gradual disappearance of species stationed in the fragments. This occurrence is the reason why only the most resistant or less specialised species manage to stay, while the most sensitive ones are relegated to the biggest fragments.

On the other hand, it is necessary to bear in mind that fragmentation operates at different scales for different species and different habitats: a fragmented landscape for a species may not be so for another having greater capability to disperse or less demanding habitat requirements (Wiens and Milne, 1989) (Fig. 3.3).

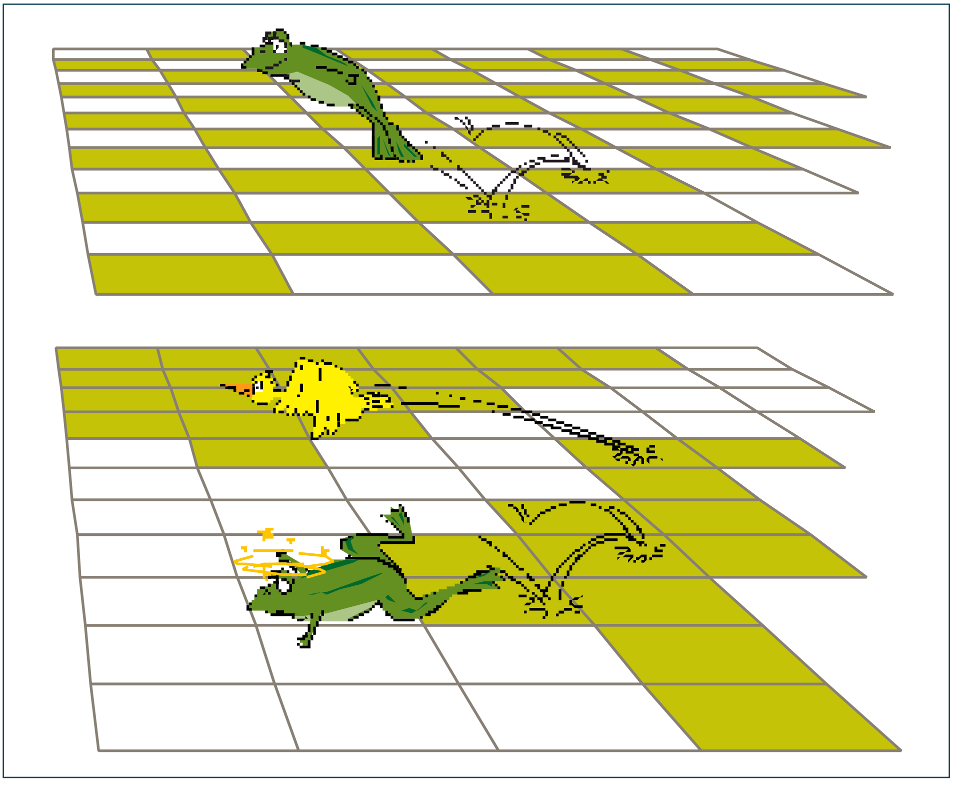

Figure 3.3. Given two species living in the same habitat, a certain spatial configuration can be deemed to be fragmented for the species with less skills to cross the matrix (amphibian). For the species having better scattering skills (bird), the same landscape is not deem to be fragmented, for all resources are available.

The size and shape of the fragments do condition to a great extent the possibilities of keeping certain populations. Thus, the smaller the fragment area, the more vulnerable it will be to external agents and the stronger the edge effect will be (table 3.1). While inside the large fragments certain internal properties and characteristics of the fragment occur, in those having a reduced area, the matrix effects and strains are reflected inside the fragment, which is why the species from the interior are highly harmed for the benefit of those species living in border areas or ecotones.

In fragments with larger habitat areas it is expected that populations be more numerous and have more possibilities to overcome possible local alterations or extinctions. Elongated and thin fragments have proportionately a longer edge (perimeter) than those being square or round in shape (Diamond, 1975). In the case of the latter shapes, it is more likely that the interior of the fragment maintain its internal conditions and that the matrix effects be limited to the fragment's edge.

Table 3.1. The edge effects are defined as the result of interaction between two ecosystems when their ecotones are very abrupt. The intensity of these effects and their possible implications for the operation of the fragment depend to a great extent on the size and shape thereof, as well as on the spatial configuration resulting from the set of fragments. The edge effects can be divided into three groups:

- Physical effects. They entail changes in the environmental conditions of the fragment's interior deriving from the modification of the micro-climate due to variations in the insolation and to the effects of wind, rainfall, frost, etcetera.
- Direct biological effects. Changes in the environmental conditions at the edge do directly affect the biological component of the natural systems. Some species are favoured by these conditions of greater radiation, higher temperature, etcetera, bringing about some species characteristic of these transition areas.
- Indirect biological effects. The changes brought about by the edges in the environment of the fragments and their structure do affect the dynamics of the interactions of the species in the vicinity of the edge. By way of example, the larger biomass (due to the greater impact of light) causes, in turn, that herbivores and insects come nearer, which results in an increase in the number of nesting birds, which attract predators and parasites.

These considerations have a clear translation into conservation measures and into the design of ecological networks in which the size and shape of the fragments become fundamentally important. Thus, protected natural areas must have sufficient size to guarantee the survival of the species and the territory's functionality. The size of the areas currently designated as protected is, probably, insufficient (Fig. 3.4).

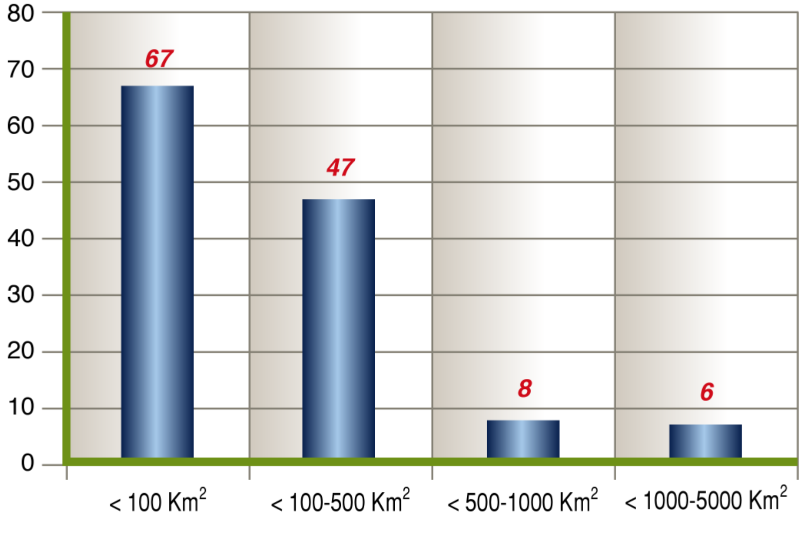

Figure 3.4. Distribution of the sizes of the Spanish natural protected areas designated as National Parks and Natural parks. The size of 52% of Spanish parks is less than 10000 hectares. Source: EUROPARC - España, 2001 database.

Against the damaging effects brought by the fragmentation of territory on the functionality and survival of the species, conservation policies must be directed towards measures that favour permeability by maintaining certain broken or unbroken landscape elements. In the final analysis, the goal is to increase the territory's connectivity.