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Wildlife Highways

Proposal by WWF Spain for a Strategic Network of Ecological Corridors connecting Natura 2000 sites

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WWF is one of the world's largest and more effective independent international organizations dedicated to the conservation of nature. WWF operates in more than 100 countries, with the support of around 5 million members throughout the world.

WWF works for a live planet and its mission is to stop the degradation of our planet's natural environment and build a future in which people live in harmony with nature, by: conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, promoting the reduction of pollution and wasteful consumption.

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OVERVIEW

A territory where the sites of natural value are connected and enables the movement of fauna and flora, the exchange of genes and, in a broader sense, the operation of ecological processes, is key for conserving biodiversity and natural resources and for facing the unwanted effects of climate change with greater guarantees.

Moreover, in Spain, subject to strong landscape transformations and the effects of climate change, stopping the processes of isolation and fragmentation of the species' habitats and searching for solutions to guarantee ecological connectivity have become especially relevant tasks for halting the loss of biodiversity.

Numerous studies have already confirmed that conservation goals cannot be reached based only on the declaration of isolated protected areas (Franklin, 1993; Krosby et al., 2010; Laurance et al., 2012; Juffe-Bignoli et al., 2014; Saura et al., 2018). This has resulted in a growing number of countries starting to consider the need to establish connectivity networks that facilitate the flow of organisms and ecological processes among those sites.

REACHING THE ECOLOGICAL CONNECTIVITY OF THE TERRITORY IS KEY FOR THE CONSERVATION OF BIODIVERSITY AND NATURAL RESOURCES, AND TO FACE THE EFFECTS OF CLIMATE CHANGE WITH GREATER GUARANTEES.

In view of this, and of the legal obligations arising from European and Spanish legislations, WWF presents in this document a connectivity vision for mainland Spain with a proposal of ecological corridors connecting Natura 2000 sites. It considers the transnational corridors, that operate as connectors between sites located in the Spanish territory and span in sections of their demarcation over to the territory of border countries (Portugal, France and Andorra). For methodological reasons, this study does not include the island territories. This proposal has been generated based on a study conducted by Polytechnic University of Madrid at the request of WWF Spain.

Priority corridors have been identified among the forest habitats of the Natura 2000 Network to guarantee the mobility of forest species. This approach has been chosen due to the wide representation of this type of habitats in Spain and in the Natura 2000 Network, as well as for the greater availability of information needed for the connectivity analyses. It has also determined which corridors are in most need to be restored to improve the network's connectivity, which are a priority for conservation, so that they at least

maintain their current conditions, and which of these corridors are acting as bottlenecks, hindering the movement of species and with particularly fragile conditions to guarantee their connecting role.

This proposal has been prepared using the best and more recent tools and methodologies available for the connectivity analysis (Saura and Pascual-Hortal, 2007; Saura and Torné, 2009; McRae and Kavanagh, 2011; De la Fuente et al., 2018) and it focuses on the need for mobility of a wide group of forest species, favouring the connection for a variety of habitats (closed canopy forests, clear forests and scrublands) and ecological processes related thereto. However, the proposal does not cover aspects such as connectivity for species and habitats of the steppe or agrarian types, nor for aquatic habitats. Without doubt, it would be of great interest to analyse these lacks in the future and add information to this study.

To conclude, the results provide explicit key information to be considered by the environmental and sectorial policies –of land planning, agriculture, or transportation- and thus meet Spain's obligations and undertakings regarding biodiversity conservation. *Wildlife Highways. WWF Spain proposal for a Strategic Network of Ecological Corridors connecting Natura 2000 sites* provides a necessary and long-term view that will also be very useful to achieve ecological connectivity among European countries.

RESULTS OF THE ANALYSIS

12 PRIORITY ECOLOGICAL CORRIDORS

17 CRITICAL AREAS FOR CONNECTIVITY

INTRODUCTION: A NETWORK OF ECOLOGICAL CORRIDORS FOR MAINLAND SPAIN

Ecological connectivity may be defined as the ease with which the mobility of species and other ecological flows take place through the territory between the numerous natural or semi-natural areas. Having available a territory where the natural areas are not isolated one from the other is vital for the survival of the species and for our own well-being, and also for facing the consequences of climate change.

In Spain, as in the rest of Europe, natural habitats (such as forests, wetlands, etc.) and semi-natural habitats (such as Dehesas) have been and are continually being destroyed and fragmented by human activity through the building of residential facilities, highways and roads, the development of intensive crops, the overexploitation of water resources, etc.

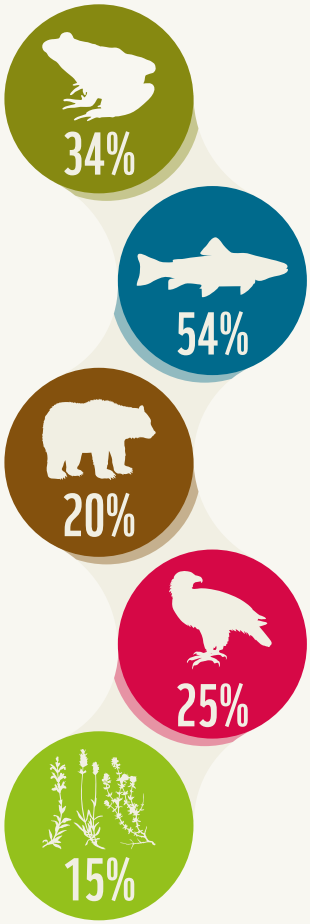
Notwithstanding the increase of the forest cover in the last decades in Spain, mainly due to the rural abandonment process, the historical process of fragmentation and loss of habitats that continue to this date have left a territory with increasingly smaller and isolated patches of vegetation that have a limited capacity for the conservation of biodiversity in the long term.

Article 3 of the Law defines an ecological corridor as a "territory of variable extension and configuration that, due to its layout and conservation condition, functionally connects natural sites of special relevance for flora and wildlife that are separated from each other, enabling, among other ecological processes, the genetic exchange between wildlife species or the migration of specimens of such species."*

One of the most important causes of fragmentation and habitat destruction has been the building of transport infrastructure, which has greatly intensified in the last two decades. Recent studies show that the impacts of infrastructures on wildlife species extend to practically the entire country (Ibisch et al., 2016; Torres et al., 2016) except in some areas that are still very far from the roads, such as the Sierra Morena. The most alarming impact is on mammals, since the roads are affecting, to a greater or lesser extent, 97.7% of the entire country and it is estimated that there has been a decrease of 50% in the number of individuals in comparison to that which would exist without these transport infrastructures (Torres et al., 2016). One could also mention the effects of other policies on the destruction and fragmentation of habitats, such as the agrarian and water policies.

Spain is the richest country in biodiversity and in turn, the most vulnerable to losing it in the European continent, according to data from the International Union for Conservation of Nature (IUCN), with the loss and fragmentation of habitats as the main cause. We have the largest percentage of threatened species in all Europe: 34% of the amphibian and reptiles,

*Law42/2007, of December 13, on Natural Heritage and Biodiversity, amended by Law 33/2015, of September 21



54% of continental fish, 20% of mammals, 25% of breeding birds and 15% of vascular plant species (MAGRAMA, 2014).

At a global scale, the quick loss and fragmentation of habitats is the world's main cause of loss of biodiversity, as set forth in the Living Planet Report (WWF, 2016). Flora and fauna species are disappearing as the size of the places where they live shrinks and the distance between them grows, at times reaching total isolation. This problem also affects the natural processes that sustain our survival: pollination, supply of water of good quality, dissemination of seeds, carbon capture, etc.

The declaration of protected areas has contributed to stop, in part, the fragmentation process and loss of habitats, at least in certain areas of the territory, thus contributing to the conservation of species and habitats *in situ*. At times, these have been the only strongholds where isolated populations of threatened species have been able to survive, such as the Brown bear and the Iberian lynx. In this regard, the creation of the Natura 2000 Network in Spain has been a fundamental step to reach the objectives of conservation of habitats and species, since this network of protected sites covers approximately 27% of our territory.

However, to be effective, conservation must go beyond the borders of the protected areas. Nature, to perpetuate itself, must be a connected system and not a set of isolated sites, wherefore it is necessary to preserve a network of interconnected natural and semi-natural sites that allow for the movement of species and the functionality of ecosystems.

In fact, despite the considerable scope of the Natura 2000 Network, the European Commission itself has assessed that 28% of terrestrial and freshwater habitats of the European red list of habitats (Janssen et al., 2016) are not sufficiently protected by the network. Therefore, to reach the ecologic coherence of the Natura 2000 Network, as provided for by the European Directives on Habitats and Birds (Articles 10 and 3, respectively), calls for going beyond the limits of the sites. By adopting the EU Strategy on Green Infrastructure in 2013[1], the European Commission foresees fostering connectivity through the green infrastructure, understood as a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, Green Infrastructure is present in rural and urban settings.

