Danube Transnational Programme
ConnectGREEN

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METHODOLOGY FOR IDENTIFICATION OF ECOLOGICAL CORRIDORS IN THE CARPATHIAN COUNTRIES BY USING LARGE CARNIVORES AS UMBRELLA SPECIES

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Output 3.1

ConnectGREEN Project "Restoring and managing ecological corridors in mountains as the green infrastructure in the Danube basin"

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These Guidelines are to a large extent based on former publications:

- manuscript "Methodology for protection of habitats of specially protected species of large mammals" developed by the Nature Conservation Agency of the Czech Republic based on results of the project "Complex approach to the protection of fauna of terrestrial ecosystems from the landscape fragmentation
- Guideline "Wildlife and Traffic in the Carpathians Guidelines how to minimize the impact of transport infrastructure development on nature in the Carpathian countries" as Output of the TRANSGREEN project

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Introduction

Green Infrastructure Strategy developed by the European Commission represents a key strategy in the European landscape policies. This strategy aims to ensure that the protection, restoration, creation and enhancement of green infrastructure become an integral part of spatial planning and territorial development whenever it offers a better alternative, or is complementary, to standard grey choices. The Green Infrastructure Strategy gives framework for the development of the Trans-European Network for Green Infrastructure (TEN-G) and integration of the GI into sectorial policy areas such as agriculture, forestry, water, marine and fisheries, regional and cohesion policy, spatial planning, etc.

The EU Biodiversity Strategy aims to halt the loss of biodiversity and ecosystem services in the EU and help stop global biodiversity loss by 2020. It reflects the commitments taken by the EU in 2010, within the international Convention on Biological Diversity.

The European Strategy for the Danube Region (EUSDR) is macro-regional strategy which defines the Danube Region as a major international hydrological basin and ecological corridor with a need of a regional approach to nature conservation, spatial planning and water management. This macro-regional strategy set up 4 pillars and 12 priority areas including preserving the biodiversity, landscapes and the quality of air and soils.

The Natura 2000 network constitutes the backbone of the EU green infrastructure. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive. The Habitat Directive in its Article 10 emphasizes the importance of the ecological coherence of the Natura 2000 network and encourages Member states to manage features which are essential for the migration, dispersal and genetic exchange of wild species.

EU legislation and respective strategies are valid for the EU Member States. Ukraine and Serbia, two Carpathian countries which are not yet members of the EU have already started with the adoption of the EU rules. Therefore for the Carpathians also Emerald network plays an important role. The Emerald network is an ecological network made up of Areas of Special Conservation Interest. Its implementation was launched by the Council of Europe as part of its work under the Bern Convention, with the adoption of Recommendation No. 16 (1989) of the Standing Committee to the Bern Convention. Its objective is the long term survival of the species and habitats of the Bern Convention requiring specific protection measures.

Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) urges the Parties to identify and prioritize important areas to improve connectivity and to mitigate the impacts of fragmentation of landscape and seascape, including areas that create barriers and bottlenecks for annual and seasonal species movement, for various life stages and for climate adaptation, and areas that are important for maintaining ecosystem functioning and mainstreaming biodiversity in sectors as infrastructure, energy and mining (CBD 2018, COP Decisions 14/8 and 14/3).

IUCN WCPA plans to introduce a new concept of protection of the Connectivity Conservation Area CCA as "A recognized large and/or significant spatially defined geographical space of one or more tenures that is actively and equitably governed and managed to ensure that viable populations of species are able to survive, evolve, move and interconnect within and between systems of protected areas and other effective area based conservation areas. The purpose of Connectivity Conservation Areas is to connect protected areas and other effective area based conservation areas and to maintain or restore ecosystem function and ecological and evolutionary process of species and ecosystems across (and between) landscapes, freshwaters capes, or seascapes for biodiversity conservation in areas that may also be used and occupied for a variety of human purposes, so that people and other species are able to survive and to adapt to environmental change especially climate change" (IUCN, 2016).

https://www.iucn.org/sites/dev/files/content/documents/connectivityconservationred.pdf

ConnectGREEN project reflects general requirements of the international legislative framework and recommendations of different strategic documents listed above.

ConnectGREEN is the project which is implemented within the Transnational cooperation programmes Danube Transnational Programme (DTP). DTP is a funding instrument contributing to the realisation of the EUSDR. As two countries of the Carpathians (Ukraine and Serbia) are not yet members of the EU this Programme plays an imporant role in the implementation of the macro-regional strategy within a defined geographical area (Danube region) because it relates also to third countries located in the same geographical area.

ConnectGREEN project aims to cope with the fast and increasing ecosystem and habitat fragmentation in the Danube region and to improve ecological connectivity between natural habitats, especially between Natura 2000 sites and other categories of protected areas in the Carpathian ecoregion of transnational importance.

ConnectGREEN project will develop a Carpathian-wide methodology and based on this the core areas and ecological corridors used by large carnivores as umbrella species. Using the methodology at the level of four pilot sites, the ecological corridors will be identified in more detail and developed specific management and restoration measures in a participative way with key stakeholders for safeguarding the ecological connectivity. The Decision Support Tool, created by the spatial planners will support this process by overlapping and analyzing a broad range of spatial data and various individual scenarios. Within the ConnectGREEN project a Strategy will be developed based on the Methodology and other project's findings on identifying, preserving and managing ecological corridors focusing on large carnivores movement needs in the region. It will be inforced by the parties to the Carpathian Convention. A capacity building programme will be set up for conservationists and spatial planners to contribute to this endevaour and ensure durable outcomes.

Together with the "twinning" project TRANSGREEN which was focused on the integrating green infrastructure elements into TEN-T related transport infrastructure, the ConnectGREEN project has an ambition to become a case study for the development the TEN-G in Carpathians and the Outputs of the project to be pilot tools for all Europe.

Chapter 1 PREFACE

This **Methodology for identification of ecological corridors in the Carpathian countries using large carnivores as umbrella species** (further in referred to as Methodology) has been developed in a close cooperation of partners in the framework of the project “Restoring and managing ecological corridors in mountains as the green infrastructure in the Danube basin” (ConnectGREEN). This methodological foundation will support the target groups in achieving the main goal of the ConnectGREEN project – to maintain and improve the ecological connectivity in the Carpathian ecoregion.

This methodology is based on the manuscript “Methodology for protection of habitats of specially protected species of large mammals” developed by the Nature Conservation Agency of the Czech Republic based on results of the project “Complex approach to the protection of fauna of terrestrial ecosystems from the landscape fragmentation”. (https://eeagrants.org/archive/2009-2014/projects/CZ02-0017).

This Methodology is the first output of the project ConnectGREEN, and enables identification of core areas and wildlife/migration corridors used by large carnivores as umbrella species.

This Methodology, together with other subsequent project results and outcomes, applied in a close cooperation of nature conservation managers with spatial planners, will contribute to translate the connectivity approach into practice and to the consistent territorial protection of the coherent network.

The target groups of this Methodology can be considered in two aspects – i) who is going to use the Methodology as a guide, and ii) who is going to use the results of the applied Methodology.

The main target group for whom this Methodology is developed to be used in practice is nature protection experts. This Methodology will provide the nature protection managers and experts with a guide in the process of identification of wildlife/migration corridors. Wildlife/migration corridors for the Carpathians will be identified based on this Methodology and further the Methodology will be tested to identify the wildlife/migration corridors in four pilot areas during the lifetime of the project. The Methodology will be replicable and accordingly adopted to the needs of countries and regions of the Carpathians.

The Carpathian region in particular countries varies as regards the occurrence and abundance of the occurrence of the large carnivores, the quality of the Habitat of large carnivores, the scientific knowledge, the legislation as well as the acceptance of large carnivores by communities and public. All these variables cause that the approach and solutions regarding the agenda of the landscape fragmentation and connectivity may be different not only between the sectors (in particular the nature protection and spatial development) but even the approaches in the same sector can be different in some regions of the Carpathians. For example the current status of landscape connectivity, the occurrence volume of large carnivores and status of the development of the infrastructure in Romania represents considerable different situation in comparison with the situation at the borders between the Czech Republic and Slovakia. The economic development and connected urban sprawl are however irreversible and it is only a question of short time when the currently “safe” regions get under immense pressure of uncontrolled development. Therefore the importance of existence of such scientific, verified and replicable Methodology, which can provide solid scientific background for decision making processes can be accepted throughout the Carpathian countries among both the nature protection and spatial development sector. The results provided by application of this Methodology in the Carpathian countries can significantly contribute to the maintenance and improvement of the ecological connectivity. Avoiding the landscape fragmentation rather than the mitigating measures is becoming not only question of money but question of ultimate responsibility to the future generation.

The outputs of the process of identification of wildlife/migration corridors based on this Methodology will consist of a set of variable data (e.g. maps of core areas, stepping stones and wildlife/migration corridors) which can be used in the decision making processes in both spatial planning and management of protected areas at different levels of decision making (local, regional, national, transboundary, Carpathian). In this context we are facing a big challenge, on one side to harmonize data on the level of Carpathians and on the other side to secure an efficient and targeted interpretation of data and its proper use on the local level. Each of the Carpathian countries has different legislation framework, different systems of nature protection as well as spatial planning. The quality and quantity of data, the level of public awareness and acceptance of stakeholders vary from country to country, which will result in different approaches of how to best apply and reiterate the results and outputs of this Methodology and how to harmonize the interests of nature protection and spatial planning.

The maintenance of the landscape connectivity is not real without its acceptance in the spatial planning documents (Valachovič 2018). The quality and acceptance of the results derived from this Methodology will be crucial for the further development of the management of wildlife/migration corridors in the Carpathians. Therefore, this Methodology will be interlinked with follow-up documents which will be developed during the project implementation, focused mainly on harmonizing interests of nature protection and spatial planning and on an efficient implementation in planning and management of the Carpathians.

The Methodology will be embedded as a part of the Strategy into the frame of the Carpathian Convention through its parties.

Chapter 2 – HOW TO USE THIS METHODOLOGY

This Methodology aims on one hand to be a practical guide that can be easily used by experts and on the other hand it has an ambition to be a comprehensive document to illustrate the topic and problems of the connectivity in a broader context. Therefore, the Methodology is designed in two sections that can be used separately from each other.

Section 1: Section 1 provides in particular **Chapters** information on the topic of the Methodology in terms of the ConnectGREEN project with specific focus on the practical steps and procedures towards identification of wildlife/migration corridors of large carnivores. The Chapter 5 *Defining the Habitat of large carnivores* refers to **Factsheets** which provide detailed description of procedures to be undertaken or respective forms for data collection.

Section 2: **Supporting documentation** provides reference material and additional information on topics like connectivity, target species, the Carpathians, main types of barriers, pro-connectivity measures, monitoring of pro-connectivity measures.

SECTION 1

Chapter 1 – PREFACE refers to main goals of the Methodology, describes who is the main target group of the document, for whom the outputs gained by applying this Methodology are envisaged and in what political framework the Methodology is expected to be used.

Chapter 3 – BACKGROUND INFORMATION ON THE METHODOLOGY briefly introduces the connectivity and fragmentation, justifies the selection of target species, brings information on migration barriers, connectivity measures, monitoring of measures. All these topics are only shortly presented within the context of the ConnectGREEN project and as framework information for the Methodology. For more information the relevant Supporting documentation is indicated.

Chapter 4 - USE OF RESULTS underlines the importance of acceptance of results provided by the Methodology and real applicability of results in practical life in the field of spatial development.

Chapter 5 – DEFINING THE HABITAT OF LARGE CARNIVORES represents the crucial part of the document and brings step-by-step instructions for the Habitat of large carnivores on both Carpathian and pilot area level. In order to keep the Chapter clear, the particular steps are aggregated into logical parts, and (where relevant) supported by Factsheets that bring further in-depth information mostly for field experts on procedures of inventory of data and its evaluation, in particular regarding species occurrence data, evaluation of barriers/critical zones etc. (Reference to particular Factsheets see below).

Factsheets to the Chapter 5:

Factsheet 01 – Availability of occurrence data

Factsheet 02 – Availability of data on environmental variables

Factsheet 03 – Collecting of occurrence data

Factsheet 04 – Inventorying barriers in corridors and critical zones (field)

Factsheet 05 – Assessment of critical zones

SECTION 2 – SUPPORTING DOCUMENTATION

Supporting document 01 – INTRODUCTION TO THE CARPATHIANS brings information on the Carpathian Mountains, Carpathian Convention, and Carpathian Network of Protected Areas.

Supporting document 02 – PREVIOUS PROJECTS AND INITIATIVES describes projects and initiatives focused on the landscape connectivity that have been implemented in the Carpathians within the last decade.

Supporting document 03 – CONNECTIVITY AND FRAGMENTATION provides general basic knowledge on connectivity, fragmentation, corridors and can serve as an introduction to the topic also for persons who are not experts in this field.

Supporting document 04 – TARGET SPECIES focuses on the three target species – brown bear, Eurasian lynx and grey wolf and brings information on the status of protection, occurrence and dispersal, ecology and ethology, migration behavior and threats.

Supporting document 05 – BARRIERS describes main types of barriers for migration of large carnivores and also includes the evaluation of particular types of barriers. The principles of evaluation of barriers are reflected in the "mapping sheets (cards)" which were developed for mappers to facilitate the field work in order to get results as unified as possible. The respective mapping sheets (cards) and inventorying instructions are described in Factsheets to the Chapter 5 Defining the habitat of large carnivores.

Supporting document 06 – CONNECTIVITY MEASURES brings the list of possible measures that can be applied to maintain or restore the ecological connectivity and mitigate the negative impacts of landscape fragmentation.

Supporting document 07 – MONITORING OF CONNECTIVITY MEASURES brings the list of possible monitoring methods that can be used to monitor the efficiency of applied connectivity measures.

Chapter 3 - CONTENT OF THE METHODOLOGY

The **ecological connectivity** is an inevitable condition for surviving of many species, both for animals and plants independently of the size of the individuals or the populations. The connectivity is becoming the key topic in the nature protection as the need for daily or seasonal/migration movements and the dispersal of organisms considered the most important aspect of life after feeding and reproduction (Hamilton 2014). Building of ecological networks is the main tool for protection of the ecological connectivity. The ecological network has three main pillars – core areas, stepping stones and corridors.

Traditionally the corridors have been viewed as linear strips (Jongman & Pungetti, 2004) sheltered by a buffer zone. In past years however, an approach of connected spatial structures of biotopes has become justified for the group of large carnivores.

For the Methodology was adopted the approach of connected spatial structures.

(For more information on general knowledge on Connectivity and fragmentation see Supporting document SD03)

The increased landscape fragmentation caused by changes in land use has negative impact on the original functions of the landscapes and biotopes e.g. permeability for migrating species. The most affected groups of species influenced by fragmentation of the landscape are those bound to the well-preserved natural environment, those which have high demands on the size of the home range or their biology includes regular or occasional migration, especially the three species of large carnivores: **grey wolf, Eurasian lynx and brown bear**. The Carpathians represent one of the last remaining strongholds for these large carnivore species. Large carnivores are very similar in ecological requirements as these species are mostly strictly tied to large forested areas with low human disturbance. Furthermore, dispersal and long distance migration is an integral part of their biology. Fragmentation of the landscape puts significant limits on movement of these species and thus threatens the existence of these species. The selected target species of large carnivores are taxa with high status of protection on both national and international levels. The protection of these species will be efficient only if both the home range areas and the migration areas are protected. Large carnivores are so called umbrella species for forest ecosystem. If we sustain their high ecological demands on migration, then the less specific demands of other smaller forest bounded species will be fulfilled.

For the identification of wildlife/migration corridors of large carnivores, data related to the ungulates can be also used, first of all data related to red deer. Data on the occurrence and movement of the deer species are often easily available and can be adapted to the needs of the ConnectGREEN project and the identification of wildlife/migration corridors of large carnivores.

The specific knowledge of the target species described in the Supporting documentation SD05 was taken into consideration while designing the subsequent chapter on defining the habitat of large carnivores as well as in the particular materials of the Supporting documentation (barriers, species, measures and monitoring). Target species will be also focused upon in the practical implementation of this Methodology in pilot areas e. g. in development of the Action plan on measures, etc.

(For more information on general knowledge on Target species see Supporting document SD04)

The increased fragmentation results from the increasing number of **migration barriers**. Migration barriers represent one of the key topics in terms of defining the wildlife/migration corridors. The wide range of types of barriers and variety of their possible impacts on ecological connectivity often do not allow comprehending all possible variations in field and do not allow offering simple solutions with general methods of application.

The general knowledge described in detail in the supporting document SD06, however, will create a basis for development of tailor-made adaptations on the local level (in pilot areas as for the ConnectGREEN project), taking into account also local micro attributes which may influence the impact of the barrier both in individual and cumulative evaluation. These findings will be permeated in strategic as well as local documents for adoption of relevant prevention or mitigation measures.

(For more information on general knowledge on barriers in respect to main types of barriers as well as the evaluation of barriers see Supporting document SD05)

Once the habitat of large carnivores according to this Methodology is identified, the **measures** to maintain and/or improve the connectivity can be developed and adopted. In the framework of the ConnectGREEN project, the measures will be drafted by experts and consulted with key stakeholders in pilot areas in the Action plan. Implementation of at least one of the proposed management measures will start in each pilot area by the end of the project. There are connectivity measures described by experts and verified in field in different regions over the world; however it is always considered to be a specific situation regarding local environmental conditions, species behavior and other variables which influence the final design of the particular measure and its efficiency.

(For more information on general knowledge on Connectivity measures see Supporting document SD06)

Hand in hand with applied connectivity measures, a proper **monitoring of measures** should be planned and carried out in order to collect information on the effectiveness of these measures. Monitoring of effectiveness provides an important feedback and allows for adaptation and fine-tuning of mitigation effects, avoiding repeating mistakes, providing new information for improving the design of mitigation measures, to identify the measures with an optimal relationship between cost and benefit or even to save money for future projects (Hlaváč et al. 2019). It is important not only to monitor the existing measures, but also to review existing studies on measures and to apply this knowledge in decision processes (e.g. in cost-benefit analysis) to avoid implementation of measures that have been proved as inefficient at other place.

Similarly as in respect to connectivity measures, there are many monitoring methods used worldwide and the local attributes such as environment, season, local conditions etc. must be taken into consideration to choose the best option in respect to selected target species.

(For more information on general knowledge on Monitoring of the connectivity measures see Supporting document SD07).

Chapter 4 - USE OF RESULTS

It is crucial to secure that the results provided by this Methodology and by the ConnectGREEN project will be accepted in practice and will find reflection in planning and implementation systems throughout the relevant sectors. This will only be possible if there is:

- political will/support to prioritize the nature protection and in particular connectivity protection and to harmonize sectors of nature protection and spatial development and improve the cooperation between the sectors
- bullet-proof data and arguments from nature protection managers in respect to the needs of the connectivity protection
- harmonization of interests of spatial development and nature protection.

The ConnectGREEN project aims to support all of the three above-mentioned conditions by:

- development of strategic documents that will be accepted on the level of the Carpathian Convention
- development and adoption of the Methodology for the identification of wildlife/migration corridors for large carnivores supported by experts from all Carpathian countries
- development of a Guideline for harmonizing the interests between nature conservation and different land uses.

The 14th Meeting of the Conference of Parties to the Convention on Biological Diversity (COP14 to CBD) in Egypt in 2018 underlined the necessity to review and adapt landscape and seascape plans and frameworks (both within and across sectors), including, for example, land-use and marine spatial plans, and sectoral plans, such as subnational land-use plans, integrated watershed plans, integrated marine and coastal area management plans, transportation plans and water-related plans, in order to improve connectivity and complementarity and reduce fragmentation and impacts on the cohesion of protected areas networks in order to achieve the Aichi Targets 5 and 11 (CBD 2018, COP Decision 14/8, CBD Aichi Targets 2010).

These ambitious, however inevitable plans must be on one hand accepted on the international and national levels by politicians and on the other hand must be feasible to be implemented on the regional and local level. To be successful in creating, maintaining and protecting ecological connectivity, a strong involvement of diverse stakeholders is crucial. To anchor connectivity projects in local and regional reality, the involvement of local stakeholders is essential, and this must be coupled with political support from ministries and regional administrations. Even more important is a continued dialogue process. Beside the fact that connectivity needs to be planned with adapted tools and legal frameworks, the implementation of ecological connectivity as a pre-condition for long lasting functioning ecosystems should be considered as a process of continuous exchange between different policy levels and communities that are being asked to undertake certain activities (Plassmann et al. 2016).

Overarching supporting action for successful use of the results of the ConnectGREEN project is the awareness raising of both professional and non-professional public concerning the real significance of landscape fragmentation and critical importance of securing the connectivity for the large carnivores and other species.

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Chapter 5 - DEFINING THE HABITAT OF LARGE CARNIVORES

5.1. Terminology:

In the phase of the development of this Methodology there was a long discussion within the expert group on terminology, in particular in respect with the term **corridor** and the term which should be used for the **expected output** (i.e. core areas + stepping stones + corridors + critical zones). Experts took into consideration international standards, agreements on use of the terminology with other projects (mainly the TRANSGREEN project) as well as national acceptance of the terminology.

