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Habitat fragmentation due to transportation infrastructure in Spain

SUMMARY DOCUMENT

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Presentation of work done in Spain under the *COST 341 Action. Habitat fragmentation due to transportation infrastructure*

The COST 341 Action on habitat fragmentation caused by transportation infrastructure began in 1998 and will conclude in November 2003. In September 1998, the Spanish Government became one of the first countries to formalise its membership, and in the ensuing years it has played an active role in the project. The most important achievements are listed below.

- Production of the ***COST 341 report. Habitat fragmentation due to transport infrastructure in Spain.***

  Overview of the current situation, including a complete review of all published information on the subject as well as all projects and studies undertaken in recent years. This is the full report which is included in the CD-ROM and summarised in the present document. It will be published by the Spanish Environment Ministry.

- Participation in the production of the document entitled ***COST 341. Habitat fragmentation due to transportation infrastructure. The European review.***

  Published by the European Commission in 2003. As part of COST, the Spanish authorities will help to distribute and publicise the document amongst the agents involved in the process.

- Participation in the production of the document entitled ***COST 341. Wildlife and traffic. A Handbook on identifying conflicts and designing solutions.***

  Distribution will begin in November 2003, and part of the Spanish contribution to the COST Action will be to ensure that it is distributed and publicised amongst the agents involved in the process in Spain.

- Creation and maintenance of **databases on bibliography and mitigation measures applied in Spain to prevent vehicle collisions with animals and permeabilise the roads and railway lines to fauna.**

  The database includes information from all the participant countries in the Action. It is now available for consultation at the Infra Eco Network Europe website (www.iene.info). In Spain, data from 237 records have been compiled on articles and unpublished documents on the subject, which can also be consulted at the same website. This information will shortly receive the additional input of 136 new records that describe measures applied in Spain to prevent animal collisions and make roads more permeable, showing the type of infrastructure involved, its characteristics, etc. This database is also expected to be made available through the Spanish Environment Ministry's website.

- Organization and dynamisation of a **National Working Group on habitat fragmentation caused by transport infrastructure in Spain**.

The Directorate-General of Nature Conservation is coordinating this Working Group, which includes representative members from the transport and environment authorities in the National and Regional Governments. They meet once or twice a year to exchange information on the subject and encourage the implementation of measures to prevent habitat fragmentation at each and every stage of the infrastructure construction process: strategic planning, infrastructure project, construction and maintenance. Experts are also invited to provide information on aspects of general interest.

- Organization of **dissemination and information seminars and workshops** on the subject.

Two events were held in the course of the Action. The first one was a meeting of the COST Action 341 National Working Group and the *Infra Eco Network Europe* in Sitges (Barcelona) in April 2000, where experts from a number of European countries were able to gather. As part of this meeting, a workshop entitled ***Nature 2000 and Transport Infrastructure*** was also held, attended by 120 Spanish professionals as well as the European experts. In 2002, another workshop was organised in Barcelona, with the collaboration of the Environment Department of the Generalitat de Catalunya, using the same approach under the theme ***Fauna and Transport Infrastructure. Fauna passages and measures to avoid collisions***. This seminar was attended by almost 130 professionals involved in environmental impact evaluation and the design and construction of roads and railway lines.

30th September 2003

COST 341. Habitat fragmentation due to transportation infrastructure in Spain

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Spanish Environment Ministry staff members helped to produce the maps and conducted the first draft analysis of effects of the transport infrastructure on areas proposed for inclusion in the Nature 2000 network.

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Chapter 1. Introduction

Presentation

Natural habitat fragmentation is one of the main causes of the loss of biodiversity in Europe and is therefore an important issue for all of the agents involved in nature conservation and territorial management. Although there are many causes of fragmentation in the landscape including urban development, agriculture, deforestation, etc., the barrier effect of linear transport infrastructure (roads, railway lines and navigation canals) is becoming increasingly serious in the most heavily urbanised countries.

Author: Cos d'Agents Rurals (Generalitat de Catalunya)

The document reviews the current state of the issue in Spain. It includes a compendium of the information available about the current and planned transport networks, the effects of road infrastructure on nature and the measures applied to mitigate its impact. The structure of the monograph was agreed by the countries participating in the COST 341 Action, and the reports drafted by each member have been used as the basis for a pan-European review on the issue (*COST 341. Habitat Fragmentation due to Transportation Infrastructure. A European review*) which compiles and contrasts the information provided by each country.

Habitat Fragmentation

This term covers the process of splitting large, continuous habitats into smaller portions that are left isolated from each other by the barrier effect, which impedes the dispersal of species. In a broad sense, this concept embraces effects such as the direct loss of portions of habitats, individual mortality caused by collision and the loss of quality in the habitats affected by disturbance generated by the infrastructure (noise, pollutant emission, artificial lighting, etc.). Taken together, these types of impact affect much larger areas than the actual road corridors and their immediate environs, and may threaten the survival of populations of the most sensitive species. The most direct effects such as roadkills are merely the most visible part of the problem, albeit the ones that have helped most to raise public awareness of the effects of road infrastructure. Other less obvious types of impact such as the barrier effect and population isolation can have much more serious repercussions, even to the point of threatening the survival of entire populations, however their effects are only detected in the medium or long term and are thus often underrated.

The spread of transport infrastructure

Transport infrastructure used to facilitate the movement of people and goods has been under construction in Europe for more than 2000 years. Initially its impact on the natural environment was moderate because of its very small scale, the low traffic density and its adaptation to the local topographic conditions, with the alignment integrated into landscape matrix. In recent decades, however, the road network has grown considerably in order to meet the increasing demand for mobility, while innovation in construction techniques has led to the creation of high-capacity infrastructure that carried a massive number of vehicles, and is superimposed on the landscape, fragmenting natural habitats and disturbing the previously existing processes and connections between the ecosystems on either side of the road.

The countries with the highest levels of urban development already have a dense road network and still plan to build thousands of kilometers of new infrastructure. In Spain, for example, the transport infrastructure network has almost reached the 700,000 Km, and by 2010 the authorities plan to have built a further 5,700 new kilometers, basically high-capacity roads and high-speed railway lines. The growing land requirements of this infrastructure, justified by the continuous increase in traffic movements, promises an increase in conflicts between road-railway development and nature conservation, further highlighting the need to define sustainable transport models and posing the challenge of trying to change the present and future network in order to mitigate its environmental impact. In practice, this requires an answer to basic questions such as how to expand the transport infrastructure network without exacerbating habitat fragmentation, and how to mitigate the impact of the present infrastructure. In order to do so, we need to integrate the knowledge of researchers, conservation technicians, civil engineers and territorial planning authorities. Only multidisciplinary work applied to each stage of the infrastructure process (planning-project-construction-operation) can ensure the minimisation of habitat fragmentation caused by transport infrastructure.