The importance of ecological connectivity is even more relevant in the current context of climate change. The restoration and conservation of ecological corridors is a broadly renowned strategy for adapting to climate change, since it allows for the dispersal of many species that will need changes in their spatial distribution, frequently to greater latitudes or altitudes, due to the new climate conditions (Heller and Zavaleta, 2009; Krosby et al., 2010).

Spain is becoming and will be one of the countries most affected by climate change. Predictions point to an increase of 4 to 6 degrees Celsius in the interior of the Iberian Peninsula by 2100, and an increase in the aridity. In this climatic context, the general trend

1 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Green Infrastructure- Enhancing Europe's Natural Capital /* COM/2013/0249 final */

goes towards a major impoverishment and relocation of biodiversity, which would have to relocate seeking new territorial areas with the most favourable climate conditions for each species, which frequently implies displacements towards greater latitudes or altitudes.

With all this, ensuring the ecological connectivity of the territory is not only one of the main conservation challenges, but it is expressly set forth in the Spanish Law 42/2007 for Natural Heritage and Biodiversity (Article 21) as a priority goal in the system for the conservation of natural resources.

While it is true that some autonomous communities have started different types of binding processes to identify and manage connecting corridors or areas of interest, Spain does not have any study to identify a national corridor network based on scientific premises that are not constrained by the administrative boundaries of a given autonomous community, and considers potential cross-border corridors with France, Andorra, and Portugal. For methodological reasons, this study does not include the island territories, which, without any doubt, should be the matter of a specific analysis.

Due to the current challenges it covers and its future and integrated vision for the entire territory, WWF Spain presents in this document an innovative and important proposal for the main ecological corridors whose restauration and maintenance must be guaranteed in the mainland Spain to preserve the biodiversity and ecological processes in our country, in keeping with our legal obligations.

This proposal is based on a study commissioned by WWF to the Polytechnic University of Madrid. The full document can be found in:

wwf.es/estudioconectividadupm

SCOPE, METHOTOLODY AND IDENTIFICATION OF CORRIDORS

This section explains the approach, the scope of the study and the methodological proposal applied. Following are the results thereof.

SCOPE AND APPROACH OF STUDY

This study and proposal of corridors have been conducted to enable the **connectivity of the forest habitats of the Natura 2000 Network** and to ensure the mobility of the species associated with this type of habitats in mainland Spain. The island territories are not included in this study for methodological reasons.

Practically the entire Natura 2000 Network has been considered as core areas to be connected

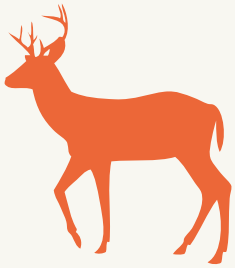
The core areas considered that must be connected are forest stands of diverse structures, coverages, and degrees of development, from scrublands to dense or closed canopy forests. Thus enabling this proposal to consider the connectivity of a very broad range of fauna species associated with mature forests and more open areas with sparce forest canopy. This relates to a major and broadly representative part of our territory, also encompassing the requirements and preferences of a large number of species associated with these habitats and practically all sites included in the Natura 2000 Network are connected: those considered as core areas to be connected represent 97% of the total SCIs areas and 87% of the total SPAs areas in mainland Spain.

Notwithstanding the broad scope of this study, it does not include a connectivity analysis for species more linked to agricultural or aquatic habitats. It is important to point out that the agricultural areas have not been deemed to be core areas, but they have been taken into account as part of the territorial matrix in which the passage of the ecological corridors has been analysed. In fact, several areas in the territory that are mainly agrarian are traversed by the identified corridors, such as the two plateaus or the valley of the Guadalquivir River, although they are narrow corridors that have connectivity limitations.

It would be advisable to supplement this proposal in the future with priority corridors for other types of species and habitats not represented in this analysis and to consider and analyse the role of other type of connectors such as the livestock trails.

In terms of the chosen connectivity approach, priority corridors have been identified from the standpoint of **mobility of a group of wildlife species: forest mammals.** Among the numerous available approaches to identify corridors, such as attaining the continuity of Scope, methodology and identification of corridors ecosystems or ecosystem services, the approach on the mobility of a group of species with a high index value was agreed upon

as most suitable at a meeting of connectivity experts organized by WWF Spain[2]. It was acknowledged that using the mobility needs and preferences of species as a baseline for the analysis enables identifying the connectivity levels and limitations thereof in a more objective manner and it was assumed that recovering the connectivity for a broad group of species also contributes to the functionality of the ecological processes and to maintaining and encouraging other ecosystem services.



Forest mammals are important connectivity indicators.

Forest mammals show a wide range of dispersal capacity, they are sensitive to changes in the cover and land use in the territorial matrix at different scales, they have a broad distribution and are often dispersing agents for other species, such as seeds. Therefore, they are especially valuable as connectivity indicators for a broader set of species and ecological processes at a broad spatial level such as the one considered herein: mainland Spain.

In this study, WWF presents a **conservation vision** necessary to ensure compliance with the Habitats Directive and the Spanish Law on the Natural Heritage and Biodiversity, as well as to reach the international conservation objectives included in the European Biodiversity Strategy to 2020, in the Aichi Targets and the Sustainable Development Goals. The restoration and conservation of the corridors proposed herein will greatly contribute to reaching other environmental goals, such as those included in the Water Framework Directive, the Floods Directive or the National Plan for Adaptation to Climate Change.

METHODOLOGY

WWF proposes a network of priority corridors that connect the forest sites of the Natura 2000 Network in Spain, including those that may pass by cross-border areas of Portugal, France and Andorra[3], and with a differentiation according to their conservation and restoration priority. Also identified within those corridors are the sections with critical conditions for connectivity. For this purpose, a combined set of internationally accepted tools and techniques have been applied to analyse connectivity: ecological network analyses, habitat availability indexes, resistance surface to movement and least-cost path analysis (De la Fuente et al., 2018). This methodology involves four steps.

2 First Connectivity Experts' Workshop, April 2015. Conclusions may be found at: http://bit.ly/TallerConectividad

3 This analysis has included the entire territory of Portugal and Andorra, in addition to the territory of France located up to 200 kms. north of its border with Spain.

1. IDENTIFICATION OF ECOLOGICAL CORRIDORS

IDENTIFICATION OF CORE AREAS + RESISTANCE SURFACES

Mapping three types of forest habitats in the Natura 2000 Network: closed canopy forest, clear forest, and scrublands, using the Forest Map of Spain 1:50,000 and the Natura 2000 Network map.

Adaptation and use of existing resistance surfaces for forest mammals by ascribing resistance values to covers defined in SIOSE (2005) for Spain and in the Corine Land Cover (2006) for France and Portugal.

IDENTIFICATION OF LEAST COST PATHS

Identification of least cost paths (corridors) that accumulate less resistance by species to moving between the core areas using the Linkage Mapper tool version 1.0.9.

REPRESENTING THE CORRIDORS WIDTH

Represent the resistance on both sides of the central axis of the corridors identified, combining the results of the Linkage Mapper tool and the resistance surface.

2. PRIORITISATION AND CLASSIFICATION OF ECOLOGICAL CORRIDORS

Prioritise the corridors that require concentrating the conservation and restoration efforts, bearing in mind the importance and likelihood of using such corridor, by means of analyses based on spatial graphs and habitat availability indexes (connectivity probability) performed with the Conefor tool.

3. IDENTIFICATION OF CRITICAL AREAS FOR CONNECTIVITY

Identification of 10% of the sections of priority corridors in which the environmental conditions (average in a radius of 1 km) pose greater resistance by the forest species to move (bottlenecks) by means of GIS analysis of the results generated in the previous items.

4. LAND USE ANALYSIS

Cartographic analysis of the overlapping of corridors with three types of covers: riverbank areas, agricultural areas and sites included within Natura 2000 Network.

1 IDENTIFICATION OF ECOLOGICAL CORRIDORS

Two necessary preliminary elements have been defined to identify ecological corridors in the mainland Spain: the core areas and the resistance surface.

CORE AREAS

Core areas are the areas intended to be linked by the corridors, since they have environmental conditions that enable the conservation of important ecosystems, habitats and populations of species having a high natural value.

The Natura 2000 Network is made up of a series of areas that have been declared, given their high environmental value, as having a vocation for conservation, and where EU Directives on Habitats and Birds require the effort of Member States work on to foster their connectivity.

This study has considered as core areas the Natura 2000 sites that have a minimum forest area of 3,500 hectares or those with at least 20% of forest area.

This selection is justified due to their high biodiversity and conservation value, their broad distribution and representation in the Spanish territory, and their presence in most of Natura 2000 sites. In fact, Spain's forest areas cover 55% of its territory and the sites selected as core areas in this study represent more than 90% of the total area of Spain's Natura 2000 sites. Analysing the connectivity between forest habitats is also justified from a methodological standpoint, because there is cartographic and ecological information available with sufficient quality regarding the distribution and classification of these habitats and the territorial matrix[4] located between these sites.