Corridor

Within projects TRANSGREEN and ConnectGREEN were adopted definitions of different types of corridors (http://www.interreg-danube.eu/approved-projects/transgreen)

Ecological corridors as landscape structures of various size, shape and vegetation cover that mutually interconnect core areas and allow migration of species between them. They are defined to maintain, establish or enhance ecological connectivity in human-influenced landscapes.

Wildlife corridors - allow the movement of a wide range of organisms between high natural value areas

Migration corridors - allow animal movement (both regular and irregular) between areas of their permanent distribution (core areas)

Movement corridors - allow animal movement within core areas (including daily movements in search of food, etc.

(for more information see Supporting documentation SD03 – Connectivity, fragmentation – background information)

Definitions of corridors differ in their meaning and therefore also their use in this Methodology reflects the content and context of the respective text.

For the purposes of this Methodology we use the term **ecological corridor** when describing the movement of animals in the context of the whole ecosystem (more generally) and the term **wildlife/migration corridor** when talking specifically about the connection between the core areas and mainly with focus on large carnivores as the umbrella species in the process of defining the ecological network (habitat of large carnivores) for large carnivores (see below).

Expected output

The output of the process is the map/layer of the patches of habitat suitability (core areas and stepping stones), corridors and critical zones for large carnivores. Finally, experts of the working group decided on the use of the term the **Habitat of large carnivores**.

It is also necessary to remark that even if the terminology on the international level in English language can be unified (as agreed for the Carpathian level), still the national terminology remains to be a reflection of national legislation framework and/or the keeps on terminology established in particular countries over years.

This chapter describes the step-by-step procedure for defining the habitat of large carnivores both on the Carpathian level and on the level of the pilot areas. The subsequent steps are aggregated into logical units with respective partial outputs which were verified by experts.

To keep the chapter consistent and well-arranged, the detailed information mainly regarding the harmonized procedure in data inventory is described in Factsheets which are the fixed part of this Chapter.

Habitat of the target species i.e. the habitat of large carnivores is identified based on the habitat preferences using the latest occurrence data for the Carpathians.

For the definition of the Habitat of large carnivores, the habitat suitability models of the target species and the connectivity model are crucial. Habitat suitability model defines areas that are suitable for permanent occurrence of the species (HSP – habitat suitability patches) and the connectivity model links particular HSPs.

The habitat of large carnivores is consisting of three categories: core areas, corridors and critical zones.

Each category of the biotope consists of different landscape segments with different environment requirements.

Core areas are represented by large areas that fulfil requirements for the permanent occurrence of the selected species. It concerns mainly forest with natural/ semi-natural conditions and environment that enables natural development of populations. Core areas can be divided into areas with already existing permanent occurrence of target species (so called functional habitat) and areas with a potential to permanently host the target species (potential habitat).

Long-term occurrence of populations of target species is conditioned by their mutual contacts. Therefore the core areas are interconnected by the network of **wildlife/migration corridors** that fulfil the migration requirements of species in a sufficient way. Corridors are led through the forest ways and isles with sufficient refugee possibilities.

Linkage areas represent a special "type" of corridor. Linkage areas are broader areas of connectivity important to facilitate the movement of multiple species and to maintain ecological processes within two or more neighboring core areas, where delineating clear wildlife/migration corridors for species is difficult due to relatively high degree of permeability.

Critical zones represent localities with significant limitations of the land permeability owing to the difficult passable migration barriers. Barriers are often concentrated in one point because of topographic conditions and create a cumulative barrier effect. Sometimes there are cases, that a separate barrier (e.g. road of lower category, rail, and arable land) would not represent a barrier in the landscape; however the accumulation of barriers creates a critical zone.

Within the project we worked with two different resolution outputs:

A. The level of the Carpathians (subchapters 5.2 to 5.5)
B. Pilot areas (subchapter 5.6)

While defining the layer of the habitat of large carnivores, the continuous verification of partial outputs of modelling is necessary in order to identify disparities on time and avoid false results that would mean inefficiency and could jeopardize the project outputs. The verification of outputs of subsequent steps at different stages of the modelling process on the level of the Carpathians was conducted by the national/local experts according to their local knowledge via desktop exercise. The verification of the model on the level of the pilot areas was conducted by local experts both through desktop verification and field surveys conducted in the pilot areas.

A. CARPATHIAN LEVEL
1. HABITAT SUITABILITY MODELING
1. Collection and preparation of input data
2. Development of the habitat suitability model 3. Definition of core areas & stepping stones
4. Expert discussion/verification of the layer of core areas and stepping s tones by national and local experts & finalization of the layer
2. CONNECTIVITY MODELING
1. Preparation of the resistance surface including barriers
2. Connectivity modelling – network of corridors (and linkage areas) 3. Expert discussion/verification/completion of the connectivity model (by national and local experts) & finalization of the layer
3. CRITICAL ZONES
1. Identification of barriers and critical zones
2. Expert discussion/verification of critical zones, adoption of the layer & incorporation of verified critical zones into the layer
4. DEFINITION OF THE HABITAT OF LARGE CARNIVORES
1. Synthesis of particular outputs – proposal of the map of habitat of large carnivores
2. Expert discussion/verification of the proposed map of habitat of large carnivores - national and local experts
3. Finalization of the map of habitat of large carnivores for the Carpathians
B. PILOT AREAS LEVEL
1. Desktop verification of corridors and critical zones
2. Field verification
3. Finalization of the layer of the ecological network for the pilot areas

A. CARPATHIAN LEVEL

5.2. HABITAT SUITABILITY MODELING

5.2.1 Collection and preparation of input data

The first step of proposed Methodology consists of collection and preparation of all data necessary to fulfil further steps. Two types of data are needed:

1. OCCURRENCE DATA – all relevant and verified observations (collected within focal regions of the Carpathians since the year 2000 up to now). Geographical differentiation, frequency, spatial precision and validity of the records on occurrence data are crucial for the habitat analysis processing and directly affect the quality of the final model. Occurrence data may include observations of a living individuals or dead animal, occurrence signs could be collected in different ways (by-chance observations, observations on permanent monitoring spots according to the Methodology, telemetry data, etc.). Possible types of data include point, linear or polygon layers of the occurrence records and should be represented as ESRI shapefiles or vector layers of open software (QGIS, PostGIS, GRASS, SAGA etc.).
   (Factsheet 01 –Availability of occurrence data, Factsheet 03 – Mapping/collecting occurrence data)

1. ENVIRONMENTAL VARIABLES – are essential inputs for habitat modeling. All relevant data on both natural and human conditions of the landscape was collected for the whole region of the Carpathians. These include following datasets:
   1.1. **Abiotic factors** – source data on topography (digital elevation model) will be collected and other datasets will be derived for it (vertical heterogeneity, solar radiation index) using specific tools of spatial analysis (focal statistics, moving window technique, etc.).
   1.2. **Habitat factors** – represent the most influential variables in the model. Combination of Global Land Cover data (pixel size 300m) and Corine Land Cover data (pixel size 100m) will be used. Generalized land cover layer as well as derived data on landscape structure (e.g. density of forest edges) will be involved as inputs into the model.
   1.3. **Anthropogenic factors** – the last groups of environmental variables cover the human influence and the level of anthropogenic transformation of the landscape. Open Street Map (OSM) will be used as a data source to derive data on distance to settlements, road density etc.
   (Factsheet 02 –Availability of data on environmental variables)

The presented data sets characterize the essential environmental conditions, i.e. factors enhancing occurrence and variables causing a reduced population density or non-occurrence of the target species.
All data were transformed into a single format on an ESRI grid (e.g. of 500 x 500 m) and subsequently into the ASCII T format, needed for further steps.

Output of the step 5.2.1: Data sets

5.2.2 Development of the habitat suitability model

Habitat suitability models represent widely used tool for the identification of the core areas and subsequently ecological networks for the protection of biodiversity. Depending on the character of records of the focal species occurrence and the methods of their collection, the types of models are selected that differ in the processing methods.
In case of the "only presence data", the most widely used approach is the MAXENT (Maximum Entropy Modelling) (Philips et al. 2017), based on complex statistical evaluation of relationship of species occurrence and environmental factors. The most important outputs of the model include raster of habitat suitability and several graphs showing importance of input variables and their influence on species occurrence.

Output of the step 5.2.2: Habitat suitability model for all 3 large carnivores on the level of the Carpathians

5.2.3 Definition of core areas & stepping stones

Habitat suitability model is a key input for several sequential analyses – definition of patches of suitable habitats and connectivity modelling. Core areas and stepping stones represent patches of suitable habitats, which differ in size. Both are defined according to habitat quality and spatial requirements of focal species. Literature review and expert discussion are needed for setting the thresholds within large and heterogeneous region such as the Carpathians. System of core areas and stepping stones provides the basis for the final connectivity model – patches of suitable habitat will be interconnected by wildlife/migration corridors. Minimum size of the core area should be 300 km^2.

Output of the step 5.2.3: Proposal of the layer of core areas and stepping stones on the level of the Carpathians

5.2.4 Expert discussion/verification of the layer of core areas and stepping s tones by national and local experts & finalization of the layer

Output of the habitat suitability model and the proposal of the core areas and stepping stones will be checked by the core project team experts and adopted according to their expert knowledge. Experts will mainly take into consideration the designated conservation areas (both national and European level) with respect to the suitable habitats i.e. excluding e.g. built-up areas or large non-forest areas, the occurrence data on target species and supporting documentation (orthophotmaps, landcover data etc.). The adopted model was sent to national and local experts and discussed within a workshop. After verification and eventual modification, the final version of the layer of core areas and stepping stones will be prepared.

Output of the step 5.2.4: Final layer of the core areas a stepping stones verified on the national level

5.3 CONNECTIVITY MODELING

5.3.1 Preparation of the resistance surface including barriers

Resistance surface represents the resistance of various landscape segments that influence less or more the movement of animals in the landscape. The resistance surface is like transformed layer of the habitat suitability – i.e. areas with the lowest habitat suitability have the highest resistance surface value (and vice versa).

Resistance surface is therefore developed by inverting the habitat suitability model and moreover by adding the layer of the fragmentation geometry, i.e. linear elements of road and settlements infrastructure, that create substantial migration barriers in the landscape. These data will be derived by using Open Street Maps datasets (OSM). The fragmentation geometry is perforated on spots where the barriers are permeable (according to OSM standards). The output of the connectivity model provides the coherent network of corridors. These are not of regular shape and the character of corridors reflects the quality of the land cover.

Output of the step 5.3.1: Resistance surface for the Carpathians

5.3.2 Connectivity modelling – network of corridors (and linkage areas)

Connectivity model interconnects particular core areas and stepping stones through the corridors and creates a coherent network. There are several methods and approaches available for the connectivity modelling such as Least Cost, Graph Theory, Resistant Kernel. The method applied in this Methodology is an innovative tool Circuitscape (McRae 2006) built on the principle of electricity conductance. In terms of landscape ecology, it concerns interlinkage of particular core areas based on resistance surface. The core areas behave like (electric) current sources and the surface is composed from parts of landscape that have different resistance to movement (like different electric resistances). The tool finds ways between each core areas with the lowest resistance to movement. So called voltage maps are then the key inputs for definition of corridors. The minimum width of the corridors should be 500 m.

Output of the step 5.3.2: First draft of corridor network/connectivity model for the Carpathians

5.3.3 Expert discussion/verification/completion of the connectivity model (by national and local experts) & finalization of the layer

The first draft of the connectivity model was sent for verification to the national/local experts and discussed. Based on their local expert knowledge, the national/local experts completed the draft of the connectivity model. According to comments, the final layer of corridors was prepared.

Remark:
As the connectivity modeling has certain limitations caused e.g. by the scale of modeling,

heterogeneity of the area, insufficient data covering in different areas etc., the inputs of experts based on local knowledge at this stage of the process of creation the map of the habitat of large carnivores can be decisive as regards final quality of the map of the habitat of large carnivores.

Example:
Valleys are an important segment of interconnection of mountain ranges. In last decades however valleys are becoming impermeable for large carnivores because of dense built-up areas. If there are two long mountain ranges merged at certain area, it is highly probable that the model will propose the corridor in this very area. The experts with local knowledge can have detailed information on zones within the built-up areas that still fulfill criteria for a corridor however the model did not displayed them. Thus, the inputs of national/local experts with detailed local knowledge will play crucial role in identifying of (still) permeable localities between (within) built-up areas.

Output of the step 5.3.3: Final layer of the network of corridors verified by national experts & VUKOZ

5.4 CRITICAL ZONES

5.4.1 Identification of barriers and critical zones

Identification and classification of basic migration barriers and potential critical zones based on GIS modeling. The **potential** critical zone is identified if there is an intersection of proposed corridors with impermeable or disturbing landscape structures/barriers.

Output of the step 5.4.1: First draft of critical zones on the level of the Carpathians

5.4.2 Expert discussion/verification of critical zones, adoption of the layer & incorporation of verified critical zones into the layer

Critical zones identified by modelling from previous step will be sent to national/local experts for verification and discussion. Based on their local expert knowledge, the national/local experts will complete the draft of critical zones. Based on information gained from the national experts, the connectivity model on the level of the Carpathians will be properly adjusted by critical zones.

Output of the step 5.4.2: Verified critical zones incorporated in the layer on the level of the Carpathians

5.5 DEFINITION OF THE HABITAT OF LARGE CARNIVORES

5.5.1 Synthesis of particular outputs – proposal of the map of habitat of large carnivores

Based on the verified data - core areas, stepping stones, corridors, critical zones form the first draft of the map of habitat of large carnivores on the level of the Carpathians will be created.

Output of the step 5.5.1: The map of habitat of large carnivores – first draft

5.5.2 Expert discussion / verification of the proposed map of habitat of large carnivores - national and local experts

The proposal of the map of habitat of large carnivores was verified by using independent occurrence data sets acquired by telemetry and/or by chance observations. Secondly, national and local experts verified the proposal.

Output of the step 5.5.2: The verified map of habitat of large carnivores on national level

5.5.3 Finalization of the map of habitat of large carnivores for the Carpathians

Based on verification run in previous step and harmonization of the national maps of habitat of large carnivores, final map of habitat of large carnivores on the level of the Carpathians will be prepared. Final output will be distributed within the project team and then to all interested stakeholders.

Harmonization of the national maps of habitat of large carnivores - unified shape of the output layer – model output (rasters of 500x500m and GIS inserts of local experts)

Output of the step 5.5.3: The final map of habitat of large carnivores on the level of the Carpathians

B. PILOT AREAS

5.6 DEFINITION OF THE HABITAT OF LARGE CARNIVORES FOR THE PILOT AREA

Based on the final map of habitat of large carnivores developed for the Carpathians in the step 5.5.3 (see above), the **habitat of large carnivores for the pilot areas** will be defined. The process will include the verification of corridors in respect to real permeability and the verification of critical zones.

It is necessary to check on all sections/parts outside the forest, all crossings with the traffic infrastructure and in vicinity of built-up areas and adjust in detail according to the real conditions. These actions are demanding on capacity and therefore in the framework of the ConnectGREEN project can be implemented under the WP 4 only in the selected protected areas.

The verification of core areas, stepping stones and connectivity model will be carried out through the desktop and field verification of (i) corridors and (ii) critical zones. The results of the verification will be transposed to the final map of habitat of large carnivores for the pilot area.

5.6.1 Desktop verification phase

5.6.1.1 Desktop verification of corridors
The ecological network defined by the Carpathian GIS model will be discussed by experts with support of existing knowledge and reference material (base map, aerial maps, knowledge of mapper, etc.). Based on this discussion, the borders (borderlines) of the whole habitat of large carnivores will be specified based on few rules (Anděl et al. 2015). Among such rules/criteria we count:

- Presence of designated protected areas
- Presence of military areas (according to national regulations)
- Respect of landscape elements which support the migration of large carnivores
- Borders of core areas are lead outside the settlements
- Borders of core areas are lead outside the arable land
- Adjust forest units will be added to the core zone (not separated by an evident migration barrier)
- Borders are delineated in regional context of the landscape

For the delineation of the core areas also the functional differences of the identic landscape elements in diverse ecological context are considered.
The borders should be led with regard to the fixed boundaries in the landscape (e. g. small green landscape structures, water courses, roads, ways, paths…).

5.6.1.2 Desktop verification of critical zones
During the "desktop verification phase", the potential problems with delimitation of Habitat of large carnivores will be identified. The majority represents potential critical zones (corridors crossing with barriers – highways, railways, cumulative effect of barriers etc.).
These identified localities will be subject of the followed-up step i.e. field verification of critical zones.

Note: In specific cases (mainly in case of serious threat of damaging the corridors) it is recommended to take into consideration also the future development plans and permeate expected impact into modelling scenarios.

5.6.2 Field verification phase - Field verification of corridors and critical zones

5.6.2.1 Field verification of corridors

The purpose of this activity is to gain solid detailed data of high quality for a qualified evaluation of the corridors.

For the verification of corridors the real detailed field mapping of the pilot areas will be conducted with focus on the corridor permeability (barriers, stepping stones) supported by

collecting complementary data e.g. on the occurrence of target species or small green landscape structures.
The field mapping will include landscape structures and features which have influence on the permeability of the corridors such as:

- Motorways, roads and railways – may include technical structures which may prevent or on the other hand facilitate connectivity
- Vineyards (may be fenced, plus the direction in which the vineyard rows are established may hamper movement of wildlife)
- Orchards, especially intensive (may be fenced)
- Pastures (may be fenced)
- Quarries and pits, both active and old
- Regulated sections of rivers, streams and ditches and other technical features for water management – sections with concrete or rocky embankment may act as migration barrier to wildlife
- Game enclosures
- Commercial or recreational fishponds (may be fenced)
- Forest nurseries (usually fenced)
- Gardens and garden clusters
- Other fenced sites (both permanent or temporary) not described above

As it is apparent from the above description, most of the landscape features with barrier effect will include linear transport infrastructure and fencing. An ArcGIS online application Survey123 was developed for easy recording of such data, mappers can also use "mapping cards for each type of the barrier. Both methods facilitate the field work and enable to get standardized data at high quality for further processing (Factsheets to Chapter 5).
Besides the data gained from the application or mapping cards, the narrative description of the specific local situation based on knowledge, experience and observation of a local expert is essential. This type of information plays a crucial role in designing and adopting the best and most efficient management measures for the locality. Standardized pictures of the location are also necessary for development of such measures.

<u>Verification of barriers</u>

Verification of barriers on the pilot area scale will require detailed field mapping of specific landscape structures with low permeability (large resistance) as well as technical features which have barrier effect on the migration / translocation of wildlife. The focus should be on structures, which could not be detected from the land cover data, satellite nor aerial imagery or those which may possess specific features resulting into their barrier effect, but as such are equally not detectable from the datasets used for Carpathian-level modelling. It is highly probable that the field mapping will reveal new critical zones which could not be identified while using only existing datasets for the modelling of Habitat of large carnivores.

The mapper will go through the corridors (sometimes through the core areas) and assess the barriers and questionable places. An ArcGIS online application and set of forms were designed with the purpose to facilitate the process of the field verification and assessment of the barriers (see Factsheets to the Chapter 5) for the mapper.

Barriers will be classified according to the classification defined in the supporting documentation SD05 i.e. in the categories C1 (critical impermeability), C2 (middle impermeability), C3 (low impermeability), RP (permeable), P (fully permeable).
The result of the classification of the barriers (or their combination) leads to definition of critical zones.

1. Whatever barrier with the class C1 is critical and leads to definition of critical zones.

2. Cumulative effect of barrier - whatever barrier with class such as C2+C2, C2+C3+C3, C3+C3+C3 etc. leads to definition of critical zones.

For the verification of both corridors and barriers it is decisive that mappers are experts with strong scientific background, mapping experience and knowledge of local conditions. Optimum results can be achieved if the experts who conduct the mapping are also persons proposing and monitoring the connectivity measures. Therefore there should be devoted an adequate importance for the selection of qualified person.

<u>Mapping of occurrence of the target species</u>
Targeted <u>field mapping of the presence of large carnivores</u> and possibly other mammals in addition (red deer, otter, etc.) will be organized to detail the delineation of the core areas and stepping stone habitats for the target species as well as to determine the more accurate corridors used by the target species for their translocation or dispersal. The field mapping may be carried out through different monitoring methods including fototraps, tracking on snow, tracking and mapping of signs of presence during spring and autumn period, etc.

<u>Mapping of small green landscape structures</u>
The pilot area scale may benefit from more precise delineation of small green landscape structures, such as hedgerows, bankside vegetation, riparian galleries, linear and dispersed woods and shrubs, small grassland patches, set-asides, etc. These small landscape structures cannot be detectable from land cover data used for Carpathian-level modeling due to the scale (pixel size) but may be vital for the connectivity model on the pilot area scale. In such case, digitalization of such landscape features based on aerial photos combined with their field verification may be necessary. This will be especially needed when refining the connectivity model in critical zones, near settlements etc.
Small green landscape structure which might be of importance for further delineation of the corridor will be signed by the mapper and transported to the GIS layer, ArcGIS online Survey123 application might be the most efficient method.

5.6.2.2 Field verification of critical zones

Based on the final map of habitat of large carnivores developed for the Carpathians (see above step 5.5.3), the potential/proposed critical zones were identified as places of intersection between the corridor and the barrier (see above step 5.4.2). The potential critical zones defined on the Carpathian level are further discussed and verified at the desktop verification by expert discussion. These potential critical zones need to be verified in field.