The COST 341 Action

In 1997, representatives of several European member countries in the *Infra Eco Network Europe* organization (IENE) detected the need to cooperate and exchange information on habitat fragmentation caused by transportation infrastructure and to receive backing by the European Commission to develop the project. This led to the implementation of the *COST 341 Action,* ***Habitat Fragmentation due to transportation infrastructure*** in 1998. Its aims were to collate existing knowledge about the issue in Europe, undertake a review of this knowledge and draft technical guidelines that should be applied by the agents involved in planning, designing, building and maintaining transport infrastructure. The countries and organizations which officially took part in the Action were:

Austria	Hungary	Sweden
Belgium	Norway	Switzerland
Cyprus	Portugal	The Netherlands
Czech Republic	Republic of Ireland	United Kingdom
Denmark	Romania	
France	Spain	*European Centre for Nature Conservation*

The specific objectives of the Action were to:

- Review the present state of habitat fragmentation due to transportation infrastructure and the experiences of defragmentation being applied in Europe.
- Publish an Integrated Manual of Good Practices and technical guidelines on applicable methods and measures aimed at the prevention, mitigation and compensation for habitat fragmentation effects that may be caused by transport infrastructure.
- Create an online database containing published and unpublished information relating to habitat fragmentation caused by transport infrastructure as well as information about measures already applied to reduce this effect and projects in progress.
- Publish a final report containing an overall description of the project's achievements and contribute to the dissemination of its results.

In Spain, information exchanges between the agents involved has primarily been done through a **COST Action 341 National Working Group,** formed by representatives of the Transport and Nature Conservation Departments of the National and Regional Governments. The Directorate-General of Nature Conservation (DGNC), responsible for the COST 341 Action in Spain, was also responsible for coordinating the Working Group.

The Group members have participated to varying degrees in the drafting of this document by providing information about studies, projects and measures, and advising on new information sources, etc. There is currently a growing interest in Spain about the issue of habitat fragmentation caused by linear infrastructure, evidenced by the constant input of new information about research projects on the issue, new fauna passages, the application of compensatory measures, etc. This has made it necessary to produce continuous updates on the initial version of the document.

Contents of the document

The monograph, which essentially follows the same structure used by all of the participant countries in the Action, consists of the following sections:

Chapter 2. A definition of the **key ecological concepts** that are used throughout the document.

Chapter 3. A bibliographic review of the **effects of transport infrastructure on the natural environment** and the causes of habitat fragmentation.

Chapter 4. A description of the main characteristics of Spain in relation to the issue, with brief comments on the country's outstanding **biodiversity and biogeographic features**. Information is also provided on the country's natural areas, particularly in relation to the **Nature 2000 Network** and the legislation that covers aspects relating to habitat fragmentation caused by transport infrastructure.

Chapter 5. A presentation of the **current state of the transport infrastructure network** and the most important results of Spanish research into the **effects of this infrastructure on nature**. The chapter also includes the results of an initial analysis of the size of the particularly sensitive areas (zones proposed for inclusion in the Nature 2000 Network and other important natural areas) that are affected by road transport infrastructure.

Chapter 6. A discussion of the aspects that have a direct impact on **road safety**, with emphasis on data concerning vehicle-animal collisions.

Chapter 7. A review of the **measures currently being applied in Spain** to mitigate or compensate the effects of transport infrastructure in relation to habitat fragmentation.

Chapter 8. A summary of the **planned construction of new transport infrastructure** and its **potential effects on habitat fragmentation**. The chapter also describes how strategies, plans and projects in the transport and environment fields are dealing with the fragmentation problem. Finally, information is provided about analysis tools for prevention in transport infrastructure, including indexes, indicators and modelling in this field.

Chapter 9. Information about the direct and indirect costs of transport infrastructure, including costs associated with road safety.

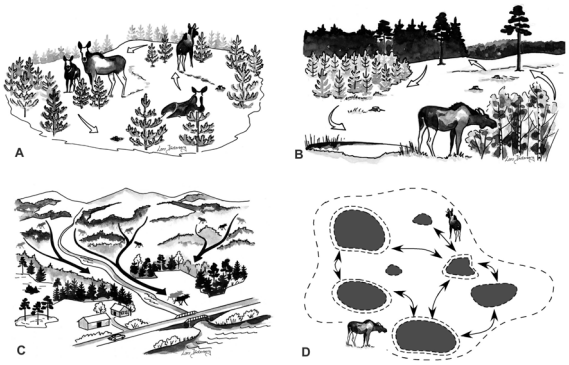
Chapter 10. The main conclusions reached on the basis of the contents of the document.

The text is supplemented with several appendices:

- **Annex I** contains **Summary tables** showing the characteristics of **specific measures applied to Spanish roads and railway lines** aimed at reducing the barrier effect, preventing animal collisions and mitigating the impact of transport infrastructure under construction on the basis of the implementation of the Habitats Directive 92/43/CEE.
- **Annex II** includes the **list of species mentioned** in the document, including their scientific names.
- **Annex III includes** the **list of people who have made a contribution** to the document by supplying information, facilitating contacts and revising the draft versions.

Chapter 2. Key ecological concepts

This chapter presents some of the key ecological concepts required to understand the landscape patterns and processes of the landscape in relation to infrastructure planning. The most important conclusions are summarised below.



Author: Lars Jäderberg (*COST 341. Habitat fragmentation due to transportation infrastructure. The European Review*)

Connectivity between habitats through the landscape is essential to ensure the survival and vitality of wildlife populations, especially for those that inhabit fragmented habitats. Connectivity can be guaranteed by conserving (or restoring) ecological corridors that maintain the continuity of the appropriate types of habitats, as well as habitat fragments relatively close to each other (*stepping stones)*. In many cases, it is also necessary to apply technical measures that act as bridges to link the appropriate habitats and overcome barriers such as roads that interfere with the dispersal of the individuals.