The connectivity analysis has been conducted separately for three types of core areas that relate to three types of forest stands included in the Natura 2000 Network: dense canopy forests, clear forests and scrublands[5], identified on the basis of the information provided by the Forest Map of Spain at a 1:50,000 scale. All steps in the methodology have been made for each of the three types of habitats deemed to be core areas.

This way the connectivity is analysed for species of forest mammals with different ecological needs and preferences for forest stands having a different structure or thickness (forests or scrubland areas with different densities). For example, species associated to dense forests, such as martens, squirrels or wildcats find better conditions for moving in this type of forests and less favourable conditions for displacement in more open areas,

4 The distribution of numerous types of forest stands set in the Forest Map of Spain at a scale of 1:50,000, considering their spatial delimitation as core areas, is available. Additionally, there is an area of resistance defined by the experts, using SIOSE (Sistema de Información sobre Ocupación del Suelo en España or Information System on the Occupation of Land in Spain), for forest animals that characterizes the potential difficulty for moving through the territory, allowing the application of the "least-cost paths methodology."

5 Dense Forest: that with a fraction of its site covered (CCF) by a tree canopy of at least 60% or in a stem or shaft development stage. Clear Forest: with a CCF of trees between 10-60% and a development of a thicket stage, stems or shafts (excludes repopulated forest stands). Scrublands: scrubland areas with no trees or with disperse trees and a CCF of less than 10%.

Figure 1a. Selected dense forest core areas.

- Natura 2000 sites with dense forests
- Areas occupied by the dense forest stands

Source: Forest Map of Spain 1:50,000

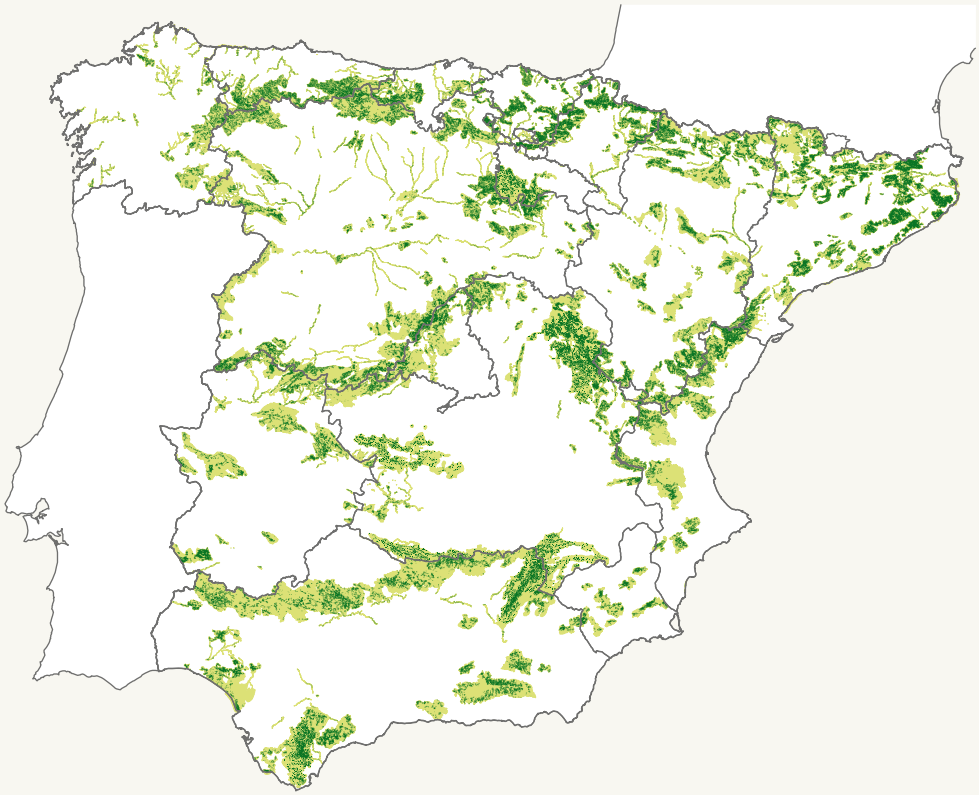


Figure 1b. Selected clear forest core areas.

- Natura 2000 sites with clear forest
- Areas occupied by clear forest stands

Source: Forest Map of Spain. 1:50,000

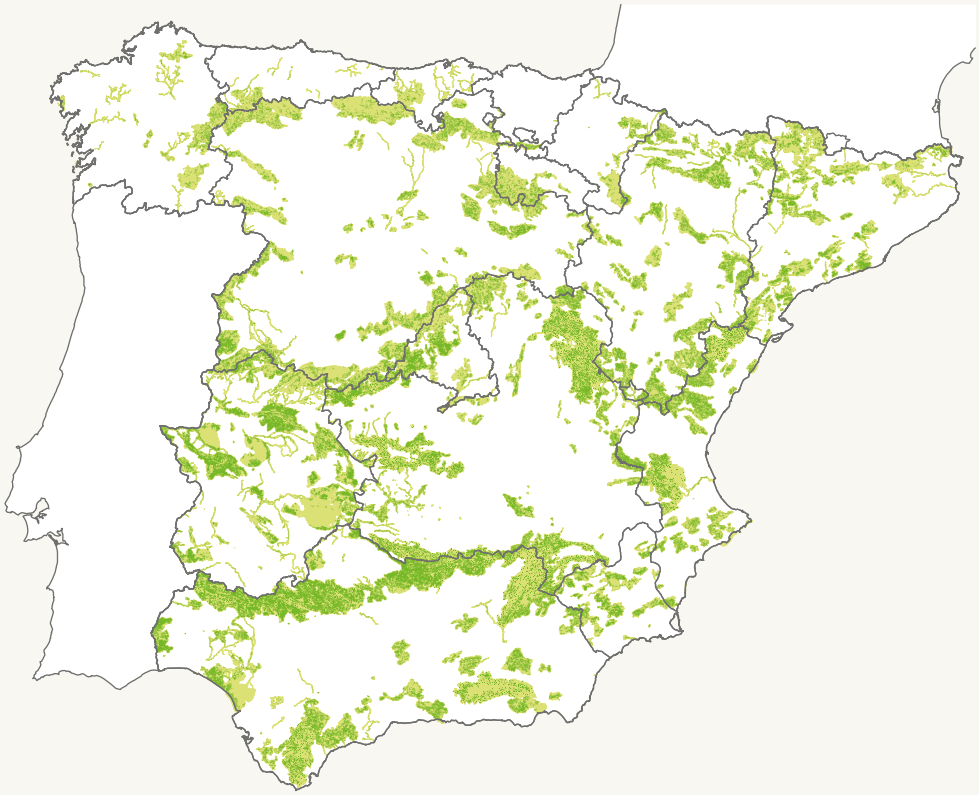


Figure 1c. Selected scrubland core areas.

- Natura 2000 sites with scrublands
- Areas occupied by scrublands

Source: Forest Map of Spain. 1:50,000

such as scrublands, while it is otherwise with species more typical of clear forests and scrublands, such as the Iberian lynx, wherefore it is advisable to conduct the analysis separately, considering different habitats and resistance values of the territorial matrix in each case.

RESISTANCE SURFACE

The resistance surface is a classification of territory represented by dividing it into cells of the same size (with a spatial resolution of 100 meters in this case) and assigning them a value that reflects the resistance or difficulty for the mobility of the species considered through such cells. From an ecological standpoint a resistance value is assigned associated to the species' reluctance to move through areas with features very different to those of their adequate habitat, due to facing a higher mortality risk, a greater energy or physiological consumption throughout the mobilization (due to lack of trophic resources, stronger insolation, and dehydration, etc.) or a combination of several of these factors (Zeller et al., 2012).

To appraise the forest species' resistance to move through the territory, a consensual resistance surface[6] has been adopted among the experts and used in numerous prior studies. It should be noted that the resistance to movement has been considered not only out of the Natura 2000 sites defined as core areas, but also in their interior to also consider the connectivity conditions within Natura 2000 sites.

This resistance surface analyses the difficulty for mobility of forest mammals species, such as the roe deer, red deer, pine marten, genet, badger, stone marten, wildcat, and other related species, through numerous types of land use[7]. For example, forest areas have less resistance to movement for these species than the lands occupied by crops, while inside the crops, those that are ligneous or with important patches of natural vegetation pose less resistance than areas with predominantly intensive herbaceous crops. The resistance values have been adjusted according to the ecological requirements of species belonging to dense forests, clear forests or scrublands, according to the three habitats considered.

Figure 2. Resistance surface for the three types of habitats.

6 Resistance surface built for forest mammals and used in prior studies (Gurrutxaga et al., 2010; Gurrutxaga et al., 2011; Gurrutxaga and Saura, 2014; MAGRAMA, 2013).