A Descriptive form of a critical zone was developed to unify the assessment of individual critical zones. In this form a mapper will provide detailed description of the area, the list of significant barriers as well as suggestion of measures to ensure the permeability for target species, all complemented by photographs and standardized maps.

A set of forms was designed with the purpose to facilitate the process of the field verification and assessment of the critical zones (see Factsheets to the Chapter 5) for the mapper.

Similarly as in case of the verification of barriers, the field mappers should be adequately educated and experienced with strong scientific background, mapping experience and knowledge of local conditions.

5.6.3 Finalization of the layer of the ecological network for the pilot areas

Based on the field verification of corridors and critical zones as described in previous steps, the collected data will be transferred into the final layer of the ecological network in the pilot area.

Two figures with the layer of the ecological network in the Czech Republic as an example of results can be found are shown below.

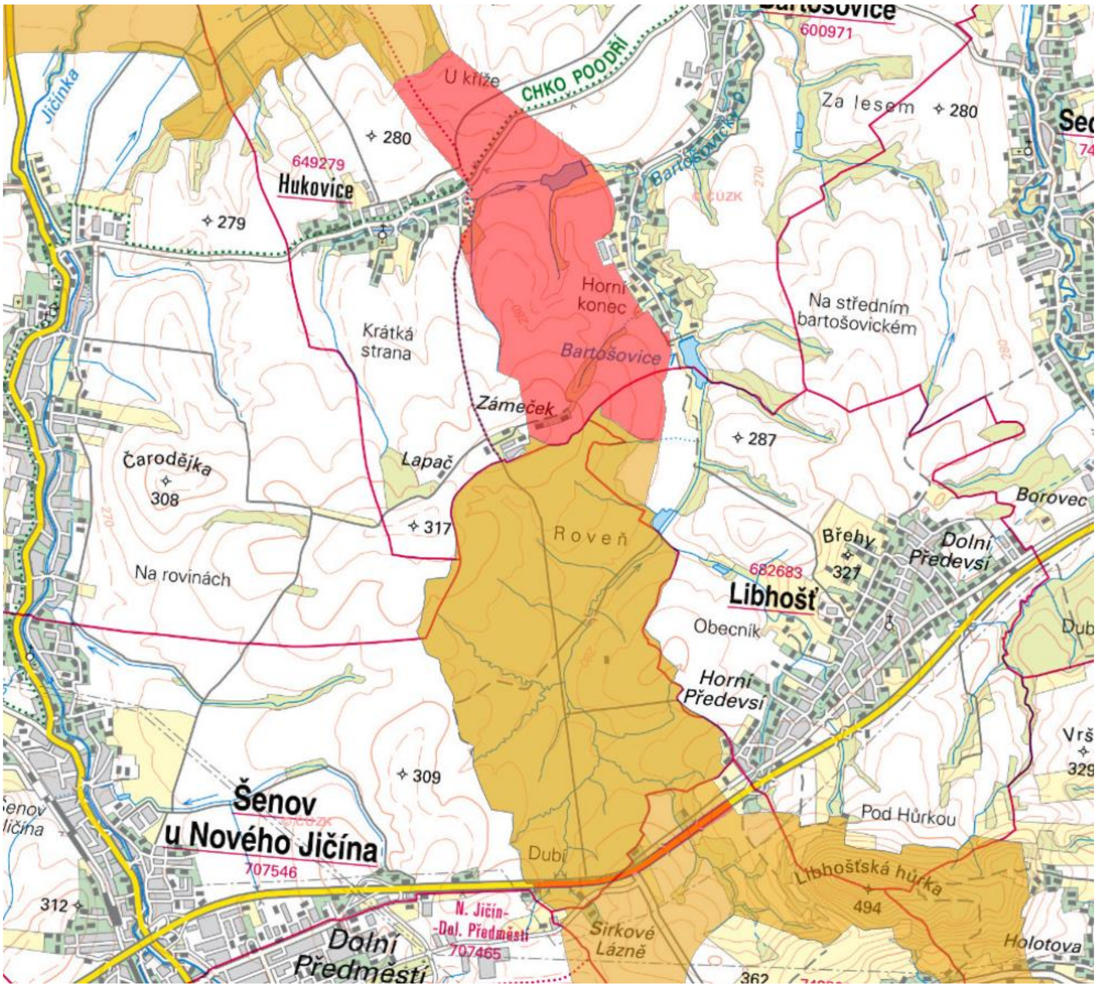


Fig. 01. Typical conduction of a wildlife/migration corridor in the middle connection from Moravskoslezské Beskydy (east site of figure) to Jeseníky (north site) – brown = corridors, red = critical zones. The map displays two features – delimitation of borders (borderlines) of ecological network and delimitation of critical zones. Borders are led based on small green landscape structures and basic parameters (whole forest area – in figure is between critical zones, minimum width of corridor 500 m, etc. – more information in Anděl et al. 2015, only Czech language version). First critical zone (up) is characterized by two main barriers – non-forest area and settlements. The second one is characterized only by primary roads but with four lanes, etc.

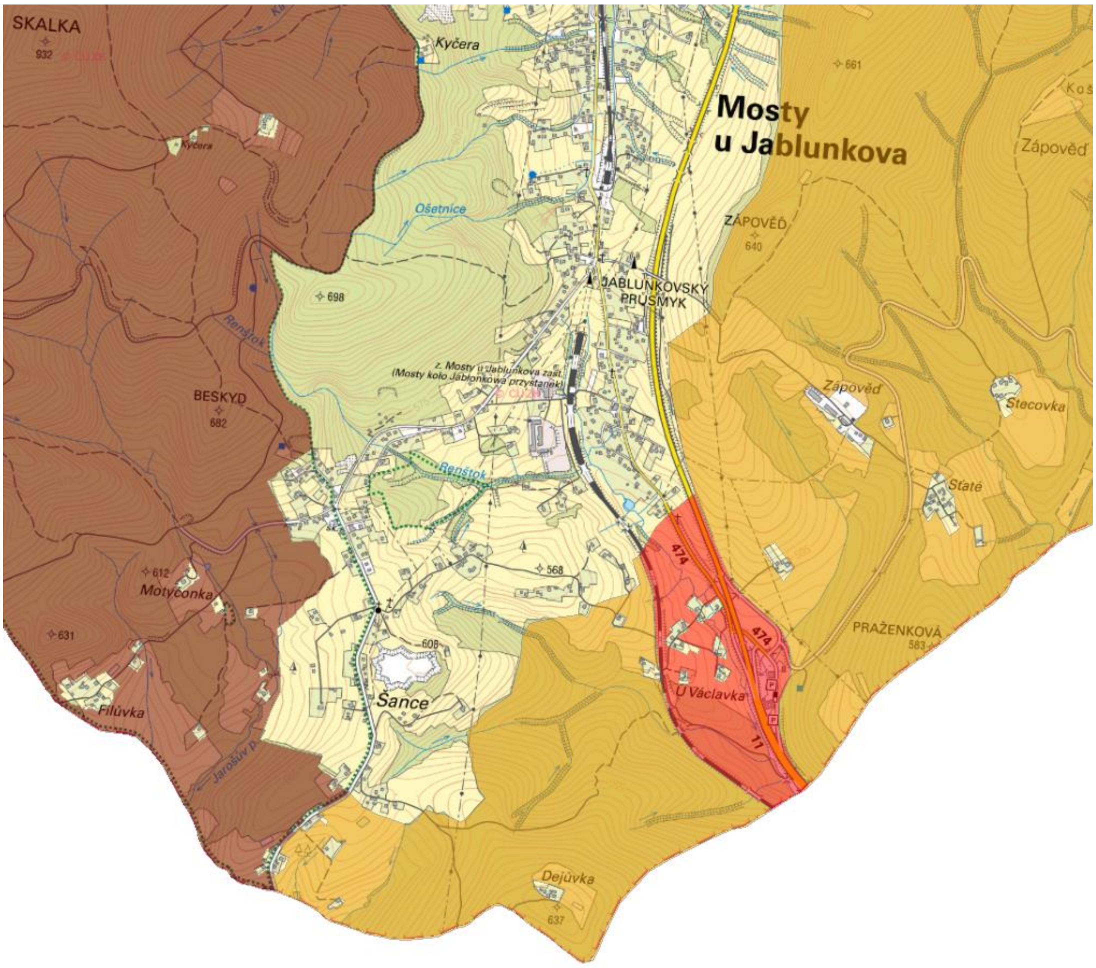


Fig. 02. A specific situation in the Jablunkov region – dark brown = core area, light-colored brown = corridors, red = critical zone. The critical zone in this part represents delimitation based on allotments from land cadaster. Main barriers are settlement, main railway (Ostrava-Žilina) and primary road (no. 11, E75, in the same direction).

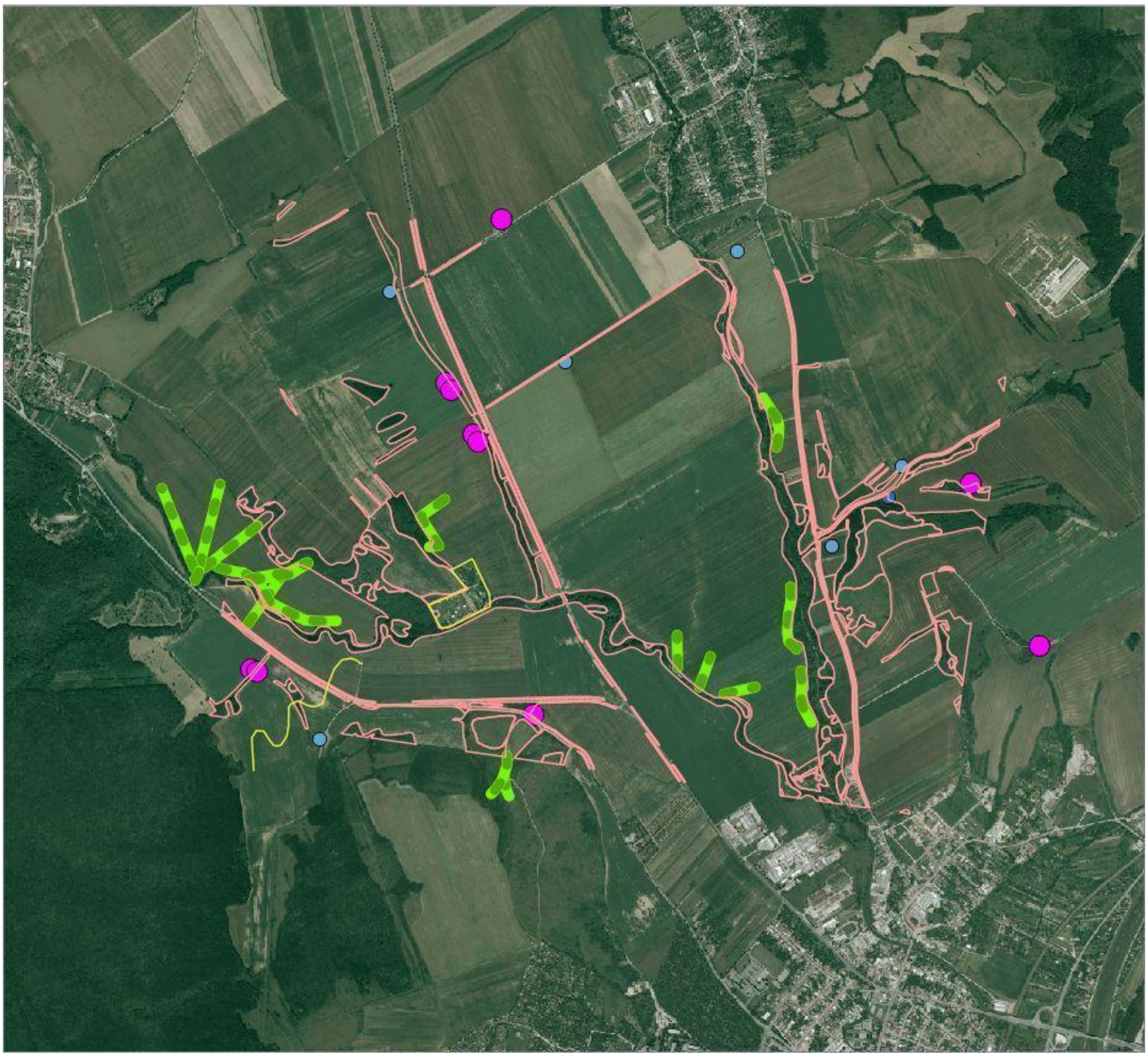
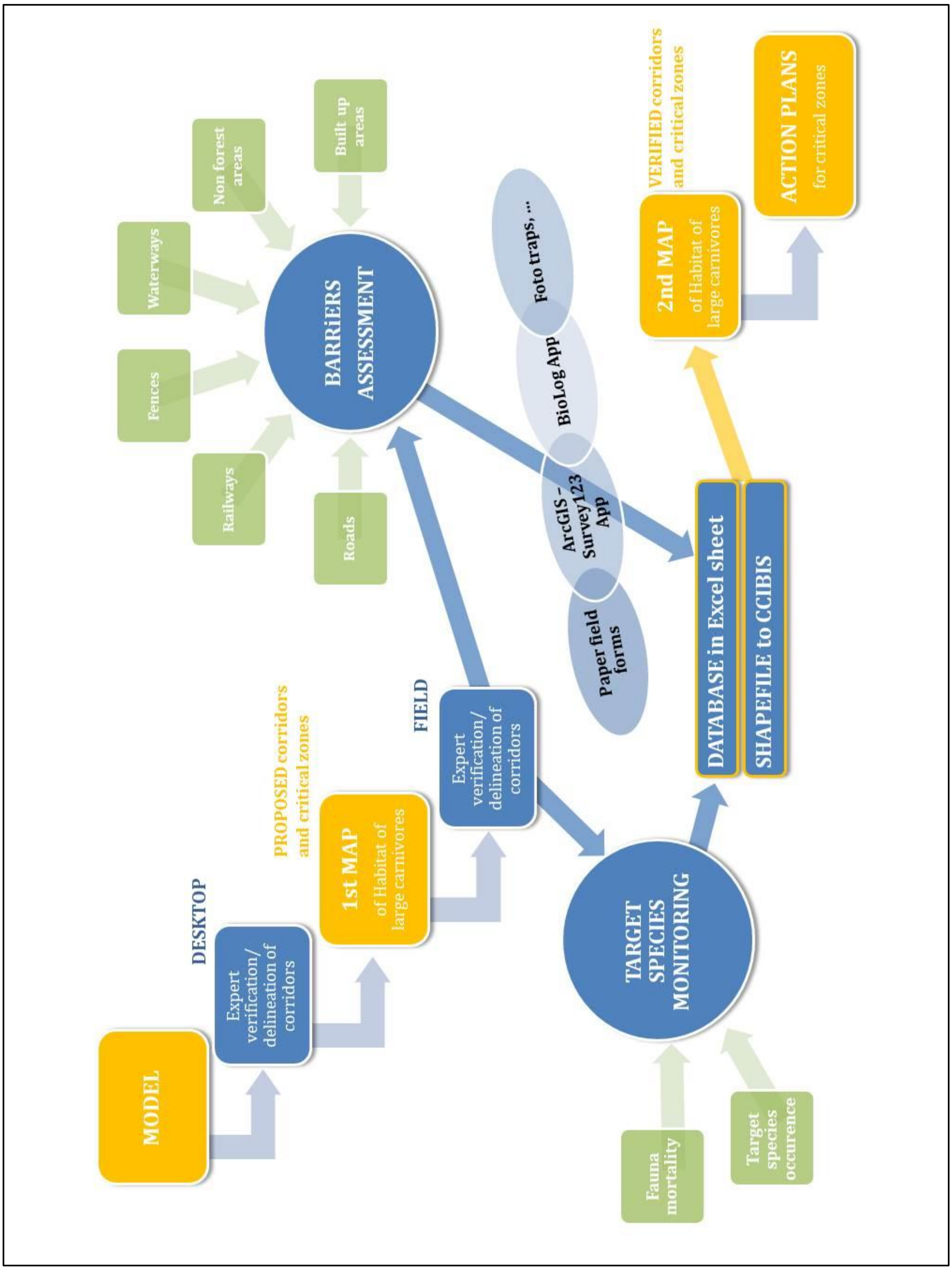


Fig. 03. Example of data sets obtained through field mapping. Animal presence data include point occurrence of various species (blue and violet points) and migration / translocation routes detected by tracking (green-dotted lines). Small landscape structures important for connectivity (outlined in pink) and migration barriers (yellow lines) are recorded as well.

Diagram 01 - Diagram on the verification of corridors and critical zones in the pilot areas



Factsheets to the Chapter 5

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Factsheet 01 – Availability of occurrence data (desktop)

Purpose of this Factsheet is to verify among project partners what occurrence data are available at the moment. As additional data to the target species wolf, lynx and bear, also the data for red deer is used

Data of occurrence					
species	**type**	**spatial scale**	**availability**	**owner**	**specific**
wolf	telemetrical	national	free		date/time of sample
		regional	license		genetic data
		local	non available/private		
	by chance	national	free		date/time of sample
		regional	license		genetic data
		local	non available/private		
others/note:					
lynx	telemetrical	national	free		date/time of sample
		regional	license		genetic data
		local	non available/private		
	by chance	national	free		date/time of sample
		regional	license		genetic data
		local	non available/private		
others/note:					
bear	telemetrical	national	free		date/time of sample
		regional	license		genetic data
		local	non available/private		
	by chance	national	free		date/time of sample
		regional	license		genetic data
		local	non available/private		
others/note:					
red deer	telemetrical	national	free		date/time of sample
		regional	license		genetic data
		local	non available/private		
	by chance	national	free		date/time of sample
		regional	license		genetic data
		local	non available/private		
others/note:					

Factsheet 02 – Availability of data on environmental variables (desktop)

Purpose of this Factsheet is to verify among project partners what environmental data are available at the moment.

Environmental data					
	type	**spatial scale**	**availability**	**owner**	**specific**
habitat	landcover	national	free		
		regional	license		
			non available/private		
	forest density	national	free		
		regional	license		
			non available/private		
	digital elevation model	national	free		
		regional	license		
			non available/private		
	vertical heterogeneity	national	free		
		regional	license		
			non available/private		
others/note:					
barriers	infrastructure	national	free		road classes / railway
		regional	license		traffic intensity
			non available/private		planned construction
	settlement	national	free		intensity of built-up areas (imperviousness)
		regional	license		
			non available/private		
others/note:					

Factsheet 03 – Collecting of occurrence data

Purpose of this Factsheet is to provide the standardized form for collection of data occurrence which carried out in the field mainly in the critical zones.

An excel sheet was created in order to collect data for further analysis.

Following attributes will be recorded:

Number (ID) of record; Name of the mapper; Organization; Date; Time
Pilot area; Name of location/critical zone; GPS X; GPS Y

Species:
Brown bear, Grey wolf and European lynx, in areas with very low density of occurrence data also red deer

Quantity:
Number of individuals

Observed:
I = individuals; M = males; F = females; J = juveniles, AJ = adult with juvenile(s); DI = dead individuals; DM = dead males; DF = dead females; DJ = dead juveniles; E = excrement; FP = footprints; P = prey

Validity:
According to Standards for the monitoring of the Central European wolf population in Germany and Poland:
C1 = hard evidence (live capture, dead animal find, genetic proof, photo, telemetric location)
C2 = Indirect signs like tracks, scats, kills and wolf dens confirmed by an experienced person
C3 = All observations that are not confirmed by an experienced person or observations which by their nature cannot be confirmed. All signs that are too old, unclear or incompletely documented

Factsheet 04 – Inventorying barriers in corridors and critical zones (field)

Purpose of these Factsheet is to provide standardized forms and procedure for the inventorying of barriers.

Following attributes will be recorded either by using ArcGIS online application Survey123 or by using paper forms. All values will be also recorded to common excel sheet.