Territorial analysis at the landscape scale is an essential part of the planning stage of transport infrastructure. The effects of this infrastructure cannot be analysed from a purely local perspective. They involve regional scale aspects related to strategic assessment as well as local-scale aspects that determine which solutions should be applied at specific points. A hierarchical approach can help to identify the most important problems and their solutions at the various planning levels. It is necessary to 'think globally, plan regionally but act locally' (*sensu* Forman 1995).

The evaluation of potential changes caused by infrastructure in a landscape requires a good understanding of the functional relationships between the various components and processes in it, inter-habitat connectivity, the state of the wildlife populations, their movements and their ecological requirements. It is important to intensify research into these fields in order to produce a sufficiently large body of empirical data.

The impact of habitat fragmentation on fauna does not display a linear progression. Beneath certain specific thresholds for each species and landscape, the impact can be mitigated or compensated. Beyond these thresholds, apparently small changes can cause unexpected and irreversible effects including the extinction of local populations. The larger the spatial scale, the longer the lead time before the effects are detected. It is necessary to spend considerable energy in identifying these thresholds and ensuring that this knowledge is applied to infrastructure planning.

The development of guidelines and practical methods to ensure that infrastructure planning is based on ecological criteria is a challenge for landscape ecology. We still have a long way to go before these operative tools are readily available, however great benefits will no doubt derive from the combination of the skills of ecologists, geographers, civil engineers, etc., with those of the authorities responsible for infrastructure planning, nature conservation policies and transport.

Chapter 3. Effects of infrastructure on the natural environment

This chapter compiles the information available in the published bibliography on the ecological effects of infrastructure. This body of information is in itself evidence of the growing concern for the issue of habitat fragmentation caused by transport infrastructure. Some of the most important aspects are summarised below.

Author: Ferran Aguilar

The existence of many integrated factors in the landscapes and display synergies which lead to the fragmentation of natural habitats. They include urban development, areas used for extensive agriculture and deforested areas. Transport infrastructures are also an important factor in fragmentation which compounds the others and, in recent decades, has intensified their effects due to the construction of large transport networks.

The main types of impact by transport infrastructure are the direct loss of habitats that are covered by roads and railways, the degradation of adjacent habitats due to disturbance by noise, pollution and other factors, the barrier effect that restricts the dispersal of many species, and mortality caused by collision with vehicles. In addition, there are also several other effects generated along the verges of the roads and railway lines such as the creation of new habitats (although these are often degraded areas that pose a serious mortality risk for the species that use them), and the effect of facilitating the dispersal of invading alien species and other impacts on the natural environment such as forest fires which in many cases are started on the verges of roads and railway lines.

The presence of killed animals on the road is one of the most obvious effects of transport infrastructure. It is also undoubtedly the one that does the most to raise public awareness of the problem. In general terms, however, the barrier effect has much more serious consequences for biodiversity conservation. Although the results are not manifested in the short term, in extreme cases barriers may lead to the extinction of local populations of species that are most sensitive to habitat fragmentation.

One of the secondary effects of transport networks is the change in the uses of land alongside the alignments: the construction of new infrastructure is usually accompanied by the development of business and shopping zones, public facilities, industrial estates, etc. It can also lead to the abandonment of farmland due to difficult access to crops and an excessive property fragmentation. The potential impact of these changes on land usage can even have more serious effects on the landscape than the infrastructure itself.

An overall approach that does not merely consider the direct effects of one particular alignment is required when assessing the real degree of habitat fragmentation caused by transport infrastructure. Bearing in mind that the infrastructure is part of the transport network, the potential synergetic effects of the series of transport alignments must be considered, along with the effects of fragmentation caused by other agents.

At present there are no valid indicators for an overall evaluation of the degree of fragmentation of a habitat. Although several methods have been proposed, the density of alignments (supplemented with their characteristics and traffic intensity) is currently one of the indicators that is most commonly used by several authors. This is, however, only a pressure indicator and does not reflect the real degree of fragmentation in the affected habitats. It should be noted that the tolerance threshold to road density varies amongst the species involved and, more specifically, their dispersal requirements, movement habits, level of tolerance to disturbance, etc.

The conservation and restoration of ecological corridors that facilitate species dispersal in humanized environments is a key requirement for the conservation of natural areas and species. In some cases, when critical conflicts arise between transport networks and biodiversity conservation, it is necessary to implement measures that re-establish connectivity and apply defragmentation projects or programmes such as the ones currently used in European countries with a high level of urban development.

Chapter 4. Relevant features of the natural environment in Spain. Governmental and legal conservation instruments

This chapter describes the main features of Spain's natural environment, it reviews the administrative and legal framework for nature conservation in this country and discusses the relationship between territorial planning and nature conservation, particularly with respect to the designation of networks of natural areas. The most relevant features are summarised below.

Author: Banco de Datos de la Naturaleza (Ministerio de Medio Ambiente)

Four biogeographic regions are found in Spain: the Mediterranean, Atlantic, Alpine and Macaronesian regions (the latter in the Canary Islands). The geographic location of Spain together with its varied relief, climate, and subsoils have facilitated the presence of an extraordinary landscape and biological diversity. This has been aided by human activity, which has interacted with the natural systems for centuries to shape the heterogeneous landscape mosaics that can still be found today.

This landscape diversity is the sustenance for the diversity of the country's fauna and flora species and habitats. It has been estimated that Spain hosts between 8,000 and 9,000 species of vascular plants and between 50,000 and 60,000 animal species. However, beyond the crude figures, the most outstanding aspect of Spain's biodiversity is the large number of endemic species, i.e., species that are not found anywhere else in the world (with the exception of Portugal in the case of some of the endemic Iberian species). They include many vertebrates such as the Iberian lynx, now the world's most seriously endangered feline, and the Imperial eagle. The responsibility for the conservation of these species stretches far beyond the national framework, making the prevention of impact that might affect these species a high conservation priority.

Habitat fragmentation caused by large transport infrastructure is a relatively recent phenomenon. Unfortunately, it has been added onto historic fragmentation caused by a range of factors including land development, agriculture, large dams and canals.

Spain has a decentralised political and public administration structure, consisting of 17 Autonomous Regions and two Autonomous cities, Ceuta and Melilla. Spain joined the European Union in 1986, and responsibility for compliance with international law, from EU Directives to the series of conventions and agreements signed by the Spanish Government, lies with the national government. The Regional Governments are responsible for issues relating to nature conservation, and are therefore able to design more detailed applications than the basic national legislation. They take charge of natural resource planning and management in their regions, and

many of them have passed their own legislation on conservation and interconnections between natural areas. They have also taken on responsibility for the designation of Sites of Community Importance (SCIs) which, together with the special protection areas for birds (SPAs), will comprise the Nature 2000 Network.