7 The categories for land use whose resistance to movement of species has been appraised pertains to the covers differentiated in the SIOSE (Sistema de Información sobre Ocupación del Suelo en España or Information System on the Occupation of Land in Spain).

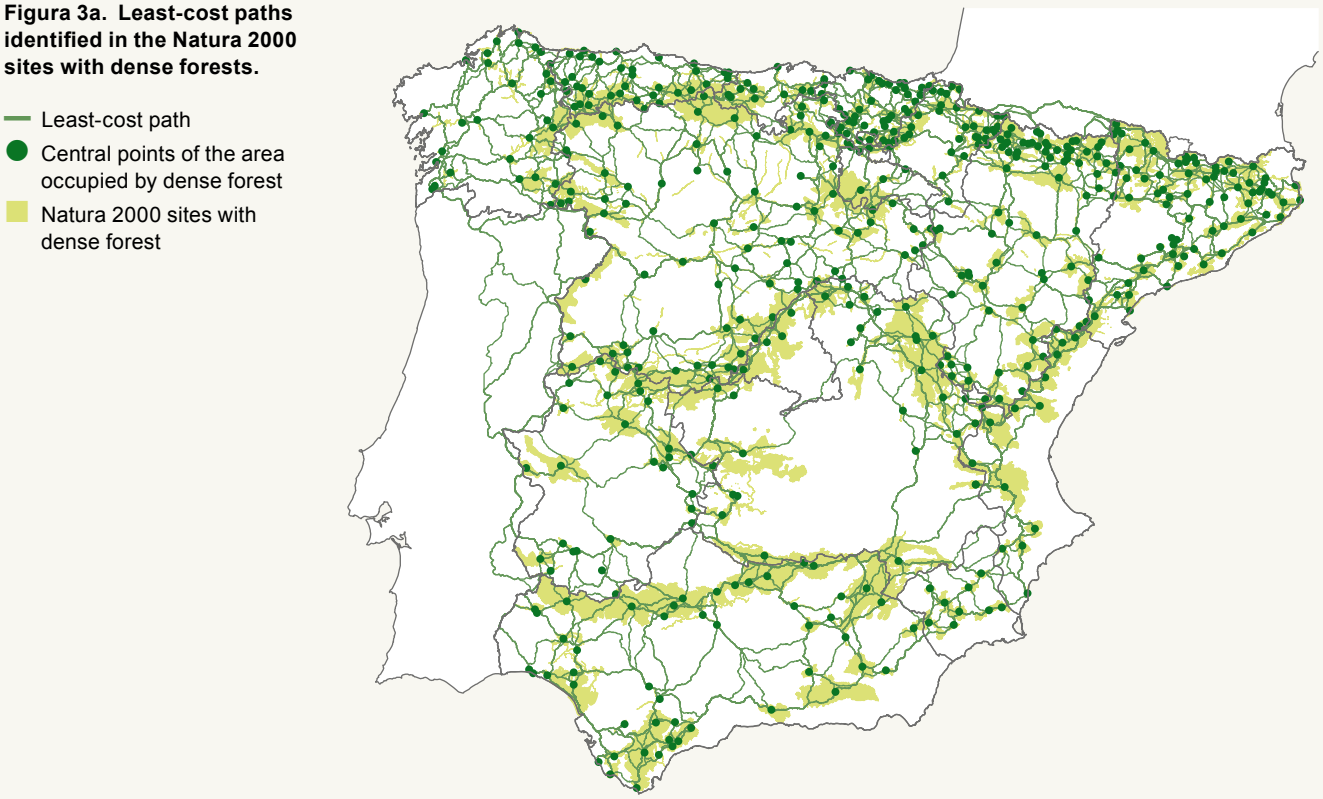
Based on the core areas and the resistance of the territory, the ecological territories that best connect and are the backbone of the Natura 2000 Network in Spain have been defined considering the preferences and movement capacity of the group of forest mammal species.

LEAST-COST PATHS

The ecological corridors identified pertain to the proposals for functional links between two or more core areas that run through the areas that imply lower accumulated resistance (less difficulty) for the movement of species.

To identify the ecological corridors one of the most widespread methodologies for connectivity analysis – identifying the "least-cost paths" through the area of resistance[8], has been applied. Paths have been obtained that while connecting Natura 2000 sites, present a lower accumulated resistance throughout for the movement of species. Following is a representation thereof for each of the three types of core areas defined.

Figura 3a. Least-cost paths identified in the Natura 2000 sites with dense forests.



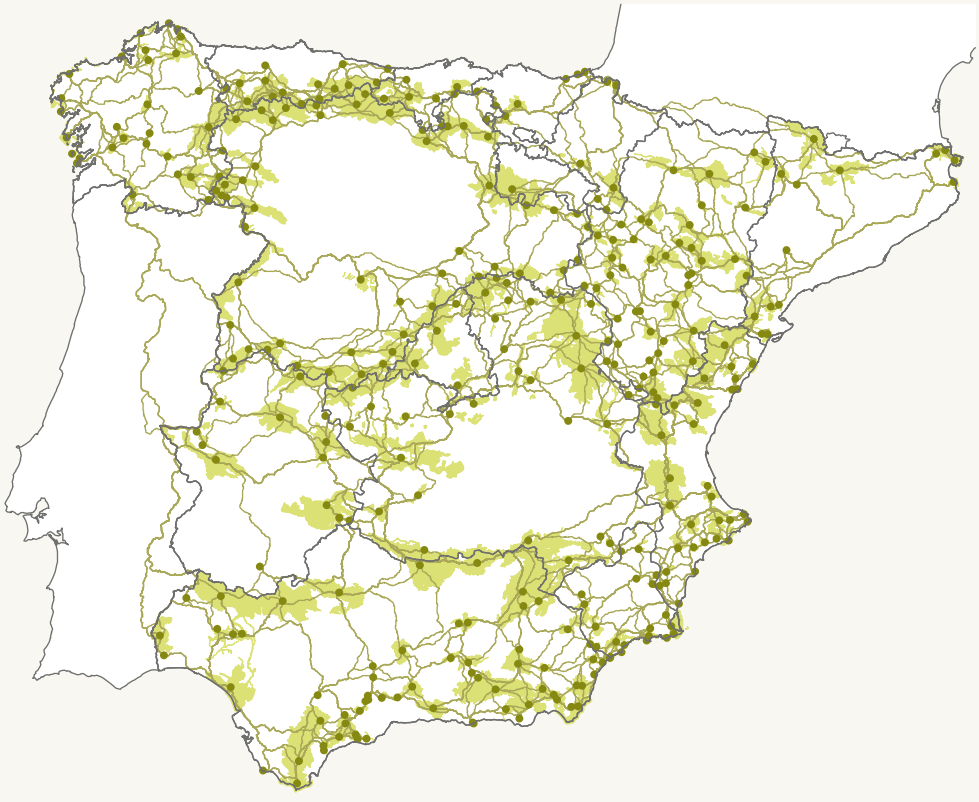
8 The least-cost paths were identified using the tool Linkage Mapper version 1.0.9 (McRae and Kavanagh, 2011).

Figure 3b. Least-cost paths identified in the Natura 2000 sites with clear forest.

- Least-cost paths
- Central points of area occupied by clear forest
- Natura 2000 sites with clear forest

Figure 3c. Least-cost paths identified in the Natura 2000 sites with scrublands.

- Least-cost paths
- Central points of area occupied by scrublands
- Red Natura 2000 sites with scrublands



CORRIDORS WIDTH

The corridors are not only characterized by the outline of their central axis given by the least-cost corridors, but also the resistance conditions and connectivity on both sides thereof have been considered to have an indication of the connecting quality of each corridor, as shown in the following map.

Hereinafter (Figure 4 et seq.) the results will be shown in maps that unify the analysis for the three types of habitats.