1. Roads

Road type
H - highways
ML - multi-lane roads
FC - first class roads
LRd - local roads
PRd - purpose roads

Traffic flow
Over 30.000
10.000 – 30.000
5.000 – 10.000
Under 5.000

Presence of mitigation measure or bridge
B – bridge
E – ecoduct
U – underpass

Technical solution
IPO - insurmountable physical obstacles
STO - significant technical obstacles
HBC - high banks and cuts
SO - surmountable obstacles
N - no technical barriers

Underbridge / Ecoduct / Underpass surface type
G - gravel
C - concrete/asphalt
Wa - water
S - soil
Wd - wood
I – iron

Surroundings description
S - shrubs
T - trees
F - forest
M - meadow
AL - arable land

Orientation (in relation to the corridor)
L - Longitudinally with the corridor (180˚)
P - Perpendicularly to the corridor (90˚)
D - Diagonally to the corridor 45˚

2. Railways

Railway category
HS -High speed rail
BB - Transit corridors, backbone network
CN - Transit corridors, complementary network
O - Other railways

Presence of mitigation measure or bridge
B – bridge
E – ecoduct
U – underpass

Technical solution
IPO - insurmountable physical obstacles
STO - significant technical obstacles
HBC - high banks and cuts
SO - surmountable obstacles
N - no technical barriers

Underbridge / Ecoduct / Underpass surface type
G - gravel
C - concrete
Wa - water
S - soil
Wd - wood
I – iron

Surroundings description

3. Fences

Material
W - Wood
M - Metal
EF - Electric fence
C - Concrete
P - Plastic
O – Other

Purpose of the fence
LTI - Linear transport infrastructure
PP - Pasture protection
SP - Settlement protection
GP - Game protection
FK - Forest nursery
O - Other

Permanent/Temporary (P/T)
P - Permanent
TP - Temporary – Pasture season
T - Temporary - other reasons

Status
D - damaged
U – undamaged

Total height
over 2 m
1 - 2 m
under 1 m

Surroundings description
S - shrubs
T - trees
F - forest

S - shrubs
T - trees
F - forest
M - meadow
AL - arable land

Orientation (in relation to the corridor)
L - Longitudinally with the corridor (180°)
P - Perpendicularly to the corridor (90°)
D - Diagonally to the corridor 45°

M - meadow
AL - arable land

Orientation (in relation to the corridor)
L - Longitudinally with the corridor (180°)
P - Perpendicularly to the corridor (90°)
D - Diagonally to the corridor 45°

4. Waterways

Width
more than 500 m
200 - 500 m
100 - 200 m
less than 100 m

Banks
M - modified banks
O - obstacles that may be partly surmountable
MinM - minor modifications of banks
N - natural banks

Surroundings description
S - shrubs
T - trees
F - forest
M - meadow
AL - arable land

Orientation (in relation to the corridor)

L - Longitudinally with the corridor (180˚)
P - Perpendicularly to the corridor (90˚)
D - Diagonally to the corridor 45˚

5. Non forest areas

Land cover
M - meadow
AL - arable land
P - pasture
Or - orchard
GC - golf course
V - vineyards
SA - sports area
O – other

Length (m)
over 10 km
5 – 10 km
2 – 5 km
0,5 – 2 km
under 0,5 km

6. Built up areas

Free space between scattered structures
less than 10 m
10 – 30 m
30 – 100 m
more than 100 m

Distance between villages
less than 50 m
50 – 100 m
100 – 500 m
more than 500 m

Percent of width of corridor
less than 25 %
25 - 50 %
50 - 75 %
more than 75 %

Surroundings description
S - shrubs
T - trees
F - forest
M - meadow
AL - arable land

Field forms

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Danube Transnational Programme
ConnectGREEN

ROADS INVENTORYING

Sheet n°……

Name: ………………………………

Date: ………………………………

Organisation: ………………………………

Location: ………………………………

N° record	Code*	N° road	Road type	Traffic flow	Orientation	Technical solution	Presence of mitigation measure	Under-bridge surface type	Surroundings description	Notes
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

**must match the code in GIS layer*

Road type

H	highways
ML	multi-lane roads
FC	first class roads
LRd	local roads
PRd	purpose roads

Underbridge surface type

G	gravel
C	concrete
Wa	water
S	soil
Wd	wood
I	iron

Presence of mitigation measure

B	bridge
E	ecoduct
U	underpass

Technical solution

IPO	insurmountable physical obstacles
STO	significant technical obstacles
HBC	high banks and cuts
SO	surmountable obstacles
N	no technical barriers

Traffic flow

Over 30.000
10.000 – 30.000
5.000 – 10.000
Under 5.000

Surroundings description

S	shrubs
T	trees
F	forest
M	meadow
AL	arable land

Orientation (in relation to the corridor)

L	Longitudinally with the corridor (180°)
P	Perpendicularly to the corridor (90°)
D	Diagonally to the corridor 45°

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RAILWAYS INVENTORYING

Sheet n°……

Name: ……………………………… **Organisation:** ………………………………

Date: ……………………………… **Location:** ………………………………

N° record	Code*	N° railroad	Railway category	Orientation	Technical solution	Presence of mitigation measure	Under-bridge surface type	Surroundings description	Notes
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

**must match the code in GIS layer*

Underbridge surface type

G	gravel
C	concrete
Wa	water
S	soil
Wd	wood
I	iron

Surroundings description

S	shrubs
T	trees
F	forest
M	meadow
AL	arable land

Presence of mitigation measure

B	bridge
E	ecoduct
U	underpass

Technical solution

IPO	insurmountable physical obstacles
STO	significant technical obstacles
HBC	high banks and cuts
SO	surmountable obstacles
N	no technical barriers

Railway category

HS	High speed rail
BB	Transit corridors, backbone network
CN	Transit corridors, complementary network
O	Other railways

Orientation (in relation to the corridor)

L	Longitudinally with the corridor (180°)
P	Perpendicularly to the corridor (90°)
D	Diagonally to the corridor 45°

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Interreg Danube Transnational Programme ConnectGREEN

FENCES INVENTORYING

Sheet n°……

Name: ………………………………
Date: ………………………………

Organisation: ………………………………
Location: ………………………………

N° record	Code*	Perm. / Temp.	Orientation	Purpose of the fence	Material	Total height	Status	Surroundings description	Notes
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

**must match the code in GIS layer*

Permanent/Temporary (P/T)

P	Permanent
TP	Temporary – pasture season
T	Temporary - other reasons

Surroundings description

S	shrubs
T	trees
F	forest
M	meadow
AL	arable land

Material

W	Wood
M	Metal
EF	Electric fence
C	Concrete
P	Plastic
O	Other

Purpose of the fence

LTI	Linear transport infrastructure
PP	Pasture protection
SP	Settlement protection
GP	Game protection
FK	Forest nursery
O	Other

Status

D	damaged
U	undamaged

Total height

over 2 m
1 - 2 m
under 1 m

Orientation (in relation to the corridor)

L	Longitudinally with the corridor (180°)
P	Perpendicularly to the corridor (90°)
D	Diagonally to the corridor 45°

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NON FOREST AREAS INVENTORYING

Sheet n°......

Name: ....
Date: ....

Organisation: ....
Location: ....

N° record	Code*	Lenght (m)	Dispersed vegetation	Land cover	Permeability	Notes
1			Yes/No			
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

**must match the code in GIS layer*

Land cover

M	meadow
AL	arable land
P	pasture
Or	orchard
GC	golf course
V	vineyard
SA	sports area
O	other

Lenght (m)

over 10 km
5 – 10 km
2 – 5 km
0,5 – 2 km
under 0,5 km

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WATERWAYS INVENTORYING

Sheet n°......

Name: ....

Date: ....

Organisation: ....

Location: ....

N° record	Code*	Name of the river	Width (m)	Orientation	Banks	Surroundings description	Permeability	Notes
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

**must match the code in GIS layer*

Surroundings description

S	shrubs
T	trees
F	forest
M	meadow
AL	arable land

Width

more than 500 m
200 - 500 m
100 - 200 m
less than 100 m

Banks

M	modified banks
O	obstacles that may be partly surmountable
MinM	minor modifications of banks
N	natural banks

Orientation (in relation to the corridor)

L	Longitudinally with the corridor (180°)
P	Perpendicularly to the corridor (90°)
D	Diagonally to the corridor 45°

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ConnectGREEN

BUILT UP AREAS INVENTORYING

Sheet n°……

Name: ………………………………
Date: ………………………………

Organisation: ………………………………
Location: ………………………………

Free space between scattered structures
less than 10 m
10 – 30 m
30 – 100 m
more than 100 m

Distance between villages
less than 50 m
50 – 100 m
100 – 500 m
more than 500 m

Percent of width of corridor
less than 25 %
25 - 50 %
50 - 75 %
more than 75 %

Surroundings description

S	shrubs
T	trees
F	forest
M	meadow
AL	arable land

N° record	Code*	Free space between scattered structures	Distance between villages	Percent of width of the corridor	Surroundings description	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

**must match the code in GIS layer*

Project co-funded by European Union Funds (ERDF, IPA)

Factsheet 05 – Assessment of critical zones

Purpose of this Factsheet is to provide standardized form and procedure for the assessment of critical zones.

Mappers in the field will fill up this standardized form in order to bring a complex picture of the area. Holistic view during the assessment is necessary; mapper thinks about causes and consequences and besides description of current state also provides suggestions, possible solutions and measures to improve the permeability of the critical zone.

The concept of descriptive forms of critical zones comes from definition of Biotope of selected specially protected species of large mammals in the Czech Republic[1].

Descriptive form of a critical zone:

ID of a critical zone; Pilot area; Date; Name of mapper; Organization

Area description:

1. Migration barriers
2. Detailed description of a critical zone
3. Suggested measures to ensure permeability

Attachments:

1. Map 1:50 000 including delineation of corridors
2. Detailed map 1:10 000 including delineation of corridors (in CZ use ZM10)
3. Detailed ortophoto map 1:10 000 including delineation of corridors and real migration paths used by animals
4. At least 3 descriptive photos

[1] Project Complex Approach to the Protection of Fauna of Terrestrial Ecosystems from Landscape Fragmentation in the Czech Republic; EHP-CZ02-OV-1-028-2015.

Descriptive form of a critical zone

ID of a critical zone: Pilot area:

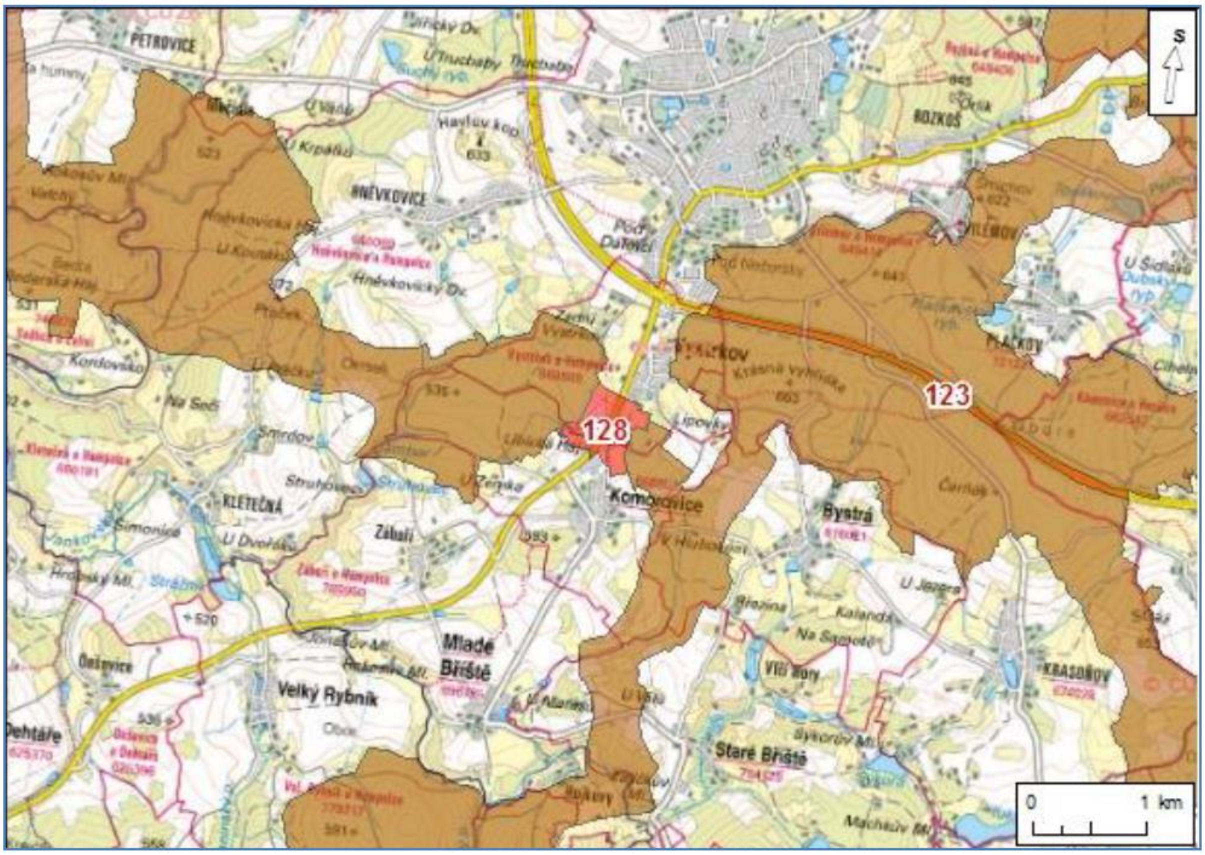
Mapper: Date:
Organization:

Area description:

1. Migration barriers
2. Detailed description of a critical zone
3. Suggested measures to ensure permeability

Attachments:

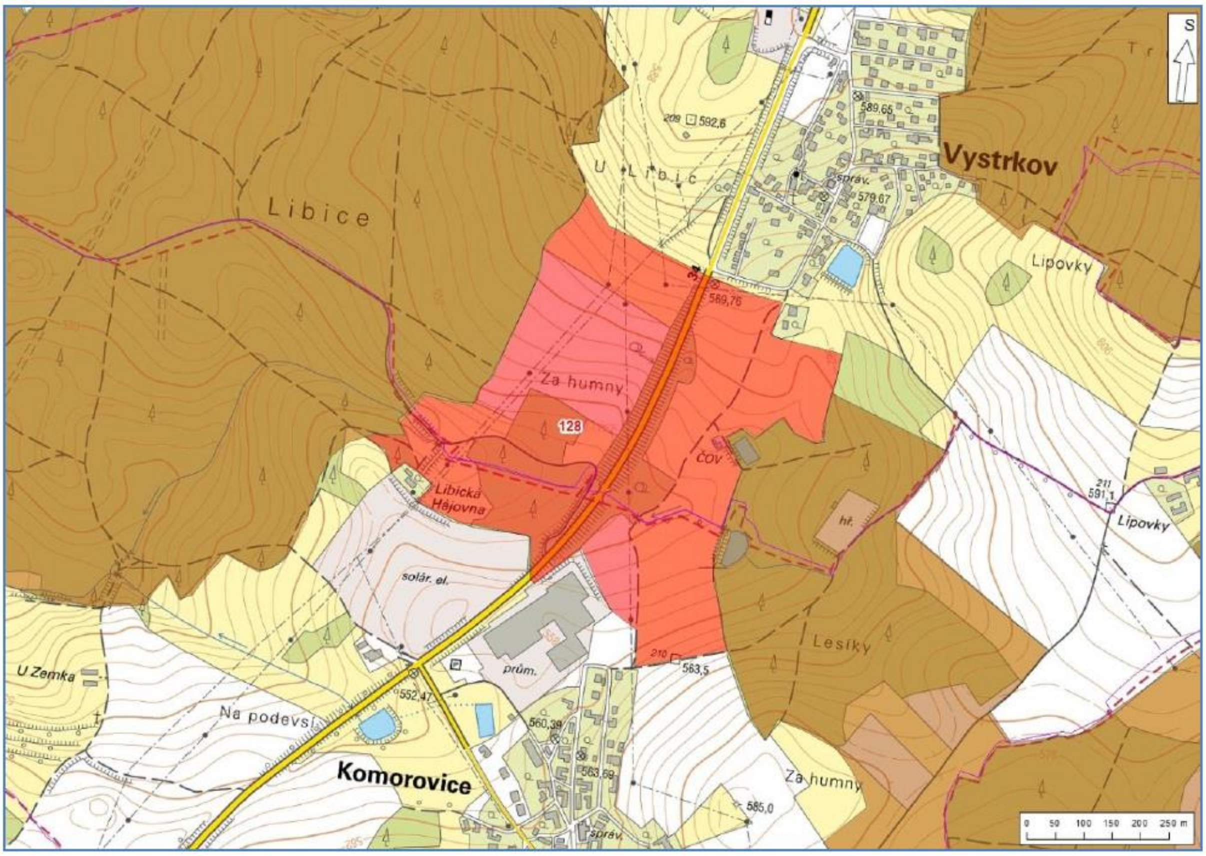
1. Map 1:50 000 including delineation of corridors



© Anděl, Gorčicová / EVERNIA

2. Detailed map 1:10 000

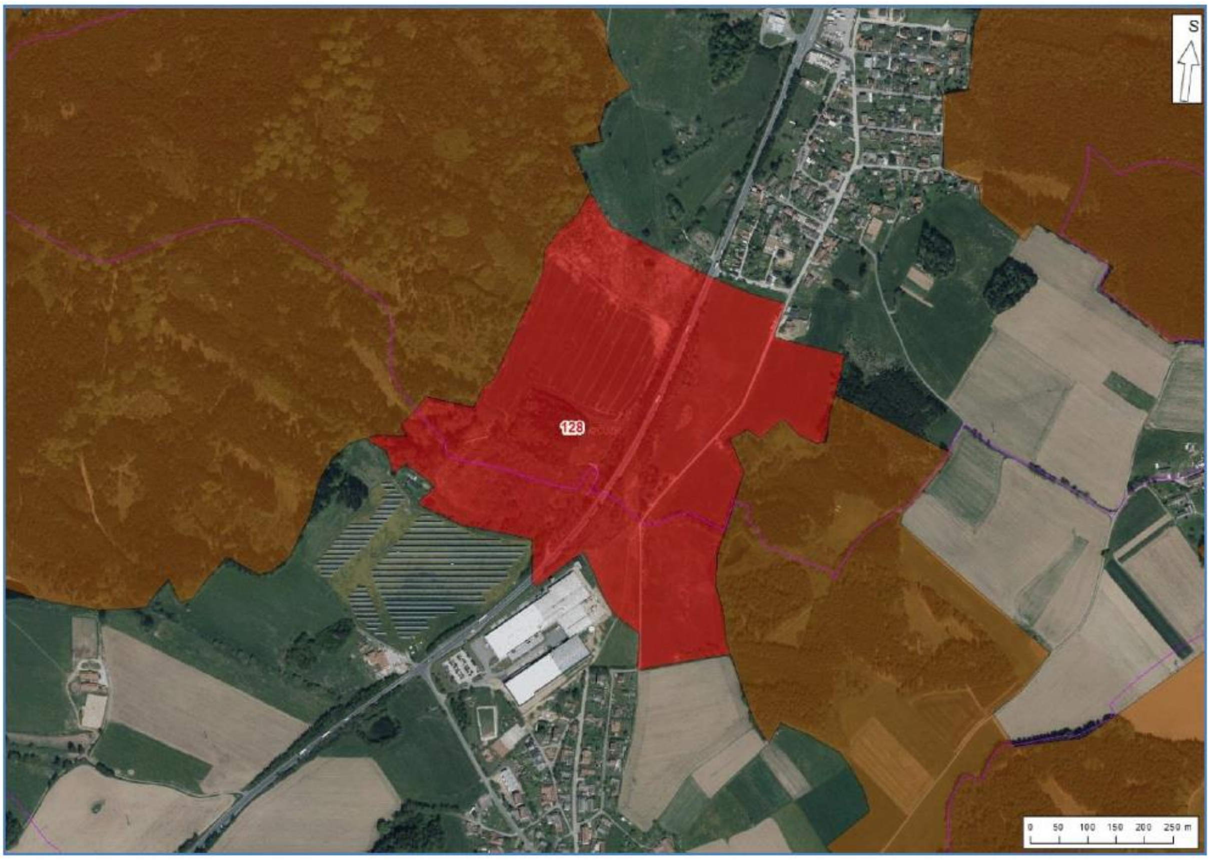
Including delineation of corridors
(In CZ use ZM10)



© Anděl, Gorčicová / EVERNIA

3. Detailed ortophoto map 1:10 000

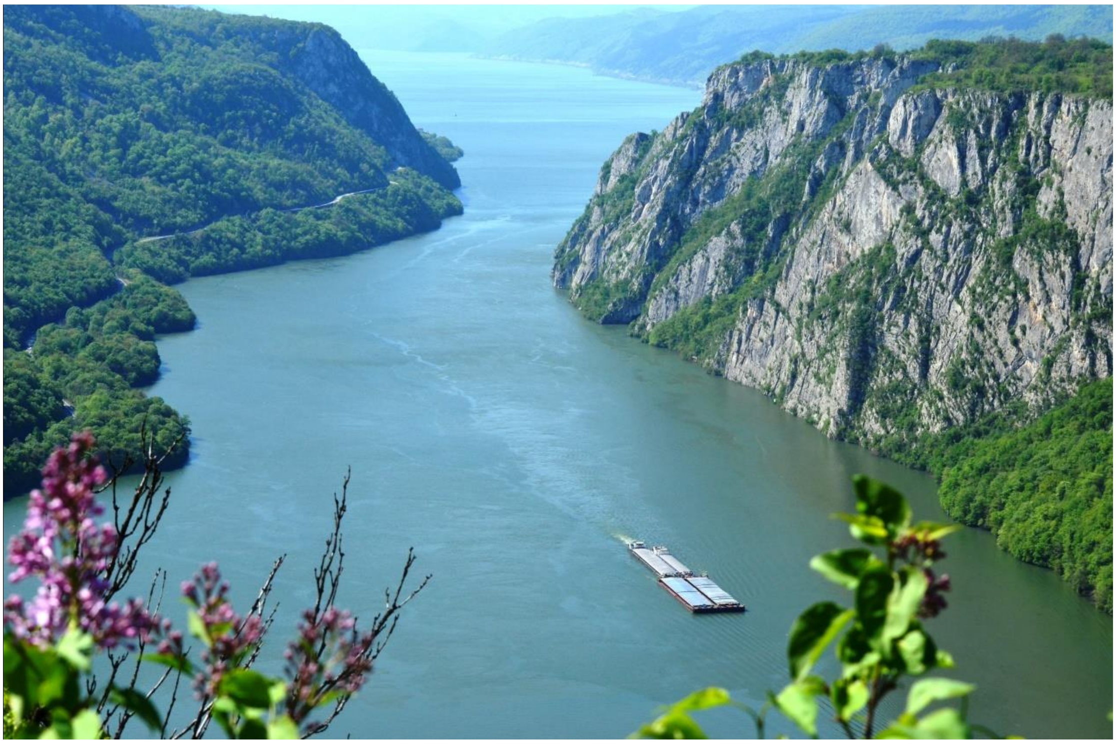
- delineation of corridors
- real migration paths used by animals (missing at this photo)



© Anděl, Gorčicová / EVERNIA

4. At least 3 descriptive photos

SUPPORTING DOCUMENTATION TO THE METHODOLOGY



SD 01 – Introduction to the Carpathians

SD 02 - Previous projects and initiatives

SD 03 – Connectivity, Fragmentation – background information

SD 04 – Target species

SD 05 – Barriers

SD 06 – Measures for securing the connectivity

SD 07 – Monitoring of the connectivity measures

SD01 Introduction to the Carpathians

© Zuzana Okániková /State Nature Conservancy of the Slovak Republic

THE CARPATHIANS

The Carpathians are the longest and most rugged mountains in Europe (Kadlečík ed. 2016). The Carpathians stretch within/across eight countries – Republic of Austria, Czech Republic, Slovak Republic, Republic of Poland, Hungary, Ukraine, Romania and Republic of Serbia. The Carpathians represent a mountain region, unique on a worldwide scale, harbouring natural treasures of great beauty and ecological value. The green backbone of Europe is providing a shelter for one of the most important large carnivore populations in this part of the globe (Egerer 2016).