The Habitats Directive (Directive 92/43/CEE) is the main legal instrument governing biodiversity conservation in the European Union. It establishes the legal basis for the development of the European ecological network known as the Nature 2000 Network. It also designates the habitats and species with high conservation priorities which must receive special attention in order to prevent the potential impact of transport networks. Different articles of the Habitats Directive provide for mechanisms to ensure that no project has a negative effect on the enclaves designated for the preservation of these species and habitats.

The Natural Areas, Flora and Wildlife Conservation Act 4/1989, which sets the guidelines for action on nature conservation issues throughout Spain, is the basis for National Catalogue of Endangered Species, which includes a list of the most vulnerable species, classifying them as *In danger of extinction*, *Sensitive to habitat disturbance*, *Vulnerable* and *Of Special Importance*. In the case of the most seriously threatened species (the first two categories), it stipulates the compulsory requirement to design Habitat Recovery Plans and Conservation Plans for each affected species. These Plans may include specific actions aimed at preventing the effects of habitat fragmentation on the species and preventing impact caused by transport infrastructure. They are thus compulsory points of reference when a new transport alignment affects the distribution area of these species.

The Environmental Impact Assessment (EIA) procedure is the main instrument used to avoid environmental impact by the transport infrastructure projects in Spain. The new Act 6/2001, which modifies the previous law on the issue, stipulates that virtually every transport infrastructure construction and improvement project must be subjected to an EIA. This provides for the prescription of impact mitigation and correction measures. Nevertheless, the analysis of pre-existing cases of habitat fragmentation, as well as those caused by new projects, requires a broader approach, given that it is necessary to consider the effects of cumulative barriers caused by different infrastructures that are superimposed on the landscape, and as well as those triggered by other causes such as the existence of areas undergoing urban development.

The Strategic Environmental Assessment (SEA), which will be implemented on the basis of the new Directive 2001/42/CE, encourages the evaluation of the effects of Plans and Programmes. This is a much more appropriate framework for the prevention of habitat fragmentation as it overcomes the limitations of the EIA applied to projects, while also permitting the evaluation of the effects of transport infrastructure plans.

Territorial and urban planning (at both the Regional and local level) play a key conservation role, particularly in the prevention of habitat fragmentation. At present a list of Protected Natural Areas has been defined for 732 sites that cover more than 4 million hectares. Many of them are already covered by Zoning and Natural Resource Management Plans, however the initiatives taken under these Plans rarely stipulate specific measures to prevent fragmentation and conserve (or re-establish) connectivity between spaces. The Nature 2000 Network will enable this area to be almost tripled.

The establishment of a true network requires not only the conservation of the core areas (natural areas of interest) but also the conservation of undeveloped land and areas with high quality habitats in order to facilitate the dispersal flows of species and avoid the isolation of the protected areas. Recently, several Regions have instigated initiatives aimed at facilitating biological connectivity between natural areas, particularly the conservation of waterways that act as conductors for the dispersal of many species. This is opening the door to positive expectations in the field of rural development and landscape protection.

Chapter 5. Habitat fragmentation caused by existing transport infrastructure

This chapter describes the current state of the transport network in Spain and reviews the results of the major research into its effects on habitat fragmentation. The most important information is summarised below.

Author: Martí Pey. Minuartia.

Both the transport infrastructure network's size and its traffic density have increased constantly in Spain over the last two decades. The national road network currently spans almost 665,000 km, of which 163,000 are tollways, motorways, fast transit highways and other divided roads that carry a heavy traffic load. There are also 15,000 km of railway lines. Although the total length of the railway network has been reduced, since 1992 several high speed railway (HSR) lines have been built or planned. The very few navigable waterways in Spain are basically restricted to the lower reaches of the Guadalquivir and Ebro Rivers, and there is very little impact of this transport infrastructure on habitat fragmentation.

The increased size of the road network is primarily based on the construction of new tollways and motorways and the widening of other roads with a lower capacity. We therefore find that not only has there been an increase in the overall length of the road network, but its effect on habitat fragmentation has been substantially intensified due to lane widening, the installation of perimeter fences, heavy traffic density and higher average vehicle speed.

Estimates of habitat loss caused by transport infrastructure have found that approximately 4,300 km^2 of the country is covered by roads. If we include the verge areas occupied by embankments, cuttings, intersections, etc., this figure rises to 6,500 km^2. Although the presence of directly affected land is small, the size of the land belts on either side of the roads is much larger due to disturbances (noise, lighting, pollutants, etc.), to which we must add the isolation effect of habitat fragments and the interception of ecological link corridors between natural areas.

The barrier effect of roads and railways restricts species dispersal via several mechanisms. Firstly, the physical barrier of perimeter fences and other elements are insurmountable for small animals; secondly, areas that are paved or lack vegetation have been found to have a dissuasive effect on several taxonomic groups; finally, research also suggests the potential dissuasive effects of the noise and the view of passing vehicles. Several projects in Spain have studied animals that cross roads through transversal structures (drains, underpasses and overpasses) as well as fauna passages. It is important to note that the variables which influence the use of these structures differ between species and groups.

Road collision with animals is one of the most widely studied types of impact. Many inventories have been compiled across Spain by volunteers coordinated by conservation groups. The results of this monitoring work have led to the identification of many critical points in the Spanish road network for several species, the largest numbers of which are amphibians (particularly toads) and the common hedgehog. Unfortunately, this effect has much more serious demographic consequences when it affects rare and endangered species.

One critical case is the Iberian lynx, whose dispersing young are often collision victims on the roads that bisect their distribution areas. It is estimated that approximately 10 million individuals of various vertebrate species die on Spanish roads each year.

The effects of transport infrastructure on areas that are protected or host species or habitats of Community interest are yet to be studied in detail. In order to palliate this shortfall, the Environment Ministry Nature Data Bank has carried out an initial evaluation using a GIS based on the layers of road networks, primarily high-capacity types (National Cartographic Database, layer BCN200), and the network of SCIs, SPAs and Protected Natural Areas (PNAs) which will make up the Spanish contribution to the Nature 2000 Network. The results of this preliminary analysis show that 5,500 ha of areas designated as Priority Habitats (on the basis of the Habitats Directive) are less than 200 m from a road, while this figure increases to 150,000 ha in a 500 m belt. In addition, 1.3% of the land in Sensitive Areas is les than 200 m from a road and 3.3% is less than 500 m. The most seriously affected Regions in this respect are Madrid, Cantabria, the Basque Country and Rioja. Finally, almost 1,300 km of roads intersect Priority Habitats, and nearly 4,000 km intersect Sensitive Areas that have a high conservation importance.