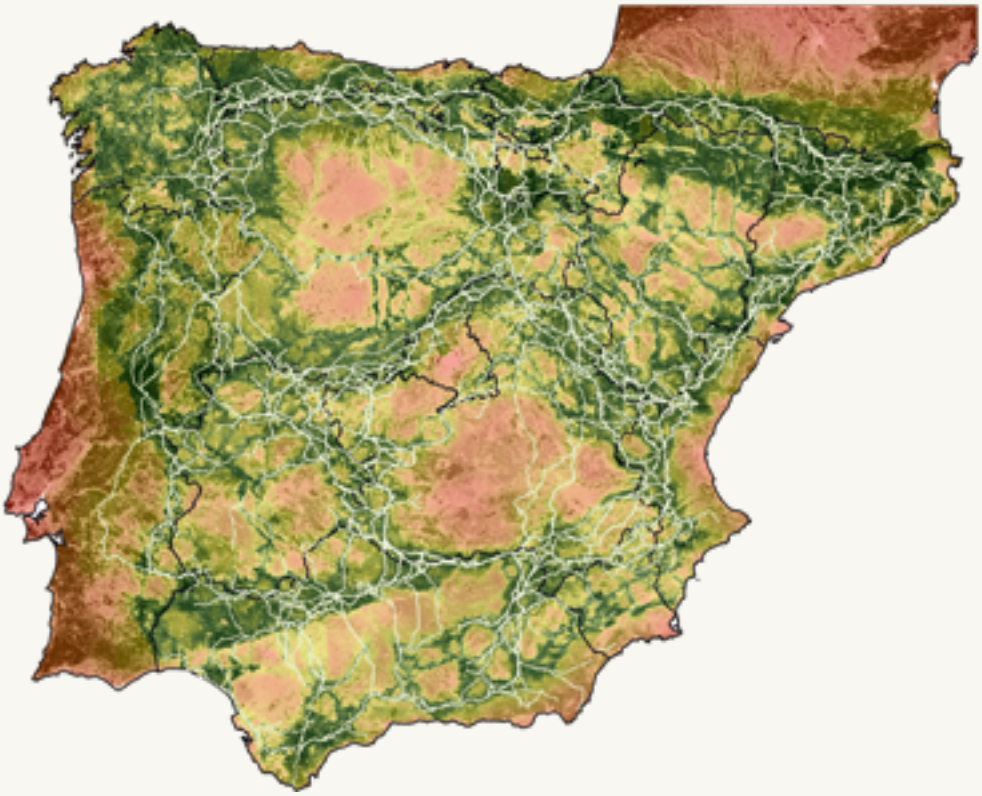
Figure 4. Least-cost paths or corridors represented as strips.

Corridor in high resistance environment

Corridor in low resistance environment

High resistance surface without corridor

Low resistance surface without corridor



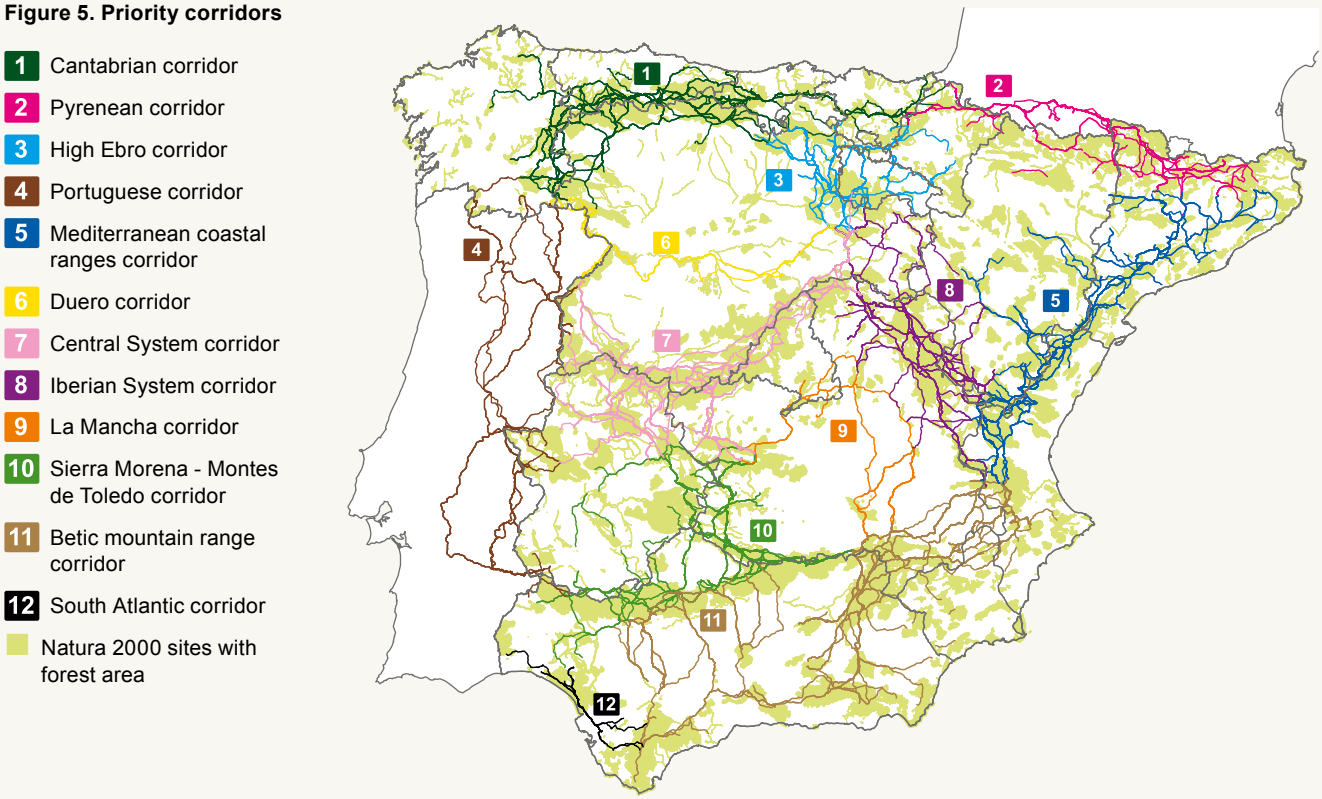
2 PRIORITISATION AND CHARACTERISATION OF ECOLOGICAL CORRIDORS

The maps of figures 3 and 4 identify a large number of corridors among the Natura 2000 sites considered. However, not all of them contribute in the same way to maintain or improve the network's connectivity. Neither is it possible to act on all of them with the same intensity with a view to maintaining or increasing their connecting function. For this reason, a **prioritisation** of the corridors has been made to concentrate the available conservation and restoration resources in the most effective manner.

A connectivity analysis tool named Conefor, developed by Saura and Torné (2009), has been used for this prioritisation. The corridors with the best conditions for connecting the core areas have been identified as priority, with a total result of 12 corridors. These corridors, whether in their current conditions or after restoration measures have been applied, are the ones that will allow the species to reach a greater area of habitats with the least effort, considering a range of medium dispersion capacity of 1 to 30 kms (valid for a very wide range of species).

The map available in this link offers a detailed visual information about these corridors.

Figure 5. Priority corridors

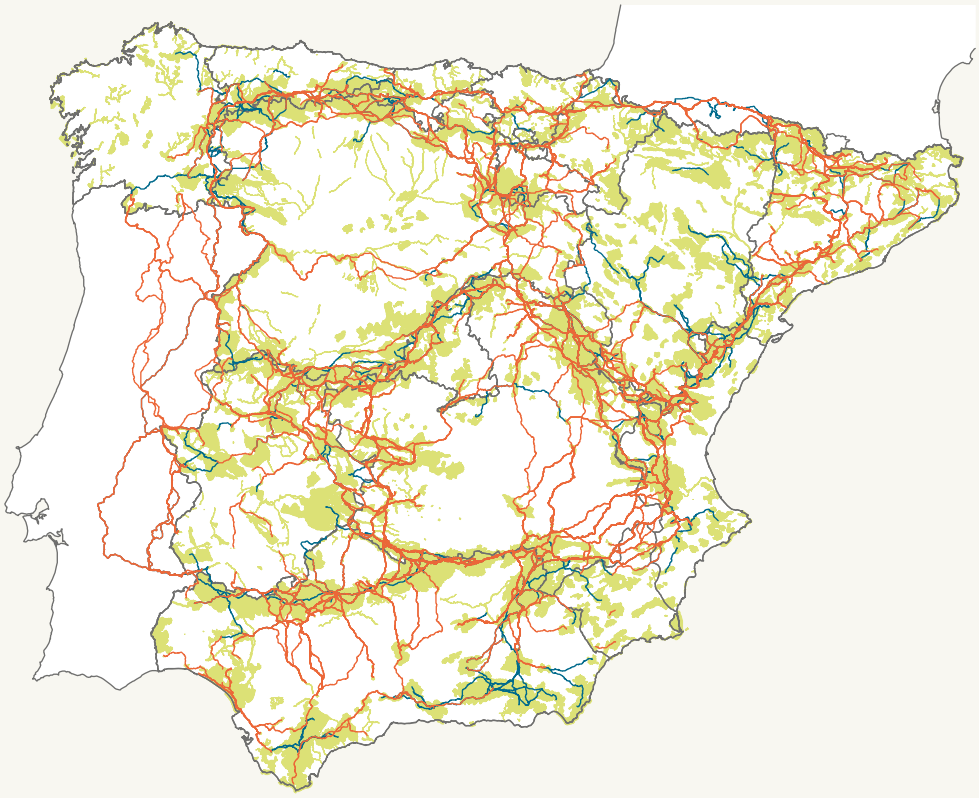


This analysis has permitted differentiation of corridors that should be conserved or restored (figure 6). **The priority corridors for conservation** are those in which the degradation of their current conditions would have a very adverse effect on the global connectivity of the Natura 2000 Network in Spain, wherefore it is important to make sure that at least their current conditions are maintained. The **priority corridors** for restoration are those in which an improvement of their conditions would result in a material increase of the global connectivity that currently exists in the Spanish Natura 2000 Network. There are cases of corridors that combine both the need for conservation and restoration, representing almost 25% of the total (De la Fuente et al., 2018), given that the deterioration of their current conditions would have a high impact on their connectivity, but the improvement of those conditions through restoration actions could greatly increase the connectivity of the network.