The Carpathian Mountains can be considered a relatively well preserved region with rich and unique natural and cultural diversity and connectivity of ecosystems. The rapid development of the region during the last few decades has increased landscape fragmentation, limiting dispersal and the genetic exchange of wildlife (Köck et al. 2014). Infrastructure development and fragmentation of the landscape and habitats, including aquatic habitats has been marked as one of the major threats to the preservation of the unique biodiversity and landscape diversity of the Carpathians (Kadlečík ed. 2016).

CARPATHIAN CONVENTION

Ensuring continuity and connectivity of habitats and species, cooperation of contracting parties in developing an ecological network in the Carpathian Mountains and protection of migration routes are among the key principles of the Framework Convention on the Protection and Sustainable Development of the Carpathians (Carpathian Convention). These principles are transferred into relevant articles of the Convention and its thematic protocols, including the Protocol on Conservation and Sustainable Use of Biological and Landscape Diversity, or the Protocol on Sustainable Transport. The Carpathian Convention is closely related to the Alpine Convention, using its experience and expertise of institutions involved. Collaboration in the field of ecological connectivity is also included in the Memorandum of Understanding for the cooperation between the Alpine Convention and the Carpathian Convention signed between the Secretariats of both Conventions. For implementation of these principles several projects have been developed and implemented in particular during the last decade.

THE CARPATHIAN NETWORK OF PROTECTED AREAS (CNPA)

The Carpathian protected areas play a crucial role in conservation of the outstanding natural and cultural treasures of the region – rich biodiversity, mosaic landscape, virgin forests, large carnivores and numerous cultural sites. Each of the Carpathian countries created their own national system of protected areas; moreover the Member States of the EU (Czech Republic, Slovak Republic, Romania, Republic of Poland, and Hungary) designated their sites to the Natura 2000 network, The Emerald network (Bern Convention) plays also an important role in ecological networking in Europe.

Since 2006 the CNPA has been working on conservation of natural resources in the Carpathians. One of the main goals of the CNPA is to contribute to establishment of ecological network – an ecological continuum within the Carpathian mountain range to improve the potential for species migrations and for conserving their habitats.

SD 02 Previous projects

There are various programmes run within the Europe with the aim to support the implementation of strategic goals set up in the strategic documents.

Several important projects and initiatives (listed below) were implemented in the region of the Carpathians (and/or the Alps and Danube river) focused on the improvement of the ecological connectivity and prevention of landscape fragmentation.

Project ConnectGREEN takes over the best results and best practices from previous or parallel implemented relevant projects and seeks to continue towards the conceptual solutions for both the nature protection and the spatial planning on the political and practical level in order to bring the most usable outputs for future projects.

Below are described several projects and initiatives that the project ConnectGREEN is interlinked with.

BioREGIO

The project Integrated management of biological and landscape diversity for sustainable regional development and ecological connectivity in the Carpathians (implemented from 2011 to 2014) facilitated communication and discussion of experience of the Alpine countries through the project partner (EURAC Research) and several exchange workshops. In this project the analysis of connectivity in the Carpathians was carried out based on GIS model and completed by site visits in pilot areas (Köck et al. 2014). The Habitat Suitability Model was used, applying the ArcGIS 10.0 tool Corridor Designer, allowing the assessment of habitat quality for selected species. This model serves as basic layer on which the most probable corridors (least cost paths) for species migration were identified. Once the suitability model was created, those areas having the highest suitability and certain ecological characteristics were selected as core areas (best habitat patches with the highest probability of occurrence). Then the most probable paths for wildlife dispersal were identified using ArcGIS 10.0 tool Linkage Mapper. The tool identified adjacent core areas and created maps of least-cost corridors between them. The result of the application of these tools is a network of least-cost paths. The resulting value of each grid cell expresses the level of connectivity between core areas and indicates which routes encounter more or fewer features that facilitate or impede dispersal for the umbrella species in the study area. In the project the analysis was made for several species, including Eurasian lynx, grey wolf, brown bear, Eurasian otter, western capercaillie, chamois and European hare. Habitat suitability models were produced for all of these species. The basic approach underpinning this study was based on the assumption that, in contrast to the Alps, ecological connectivity still exists in the Carpathians, and the project had to identify the migratory paths, which ought to be protected (Köck et al. 2014).
http://www.bioregio-carpathians.eu

TRANSGREEN

TRANSGREEN project (Integrated Transport and Green Infrastructure Planning in the Danube-Carpathian Region for the Benefit of People and Nature; January 2017 - June 2019) aims to contribute to an environmentally-friendly and safer road and rail network in the Carpathians as a part of the wider Danube river basin by integrating green infrastructure elements into TEN-T related transport infrastructure development at the local, national and transnational level across relevant sectors. This will contribute to improve plans and planning security for transport infrastructure projects taking Green infrastructure into account, deepened coordination and cooperation of relevant stakeholders. Within the project practical solutions for an environmentally-friendly and safer transport network in the Carpathians will be elaborated and implemented.
http://www.interreg-danube.eu/approved-projects/transgreen

COREHABS

COREHABS project (Ecological corridor for habitats and species in Romania) is located all over the territory of Romania and includes both territories inside and outside of the protected areas. The project aims to identify, analyze and promote ecological corridors nationwide. Development of methodologies to establish the ecological corridors, including the designation criteria for them, identification of critical areas and the training of specialists for better management and monitoring of them will be part of the project. The COREHABS project will provide effective mechanisms for identifying, evaluating, monitoring and management of the connecting elements (corridors, areas of passage, etc.) enabling the development of a coherent network of the protected areas.

http://www.corehabs.ro/en/

ECONNECT

Project Restoring the web of life (ECONNECT) was striving towards an ecological continuum across the Alps. Therefore, besides protected areas as core zones, it focused on linking these areas in order to achieve connectivity between alpine ecosystems. To achieve an ecological continuum across the Alps, the ECONNECT project considered not just the purely naturalistic aspects (such as, for example, sustainable land use) but also the economic and social dimensions which are just as important in promoting ecological networks. The main objective was the protection of biodiversity in the Alps through an integrated and multidisciplinary approach aimed at encouraging the promotion of an ecological continuum across the Alpine region. Particular attention was given to the regions high in biodiversity value to establish and increase the links between them and towards other neighboring ecoregions (e.g. the Mediterranean or Carpathian regions).
http://www.econnectproject.eu/cms/?q=homepage/en

AKK - THE ALPINE-CARPATHIAN CORRIDOR

The aim of the AKK projects was to safeguard the ecological connectivity between the Alps and the Carpathians within the CENTROPE region. The projects strengthened conservation management for the protected areas along the Alpine-Carpathian Corridor and neighboring habitats. The strategy was to secure migration and genetic exchange among wildlife populations through the construction of eco-ducts (green bridges) over motorways in Austria and Slovakia and through the creation of suitable habitat patches or stepping-stones for migrating animals and through increased public awareness.

https://ec.europa.eu/regional_policy/en/projects/austria/innovative-alps-carpathians-corridor-re-establishes-a-major-migration-route-for-wild-animals

http://www.alpenkarpatenkorridor.at

JECAMI

JECAMI is a framework – Joint Ecological Connectivity Analysis and Mapping Initiative. JECAMI is a web application based on Google Maps API, built by the Swiss National Park to help users analyze the connectivity and barriers of the landscape and to assess an area based on very specific criteria. The application was initially built using version two of Google Maps API in 2010, and rebuilt using Google Maps API v3 in 2014. JECAMI incorporates a set of methodological ecological connectivity approaches. The tool is enriched with exhaustive documentation on data and methodology, as well as geoprocessing tools, which allow the user to analyze certain areas in detail or calculate a path of an animal through its habitat. In order to stimulate discussion on structural and functional connectivity, JECAMI allows for a comparison of the two approaches, the so-called "Continuum Suitability Index" (CSI) and Species Map application (SMA), respectively. In certain regions, the potential of the application for aquatic and semi-aquatic species (Connectivity Analysis of Riverine Landscape – CARL) was tested. The CSI was built for two spatial scales: a general approach with consistent but coarse data over the entire Alps and a more spatially and thematically detailed approach within several sub-regions.
https://www.jecami.eu
https://www.alpine-space.eu/projects/alpbionet2030/en/home

Complex Approach to the Protection of Fauna of Terrestrial Ecosystems from Landscape Fragmentation in the Czech Republic

The primary objective of the project was to prepare a draft of comprehensive methodology for the protection of landscape connectivity for the key relevant groups of terrestrial animals. The outcomes are conceived in such a manner so as to allow their practical application in urban planning, especially as underlying analytical documents for urban planning. This objective, when reached, should have a major effect on the protection of biological diversity in the Czech Republic.

The public awareness part of this project aimed at contributing to the protection of connectivity in the landscape, both by informing the general public about this issue and by improvement in the decision-making processes thanks to the presentation and providing access to the resulting methodological materials to professionals and state administration.

http://www.ochranaprirody.cz/en/eea-grants/eea-40-fragmentation-of-the-landscape/

Territorial System of Ecological Stability (TSES) in Slovakia

The landscape planning approaches in Slovakia have begun in 1980s with introduction of the LANDEP (Landscape Ecological Planning) methodology, representing an integrated approach for optimizing the landscape structure and composition aiming for balance between socio-economic activities and natural conditions, thus ensuring sustainable use of natural resources. Currently, elaboration of TSES documentation is part of the territorial planning process in Slovakia and the outputs represent legally binding documents. As defined in the Act Nr. 543/2002 on Nature and Landscape Protection: The Territorial System of Ecological Stability is such a spatial structure of interconnected ecosystems, their constituents and elements, which provides the diversity of conditions and forms of life in the landscape. This system consists of biocenters, biocorridors and interacting elements of supra-regional, regional or local importance.

http://www.sazp.sk/zivotne-prostredie/starostlivost-o-krajinu/zelena-infrastruktura/uzemny-system-ekologickej-stability-uses.html

Territorial System of Ecological Stability (TSES) of the Czech Republic

Territorial System of Ecological Stability has a long history in the Czech Republic. In 1992, TSES was included into Act No. 114/1992 on the Protection of Nature and the Landscape, and became one of the main pillars of general protection. The Act on the Protection of Nature and the Landscape defines TSES as a mutually integrated complex of natural and altered, although nearly natural, ecosystems, which maintain a natural stability. In addition, the issue has also been included into the country's spatial planning legislation, i.e. the Building Act. From a point of view of spatial planning, the TSES is one of the natural limits of land use within the particular territory, which has to be identified and taken into account during the spatial planning procedure. Therefore, the TSES acquires a general obligatory character within the process of approving land-planning documentation. In practice, the ecological network should also be considered when elaborating proposals for comprehensive land consolidation/re-plotting and Forest Management Plan.

https://www.mzp.cz/cz/uzemni_system_ekologicke_stability

Ecological network Hungary NÖSZTÉR project

As an implementation of the EU Biodiversity Strategy 2020 the NÖSZTÉR project (KEHOP-4.3.0-15-2016-00001) aims to map the entire Green Infrastructure and its elements of Hungary. In EU Biodiversity Strategy 2020 green infrastructure is defined as a strategically planned network of natural and semi-natural areas with environmental features that are designed or managed to deliver a wide range of ecosystem services. This project is intended to improve and strengthen information about GI, and comes in response to the need to "review the extent and quality of the technical and spatial data available for decision-makers in relation to GI deployment" identified in the Commission Communication on GI, Green Infrastructure (GI) Strategy (COM(2013)249). It also delivers on the requirements of the EU Biodiversity Strategy to 2020, which calls for the strategic deployment of GI supported by a robust evidence base developed through the MAES process1 on the mapping and assessment of ecosystems and their services.

http://www.termeszetvedelem.hu/kehop-430-15-2016-00001

HARMON: Harmonization of Green and Grey Infrastructure in Danube Region.

The aim of the project was to contribute to securing and fostering ecological connectivity by ensuring the ecological requirements/sufficiency of areas of high biodiversity value while developing linear transportation infrastructures in the Danube Region. Project aimed to contribute to achieve the TEN-G (Trans-European Network for Green Infrastructure) goal.

Main deliverable of the project was the document: Moţ, R., Georgiadis, L., Ciubuc, F., Grillmayer, R., Kutal, M., Gileva, E., Voumvoulaki, N., Hahn, E., Sjölund, A., Stoian, R.; 2019. *State of Play Report on Harmonization of Green & Grey Infrastructure in Austria, Bulgaria, Czech Republic and Romania.*

http://www.interreg-danube.eu/Seed Money Facility project: HARMON

Ecological Connectivity in the Danube Region.

Danube Transnational Programme, Danube Region Strategy

The main output of the project is the study "Ecological Connectivity in the Danube Region"

The objective of this study is to implement the EU strategy on Green Infrastructure within the area of the EUDSR and thus to support the objective of a Transnational Network of Green Infrastructures (TEN-G). Within this study, the status of green infrastructures and ecological connectivity in the Danube River Basis was analyzed, mainly the spheres of connectivity at land, water and air. The study provides a sound foundation how the GI-strategy of the EU can be practically implemented in the Danube River Basin. In a subsequent step, this shall serve as a basis for the elaboration of concrete project proposals for further implementation. Key elements of the study include: delineation of the project area (Danube Corridor, linkages to the Alps and Carpathians); overview on the status quo regarding projects and national objectives in the individual states in the Danube River Basin; overview on cooperation between the countries; overview on basic information available on Green Infrastructures in the respective countries; thematic and spatial gap analysis; proposal of measures and projects to improve, restore or maintain ecological connectivity in the Danube River Basin; definition of starting points for concrete measures and projects; overview on similar experiences of other macro-regions to be transferred to the Danube River Basin; outline of potential contributions of the EUSDR and PA06 to the implementation of the EU Green Infrastructure Strategy (Huber, 2018).

https://nature.danube-region.eu/the-study-ecological-connectivity-in-the-danube-region/

The Guidance on Safeguarding ecological corridors in the context of ecological networks for conservation"

The IUCN/Connectivity Conservation Specialist Group initiated to develop "The Guidance on Safeguarding ecological corridors in the context of ecological networks for conservation" which was in open global consultation phase until 30th of September 2019.

The guidance has been drafted to help guide the global shift in conservation practice from that of individual protected area conservation to that of large landscape in context of jurisdiction, terminology, to provide clarity about the purpose of ecological networks for conservation and to define the physical spaces that function to connect protected and conserved areas. The Guidance will help the planning, decision-making, managing of conservation of ecological networks.

The ConnectGREEN project will follow the process of finalization of this document and reflect it appropriately.

https://www.iucn.org/sites/dev/files/content/documents/2019_6-28_consultation_draft_safeguardingecologicalcorridorsinthecontext_.pdf

SD 03 Connectivity and Fragmentation

© Mircea Verghelet/PCNP

Ecological connectivity and fragmentation, ecological networks and corridors

Ecological connectivity is the degree to which the landscape facilitates or impedes daily and seasonal wildlife's movements along resource patches and wider ranges. Landscape is the setting for all human and wildlife activities, providing the basis of human welfare and the resources necessary for the other life forms. As humans need to move freely to assure continuation of their activities, also wildlife needs connected landscape structures for continuous exchange of genetic resources, for getting food, or for other specific seasonal needs in their year life cycle. In recent decades, humans have often shaped and profoundly altered landscapes with little thought given to the cumulative impacts and at a pace that is unprecedented. Decision making on transport infrastructure, spatial planning and urban development has not taken the value of landscape much in consideration. Biodiversity and landscape quality are often marginalized. The fast modernization of the Carpathian countries with urgent demand of extended transport networks and crucial changes on land use may increase the risk of landscape fragmentation, limiting dispersal and the genetic exchange of wildlife species. These artificial and often insurmountable barriers along traditional dispersal paths also raise the risk of collisions with vehicles. Ecological connectivity between large natural and protected areas is essential for species, which require large habitats, have low densities of occurrence and react sensitively to landscape fragmentation. Wildlife corridors can provide a solution to fragmentation, since they are "landscape elements which serve as a linkage between historically connected habitat areas". Ecological connectivity is not only fostering the welfare of wildlife populations, but also represents an indispensable value for human society and the economy, as it plays a central role in ecosystem functioning (Köck et al. 2014) and the cohesion of the protected areas' networks.

Connectivity

The connectivity is the degree to which the structure of a landscape helps or impedes the movement of wildlife (Taylor et al. 1993). Connectivity is a parameter of landscape function, which measures the processes by which sub-populations of the particular species are interconnected into a functional demographic unit. A landscape is well connected when organisms or natural ecological/evolutionary processes can readily move among habitat patches over a long time. Thus, connectivity refers to the ease with which organisms move between particular landscape elements and features, within the landscape. It depends on several attributes of the species, as well as the interaction between the species and the landscape especially on the connectivity resistance in and out of the natural patches.

There are several concepts of connectivity. Commonly used in conservation science are four major types of connectivity (Worboys et al. 2010):

- Habitat connectivity – connecting patches of suitable habitat for a particular species or species group,
- Landscape connectivity – connecting patterns of vegetation cover in a landscape,
- Ecological connectivity – connecting ecological processes across landscapes at varying scales,
- Evolutionary process connectivity – maintaining the natural evolutionary processes including the evolutionary diversification, natural selection and genetic differentiation operating at larger scale.

Ecological connectivity can be regarded from a structural or a functional perspective. Structural connectivity describes the shape, size and location of features in the landscape (Brooks 2003). Functional connectivity entails the extent to which a species or population can move among landscape elements in a mosaic of habitat types (Hilty et al. 2006). Structural connectivity integrates better with spatial planning, as selected features in the landscape can be incorporated in a land use system, while interrelations between habitats are vastly more difficult to define and delineate. For this reason, structural connectivity should be the first consideration in spatial planning processes. Nonetheless, functional connectivity has to be considered, when specific requirements of important species (isolation or dissection of relevant habitats) are concerned, and landscape dynamics are changing the mosaic of habitats.

Fragmentation

Functional and interconnected ecosystems enable the development and maintenance of functions that positively affect biodiversity. The economic development however deteriorates originally well-connected habitats and has several ecological effects on nature, among the most important are loss of wildlife habitat, fragmentation (barrier effect), fauna traffic mortality, noise and light disturbance etc. (Hlaváč et al. 2019).

Habitat loss mostly caused by the growing needs of humans is the greatest threat to the biodiversity. Even relatively small habitat loss may have a fatal impact on the survival of some species as the connected barrier effects (fragmentation) comes into force.

Mortality of fauna caused by the collisions between the animals and vehicles represents also a very significant negative effect to biodiversity caused by the economic development. Direct mortality depends on several factors, such as the roads density. The number of animals killed on roads and rails is reaching values so high that it is endangering the survival of local populations or even of some sensitive species in particular parts of Europe. The safety of the traffic for humans as well as material damages also play an important role in searching for long-term and efficient solutions.

Fragmentation is a dynamic process, generally human-induced, that divides a natural environment into more or less disconnected fragments, thus reducing its original surface area. It also affects the physiology, the behavior and the movement patterns of many plant and animal species (Debinski and Holt 2000). It is a process linked to progressive environmental change (land use, intensive agriculture, urbanization, territorial infrastructure) and weakens the maintenance of viable populations and the persistence of communities, habitats, ecosystems and ecological processes. Being unable to move between patches renders species vulnerable to local and regional extinction.

The impacts of environment fragmentation are demonstrated with a delay – when the problems are dealt with in time they begin to be apparent, it is usually too late. The landscape is already irreversibly altered and corrective measures are either financially particularly demanding or totally impossible.

Fragmentation of originally coherent and continuous areas into isolated islands can have fatal consequences for population survival in long-term perspective. Fragmentation of land mostly impacts the species which are inhabiting protected natural areas, have considerable requirements on size of home ranges / habitats and the biology of which requires regular or occasional long-distance migration. In Carpathian conditions three species belong under these characteristics – wolf, lynx and bear. In an intensively used land by humans, the most efficient method of avoiding fragmentation of populations is defining a sufficiently dense network of wildlife/migration corridors which interconnect individual sites of species occurrence. These corridors are then necessary to be implemented into master plans in order to ensure their protection from being further built-up.