Chapter 6. Road safety and vehicle-animal collisions

This chapter reviews the information available on the problem of traffic accidents caused by the presence of animals on roads. Although few studies have been conducted in Spain, several patterns and trends have already been detected. They are summarised below.

Author: Jiri Dufek

Of all accidents involving animals, 12.6% produce human victims. Although this is numerically unimportant in comparison with other causes of accidents, the figures available on the national road network show that there are at least 10 deaths per year caused by collisions between vehicles and animals, while at least 100 people are seriously injured each year due to the same causes. However, estimates based on the complete highway network suggest that this figure might actually be above 35 per year, with almost 300 serious injuries. Considering the total number of victims of this type of accident, minor injuries make up 74.0%, serious injuries 22.6% and mortalities 3.4%.

More than 90% of collisions between vehicles and animals (with both victims and material damage) happen on conventional highways, mainly due to the much greater length of these types of thoroughfares than high-capacity motorways, but also due to the fact that conventional roads do not usually have perimeter fencing. The annual rate of accidents involving victims per 1000 km is 3.3 on high-capacity infrastructure and 5.5 on conventional roads.

Accidents are more serious on high-capacity motorways than on conventional roads due to the much higher average speed of the vehicles. The annual number of mortalities per 1,000 km on high-capacity roads is double the number for conventional roads (0.42 and 0.20 respectively).

Published figures show that the provinces with the highest number of collisions with animals in recent years are in north-western, central and south-western Spain, although not enough figures are available for the whole country to produce a detailed distribution map.

The majority of accidents linked to the presence of animals are caused by domestic or farm animals, which are also responsible for a higher proportion of human victims and material damage, due to their large size in most cases (especially horses and cattle) and their greater frequency of involvement in accidents on high-capacity roads. The wildlife species involved most often in collisions with vehicles include wild boar (roughly half) followed by roe deer and red deer.

Studies currently underway in Soria Province show a constant increase in the number of collisions with roe deer, red deer and wild boar in recent years. This is probably related to the geographic and demographic expansion of these ungulates, although road quality improvement works may also play a role as higher speeds are now possible.

The time factor plays an important role in the incidence of collisions between vehicles and animals. Firstly, there is a daily variation in the frequency of collisions. There are more accidents at twilight and at night, especially in the case of wild animals which are more active at these times, unfortunately coinciding with the periods of poorest visibility for

drivers. Secondly, there is also a variation in the number of collisions during the week. There are more incidents involving both wild and domestic animals at weekends and public holidays, when more cars use inter-urban roads. The weekly variation is also influenced by the game season due to animal movements triggered by hunters. Collisions between vehicles and wild boars are more frequent on days following an organised hunt. Finally, there is also a variation in the frequency of collisions in the course of the year which, in the case of wildlife, appears to be related to the life cycles of the species involved (rutting, dispersal, etc.). In the case of roe deer, accidents are more frequent in spring and summer while the peak period for accidents with wild boars occurs in autumn and winter.

Chapter 7. Mitigation and compensation measures for the effects of habitat fragmentation

This chapter discusses the current state of the measures applied in Spain to mitigate the effects of transport infrastructure on habitat fragmentation, particularly in the light of the intensification in recent years of the construction of specific fauna passages and the adaptation of other transversal structures that animals can use to cross the roads. The most notable aspects are summarised below.

Author: Junta de Castilla y León

The measures aimed at mitigating the impact of the new transport infrastructure are designed in the course of the EIA, defined in the Environmental Impact Declaration (EID) of each project and published in the Official Gazettes of the governments involved in the EIA. A clear deficiency of inventories and analyses of effects on fauna in the EIAs have been detected. This lack of essential data has a direct, negative influence on the EID when it comes to establishing mitigation measures. There are no compulsory standards or regulations in the design of measures aimed at preventing the effects of habitat fragmentation.

A questionnaire was distributed amongst the representatives of the National Transport and Environment Departments involved in the COST Action 341 National Working Group. The answers contained in these questionnaires were the source of most of the information contained in this section, although experts and official organisations with information on the subject were also consulted. A total of 168 questionnaires were returned, and as a result, it was possible to compile data on more than 550 measures aimed at permeabilising structures and reducing the number of collisions between vehicles and animals, as well as on 15 projects for compensatory measures.

With respect to the mitigation of the barrier effect, information was provided about 5 tunnels, 1 false tunnel and 7 viaducts, constructed specifically to enable fauna to cross the roads. The first structures to be built specifically for fauna passages were installed in Galicia between 1997 and 1998. At present, the database contains information on 5 overpasses and 56 underpasses built exclusively for fauna on Spanish roads and railway lines, although this inventory is not exhaustive. The overpasses have modest dimensions ranging from 12 to 25 m wide, and are thus much narrower than the large ecoducts or green bridges that have been built in other European countries, which in some cases span more than 50 m. A wide variety of underpasses have been built, from small pipes with dimensions of 0.25 m x 0.20 m for amphibians, to box sections measuring 10 to 20 m wide for large mammals. In general, however, they have more modest dimensions. Some of the under- and overpasses are specifically designed for wolves, Iberian lynxes and otters. The most commonly applied measure is the adaptation of culverts and other underpasses or overpasses, which were initially designed for other purposes such as the re-establishment of public livestock routes, streams, forest tracks, roads, etc., but can be made compatible with their function as fauna passages. In a sample of more than 300 adapted structures, it was found that the most frequently used adaptations include oversizing, conditioning the base with natural materials (e.g., concrete to cover corrugated iron), the construction of lateral concrete banks which are

kept dry while water passes through the structure, the revegetation of accesses and the replacement of stepped culverts with stony ramps at the drain outlets.

Vehicle collisions with animals are a cause for concern due to their effects on road safety, and in Spain a range of measures are being used to prevent these accidents. The inventory shows that the most common measure is the installation of perimeter fences in the most vulnerable sections (in some but by no means all cases combined with fauna passages). Another widely used measure is the installation of standardized signs that warn of the presence of wild animals. Unfortunately, their profusion along roadsides has led to a low level of respect by drivers. For this reason, in some natural areas special signs (in some cases large-format) have been installed to insist that wild species often cross the road in the vicinity. In the Navarra Region, signs combined with flashing lights have been installed in the most dangerous sections. Reflectors and olfactory repellents are used in Castile and Catalonia, although their real effectiveness has not been confirmed. None of these measures have proven to be fully effective, and detailed studies are necessary to define the best option in each case.