Figure 6. Priority corridors for conservation or restoration.

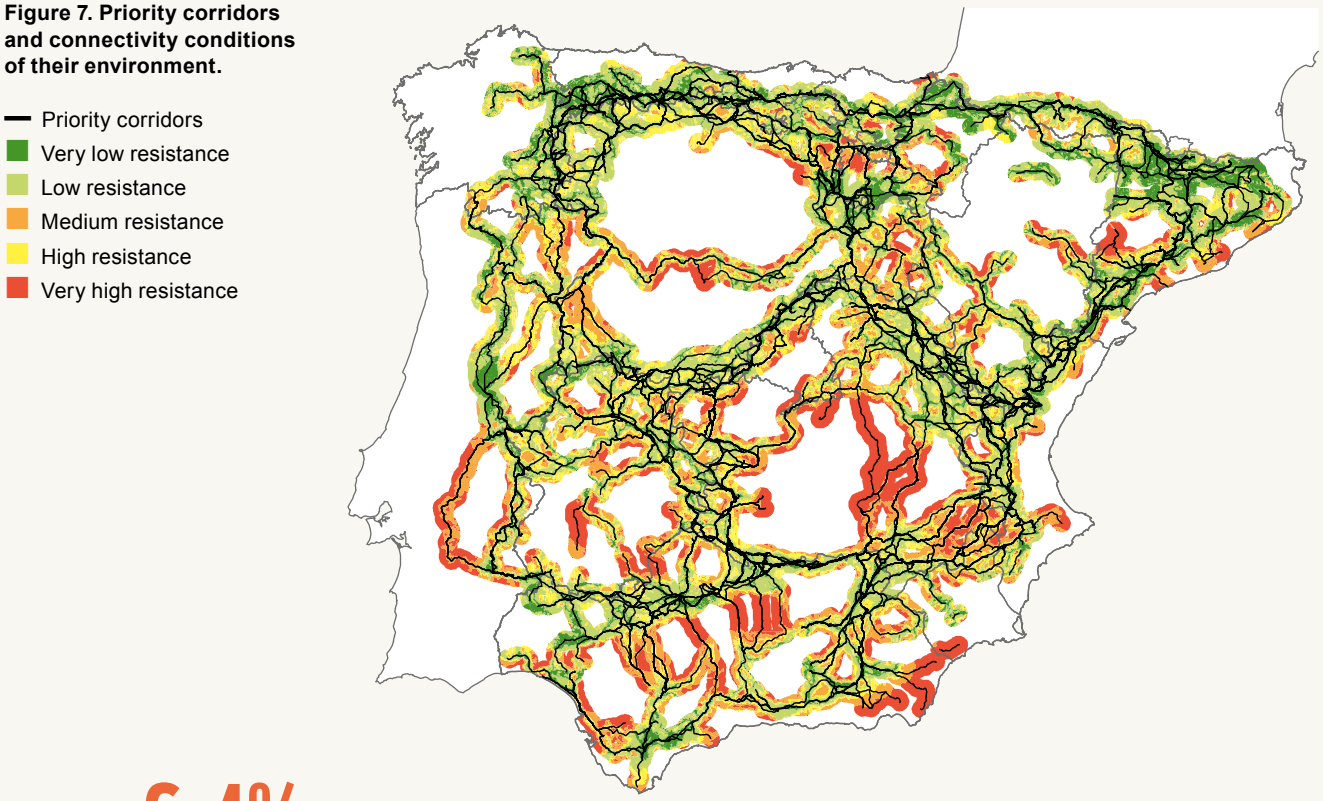
- Priority corridors for restoration
- Priority corridors for conservation
- Natura 2000 sites with forest area

The restoration view prevails in the corridors that have both needs.



The connective quality of the environment of priority corridors can be seen in the map of Figure 7.

Figure 7. Priority corridors and connectivity conditions of their environment.



6.4%

of the area of mainland Spain is priority for the ecological connectivity of the Natura 2000 Network.

The results of the analysis show very wide corridors and broad favourable and permeable environments such as the corridor that runs along the Cantabrian mountain range, and other corridors with tight bottlenecks that run squeezed and constricted through landscapes with high hostility and resistance to the movement of forest species, such as the corridors that cross the Guadalquivir valley or those that run from the Eastern Sierra Morena to the Iberian system, through the La Mancha plateau.

There is some scientific consensus regarding a minimum width needed for the ecological corridors to enable the movement of most species. If the priority corridors identified have a medium width of 1 km in order to be robust and stable, we would be considering a total extension of 6.4% of mainland Spain (3,136,906 hectares or 3,436,293 if we also include the corridors that run through France, Portugal and Andorra). If we exclude the areas protected by the Natura 2000 Network, we would be referring to almost 3% of the mainland area having a key connector role and not included in this network, although they could be, under another form of protection or management.

3%

is not included in the Natura 2000 Network.

3 IDENTIFICATION OF CRITICAL AREAS FOR CONNECTIVITY

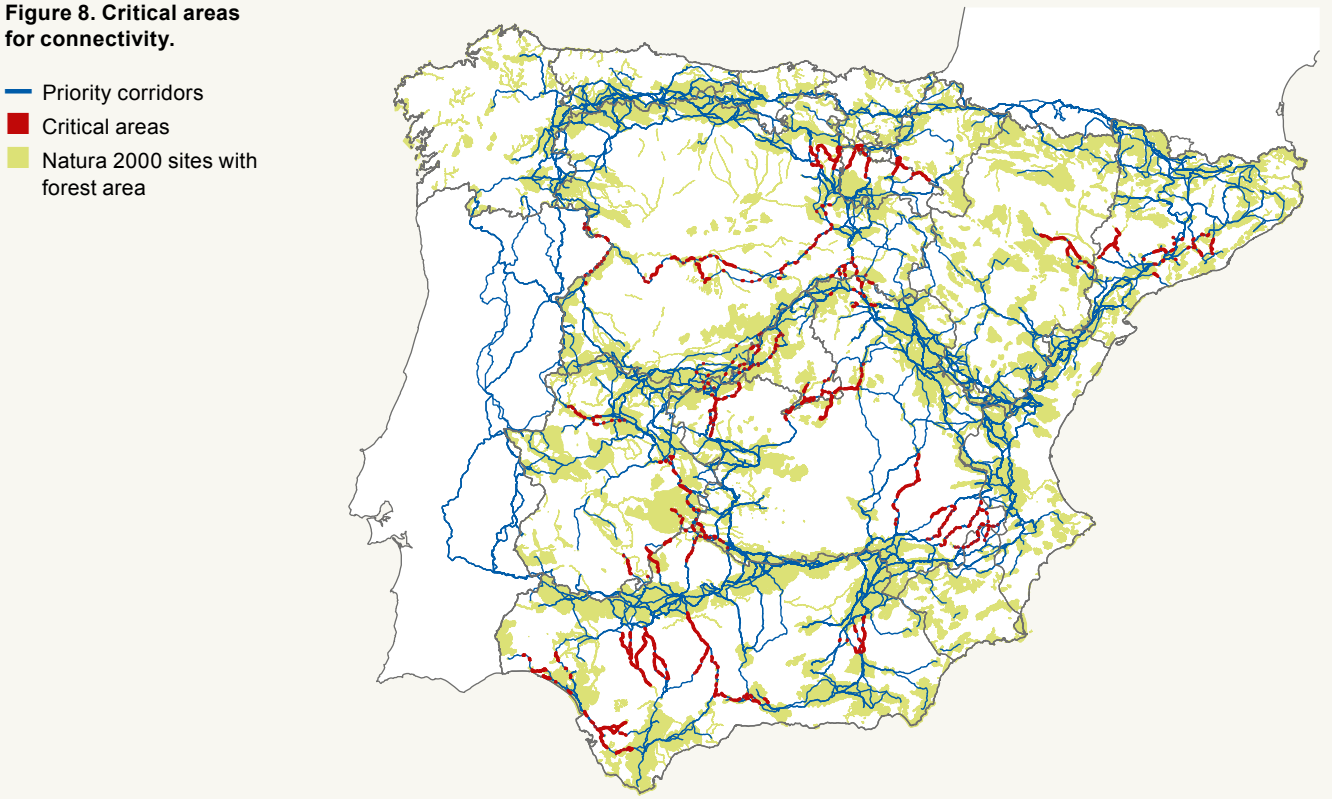
This study identifies the most critical areas for connectivity in Spain. They are sections of priority corridors that only maintain a narrow strip with favourable conditions and that run through an immediate surrounding that is significantly hostile and degraded with high resistance. These are, therefore, **important bottlenecks** for connectivity.