Towards understanding fragmentation as most crucial primary effect on nature by linear infrastructure, the following concept tools (described in Table SD03.1) have to be used as a requirement for securing ecological connectivity:

1. Genetic isolation as the main problem;
2. Habitat fragmentation and land degradation as the main cause;
3. Ecological and landscape connectivity as the main aim;
4. Green and Grey Infrastructure as the main crossing point and conflict areas;
5. Sustainability as the main objective; and,
6. Avoidance and Mitigation as the main solution (*the mitigation hierarchy includes avoidance – mitigation – compensation as the basic three options, but, especially when avoidance is selected to avoid the intersect an important/protected area by an TLI, then mitigation (and compensation where is necessary) is the next choice to support the cohesion of their area with other important/protected areas as network under the "threat" of the fragmentation of this TLI can cause*.)

These concepts are actually the objectives of the development of a transportation project towards minimizing the impact on ecosystems and landscape's cohesion.

Table SD03.1: Basic concepts for ecological connectivity

	Ecological connectivity concepts	Logical framework concepts	Description
1	***Genetic isolation, wildlife mortality and loss of bio-engineering functions***	***Main problems***	The main environmental problems related with the development of TLI are the genetic isolation, wildlife mortality and the loss of bio-engineering and ecosystem functions which can cause significant changes in habitats that makes it impossible that the original community of species can persist.
2	***Habitat fragmentation***	***Main cause of the problems***	The lack of genetic exchange is caused by the habitat fragmentation on both terrestrial and aquatic ecosystems.
3	***Securing the ecological connectivity***	***Main aim***	The main aim is to secure the ecological connectivity in important natural areas, as species' basic habitats or ecological corridors when they are intersected by TLI.
4	***Sustainability***	***Main objective***	Sustainability and quality has to be achieved in three different perspectives: Social, Environmental and Economic.
5	***Green and Grey infrastructure***	***Main crossing point and conflict areas***	Adopting the concepts of Green Infrastructures, the Natural Capital and the Ecosystem Services and identifying the main "crossing points" that Grey (technical/linear/transportation) infrastructures cross through Green Infrastructures/natural areas as conflict points is necessary.

Ecological network

An ecological network is a representation of the biotic interactions in an ecosystem, in which species (nodes) are connected by pairwise interactions.

The ecological network is a system of areas model that has been developed over the past years with the broad aim of maintaining the integrity of environmental processes. Based on this, the landscape should be zoned in such a way that intensively used areas are balanced by natural zones that function as a coherent, self-regulating units. The approaches that are usually classified as ecological networks share two generic goals, namely (1) maintaining the functioning of ecosystems as a means of facilitating the conservation of species and habitats, and (2) promoting the sustainable use of natural resources in order to reduce the impacts of human activities on biodiversity and/or to increase the biodiversity value of managed landscapes. In achieving these goals, a number of elements can be discerned which together characterize all ecological networks. These are: (a) a focus on conserving biodiversity at the landscape, ecosystem or regional scale; (b) an emphasis on maintaining or strengthening ecological coherence, primarily through providing for connectivity; (c) ensuring that critical areas are buffered from the effects of potentially damaging external activities; (d) restoring degraded ecosystems where appropriate; (e) promoting the sustainable use of natural resources in areas of importance to biodiversity conservation. These functions are reflected in ecological networks as a coherent system of areal components:

- **core areas**, where the conservation of biodiversity takes primary importance, even if the area is not legally protected,
- **corridors** (incl. stepping stones), which serve to maintain vital ecological or environmental connections by maintaining physical linkages between the core areas (CBD 2006).

It is well established that ecological connectivity cannot be limited only to protected areas but should be constructed via natural and semi-natural habitats and landscape structures to create an ecological continuum outside of the protected areas. This interconnection of habitats is of particular relevance for migrating and large home range species.

It is worth considering connectivity on a larger scale, but it is fundamental to act at local scale, because the loss of local connectivity has also consequences at regional and international scales. Ecological connectivity follows the phrase "Think globally, act locally" (Geddes 1915).

Core areas

Core areas represent areas fulfilling the habitat and size criteria for sustainable occurrence of target species with sufficient food supply, shelters and breeding conditions (Romportl et al. 2017).

Migration

Animals need to relocate due to three different reasons:

a) Daily movement for securing search for food, shelter, and breeding partners. For this, they must find movement paths in order to connect suitable habitats' patches for food or shelter in their particular home ranges. Daily movement paths sustain normal life of wildlife and are often of shorter distances.

b) Migration as a specially defined movement pattern resulting in at least two different home ranges which are not overlapping. Reasons for migration are various, either animals are overcoming lack of food by migrating to a different place, or they try to find better breeding places for their offspring, or the dispersion of younglings is pushed away from their original home ranges.

c) Also adult animals frequently migrate out of their home ranges for no obvious reasons. The causations of these migrations are not always well known.

What we know for sure is that the migration of these species in land is a precondition of their long-term survival. Thanks to these movements the populations can compensate for local losses, find and settle new habitats and adjust to changing conditions of the environment. Immigration and emigration additionally ensure necessary exchange of genes among individual sub-populations which helps sustaining genetic variability and good condition of populations.

Corridors

Terms

Due to the different reasons and character of the locomotion of animals as well as different perspective of sectoral approaches, there are plenty of terms used for corridors slightly differing in their meaning such as conservation corridors, dispersal corridors, ecological corridors, movement corridors, landscape corridors, migration corridors, linkages etc.

For example:

- the Central American Commission for Environment and Development defines a biological corridor as geographically defined area which provides connectivity between landscapes, ecosystems and habitats, natural or modified, and ensures the maintenance of biodiversity and ecological and evolutionary processes.
- Eionet defines corridor as a narrow, linear (or near-linear) piece of habitat that connects two larger patches of habitat that are surrounded by a non-habitat matrix, thereby facilitating movements of animals and dispersal of plants and other organisms.
- Corridors — in the sense of functional linkages between sites — are essentially devices to maintain or restore a degree of coherence in fragmented ecosystems (CBD 2006).

The terminology used in context of connectivity and in particular corridors, differs slightly from country to country. The terminology used in national languages may differ from the terminology used on regional (Carpathian) or global level. The terminology used at national level is bound to legislation and there is no justification to interfere and change.

Nevertheless, in context of this Methodology it has been shown, that there is a need for unification of English terminology on the regional Carpathian level, taking into consideration both international standards and Carpathian practice.

On the one side, the terms used in context with corridors on the global level are movement and migration corridors, whereby the term migration is usually connected to the large-scale migration (Worboys et al. 2015).

On the other side, in the Carpathian region there have been several projects implemented in the last decade that anchored certain type of terminology in terms on connectivity topic.

Within projects TRANSGREEN and ConnectGREEN was adopted definition of ecological corridors as landscape structures of various size, shape and vegetation cover that mutually interconnect core areas and allow migration of species between them. They are defined to maintain, establish or enhance ecological connectivity in human-influenced landscapes.

- Wildlife corridors - allow the movement of a wide range of organisms between high natural value areas
- Migration corridors - allow animal movement (both regular and irregular) between areas of their permanent distribution (core areas)

- Movement corridors - allow animal movement within core areas (including daily movements in search of food, etc.).

Function of corridors

Wildlife/migration corridors are an important component of functional ecological networks. Corridors are connecting primary wildlife habitats and improve the functional connectivity of habitats. These keep landscape permeable for animal movements and reduce its resistance. Wildlife/migration corridors are used for different purposes, in different patterns, and at different scales, depending on the species. One way to identify a corridor is by the species-specific needs and the movement function they provide.

In principle, linking isolated patches of habitat can help increase the viability of local species populations in several ways:

• by allowing individual animals access to a larger area of habitat — for example, to forage, to facilitate the dispersal of juveniles or to encourage the recolonization of “empty” habitat patches

• by facilitating seasonal migration

• by permitting genetic exchange with other local populations of the same species (although this generally requires only very occasional contact)

• by offering opportunities for individuals to move away from a habitat that is degrading or from an area that is under threat (which may become increasingly important if climate change proves to have a serious impact on ecosystems)

• by securing the integrity of physical environmental processes that are vital to the requirements of certain species (such as periodic flooding) (CBD 2006).

In an optimal or primary habitat, wildlife can move freely without overcoming obstacles. However, various obstacles can hinder wildlife movements including natural barriers like rivers, steep slopes, canyons or other non-suitable topography. In a human-dominated landscape, anthropogenic structures including settlements, railroad, and especially road infrastructure can seriously impede wildlife movement. We can even find many examples where wildlife movement is already not possible, often also in combination with natural barriers. Functional corridors have a low level of fragmentation whereas the least functional corridors are characterized by high fragmentation and little movement.

In suitable habitats, wildlife can move unhindered and does not necessarily use wildlife /migration corridors. In fragmented landscapes however, wildlife movement is often limited by human infrastructure. Therefore, it is very important to identify wildlife/migration corridors in order to implement mitigation measures which keep them functional.

Securing function of corridors is crucial in transport project implementation when implementing the mitigation hierarchy avoidance is the priority when roads and railways are planned to intersect protected areas. This choice demands to implement the choice of mitigation for the final alignment towards securing the ecological connectivity outside of the protected areas and the functionality of the wildlife corridors between them.

Defining corridors

Corridors vary enormously in scale: from a tunnel to allow amphibians to pass under a road to intercontinental flyways for migrating birds. They also take many different forms. In general, three broad kinds of landscape corridor can be distinguished:

- a linear corridor (such as a hedgerow, forest strip or river)
- “stepping stones”, that is, an array of small patches of habitat that individuals use during movement for shelter, feeding and resting
- various forms of interlinked landscape matrices that allow individuals to survive during movement between habitat patches (Bennett and Mulongoy 2006).

Traditionally the corridors have been viewed as linear strips sheltered by a buffer zone. In last years however, an approach of connected spatial structures of biotopes has become justified for the group of large carnivores which is more close to the sense of linkage areas wider perspective.

SD 04 Target species

In most mammal populations, under normal conditions, there is always a part of the population that does not maintain permanent home ranges and moves over large distances. These are frequently adolescent individuals pushed away from their home areas; in other cases, older full-grown individuals migrate. For many species, the motivation and principles of this migration have not been entirely clarified as yet; however, it is certain that these migrations are crucial for the survival and wellbeing of the population. Migrations from prosperous parts of the population make it possible to permanently populate less suitable habitats, where an isolated population would become extinct within a short time. Migration makes it possible to compensate for fluctuations in numbers caused by a temporary worsening of habitat, epidemics, natural disasters, etc. On the other hand, migration makes it possible to discover new habitats and areas that are temporarily suitable. Immigration and emigration within an existing habitat also provides the necessary genetic exchange to ensure that the variability of the genetic pool is maintained.

The target species for the ConnectGreen project are the 3 large carnivores, the Brown Bear (*Ursus arctos*), the Wolf (*Canis lupus*) and the Lynx (*Lynx lynx*). The target species occur strictly in forested mountain or foothill areas. Their spatial demand on home range size is large and comprises usually hundreds of square kilometers. Their core, relatively continuous population inhabits the northern, eastern and southern Europe (Scandinavia, the Carpathians and Dinaric mountains), but the population density is low due to territorial aggression. Sub-adult individuals during their dispersal behavior are forced to seek available niche for reproduction and they have to migrate considerable distances, often across national borders. Long-term survival of these populations is considerably threatened by other factors such as poaching and many populations would probably disappear without strengthening through the process of natural immigration of new individuals (or even by reintroduction interventions). Small populations are generally more prone to disturbances such as the emergence of new barriers, habitat loss and change, increase in poaching, etc.

Brown bear (*Ursus arctos* Linnaeus, 1758; order Carnivora; family Ursidae) is the most widespread bear in the world, with a Holarctic distribution in Europe, Asia, and North America, ranging from northern arctic tundra to dry desert habitats.	
Occurrence and dispersal	The Carpathians host the second largest population of brown bear in Europe, about 8,000 bears in Slovakia, Poland, Ukraine and Romania. Bears are important management indicators (umbrella species) for a number of other wildlife species (Linnel at al. 2007).
Reproduction and social behaviour	The breeding season is between May and August and give birth of 2-3 cubs (350-400 gr each) during winter sleep every 2 years. The dominant male is able to migrate through home ranges of several females to breed. The cubs stay with mother usually two or three years. After bears reach the sexual maturity (3 years), they start to explore suitable territory overcoming longer distances, mainly during the breeding period. They sign the large territory by urine (effluvium signs) and by bark exfoliating (visual sings). Bears belong among long-lived species, they live over 30 years (Nowak 1999).
Food	Bears are typical omnivores. The main part of their diet composes of roots, leaves, buds, seeds and forest fruits (like berries, plums, cherries, wild pears

	etc.), and also insects like ants, honey from the bee nests. The food composition varies by the season and natural food supply in the environment.
Role in ecosystems	As the brown bear consumes a large variety of fruits and seeds contributes to disperse of plant species while as is also consumer of carcasses prevents spread of various diseases and therefore fulfils a sanitary function in the ecosystem.
Habitat preference	The bear occupies various ecosystems – tundra, alpine meadows and continuous forests. In the Carpathians, the bear prefers habitats of mountain coniferous and mixed forests, primeval forests with dense undergrowth, requires undisturbed habitat with several refugees/shelters possibilities. In last decades in Slovakia the bears penetrate the lower altitudes of the beech and oak forests with sufficient food supply during the season (Find'o et al. 2007). The selection of the suitable breeding environment depends on the food availability, remoteness and certain impenetrability of the area with minimum anthropogenic disturbance. Several studies and habitat models show that the bear prefers remote, steep, forested and scrub habitats with higher altitude and low amount of infrastructure. The less suitable habitats are pastures and agriculture land, however they are used for food supply at nights. This different preference between isolated and quite places for day sleeping and foraging areas demands local movements in a daily base and crossing the ecotone zone between forested and agricultural ecosystems. This daily movements' needs determine the status of possibilities to cross artificial barriers as roads especially when they are constructed on the zone of ecotones which is usual practice in ranges with extensive valleys as in Carpathians. The home ranges may vary significantly (50 – 500 km^2) and depend e.g. on the density of the population, anthropogenic limitations (roads)…
Migration	Migration behavior of the bear varies depending on geographical areas and even the individuals have different migration behavior patterns. Despite the bear is bound to the undisturbed forest habitat, during the migration it is also tolerant to the open areas with an ability to overcome anthropogenic barriers (roads, fences). There are seasonal migrations - bears following an abundant food resource, or to denning sites, female with cubs exploring adjacent territories not overlapping with dominant males and dispersals of juveniles. The migration distance depends on habitats, sex and the age of individuals. The bear is able to overcome tens of kilometers during few days and occupy a large area during the migration.
Main threats	Brown bears have a low reproductive rate and are very vulnerable to human-caused mortality, to habitat changes and to landscape fragmentation. Motorways represent the most relevant barriers to the bear. Although being road-killed it does not pose a threat for conserving this species, the planning of motorways in the Carpathians should consider the large habitat requirement of the Carpathian brown bear. Additional identified threats, such as poaching and decrease of suitable habitat due to the expansion of human society, may increase the risk of conflicts with this species and have to be investigated locally. As for the wolf and the lynx, a Carpathians-wide management plan would be needed.

The grey wolf (*Canis lupus* Linnaeus, 1758; order Carnivora; family Canidae) is the second largest predator in Europe, after the brown bear, with a Holarctic distribution in Europe, Asia, and North America. In the 60-ties and 70-ties of last century the grey wolf population decreased significantly in Europe, however nowadays the population is stabilized.	
Occurrence and dispersal	In the Carpathian countries, the wolf population represents around 30% of the total European population and it is mainly distributed in Romania, Ukraine, Poland and Slovakia. The Carpathian population of grey wolf counts more than 5000 individuals (Linnell et al. 2007).
Reproduction and social behaviour	The grey wolf belongs to canine and lives with a social family life in a pack all year round. The dominant leading pair – alpha male and female have usually a privilege right for reproduction. The oestrous of the wolf female lasts 5-7 days a year, in the spring between January and March. The female grey wolf breeds 1-11 cubs at a well-hidden place. The pack is composed mainly from subadults that contribute to common feeding and protection of the wolf puppies. The position within the pack is hierarchized and the hierarchy relations may change several times during the year. The most of aggressive conflicts within the pack take place in the breeding season while splitting packs is usual determining the need of dispersal behavior of new shaped packs in other territories and home ranges. The size of the pack in the Carpathians is usually 4-5 members (Nowak et al. 2008). The pack inhabits a large territory which it actively defends from other packs and marks the area with urine and droppings. The grey wolf lives in the wild for 10 years. The sexual maturity occurs at age of two years and at this stage they start to leave the family territory and migrate to new territories rich in food and habitat quality.
Food	The wolf is a true generalist that feeds opportunistically on what is the most available in its habitat and is very adaptive with regards to the food scale. In the Carpathians the grey wolf preys mainly on ungulates, occasionally also smaller vertebrates or carcasses, sometimes it also feeds on plants.
Role in ecosystems	The grey wolf is the apex predator naturally focusing on weak, old or sick individuals. It is the natural regulator of the ungulates status in the forest environment and contributes to its regeneration while as the bear consuming carcasses has a sanitary role in the ecosystems
Habitat preference	The last genetic studies distinguish (in Central Europe) a so called „lowland" population of the wolf in Poland and Germany and northern Czech Republic, and the „Carpathian" population with preference on the mountain areas. In general, the wolf is adaptable with preference of areas with low settlement density, with low level of the land use and with good food supply. These requirements are fulfilled by mountain and hill country areas with high forest coverage as well as areas of current and former military training areas. The requirements on environment differ considerably during the breeding season and the migration period. During the breeding season the wolf prefers habitats with high forest cover rate (up to 70%), food availability and water access. Due to the adaptation ability, wolves can inhabit also areas with lower forest coverage rate with sufficient wetlands, meadows and pastures. During the breeding season the wolves are very sensitive to anthropogenic factors. The range of territories depends on the habitat type, season, food availability

	and the number of individuals in the pack; it may vary between 70 – 200 km^2 (Anděl et al. 2015).
Migration	In contrary to breeding season when the tolerance to human factors is critical for wolves, during the migration wolves increase the tolerance against the barriers and are able to overcome the roads, non-forest areas even close to the human settlements, however mainly during the night or in the early morning. When leaving the pack, wolves overcome much longer distance as common movement, whereby the males and females dispose with equal potential for long-distance migration. There are however many differences between populations and individuals in ability to overcome the migration barriers in terms of habitat quality, food availability. During the migration the wolf is able to move across tens or even hundreds of kilometers (e. g. a distance 200 km during 2 months).
Main threats	All Carpathian countries have signed the Bern Convention, but effective legislation for the protection of wolf has been adapted to local situations. The species is strictly protected only in some countries (e.g., Poland), where compensation for the damage they cause is offered by conservation agencies, whereas in others (e.g., Ukraine) it is still considered a pest and bounties are paid for its removal. The main threats are then found at local/national level. Poaching and human encroachment are the most significant threats to the wolf's habitat and survival. Competition with hunters is often a reason for eliminating wolves. Wolves usually tolerate disturbance by roads and tourism as long as they have safe retreat areas to escape human pressure as they are vulnerable in drastic habitat changes and to landscape fragmentation. Although wolves may survive in the most diverse types of habitat, vegetation cover and availability of some food resources are at least two limiting environmental factors.