Most of the compensatory measures used at present are stipulated in the EID of projects for tollways, motorways and HSR lines that affect areas to be included in the Nature 2000 Network, in application of Article 6 of the Habitats Directive. Information on 15 of these projects is included. The actions are quite varied, and include riverine bank restoration, habitat improvement, the recovery of degraded areas, funding for species recovery plans and others. These compensatory measures should be applied under clearly exceptional circumstances: the basic principle established by the Directive is prevention, i.e., effects on the species and the priority habitats included in the Nature 2000 Network must be avoided. Moreover, the studies, monitoring, environmental education and dissemination activities should be regarded as supplementary, not basic actions given that compensation is aimed at achieving zero net loss, i.e., that all disturbed habitats must be replaced by quality habitats that can perform the same functions as the areas in their previous state, with an area equivalent to or greater than the affected zone.

Despite the fact that the effectiveness of the measures should be monitored within the framework of the Environmental Monitoring Plans (EMPs) established by the EIA procedure, all of the cases documented in this research are studies that have been unrelated to EMPs and commissioned by different public bodies. The first cases were begun in 1991 and to date, 9 fauna passage monitoring studies have been documented in Spain.

Chapter 8. New infrastructure construction and prevention of habitat fragmentation

This chapter is a review of plans for the construction of new transport infrastructure in Spain and the tools available to analyse and prevent habitat fragmentation that may occur in the landscape. The most relevant information in the chapter is summarised below.

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Plans are underway in Spain for heavy investment in linear infrastructure over the next few years, with the construction of approximately 5,700 kilometers of new road and railway infrastructure. The majority of these new alignments are tollways, motorways and HSR lines. Many of them will be located in regions which have had a slower level of economic development to date, associated with a better conservation state of their natural systems. Perimeter fencing of this infrastructure and its expected high-intensity of traffic will presumably create a serious barrier effect, although the construction of tunnels and viaducts required by the steep mountain terrain in many areas and the requirements of alignments that permit high traffic speeds may alleviate this impediment in some regions.

Several existing roads are to be widened, although the length of improvement and restitution works is much smaller than in the case of new alignments. Some of these works will intensify the pre-existing effects caused by barriers and habitat fragmentation: these types of road improvement usually lead to higher traffic speeds, road widening and fencing in some sections as well.

To date, habitat fragmentation due to the construction of linear infrastructure has received little attention in the environmental and transport strategies and policies of the regional and national governments. However, some of the recently published documents including the *Spanish Strategy for Biodiversity Conservation and Sustainable Use* mention the need to consider this effect in conservation policies. This could facilitate the consideration of habitat fragmentation as well as its inclusion in SEAs. In addition, the draft *Guidelines for the Production of Plans for Sustainable Development in Manufacturing Industry*, which derive from the above-mentioned *Strategy*, includes a section on the transport sector. It proposes priority actions for the prevention, correction and mitigation of impact and disturbance in the natural environment, including a large number of proposals that refer to habitat fragmentation. It also insists on the need to prioritise biological connectivity in the planning process of new infrastructure, the implementation of SEAs and the improvement of the standard of Environmental Impact Studies (EIS) and environmental monitoring programmes.

At the Regional level, several Regional Governments have already defined their strategies for biodiversity conservation, which cover the issue of habitat fragmentation caused by the transport infrastructure. Other Regional Governments have designed actions relating to biological connectivity, envisaged in environmental plans and programmes. In other cases, the mechanism for including habitat fragmentation aspects in the construction projects for linear infrastructure focuses on the EIS, although this does not enable environmental aspects to be included in the planning stage. The Natural Resource Ordination Plans are another tool that provides for the consideration of habitat fragmentation prevention.

Other fundamental tools for the prevention of habitat fragmentation include funding for measures that facilitate territorial connectivity in programmes covered by Cohesion and Structural Funds, increasingly stringent environmental requirements for the use of European funds to finance infrastructure projects and, in the future, the application of SEAs to the evaluation of new transport infrastructure development plans and projects, incentivated by Directive 2001/42/CE.

Transport-associated plans and projects in Spain usually analyse environmental effects such as noise, air pollution and land occupation, but they rarely tackle the issue of impact on habitat fragmentation. The *Transport Infrastructure Plan 2000-2007* is the blueprint for transport planning in Spain. This plan has not undergone a SEA, and its overall impact is therefore unknown. Each of the projects covered by it will therefore have to undergo an individual EIA procedure.

If we wish to improve the tools for evaluating the impact of the existing infrastructure and prevent further impact by future projects using more effective territorial planning, further research in this field is absolutely essential. The resulting information will then facilitate the design of validated indicators and indices of habitat fragmentation to be used as a reliable basis for monitoring environmental trends and tendencies in the operating infrastructure. The European Environment Agency is promoting the Transport and Environment Reporting Mechanism project (TERM) on transport and environment indicators. It has defined two indicators for fragmentation, although they do not reflect the real effect on the ecological processes linked to this phenomenon. The Spanish system of environmental indicators does not propose indicators for habitat fragmentation caused by transport infrastructure, although it does so for the sub-area of biodiversity, for which it proposes two indicators, one on pressure and another on the state, both linked to the effect of roads.

In the Spanish Regions, one outstanding case is the use of indicators on habitat fragmentation in Navarra during the drafting process of proposed SCIs (isolation index, fragmentation index, infrastructure density, ecological connectivity, and size and shape of the territorial units to be included). The Navarra Regional Government also applies an index aimed at evaluating habitat fragmentation in the metropolitan area and the surrounding ecosystems in Pamplona. In other studies, indices of sensitivity by ecologically important vertebrate species to the barrier effect have also been used.

When drafting models that can be used to simulate various scenarios relating to the impact of new transport infrastructure, it is essential to have access to basic information on landscape matrixes and the different functions of their components (zones of high conservation importance and ecological links between them), as well as complete, up-to-date maps of all the existing and planned transport infrastructure. The application of models in Spain is hindered by the diversity of digital map formats in use, the different degrees of detail in the databases held by each Regional and National Government body, and also the difficulty of transferring information from one database to another.