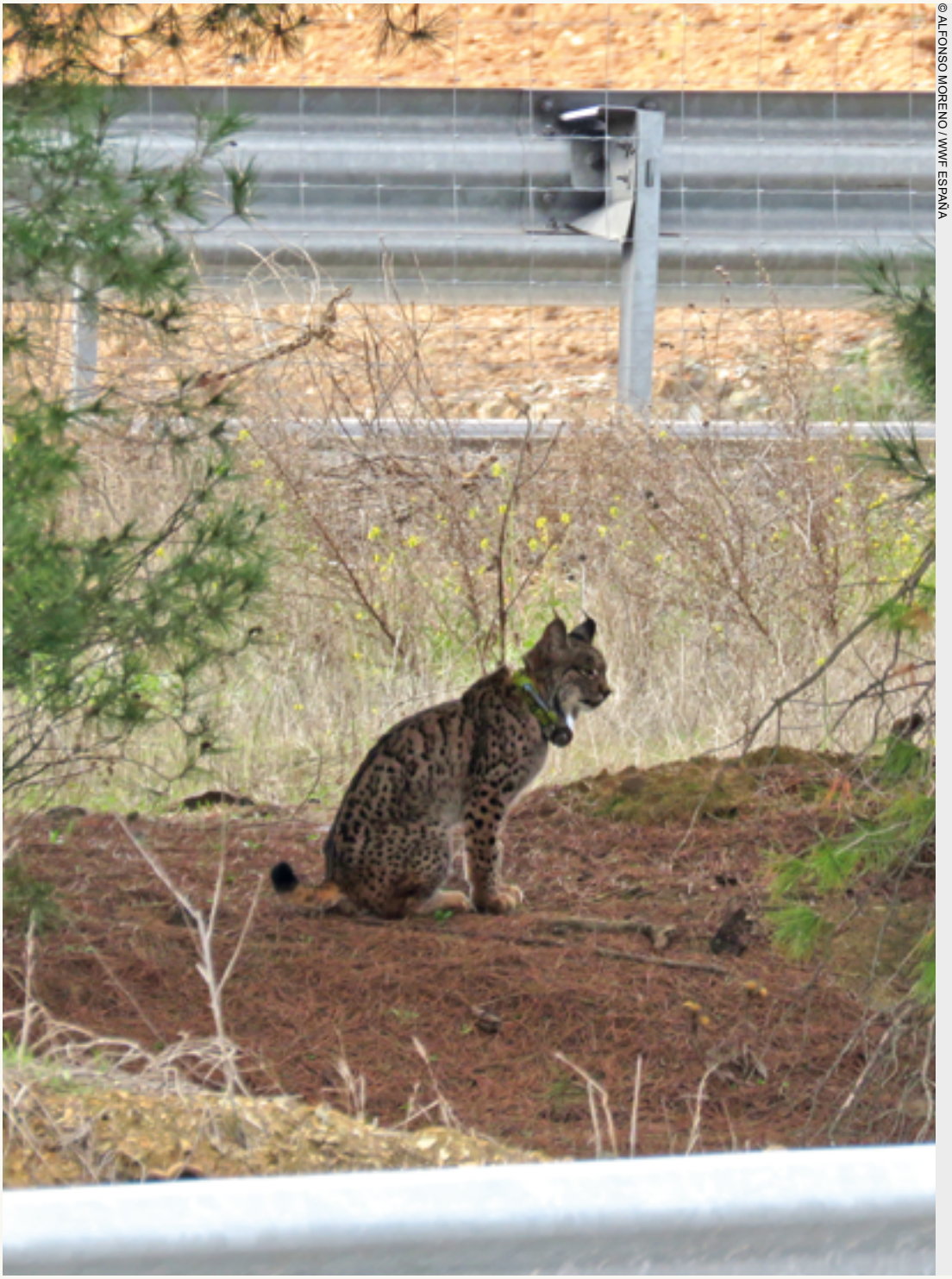
The importance of these areas is critical because of their fragility, given that there is a high risk that they transform or are eliminated when they run through areas dominated by more intensive land use. The additional degradation, loss or non-restoration of those sections would imply the loss or the significant deterioration of the quality of the corridor as a whole and a major reduction of connectivity at national level.

A total of 17 **critical areas** have been identified, 10% of the sections, conducting a GIS analysis of priority corridors in which the surrounding conditions pose a greater resistance for the movement of forest species.

In the map available in this link there is more information about these critical areas, such as the name, location, and land use.

Figure 8. Critical areas for connectivity.





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The presence of large transport infrastructures fragments the territory and hinders the mobility and dispersion of species. Road deaths have become the first cause of mortality of the Iberian lynx, with 121 road deaths in the last 10 years.

4 ANALYSIS OF LAND USE

To expand the information about the types of covers or land uses that are traversed by the priority corridors, an analysis has been conducted on their degree of overlapping[9] riparian areas[10], agricultural areas[11] and the entire Natura 2000 Network (and not only the Natura 2000 sites considered as core areas[12]).

This analysis shed the following results:

> Priority corridors tend to run mostly along riverbanks. A total of 1.28% of their area runs along riverbanks. Although at first glance this could seem a small value, it is a large percentage considering the small area occupied by riverbanks in the entire mainland territory (0.68%). It should be noted that the coincidence of priority corridors with riparian forests with a need for restoration is greater than those that have a need for conservation.

> Priority corridors usually do not traverse agricultural areas, because this study mainly focuses on forest habitats and species that generally pose greater difficulty to move through those areas. This notwithstanding, it should be noted that almost 10% of the corridors' area runs through these areas. The same as for the preceding case, the coincidence of corridors with agricultural areas is greater for those in need of restoration than for those requiring conservation.

> A large proportion of corridors runs through landscapes with more than half of their area included in the Natura 2000 Network (56.7%). This is due in part to the fact that they start from the interior of those sites, and even bearing this effect in mind, the corridors show a clear trend to select them in a positive manner (De la Fuente et al., 2018). It is worth noting that more corridors with a conservation priority run within the Natura 2000 Network than those having a restoration priority

> In a considerable number of cases, the priority corridors run outside the Spanish territory, the most frequent and longer being the corridors that run through Portugal, although there are some in the French side of the Pyrenees.

9 The area of corridors and critical areas for connectivity considered in this overlapping with information about the types of covers pertain to the area occupied by the least-cost path defined with a spatial resolution of 100 meters.

10 The riverbank areas have been defined as those located at up to 100 meters of the rivers, considering the primary and secondary rivers identified in the National Cartographic Basis 1:200,000 of the National Geographic Institute of Spain. The analysis conducted by De la Fuente et al. (2018) is similar, but it focuses on the areas classified as riparian forests, according to the Forest Map of Spain, scale 1:50,000.

11 Agricultural areas identified in the Forest Map of Spain, scale 1:50,000.

12 Other supplementary analyses may be found on the areas traversed by the corridors in De la Fuente et al. (2018)..

As to the 17 critical areas for connectivity represented in figure 8, a more detailed analysis of the types of cover existing in their surroundings has been made, characterized by SIOSE, and it has been determined that those surroundings are mainly agricultural or forests without trees[13]. Specifically, there prevails the presence of arable crops, especially in the areas located east of Castilla-La Mancha, while olive groves acquire great importance in the southern third part, where there is also an important area occupied by artificial uses. The use of forests without trees (such as grasslands and lands without vegetation) prevails in the critical areas located mainly in the western half of the mainland.

PRIORITARY ECOLOGICAL CORRIDORS FOR FOREST MAMMAL SPECIES RUN BY RIVERBANKS AND THROUGH NATURA 2000 SITES. THEY ARE SELDOM LOCATED IN AGRARIAN LANDSCAPES.

13Forests without trees is one class of forest area and it is defined as having a CGF <5% of forest tree species, if any, and is formed by what is called treeless scrubs, populated by species of scrubs or natural grasslands, considered wastelands or with weak human intervention, with or without trees.

CONCLUSIONS

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HETEROGENEITY OF THE CONDITIONS OF ECOLOGICAL CORRIDORS IN THE TERRITORY

This study has brought to light the **complexity and territorial heterogeneity of priority corridors,** some having great width and broad favourable and permeable surroundings, and other narrow ones that run wedged in a hostile environment with high resistance for the movement of forest species and frequent bottlenecks for connectivity.

The corridors with the best conservation conditions tend to concentrate along the main mountain massifs of mainland Spain, while the **most fragile corridors tend to traverse landscapes with an intense agricultural use and low forest coverage** benefitting from the small relatively permeable strips in the territorial matrix that separates the forest sites of the Natura 2000 Network.

Therefore, it is concluded that there are certain corridors in which priority should be given to the conservation of their current conditions and functionality, avoiding their potential deterioration, and others with poorer or more limited characteristics where restoration efforts should concentrate so they may contribute their full potential as connectors and improve the connectivity of the Natura 2000 Network and the territory.