The Eurasian lynx (*Lynx lynx* Linnaeus, 1758; order Carnivora; family Felidae) is the largest felid found in Europe. In 19th and first half of the 20th century, the Eurasian lynx disappeared at local level almost in the whole Western and Eastern Europe, only in the Carpathians a relatively dense population survived. After successful reintroduction throughout Europe, the Eurasian lynx lives now also in France, Switzerland, Slovenia, Germany, Austria.	
Occurrence and dispersal	Lynx prefers large mountain forests; nowadays it penetrates also forest areas of the hill landscape. During migration the requirements on forest decrease substantially, however even though it is still highly bound to the areas with high forest coverage
Reproduction and social behaviour	Lynx is a solitary, territorial species with a large home range ca 150 – 250 km^2, males even larger (Hlaváč and Anděl, 2001). Males and females live most part of the year separately, they meet in the short breeding period (January-March). Outside the breeding season males and females strictly defend the territory against the individuals of the same sex, with minor exceptions mainly with regards to males. The territory of the male covers several female ranges. The estrus of the lynx female lasts 1-3 days and the ovulation is induced only after several matings with the male. The Eurasian lynx gives birth to 2-3 cubs, with a high rate of cubs' mortality (50 %). Young lynx leave mother at age of 8-10 months, males reach sexual maturity at 33 months, female at 21 months.
Food	The lynx feeds mainly on ungulates. The main prey is represented by the roe deer, the red deer, the European hare and the wild boar, sometimes small vertebrates, fox, cats and birds.
Role in ecosystems	The Eurasian lynx is the apex predator and is the natural regulator of the Cervidae status in the forest environment and contributes to the balance in terms of the forest regeneration.
Habitat preference	The Eurasian lynx is strictly bound to the large forest areas in mountain and sub-mountain areas. The remote places with a rugged terrain with supply of refugees serve as the resting areas. The areas with a close ground suitable for stalking the prey are selected by the lynx as hunting areas. The preferred habitat consists of mixed forests between 700 and 1500 m a. s. l. with home ranges between 100 and 3000 km^2. Lynx inhabits also lowland areas – as long as there is a big and relatively old forest complex present
Migration	In the spring the young individuals leave the mother's territory family range and may migrate long distance to search the suitable territory. The migration distance differs by individuals, however the males may have to migrate longer distances to find unoccupied territories by a dominant male while female juveniles are tolerated in the adjacent areas by their mother, females prefer to stay in close vicinity of the mother. During the migration the requirements on the quality of the forest habitat decrease, however still the high forest coverage is essential (at most within the three target species).
Main threats	The main threats to the Eurasian lynx are poaching, habitat loss and fragmentation. Although the population has benefitted from the ban on legal international fur trade, poaching still represents a major threat as lynx is considered a competitor of hunters for roe deer. Habitat loss, fragmentation and lack of prey species are also significant threat to the Eurasian lynx

Large carnivores (bear, wolf, lynx) - National status of protection	
Czech Republic	○ Red list of Vertebrates of the Czech Republic, ○ Specially protected species and critically endangered according to the Act No. 114/1992 Coll. on Nature and Landscape Protection and related Decree No. 395/1992 Coll. ○ Act No. 449/2001 Coll. on game management, the species is understood as game that may not be hunted
Hungary	○ Highly protected by Protecting act: 13/2001. (V.9.) KöM directive about disclosure of protected and highly protected plant and animal species, highly protected caves, and protected plant and animal species important for the European Union
Poland	○ The Act on the Protection of Nature, 16 April 2004. ○ The Act on the Protection of Animals, 21 August 1997
Romania	○ Government Emergency Ordinance no. 57/2007 on the regime of natural protected areas, conservation of natural habitats, wild flora and fauna approved with amendments and completions by Law no. 49/2011 with subsequent amendments and completions. ○ Law no. 407/2006 on hunting and protection of the hunting fund, with the subsequent modifications and completions
Serbia	○ Law on nature protection ("Official Gazette of the Republic of Serbia", No. 36/09, 88/2010, 91/2010 and 14/2016 and 95/2018 – other law). ○ Law on breeder and hunting ("Official Gazette of the Republic of Serbia", No. 18/2010 and 95/2018 - other law). ○ Regulation for promotion and protection of strictly protected and protected species of plants, animals and mushrooms ("Official Gazette of RS", No. 5/2010, 47/2011, 32/2016 and 98/2016). ○ Law on the confirmation of the Convention on the conservation of migratory species of wild animals ("Official Gazette of the Republic of Serbia", No. 102/2007).
Slovakia	○ Strictly protected species according to the Act No. 543/2002 Coll. on Nature and Landscape Protection. Hunting of bears is possible only on the basis of the exception of the Ministry of the Environment of the SR according to the § 40 regarding with § 35 of the Act No. 543/2002 Coll. on Nature and Landscape Protection. Hunting of wolves the wolf is strictly protected during all the year only in territories mentioned in the Decree. In the remaining territory of the Slovak Republic, it is forbidden to catch, injure, kill the animal and destroy its habitats especially burrows with cubs in the period from 16th of January till 31st October of the calendar year
Ukraine	○ Law of Ukraine on Natural Protected Areas of Ukraine, 16 June 1992 The law defines categories and regime of natural protected areas in Ukraine, management of protected areas, order of establishment of new protected areas, protection measures, types of violation of law on protected areas. ○ Law of Ukraine on Ecological Network of Ukraine, 24 June 2004 The law includes terminology related to ecological network, principles of its formation, protection and use, elements of ecological network, management, funding, monitoring and control

	○ Law of Ukraine on Red Book of Ukraine, 07 February 2002 The law establishes regime of protection of rare and endangered species of fauna and flora in Ukraine, proprietary rights, management bodies, categories of species and order of identification and approval of species peculiarities of use of flora and fauna subject to the Red Book of Ukraine

Large carnivores (bear, wolf, lynx) - International status of protection
○ IUCN – LC (least concern) with a stable population trend ○ Habitat and Species Directive 92/43/EEC – Annex II and IV ○ CITES – Annex II ○ Bern Convention – Annex II (Strictly protected species) ○ European Action Plans for species

SD 05 Barriers

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1. Main types of barriers

Migration barriers are generally referred to as natural and anthropogenic structures in the landscape which impede the free movement of animals (Anděl et al. 2010). Migration barriers can be classified in respect to the different factors such as barrier strength, duration of barrier effect and the type of the barrier.

Barrier strength is defined as its resistance, whereas permeability represents the contrary quality. As to its strength, a barrier may range from entirely impermeable to minimally resistant. Entirely impermeable barriers are fundamental as they can discontinue the whole wildlife/migration corridor.

The duration of the barrier effect, i.e. permanent or temporary, plays a decisive role as to the risk it poses. Permanent barriers, such as settlements or transport infrastructure, represent the most severe threat. They alter the environment for the period of 50–100 years and, from our point of view, may be perceived as definite. By contrast, certain fences constitute a temporary obstacle and still can be managed consequently. Thus when environmental impacts are in assessment process it’s crucial to be take in to account if they have fragmentation effects in irreversible perspectives.

In this paper we deal with the barriers resulting from the human activities. For mammals and particularly our target species, these are the crucial barriers:

- Linear infrastructure (roads, highways, railways)
- Settlements/Built-up areas
- Fences (e.g. permanent mesh/wooden pasture fencing, game enclosure)
- Unsuitable biotopes (treeless areas, agricultural land, rivers and water areas, etc.)

Permeability of the barriers for particular species depends on many factors. The most important factors are: barrier resistance, durability of the presence of the barrier, type of the barrier/object and of course the overall situation, i.e. the setting up of the barrier in the landscape as well as the cumulative effects of other surrounding barriers (Anděl et al. 2010).

Linear transport/Roads, railways

This category of barriers includes transport roads higher and lower classes (including different purpose roads such as touristic/cycling roads) and railways. These linear barriers intersect the landscape and in basics have two negative impacts to the animal populations: direct mortality and barrier effect due to restricted migration caused by the fragmentation of the populations in irreversible perspectives especially in cases of fenced motorways and railways.

The mortality results from the attempts of animals to cross the roads and the mortality rate depends on the type of the road and the transport intensity in combination with the status and distribution of local wildlife population. In general, despite the lower intensity of the transport on the roads of lower class, the total mortality is higher on the roads of lower class given by a higher total number of kilometers of this road category and due to the higher number of attempts to cross these not-totally-fenced roads. In contrary, the relative mortality related to a unit (e.g. 1 km of the road) is highest on the highways because of a high intensity of the transport (Anděl and Hlaváč, 2008).

Barrier effect is more obvious in fenced highways or in highways and roads of higher class. On the other hand unfenced lower class roads with high volume of traffic have the operate as “alive” vehicle fence, thus have a stronger barrier effect because in some sections they are almost non permeable for fauna species.

Other negative impacts on the populations of large carnivores caused by transport infrastructure are noise disturbance, light disturbance and visual contact which increase the overall cumulative impacts on barrier effect. These factors may play an important role while using the so called wildlife crossing objects. Negative impacts of habitat loss and degradation during construction are connected with the planning of new communications, renovation and widening of the existing ones. Due to the minor area of affected biotopes its importance is not very significant (in comparison with other mentioned impacts), however there is still land take with direct and indirect impacts like draining the construction site, changing water regime, etc.

Settlements

This category of barriers includes human settlements and continuously built-up areas as well as various industrial, agricultural, mining, storehouse, commercial estates including touristic infrastructure. The type of settlements has different impact on the fragmentation and reduction of large carnivore’s habitats as the landscapes are modified differently from the different anthropic activities (agriculture/mining/tourism etc.).   Their negative impact is accentuated by their irreversible character. As soon as such objects exist it is hard to find any practical measure which could make the barrier permeable for fauna (Anděl et al. 2010). As far as migration of the large carnivores is taken into consideration, the most serious problems are continuously built-up areas along rivers and scattered settlements at foothills that are connected to further barrier elements such as fences and agriculture buildings (Anděl et al. 2010).

Fences

This category includes game enclosures and various fenced areas – mostly orchards, vineyards, crops and pastures (as we separated the fences of motorways and high-speed railways). Fences create surface barriers with very variable area. The type and technical design of fences varies and influences the conditions for permeability of the landscape for animals. Barrier effect of specific types of fences depends on many factors, mainly on the size and design, materials used and placement in the landscape. The barrier effect varies for different animal species (even among the species group it can be very individual and variable). In general, large carnivores have better ability to overcome barriers in the form of various fences than the ungulates, which in case of electric fence barrier often suffer a conditional psychological block that prevents them to overcome the barrier. Another important factor is the durability (permanency) of installed fence. Fences installed on pastures are usually removed or at least switched off after the grazing period. Fences represent only a potentially temporary barrier. This is certain advantage in comparison to some other barrier types as the fences represent a relatively easily removable barrier with low cost of the removal (Anděl et al. 2010). In case of fences, the measures for the permeability of the landscape can be considered.

Water courses and other water bodies

Water bodies facilitate the migration of species in the landscape and create one of the most important structures in the ecological network in the landscape. Watercourses and water bodies are category of barriers between the linear and spatial category. There are two main factors which influence the permeability of the water courses and water bodies for large carnivores – the width and the technical solution. Thus despite the fact that large carnivores can swim a water body can be a barrier for them. This type of barriers is mainly considered for the cumulative barrier effect. On the other hand in case of rivers with their riverbanks' vegetation they function as wildlife/migration corridor along its length.

Unsuitable biotopes

This category includes larger areas of biotopes, that are not suitable with respect to ecological requirements of the target species and therefore animals avoid them. This secondarily induces creation of further territorial barriers for migration or spreading out of the target species. With regards to the species connected to the forest biotopes, the unsuitable biotopes patches represent treeless areas, mainly intensive agricultural land (aggregated field missing trees or scattered green spots). Permeability of different habitat patches can influence the total functional connectivity of wildlife/migration corridors. Establishing effective and science-based methodologies for measuring habitat and landscape fragmentation is essential towards recognize the scale of the problem of reducing ecological connectivity globally in realistic base and promote effective solutions in practice (*Spanowicz & Jaeger 2019*). Large carnivores differ in their ability to overcome this type of the barrier, for some of them (e.g. wolf or some ungulates) this type of the barrier does not represent a significant obstacle. This type of barriers is mainly considered for the cumulative barrier effect.

2. Assessment of barriers

Practical assessment of barriers should take into consideration the two basic principles i.e. **individual assessment** of each barrier and consideration of **the cumulative effect** of barriers when a complex of more than a barrier exists or is under planning.

2.1. Individual assessment of barriers

The practical significance of each barrier for migration varies. The risk it poses depends upon the species of interest, location, technical solutions, wildlife/migration corridor, other concurrent environmental and landscape qualities, etc. The importance of the barrier is not only the question of its dimensions. An otherwise functional wildlife/migration corridor may be completely discontinued by a wall surrounding a plot or by a single family house. These types of barriers represent rather simple spots in the landscape and cannot be assessed merely based on analysis of maps. Each barrier in a wildlife/migration corridor has to be addressed individually in the field, directly on the location and its effect has to be evaluated in an overall cumulative impact in the case of multiple barriers existed. General maps of migration barriers are more of an indication importance and allow determination of potentially threatened locations.

The evaluation of the permeability of selected type of barriers for the target species remains complicated; however a set of supportive matrix was elaborated to help the mappers in defining the critical points (including the ranking). The classification defines a rank of five classes of permeability for each type of the barrier:

1. **C1 - critical impermeability,**
2. **C2 - middle impermeability,**
3. **C3 - low impermeability**
4. **P - means permeable,**
5. **PF - fully permeable.**

This critical rate of the barriers (C/P) is given by the technical parameters and also by combination of partial barriers that separately would not present a significant threat for the connectivity. Each crossing of the biotope with the barrier is evaluated individually based on the specific data for the particular locality as well as for the individual species. Categorization of barriers in the matrix serves as a supportive tool for mappers. For determination of critical points, the functional continuation of the biotope network is important. Therefore some spots may appear as not a very significant barrier. However the future loss of a wildlife/migration corridor would endanger the functionality of the whole biotope. As mentioned above the following landscape structures are considered as significant migration barriers: highways and roads, railways, waterways, water courses, artificial channels and natural or artificial water reservoirs, non-forest areas, settlements and fences.

Highways and roads

The linear transport infrastructure is the most significant migration barrier on wildlife/migratin corridors, in particular highways and road network. This barrier effect is determined by a combination of following three factors: (i) the existed and future road routes, (ii) technical solutions of the construction, and (iii) traffic flow parameters.

In principle, the routing of the road is essential for the impact on the environment. In future/on plan roads an avoid fragmentation approach has to be adopted while in existed roads a defragmentation approach has to be implemented to recover the ecological permeability of the wildlife/migration corridors. In case of pairing or parallel development of existed and a new roads a cumulative impacts has to be considered taking the appropriate mitigation measures. The assessment of the barrier effect itself focuses on technical solution and traffic flow (with a retrospective evaluation of the route) on locations where roads cross the Habitat suitability patches (core areas and stepping stones – see chapter 6).

Technical solutions are assessed within a field survey on site. Traffic flow data can be obtained from transport authorities.

Matrix 1 - Classification of roads and motorways by their permeability for large mammals.

Class	**Specification**	**Technical solution/Status of permeability**	**Traffic flow/daily average**
C1	Motorways and expressways	Insurmountable physical obstacles (steep slopes and cuts, noise barriers, abutment, stone walls, etc.) lacking any wildlife passing objects	Over 30.000 vehicle per day
C2	Other multi-lane roads	Significant technical obstacles, high banks and cuts which may be partly surmountable	10.000 – 30.000 vehicles per day
C3	Other first class roads	Roads with surmountable physical obstacles (central or side guardrails)	5.000 – 10.000 vehicles per day
P	Local roads	No technical barriers	Under 5.000 vehicles per day
PF	No roads		

Source: Protection of landscape connectivity for large mammals (Anděl et al. 2010)

Highways, expressways and other roads (mostly multi-laned) characterized by the multi-laned traffic with high intensity and accompanying technical measures (fences, noise walls, etc.) are considered as important obstacles. Sometimes also a road with a single stripe but with high traffic intensity is considered as significant barrier. Other categories of roads (other first class roads, local roads) are considered as cumulative barriers. It is also important to consider the rhythm of the traffic during the day or during the weekend, in some time sections of the day the permeability might be better and in some locations the traffic on the weekends can decrease significantly, thus the average data still can be reviewed in more detail.

It is important to focus on structural barriers represented by all linear features (as these are not identifiable from satellite imagery and not related with type/class of feature) - even local roads with low traffic would represent significant barriers due to structural details of the construction.

Solutions for this type of barriers are bridges or tunnel constructions for terrain irregularities or building of the wildlife passing object (underpass, overpass) (Matrix 1).

Remark: In case that the corridors on roads and highways are covered with functional migration objects, the crossing is not evaluated as critical point. In such case the corridor is evaluated as permeable for a group/s of species, depending on object’s characteristics.

Railways

Similarly as roads, the railways represent a significant migration barrier. The barrier effect is determined by a combination of the following three factors: (i) selected route of the future railway, (ii) technical solutions to the construction, and (iii) traffic parameters.

The route of the future railway is essential for the future impact on the environment. The assessment itself focuses on the technical solution and category of railway on locations where railways cross the Habitat suitability patches (core areas and stepping stones – see chapter 5).

Technical solution is assessed within a field survey on site. Categories of railways can be obtained from the relevant Railways company/authority.

Matrix 2 - Classification of railways by their permeability for large mammals

Class	Railway category	Technical solution
C1	High speed rail	Railways lined with steep slopes and cuts, other technical obstacles; physically insurmountable
C2	Transit corridors, backbone network	Railways with significant physical obstacles, which may be partly surmountable
C3	Transit corridors, complementary network	Railways with minor modifications of terrain
P	Other railways	Railways at the level of the surrounding terrain, no obstacles
PF	No railways	

Source: Protection of landscape connectivity for large mammals (Anděl et al. 2010)

Railways acting as primary migration barrier are relatively rare in the project area. It concerns railways with accompanying technical elements (abutment wall, steep embankments, etc.). Traffic intensity on rails in the Carpathians is not so high in comparison to the Western Europe yet, however there are several areas, where the rails contribute significantly to the barrier effect. This type of barriers in the Carpathians represents a potential migration threat in the landscape (e.g. transport corridors of the European importance such as Prague – Pardubice – Brno – Vienna), especially if constructing fenced high-speed rails in near future (e.g. at Hungary – Slovak borders with impact on the project pilot area Cerová vrchovina – Bükk Mts., or the high-speed railway connecting Bratislava and Žilina in Slovakia).

Water courses and other water bodies

Water courses and other water bodies may become a barrier for migrating target species in two aspects – the size of the water body and the technical solution. Despite the fact that the selected target species are relatively good swimmers, the unsuitable technical solutions (mainly concerning banks) represent a crucial barrier effect.

The assessment focuses on both aspects – size expressed by the width and technical solution on locations where water courses cross the Habitat suitability patches (core areas and stepping stones – see chapter 5).

Technical solution is assessed within a field survey on site.

Matrix 3 - Classification of watercourses and other water bodies by their permeability for large mammals

Class	Size of water body	Technical solution on banks structure/ Technical parameters of the banks
C1	Width more than 500 m	Watercourses with modified banks that entirely inhibit access
C2	Width 200 - 500 m	Watercourses with significant technical obstacles that may be partly surmountable
C3	Width 100 - 200 m	Watercourses and reservoirs with minor modifications of banks
P	Width less than 100 m	Watercourses and reservoirs with natural banks
PF	No water bodies	

Source: Protection of landscape connectivity for large mammals (Anděl et al. 2010)

Water objects represent transition between the group of linear and wide area barriers. Inappropriate artificial modifications of river banks (stones, supporting walls) as well as the width of the water surface typically for the water reservoirs are considered as barriers. Water courses and water areas except large water reservoirs are mainly part of cumulative barrier in the landscape.

Fences

Since fences vary enormously in types and applications, they are hard to classify. They encompass game enclosures, vineyards, pastures, and a number of other areas. A fence is a barrier that, in some pasture areas, may reach a considerable size. In addition, its type and location may be altered each year. Despite the Methodology issues, the measures focusing on the protection of the landscape connectivity should take this type of barriers into consideration, particularly at the level of spatial planning of individual municipalities.

Classification of the landscape permeability is generally a complex task and always requires field surveys. The following two aspects are considered: (i) permeable distance between two fenced areas, (ii) technical parameters of the fence.

Matrix 4 - Classification of fences by their permeability for large mammals.

Class	Distance between fenced areas	Technical parameters of the fence
C1	Continuous fences without interruption	Stable, tall fencing (over 2 m); wire, concrete, sheet metal; insurmountable for migrating animals
C2	Less than 30 m	Stable, hardly surmountable electric fencing
C3	30 – 100 m	Stable, non-electric fencing difficult to surmount
P	More than 100 m	Surmountable fencing (e.g., wooden fence) and temporary fencing
PF	No fence	No fence

Source: Protection of landscape connectivity for large mammals (Anděl et al. 2010, EVERNIA s.r.o. 2010)

Fences have similar barrier effect as settlements. For example fenced hunting areas, munition stocks and similar zones with high fence are considered as impermeable barrier. The pastures fences, however, can be in certain cases highly permeable and even dismantled in the non-use period. The use of the electric fences depends on the character of the land and connecting type of the use of the land and therefore it may vary within the Carpathians. The barrier problem represents fenced pastures combined with the scattered settlements when the fence hinders the migration between scattered settlements. The quantification of the barrier effect in this case is quite difficult (Matrix 6). A fence is mostly considered as cumulative barrier.

Non-forest areas

Non forest areas constitute the most significant groups of barrier habitats, because large carnivores tend to instinctively avoid open spaces. The classification is based on assessment of the non-forest landscape lacking tree species and a landscape with dispersed vegetation.

Matrix 5 - Classification of non-forest areas by their permeability for large mammals.

Class	Landscape lacking tree species	Landscape with dispersed vegetation
C1	Over 5 km	Over 10 km
C2	2 – 5 km	5 – 10 km
C3	0.5 – 2 km	2 – 5 km
P	Under 0.5 km	Under 2 km
PF	Forest	Forest

Source: Protection of landscape connectivity for large mammals (Anděl et al. 2010)

Non-forest areas are considered a part of the cumulative barrier effect. Non-forest areas represent unsuitable conditions for the target species, which prefer continuous tree vegetation. The non-forest area that is several kilometers long and composes of an intensively managed arable land is considered as separate (individual) migration barrier. The fewer natural elements (tree or shrub vegetation) occur in the landscape, the more is the non-forest area considered as the barrier. In addition, if the non-forest area is supplemented by further migration barriers (such as roads, rails, rivers), the size of non-forest area considered as permeable land for target species is decreasing. Non-forest areas create one of the several cumulative barriers at many critical points, often accompanied by the roads of lower category, rail or water course.