Chapter 9. Economic aspects

This chapter highlights the paucity of figures on external costs of transport infrastructure, particularly with respect to the prevention and mitigation of habitat fragmentation. Nevertheless, several data are provided and juxtaposed against the framework provided for total investment in the construction of transport infrastructure.

Author: Minuartia

The majority of financial investment in linear transport in Spain is earmarked for the construction of new high-capacity infrastructure, both roads and railways. For the 2000-2010 period, the new Transport Infrastructure Plan (TIP) envisages an average annual budget for transport infrastructure of €9,400 million, equivalent to 1.37% of the GDP. In specific reference to roads, the TIP for this period envisages a total of €21,046 million, of which €19,844 million will be for new highways and €1,202 million for upgrading existing roads. The same figures reveal that the average cost per kilometre of these new high-capacity roads will be approximately €3.9 million. The new tollways have a higher average cost, reaching €5.0 million. Investment in improvements and upgrading of existing roads has an average cost of €450,000 per km. The TIP also plans to spend €40,500 million in the same period on railway lines- almost 40% of the total investment in infrastructure.

Studies at a pan-European scale show that external costs of the transport sector can be as much as 8.3% of the GDP. This figure is broken down into 5.5% of the total for environmental costs, 2.3% for accidents and 0.5% for traffic congestion. In contrast, income from fuel taxes only makes up 2.5% of the GDP, far from the amount needed to cover the external costs.

Another fundamental aspect, investment in actions aimed at reducing the impact of transport infrastructure, ranges from 1.0% to 3.5% of the total works budget for both direct and indirect costs. The cost of mitigation, compensatory and environmental integration measures is usually 5% of the total, although in some exceptional cases it can reach 15%.

Most of the investment in the reduction of habitat fragmentation is spent on adapting transversal structures for use as fauna passages, i.e., the adaptation of culverts and the construction or adaptation of overpasses. In some recent initiatives, the latter types have had an average cost of €287,885 in the case of mixed passages for traffic and animals, and up to €360,000 if they are specific fauna passages. Underpasses cost between €12,000 and €20,000. The maintenance cost of this infrastructure then has to be added to the initial construction investment. Monitoring is also necessary to ascertain the cost / effectiveness ratio of these types of measures.

Figures supplied by insurance companies on the costs associated with vehicle-animal collisions show that there are approximately 5,000 accidents involving animals per year, with claims averaging €2,700. Other sources suggest that the average specific cost of accidents involving wild boars is €1,134, and €816 for collisions with roe deer. Figures on personal injuries in accidents caused by animals refer to 1990 figures on average amounts claimed for minor injuries, serious injuries and deaths. These figures and estimates of the number and severity of injuries in accidents involving wild animals yield an annual cost of approximately €851,000.

Chapter 10. General conclusions and recommendations

I. Spain's geographic situation has led to a highly diverse range of biogeographic regions in the country which, along with the heavily broken relief and the varied land uses generated by human activity, has configured a landscape mosaic with an e**xtraordinary biological diversity**. The Iberian Peninsula hosts numerous endangered and endemic species under pan-European protection. This has led the Spanish Government to contribute almost 25% of the total land area proposed for inclusion in Europe's Nature 2000 Network. Inter-habitat connectivity is essential to ensure the survival of many species and habitat fragmentation is thus a threat to the conservation of the country's biological diversity. The constant increase in fragmentation is due to several factors that act in synergy. They include the intense development of urban land, the modernization of agriculture and, above all, the spread of the transport infrastructure network which is exerting heavy pressure on the natural areas and their environs.

Author: AUDASA

II. The current transport infrastructure already spans 700,000 kilometers and construction is now underway to create **a substantial increase in the size of the linear transport network** in the 2000-2010 period, estimated to cover a further 5,700 kilometers. All of this new infrastructure, most of which will be high-capacity (tollways, motorways and HSR lines), is a potential source of habitat fragmentation and may well have a serious impact on biodiversity conservation. It is therefore essential to intensify the awareness-raising process and information exchange amongst the agents involved in transport infrastructure planning and construction. This in turn should promote an accurate analysis of potential impact and lead to the inclusion of measures that will ensure its minimization.

III. One of the types of impact caused by the present transport infrastructure network is the **direct loss of habitats.** Approximately 6,500 km^2 of Spain's land area is calculated to be covered by road and associated features such as embankments, cuttings and intersections, yet no accurate details are available on the size of the Protected Natural Areas or zones classified as priority areas under the Habitats Directive 92/43/CE which are directly or indirectly affected by this type of infrastructure.

IV. Another important effect of the transport infrastructure is **collisions with animals**. More than 10 million individuals of different vertebrate species die each year in Spain due to this cause. The most serious type of impact, however, is not the total number of individual mortalities but rather the effects on species of high conservation importance such as the Iberian lynx, in danger of extinction, for which collisions rank as its major cause of mortality. Collisions between vehicles and animals are also a road safety problem, which are exacerbated by heavier and faster traffic. Most accidents involve farm animals, but in recent years the number of collisions involving ungulates such as roe deer, red deer and wild boar, have increased in parallel to the size of their populations in many Regions. The detection of critical points where most collisions occur and, more specifically, the variables that determine their location is a priority aspect for the location of fauna passages, the design of collision prevention measures and the enhancement of road safety initiatives.

V. Designers try to mitigate the **barrier effect** of transport infrastructure on animal movements by building specific fauna passages and adapting culverts and other transversal structures that can be used by animals that need to cross. A large number of studies on this aspect have shown that there are essentially two types of mechanisms. On the one hand, perimeter fences are a physical barrier to the movement of certain species while on the other, paved surfaces and moving vehicles have a disincentive effect on several taxonomic groups. Research published to date shows that the consequences of the barrier effect vary greatly, depending on the species that are affected and the state of their populations. In addition, the characteristics that facilitate or hinder the use of the fauna passages and other adapted transversal structures also vary with the type of species involved. It is therefore essential for the design of fauna passages to be based on a thorough understanding of the requirements by the species that are expected to use this feature if they are to be at all effective.