EXISTENCE OF CRITICAL AREAS FOR CONNECTIVITY

This study shows that there are critical areas strategically located in priority corridors among the Natura 2000 Network, which pertain to especially fragile and narrow sections. These sections are **bottlenecks for connectivity since they are surrounded by an environment with high resistance to the movement of species and need urgent conservation and restoration action.** This urgent and priority action is key to maintain or improve the connectivity of the whole territory and thus avoid a greater deterioration of the functionality of the Natura Network.

IMPORTANCE OF RIVERBANKS FOR CONNECTIVITY

The priority corridors identified frequently run along riverbanks, especially the corridors in need of restoration.

These results highlight the value of riverbanks and the vegetation existing there as key corridors connecting the Natura 2000 Network sites. Sometimes these are the only permeability element across landscapes that are mainly hostile to the movement of certain species. The results obtained prove the need for concentrating great

restoration efforts in rivers and banks, for which it is necessary to lay out the demarcation from the public hydraulic domain and recover the structure and functions of the riparian forests.

THE ROLE OF AGRICULTURAL ZONES

Priority corridors generally do not run through crop areas, given the type of habitat and species considered in the study. However, it is still important to consider the length of priority corridors that traverse agrarian landscapes and, moreover, the critical areas for connectivity, either because there are no more adequate options for the movement of forest species in some areas, or because they have a certain degree of homogeneity and presence of forest stands or remainders of natural vegetation that provide permeability to these landscapes.

These results lead to concluding that **their permeability is vital to guarantee connectivity nationwide,** even though the agricultural landscapes present the most restrictive and limiting conditions for the movement of forest species, especially regarding highly intensified and homogeneous agricultural areas that lack refuge and food.

In this regard, **agricultural areas may foster the movement of species when they have a certain degree of heterogeneity and less intensive practices are applied.** Generally, evidence shows that species and corridors preferably seek those areas that have a certain frequency of patches of remaining natural vegetation with permanent woody crops, as has been shown for some emblematic species such as the Iberian lynx. (Gastón et al., 2016).

THE NATURA 2000 NETWORK AND ITS CONTRIBUTION TO THE TERRITORY'S CONNECTIVITY

The corridors identified run through a large proportion of landscapes included in the Natura 2000 Network and to a greater extent, priority corridors for conservation. Results allow concluding that **Natura 2000 sites generally have better conditions for connectivity than those located outside this network of protected sites.** However, Natura 2000 sites are not entirely free of limitations for connectivity, since a certain number of bottlenecks have been detected within the network itself (as seen in Figure 8). For this reason, a proper management of the connectivity of the sites of the Natura 2000 Network must also include actions within its own sites with sufficient relevance and concretion in the management plans of the Natura 2000 Network.

SUPRA-AUTONOMOUS CONNECTIVITY

The layout of priority corridors runs through numerous autonomous communities, and through a large portion of the critical areas for connectivity. This reinforces the idea of **the need to adopt a national and supra-autonomous approach when trying to maintain and recover the territory's connectivity,** jointly coordinating and starting up all the actions needed for planning, financing, restoration, and conservation on the ground, without prejudice to other efforts at a regional or sub-regional level.

SUPRA-NATIONAL CONNECTIVITY

The study concludes that there is a considerable number of corridors among Natura 2000 sites in Spain that run outside the Spanish territory, especially through Portugal, which strengthens **the benefit and the need to consider and manage connectivity under a supra-national perspective,** especially within the frame of the Iberian Peninsula.

WWF REQUESTS

The proposal for ecological corridors presented by WWF Spain is the first step for reaching ecological connectivity of the territory nationwide and, consequently, towards the functionality of the Natura 2000 Network in Spain and the long-term achievement of the conservation goals for which it was established. This will contribute to the compliance of international agreements and undertakings such as the EU biodiversity strategy to 2020, the Aichi targets of the Convention on Biological Diversity or the national objectives set in the Spanish Law on Natural Heritage and Biodiversity.

This proposal sets a framework for numerous administrative levels to develop other supplementary connectivity networks at a more detailed scale (regional, sub regional o district and local).

WWF Spain believes that only through a conservation vision and a strategy structured around the ecological connectivity of the territory we will be able to face the main present and future conservation challenges, such as climate change, the extinction of species or the maintenance of environmental services.

For all this, the competent administrations must start developing concrete initiatives to achieve the territory's ecological connectivity.

FOR THIS REASON, WWF SPAIN REQUESTS

SPANISH MINISTRY OF ENVIRONMENT

1

To integrate this connectivity network into the numerous instruments for state planning.

> To include this proposal in the National Strategy for Green Infrastructure, Connectivity and Ecological Restoration (IVCRE), which must be approved in consensus by the autonomous communities in 2018, according to the legal term set[14].

> To consider this proposal in the processes for environmental assessment of projects and in the strategic environmental assessment of state plans and programs that affect the territorial matrix, taking this connectivity network as cartographical reference to establish specific regulations in the regions having connective interest.

> To integrate this proposal and the IVCRE Strategy into the National Climate Change Adaptation Plan and the future Law on Climate Change and Energetic Transition.

> To consider the conservation and improvement of this corridor network in any type of sectorial plan that affects the territory (such as infrastructure plans, plans for the modernization of irrigation, etc.), as well as in policies with major relevance, such as the Common Agrarian Policy, in its next reform..

14 Law 33/2015, which modifies Law 42/2007, of December 13, on the Natural Heritage and Biodiversity provides that a State Strategy for Green Infrastructure and Ecological Connectivity and Restoration should be approved within a term of no more than 3 years from the date the Law 33/2015 entered into force.

2 **To drive the application of the following existing instruments and tools for conservation** throughout the national territory, especially in the 17 critical areas for connectivity.

> Carry out the demarcation and recovery of the Hydraulic Public Domain, starting by the critical areas for connectivity, reactivate the National Strategy for Restoration of Rivers and recover the full functionality of riparian forests, and river sites, as a measure for fostering connectivity.

> Ensure that the management plans for Natura 2000 sites include concrete objectives and measures to guarantee connectivity among them and the restoration of areas that pose limitations on connectivity that may exist within those sites.

> Approve the Royal Decree for the preparation of natural resources spatial planning, foreseen in Article 17 chapter IV of the Spanish Law on Natural Heritage and Biodiversity, as an instrument for spatial planning beyond the limits of the protected areas.

3 **To restore on a priority basis the 17 critical areas for connectivity to guarantee their full functionality.** For this purpose, a *restoration plan* should be developed with the cooperation of the autonomous communities affected, to include the following elements:

> Demarcation and characterisation of each of these areas, identifying the main problems and obstacles that limit connectivity.

> Definition of the necessary instruments for restoration and improvement.

> Establishing an action plan and its financial endowment.

> Including a participatory process for the decision-making and involving the local population.

4 **To guarantee the funding needed to attain territorial connectivity:**

> Endow the Fund for the Spanish Natural Heritage and Biodiversity with a specific budget item for ecological restoration and the recovery and improvement of connectivity.

> Increase the endowment of measures of the Programs for Rural Development of the FEADER funds that contribute to maintaining and restoring the ecological connectivity in agrarian areas and foster their application in a spatially coherent manner in the territory.

> Increase the dedication of European Regional Development Funds (ERDF) for large-scale restoration actions in critical areas for connectivity, using the numerous strategic investment priorities in the Regulations that enable actions for adapting to climate change, green infrastructures, and the restoration of ecosystem services, such as Articles 5.5.a) and 5.6.d).

5 **To integrate the current connectivity network into the numerous international planning instruments.**

> Incorporating this connectivity network and the necessary and timely conservation and restoration actions in the pertinent memoranda of understanding with Portugal and France.

> Proposing this methodology and the connectivity network identified as a model to follow by the European Commission in order to meet its connectivity and restoration objectives, as well as to be considered in the trans-European corridors proposal TEN-G (*Trans-European Network for Green Infrastructure*) that is intended to be developed.

TO THE AUTONOMOUS COMMUNITIES

To integrate this connectivity network into the numerous regional planning instruments, specifically into:

> The regional guidelines for spatial planning of the autonomous communities (also known as Integral spatial planning of the territory) that serve as basis for the content of:

- the territorial autonomic sectoral plans,
- the integral spatial planning of the territory at a sub-regional, district scale, and municipal spatial planning.

> The processes for strategic environmental assessments of spatial and sectoral plans at autonomous communities level, considering such connectivity network as benchmark cartography to integrate in the spatial planning processes.

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Ecological corridors in figures

6.4%

of mainland Spain is a priority for the ecological connectivity of the Natura 2000 Network.

12

priority ecological corridors identified by WWF Spain.

17

critical areas for the connectivity of the Natura 2000 Network.

27%

of mainland Spain is part of the Natura 2000 Network.

WWF

Why we are here
To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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