VI. The **EIA procedure** is the main mechanism that is currently applied to all new transport infrastructure projects, as well as to some of the upgrading works, with a view to mitigating their environmental impact. Rarely, however, do EIS consider habitat fragmentation overall and the analysis of alternatives to the project do not usually evaluate fragmentation caused by the different options. Assessment is usually based on a cartographic analysis of the alignment options under consideration and their environs, but do not consider the impact at a sufficiently broad regional scale to appreciate the effects generated by the new barrier on the habitats and species in the natural areas of conservation importance nor in the ecological link corridors. Moreover, they usually do not analyse the synergies triggered by the new alignment when it is added to those that already exist, or other elements that cause fragmentation such as built-up areas. The inclusion of a broader analysis at the appropriate territorial scale would enable the impact to be detected with more precision. It is therefore important for Government Departments to facilitate access to up-to-date information on the aspects needed to undertake these analysis, including the boundaries of natural areas, habitat maps, species distribution atlases, and areas covered by existing, under construction and planned networks. Another aspect that would improve the EIA procedure would be

the establishment of compulsory minimum regulations or standards with respect to the location of fauna passages and the conservation of the ecological links between natural areas.

VII. One part of the COST 341 Action was an inventory of the **measures currently being applied to avoid and mitigate the impact** of the transport network on habitat fragmentation. The results show that the use of these measures has intensified considerably in recent years. The first passages for the exclusive use of fauna were built in 1997 and now it is common practice to include this type of structure in the alignment. In general, however, the passages are very small (the largest examples are no more than 20 metres wide), and their usage by animals is often combined with other functions such as drainage and even vehicle transit. More effective animal passages can be constructed by increasing their size and improving both the entrances and the actual structure. The most effective features for permeabilization are tunnels, false tunnels and large viaducts that are specifically designed to re-establish the link between habitats that are intercepted by the infrastructure. More encouragement for the construction of these types of elements is needed, especially when the alignments affect highly sensitive areas.

VIII. The application of **compensatory measures** is beginning to become standard practice due to the implementation of Article 6 of the Habitats Directive 92/43/CE in zones where new transport infrastructure affects areas that have been proposed for inclusion in the Nature 2000 Network. These compensation projects require serious financial investment to recover the affected species and habitats. However they should be regarded as an exceptional tool, given that the principle established by the Directive is prevention. This means that steps should be taken to prevent effects on SPAs and Areas of Special Conservation Interest, and that alternative alignments (or alternative forms of transport) should be sought to prevent negative impact on these areas. Another important aspect is that the purpose of compensation is to achieve what is known as "zero net loss", i.e., that every disturbed habitat is replaced by a quality habitat that can perform the same functions as the initial ones in a zone with the same or greater area than the affected zone. Research, monitoring, environmental education activities, etc. should be therefore be regarded as complementary activities, and compensation should not be focused on these types of actions.

IX. Under the new 2000-2006 Programming period for the use of European funds, the environmental requirements will become increasingly stringent for new infrastructure projects. This makes it all the more necessary to **improve the impact prevention tools**. Both the Spanish Strategy for Biodiversity Conservation and the Spanish Strategy for Sustainable Development emphasise the need to implement habitat fragmentation prevention actions by means of territorial and industrial planning and development policies, while at the same time mitigating the side-effects of the transport infrastructure. In order to ensure that these objectives are achieved, fragmentation prevention mechanisms must be included in the various aspects of natural resource planning and management (natural resource planning, management plans for protected natural areas, species recovery plans, etc.) as well

as in territorial planning (regional development plans, general urban zoning plans, by-laws, etc.) in addition to the obviously important core plans for industrial development and transport infrastructure.

X. Another essential element in the prevention of habitat fragmentation is the analysis of the effects of infrastructure programmes and development plans under the new **Strategic Environmental Assessment** promoted by Directive 2001/42/CE. In this context, it is advisable to subject the new 2000-2007 Transport Infrastructure Plan to the SEA procedure, with special emphasis placed on its effects on the areas that will become part of the Nature 2000 Network and the ecological links in order to ensure their long-term conservation. This requires the establishment of specific objectives, methodologies and criteria in order to focus on the problem. In this context, it should be noted that the European Strategy for Biodiversity Conservation recommends that each country should establish networks that integrate core areas of special conservation importance, buffer zones around them and ecological links that enable the connections between these areas to be maintained. The definition of the Nature 2000 Network is now being completed in Spain, and both the National Government and some of the Regions have already begun pioneer experiments in the analysis of territorial connectivity between protected areas, the first step in the definition of a true network of interconnected spaces. These landscape and connectivity analyses are indispensable for the evaluation of habitat fragmentation caused by infrastructure that is planned, under construction or in use, and are also of crucial importance in SEA.

XI. **Monitoring**, both in terms of changes to habitat fragmentation and the effectiveness of the measures proposed to prevent or mitigate their consequences, is another aspect that should be given a powerful impetus. The effectiveness of the measures put into practice is already being evaluated in some projects, although this is not a general rule, nor is it done using standardized methods that permit a comparison between results. The lack of a clear definition of the objectives of the measures is often a hindrance to the design of monitoring programmes and the evaluation of their effectiveness. Most of the projects focus exclusively on monitoring fauna passages and other structures that can potentially facilitate the animal movements, and check which species use them. The dissemination of these results is a vital step towards ensuring that future investment funds will be spent on the most effective measures and the impact is mitigated most successfully. Although most of the results have been published in specialist journals, it is still important to recommend their reading and to intensify their dissemination by other means such as training courses and the inclusion of this material in education courses for engineers who will be responsible for infrastructure design, construction and management. In addition, there is a striking lack of methods which could facilitate an integrated analysis of current land uses and assessment of existing habitat fragmentation, with a view to covering the rest of the sources of this impact in addition to the transport infrastructure. Geographic Information Systems (GIS) are a fundamental tool in this type of analysis, however it would be advisable to also define validated models that can be applied to the integrated evaluation of habitat fragmentation caused by a range of factors, as well as indicators to be used as the basis for monitoring variation trends.

XII. The complexity of the prevention, mitigation and analysis of habitat fragmentation caused by transport infrastructure is due to the need for approaches at different scales (regional and local), and also the need to consider the synergies produced by the new infrastructure when it is added on to existing public works and other agents that also cause fragmentation. For this reason, the main **future challenge** consists of ensuring that this impact is approached holistically, from the perspective of territorial and landscape analysis, and that it is taken into serious consideration at each stage in the lifetime of the infrastructure, from planning to operation. This necessarily requires in-depth cooperation between professionals in different fields as well as the involvement of authorities at every level, including territorial planning. Only awareness-raising and interdisciplinary work amongst these groups will permit the effective reduction of the negative impact caused by fragmentation on biodiversity conservation.