Settlements/Built-up areas

Urban built-up areas are generally considered as critical impermeable barrier. The level of permeability depends on the character of the built-up area, its extent, the density and the distribution of individual objects. Specifically unfavorable in terms of fauna migration in the Carpathian conditions is the urban sprawl in the valleys and scattered character of settlements at foothills.

The urban areas are generally classified by C1 – critically impermeable. The classification used in this Methodology aims at areas between settlements, i.e. the extent of free zones permitting migration. Spaces between settlement complexes and among isolated structures scattered in the landscape influence the class of the permeability. In specific cases also the length of the passage must be taken into account.

Matrix 6 - Classification of settlements by their permeability for large mammals

Class	Free distance between villages, towns	Free space between scattered structures
C1	Continuous built-up area, less than 50 m	Scattered structures, less than 10 m
C2	50 – 100 m	10 – 30 m
C3	100 – 500 m	30 – 100 m
P	More than 500 m	More than 100 m
PF	No settlement	No settlement

Source: Protection of landscape connectivity for large mammals (Anděl et al. 2010, EVERNIA s.r.o. 2010)

Settlements (living areas, commercial and industrial zones, etc.) represent an impermeable anthropogenic barrier. The only way to overcome this barrier is to pass it in a sufficient distance. Unfortunately the density of settlements is so high at many critical points that the passing is not possible. Some areas in the Carpathians are characteristic by the scattered settlements, where the barrier does not present a compact built-up area but a scattered hillfoot settlement. Many studies however showed/proved that large carnivores are quite tolerant during migration season. The threshold values for barrier effects are shown in the Matrix 6. The similar problem as settlements is represented by potential development areas, which is to be considered as future impermeable barrier.

2.2 The cumulative effect of barriers

Individual barriers may have a cumulative effect. High density of even partially permeable barriers can result in an overall impermeability of the landscape. The proposal of wildlife/migration corridors has to consider this fact. For this reason, migration barriers are being incorporated in the modelling of habitat suitability (see Chapter 5).

The individually assessed barrier effects should be viewed and interpreted in a cumulative scope. A landscape composed of a dense network of migration barriers becomes poorly permeable even when individual barriers do not represent a significant limiting factor. The cumulative effect of barriers should be assessed at both local and national level.

At the local level – the field survey and verification of permeability of the wildlife/migration corridor on the given location should seek to assess the potential cumulative effect of all existing barriers. Most frequently, these include a combination of two road classes (e.g., a motorway and its supporting side road), roads and railways, a settlement and a road, a watercourse with managed banks and a parallel road, etc. Vast non-forest areas largely increment the cumulative effect of barriers. The final level of barrier accumulation and the permeability of the site have to be evaluated by experts within a field survey directly on site.

At the national level – based on the structure of settlements, the density of settlement and road network, and the distribution of non-forest areas, areas that pose more potential threat as a whole should be identified. With the support of habitat modeling, core areas and critical points at national level can be illustrated in maps providing an overview on land fragmentation/connectivity on national and supranational levels.

The categorization of barriers described in subchapter above in a matrix system helps to identify the critical points and is useful for mappers working in the field. The final decision on barrier identification is recorded in the attribute matrix of the layer. The classic binary code evaluation is usual:

- 1 – barrier (class C1, C2, C3)
- 0 – without barrier (class P, PF) (Matrix 7)

The attribute matrix consists of 7 columns representing partial migration barriers. Below is brief description of barriers concerned:

- HIGHWAYS – highway, high-speed roads and multilane roads
- ROADS – other roads
- RAILS – all categories, barriers represent mainly technical measures (high embankments, abutment walls etc.)
- BUILT-UP AREAS – built-up (settlements, scattered settlements, industrial and agriculture zones)
- POTENTIALLY BUILT-UP AREAS (settlements, scattered settlements, industrial and agriculture zones)
- PERMANENT FENCE – fenced areas, fenced road, pastures, fenced game preserves, vineyards and orchards
- TEMPORARY FENCE – fenced areas, fenced road, pastures, fenced game preserves, vineyards and orchards
- WATER AREAS – wide water area, impropriate modified banks of water flows
- NON-FOREST AREAS – unsuitable biotope, intensively used agricultural land

ID of the critical point	Highways	Roads	Rails	Built up areas	Potentially built-up areas	Permanent fence	Temporary fence	Water areas	Non-forest areas
3	0	1	0	1		0		0	0
4	0	1	0	0		0		0	0
5	0	1	0	1		0		0	0
6	0	1	0	1		0		0	1
7	0	1	1	1		0		1	0

Matrix 7 - Records on permeability of barriers in the attribute table of the final layer

Source: Methodology for Protection of landscape from fragmentation according to the forest ecosystems (Anděl et al. 2017)

The permeability of a barrier is influenced/determined not only by the possibility of crossing. To the barrier effect many other disturbing anthropogenic processes contribute (light, noise and smell from the traffic, human activities in vicinity of settlements, etc.) with very difficult quantification of their influence. So far it was not proved to what extent the particular stress factors influence the migration of species. It is assumed that the resistance of migrators is a reaction on the overall effect of migration barriers. Note that species ethology and behavioral ecology may play an important role here as well - a crossing point within the territory of a wolf pack will be intensively marked and therefore may be avoided by dispersing non-resident individuals.

SD 06 Measures for securing the connectivity

CBD voluntary guidance on the integration of protected areas and other effective area-based conservation measures into wider land- and seascapes suggested *inter alia* to prioritize and implement measures to decrease habitat fragmentation within landscapes and seascapes and to increase connectivity, including the creation of new protected areas and the identification of other effective area-based conservation measures, as well as indigenous and community conserved areas, that can serve as stepping stones between habitats, the creation of conservation corridors to connect key habitats, the creation of buffer zones to mitigate the impacts of various sectors, to enhance the protected and conserved areas estate, and the promotion of sectoral practices that reduce and mitigate their impacts on biodiversity, such as organic agriculture and long-rotation forestry as well as to mainstream biodiversity in sectors as infrastructure, energy and mining (CBD COP14 2018, Decisions 14/8 and 14/3).

Different types of barriers may represent different degree of permeability for different species. The barrier which is impermeable for the brown bear may be at certain conditions permeable for example for the Eurasian lynx. In general, on the one hand, water courses and water objects as well as non-forest areas can be at certain conditions considered as permeable barrier, on the other hand the built-up areas usually represent impermeable barrier. For this, in this chapter we will not focus on measures for these types of barrier. For our target species we will discuss mainly measures related to the linear transport infrastructure as main cause of irreversible impacts on ecological connectivity.

The main risk of linear transport infrastructure is mainly fragmentation of populations of large carnivores and direct mortality of animals. Measures mitigating fragmentation however are often contraindicative for measures preventing mortality (e.g. fences). It is therefore necessary to combine the measures (e.g. fences) with sufficient number of overpasses or other mitigation objects for supporting wildlife permeability of transport infrastructure.

The topic of this supporting document is the description of individual technical measures designed to mitigate the negative effects of transport infrastructure, decrease risk of collisions between vehicles and animals and also to lower disturbing effects of traffic on fauna.

Large carnivores occur in large areas in low human population densities. They are mostly rare and protected, and fragmentation of their environment can cause their extinction in vast areas. Long migrations and movements in distances of hundreds of kilometers are typical for this group. At the same time these animals are sensitive to disturbances and have the highest requirements for parameters of fauna passages. It is always necessary to deal with several specific issues when ensuring permeability of transport infrastructure for these species. It is first of all determining density of passages which will be sufficient for long term survival of the species. This issue is often questioned for the effectivity of the wildlife passages. With small population abundances the frequency of using the passages is often low, which tempts to consider such constructions as useless. This opinion is also supported by the fact that fauna passages for this group of animals are extremely financially demanding. Also the parameters of passages, especially of special overpasses (ecoducts) are often subject of discussions. Recommendations vary in different areas, which can be partly caused by specific environmental conditions and different behaviour of animals in these areas. Another important factor that has to be taken into account in case of large mammals is traffic safety, since collisions with these animals are very dangerous for vehicle occupants.

Measures to reduce barrier effect and animal mortality are divided into two main groups:

A. Measures allowing and facilitating safe crossing of infrastructure (wildlife passages)
B. Measures preventing traffic-kills and human casualties:
    1. measures preventing animals to enter infrastructure
    2. measures for warning animals of transport infrastructure or of approaching vehicles
    3. measures for warning drivers about approaching animals or about accident risk sectors (warning signs, speed limitation, warning systems based on animal detection)

A. Measures allowing safe crossing of infrastructure (fauna passages)

Wildlife overpasses/ landscape bridges

Overpasses are bridges where animal migration takes place above the level of traffic. Many overpasses are used on road constructions to convey other communications (roads, railways, field and forest paths), but their usability for animal migration is limited without other adjustments.

Wildlife overpasses and landscape bridges are purpose-built bridges, usually built over a road with several lanes and/or high-density and fast-driving traffic, over high-speed railway lines or over a combination of both. They are a costly but effective means for minimizing, at least locally, the fragmentation effect of transport infrastructure for all terrestrial groups of animals.

Main goal of all types of overpasses is to mediate the migration of the broadest possible spectrum of species. The aim of the landscape bridges should be to connect habitats at an ecosystem level. This requires the simulation of the habitats on either side of the infrastructure on the overpass, taking into account vegetation and environmental factors such as soil type, humidity, temperature and light. This means, for example, that the connection between forests requires at least elements of similar forest habitat on the overpass. Wildlife overpasses of course also attempt to mimic the surrounding habitats as much as possible. However, taking into account smaller parameters of such overpasses, this simulation might be more difficult.

Modified bridges – multifunctional overpasses

There are numerous bridges for local roads, forestry or agricultural use. They are usually covered with concrete, asphalt or tarmac and are hardly used by animals. By simple addition of an earth-covered strip an improvement can be achieved. Such earth-covered or vegetated strips are used by invertebrates, small vertebrates, carnivores and occasionally by ungulates. They favour the dispersal of animals. Overpasses adjusted in this way can significantly contribute to reducing barrier effect.

This measure has so far been overlooked, although it is not very costly and is of real importance especially in flat agricultural landscape with lack of natural possibilities for animal migration.

Viaducts and river crossing

These are large bridges overcoming wide valleys or watercourses. Basic characteristics of such objects are: above-standard dimensions regarding animal migration, natural surface under the bridge, enough light for vegetation and possibility to suitably integrate the object into its surroundings. Thanks to these parameters, they allow the connection of entire ecosystems and are therefore suitable for migration of all species groups, from invertebrates to large mammals.

Underpasses

These are bridges either constructed for the migration of medium-sized and large mammals or constructed for the topographic reasons. They interconnect traditional migration routes of animals determined in migration studies. They are suitable especially in mountain areas, in places of crossings with watercourses or where the road is led in an embankment. There is usually not enough light and water in these objects for vegetation to grow, which is for some groups of species a limiting factor (mostly invertebrates). Shorter height may be less suitable for birds or bats. The geometry of underpasses and details of the size of the three dimensions is crucial for their effectiveness on their permeability status for several species expressed of the indication of Openness Index (**O. I.** = **W**idth * **H**igh / **L**ength). The larger the OI the more effective the underpasses on wildlife permeability.

Adoption of the bridge objects in the phase of project/construction documentation development can lead to construction of fauna passages that fulfill criteria also for more demanding fauna species (large carnivores).

Modified and multifunctional underpasses

There is commonly a large number of bridges on communications leading over field and forest paths, watercourses or railways and other roads. Often even simple and financially not very demanding optimization of these objects is of an essential importance in reducing barrier effect of roads. The basis lies in keeping a strip with natural surface for migration.

B.1 Measures preventing animals to enter infrastructure

Fences

Fencing limits the entry of animals to a road, it is currently the main measure used to reduce animal mortality on roads/railways. At the same time, fencing guides animals to wildlife passages. It constitutes the basic measure in places with high traffic mortality - that is on express roads, motorways, railways. On the other hand, in case of lower category roads, fencing is recommended only in critical places with high risk of collisions between vehicles and animals. Fencing increases barrier effect of the road and therefore it is always necessary to combine it with fauna passages.

Functional fencing cannot be overcome by animals and has to meet the following basic requirements:

- Sufficient height with over hung on the top when necessary (e.g. for bears) – animals

must not jump over the fence
- Suitable size of mesh – animals must not crawl through the mesh of the fence
- Suitable anchoring or continuation in horizontal level – animals must not crawl or dig under the fence
- Suitable termination – it should be designed in a way that prevents animals from going around the fence and getting on the road; fences should therefore be terminated for example by bridges or by the built-up area
- Intact construction – animals must not crawl through gaps or damaged parts of the fence
- Placement on both sides of a road – animals that get from one side onto the communication and cannot leave it on the other side have to go back, which significantly increases the risk of collisions with vehicles
- Escape possibility for confused individuals (escape ramps or on-way escape gates)

With regard to functionality, especially (i) placement of fencing, (ii) construction and (iii) maintenance parameters are important.

Noise walls

Noise barriers are constructed close to human settlements to reduce noise emissions, although in certain situations they are erected to protect, for example, colonies of breeding birds from disturbance. However, even if not constructed for wildlife they have to be treated in this chapter because they can increase habitat fragmentation even more than fences. In densely built-up areas noise barriers do not usually provide any problems in this respect. In more natural surroundings they are complete barriers for all terrestrial animals.

Non-transparent screens

Noise barriers built of concrete, wood or other material are complete barriers for animals. In natural environments they must therefore be combined with fauna passages. This has to be considered also in cases of low noise screens along railway lines, which may hinder the movement of small vertebrates like snakes, which without barriers would not have been greatly affected by the railway line. In combination with passages noise screens can function as guiding structures. Noise screens are usually built on a solid concrete base. They thus completely isolate the road verges from the surrounding habitats. For small animals, especially invertebrates, they are therefore a more complete barrier than fences. No experience exists as to the effects on the animal populations or regarding possible solutions to reduce the barrier effects, such as small openings at the base of the structures.

Transparent screens

Transparent screens are erected in areas where planners wish the drivers or passengers to be able to see the surrounding landscape. They entail a high risk of mostly fatal collisions for birds, which don't recognize the wall as an obstacle, in particular where natural vegetation can be seen through the glass or where the glass reflects bushes or trees. It has been shown that with appropriate markings the number of collisions can be reduced substantially.

Design

- Vertical markings are recommended, although other types may also be effective.

- Marking strips should be 2 cm wide with a distance between the strips of a maximum of 10 cm (or 1 cm wide, distance 5 cm).
- Light colours are preferable to dark ones, because they are more visible in the twilight.
- Markings should be applied on the outer side of the wall (i.e. away from road) to avoid reflection.
- Silhouettes of birds of prey are not recommended. They are only effective to prevent collisions if put up at a very high density.
- No reflective material or glass should be used.

Points for special attention

- Wherever possible, transparent screens should not be built. Non-transparent walls can be covered with bushes or climbing plants.
- No trees or bushes should be planted in the vicinity of transparent noise barriers because this increases the risk of collisions. Where trees or bushes are planted as mitigation measures, no transparent noise barriers should be built (Clevenger and Huijser 2011).

B.2 Measures warning animals of transport infrastructure or of approaching vehicles

Artificial deterrents

Artificial deterrents aim at keeping mammals away from roads or railway lines. This group of measures includes ones that modify the behaviour of animals so that they are able to register coming vehicle or train soon enough. These measures are mainly targeted at deer. Various systems exist based on optical, acoustic or olfactory devices. Experience shows that the effectiveness of such measures is usually very limited.

i) Sight – visual deterrents: lights, lasers, reflectors, mirrors (they reflect lights of vehicles into the surrounding landscape, which discourages animals from entering the road in front of the passing vehicle).

ii) Hearing – acoustic deterrents: devices with recordings of disturbing noises activated before passing of a train, etc.

iii) Smell – olfactory deterrents: take advantage of the fact that animals naturally avoid places with olfactory traces of predators or humans. (Hlaváč et al. 2018).

B.3 Measures warning drivers about approaching animals or about accident risk sectors

Warning signs and warning systems with sensors

Warning signs aim at influencing the behaviour of drivers in order to reduce the number and severity of collisions between large mammals and cars. Standard traffic signals are placed in areas where collisions often occur. They also exist for amphibians, waterbirds and other animals. However, research has shown that drivers do not pay much attention to signals on their own and in particular do not reduce their speed. Therefore systems have been developed to increase their effectiveness.

- Wildlife warning signs should be placed only in places where there is a high risk of collisions, because the more widespread they are, the less people pay attention to them.
- Putting up signs only during critical seasons could make people more attentive to them.

Wildlife warning systems combined with heat sensors have shown to be able to reduce the number of collisions. Heat sensors in the vicinity of the roads detect approaching mammals up to a distance of 250 m. The sensors trigger the fibre optic wildlife warning signs which are combined with speed reduction signs (30-40 km). Normally the signs appear dark and the light points are only visible when activated. The system can be powered by solar energy. Wildlife warning signs without speed reduction are less effective.

Increasing visibility

Different ways of designing and managing habitats alongside roads and railway lines are used with the aim of reducing the number of collisions. Some are designed to prevent animals from moving onto the road surface by attracting animals elsewhere, others by influencing the behaviour of animals or by making animals more visible.

This includes first of all cutting down trees and bushes in immediate surroundings of the communication, so that drivers can register approaching animals sooner. Moreover, removing vegetation reduces the attractiveness of the road surroundings for animals. This requirement is part of regulations on vegetation adjustments in case of motorways - grassy belt is usually left on the sides. Roads of lower categories are more problematic, since vegetation often reaches all the way to the road.

Another measure is road lighting. It makes visibility better for drivers and animals can avoid these areas thanks to it. However, lighting has negative effects on other species such as insect and bats, therefore this measure cannot be in general recommended.

SD 07 Monitoring of the connectivity measures

In this Supporting document we will focus on monitoring of the measures discussed in the Supporting document 06 – Connectivity measures. The monitoring of connectivity measures can be in principle divided in two categories: (i) monitoring of the behaviour of animals for the identification of the future mitigation measures – what measure at what place, etc. (incl. monitoring of mortality), and (ii) monitoring of the efficiency of already implemented mitigation measures.

Monitoring methods described below represent a list of possible methods and is not exhaustive. The selection of proper methods is always influenced by many factors such as the target species, season, local conditions, etc.

As already mentioned in the Introduction of this project the ConnectGREEN project is a complementary project to the TRANSGREEN project. Within the TRANSGREEN project was developed a Guideline "Wildlife and Traffic in the Carpathians Guidelines how to minimize the impact of transport infrastructure development on nature in the Carpathian countries. The Guideline consists of a separate chapter dealing on the monitoring methods with respect to different fauna species. As for the ConnectGREEN project, the target species are large carnivores, in this part of supporting documentation we focus on subject of evaluation and common methods of monitoring related to the animal group "large carnivores"

The subject of evaluation create:

- Identification and use of wildlife/migration corridors
- Mortality caused by traffic
- Effect of fragmentation on populations (monitoring genetic variability)
- Use of the environment in wider surroundings of construction (telemetry)
- Effectiveness of fauna passages

The common methods of evaluation are:

- Tracking on snow and mud
- Phototraps and cameras
- Direct observation (bear – long-term network of observation places in the autumn)
- Telemetry
- Genetic analyses – it is possible to determine individuals and their relations or population abundance from found excrements
- Mortality on roads

GLOSSARY

Barrier effect - Combination of different factors (technical structures and their parameters, disturbances, fauna mortality) that together decrease the probability and success rate of crossing linear infrastructure by wildlife.

Biodiversity/Biological diversity - The richness among living organisms including terrestrial, marine and freshwater ecosystems and the ecological complexes of which they are a part. It includes diversity within and between species and within and between ecosystems as well the processes linking ecosystems and species.

Biotope - The area inhabited by a distinct community of plants and animals. Biotope is commonly used among central European ecologists to describe distinct land units and vegetation patches identified from an anthropocentric perspective. Biotope is often confused with and exchanged by the term habitat.

Buffer zone - Peripheral areas intended to enhance protection of sensitive habitats, e.g. protected sites, from negative impacts of infrastructure such as pollution or disturbance.

Connectivity - The state of structural landscape features being connected, enabling access between places via a continuous route of passage. The physical connections between landscape elements.

Connectivity Conservation Area - A recognized large and/or significant spatially defined geographical space of one or more tenures that is actively and equitably governed and managed to ensure that viable populations of species are able to survive, evolve, move and interconnect within and between systems of protected areas and other effective area based conservation areas.

Core areas - Areas meeting the habitat and size requirements of target species for their sustainable permanent occurrence and providing them with sufficient food supply, shelters, breeding and dispersal conditions.

Corridor - Tract of land or water connecting two or more areas of habitats that aid animal movement across the landscape. See also 'Wildlife corridor'.

Ecological connectivity - The binding or interconnection of eco-landscape elements (semi-natural, natural habitats or buffer zones) and biological corridors between them from the point of view of an individual, a species, a population or an association of these entities, for whole or part of their developmental stage, at a given time or for a period given to improve the accessibility of the fields and resources for fauna and flora.

Ecological/wildlife corridor Landscape structures of various size, shape and vegetation cover that mutually interconnect core areas and allows migration of species between them. They are defined to maintain, establish or enhance ecological connectivity in human-influenced landscapes.

- Wildlife corridors - allow the movement of a wide range of organisms between high natural value areas

- Migration corridors – allow animal movement (both regular and irregular) between areas of their permanent distribution (core areas)
- Movement corridors – allow animal movement within core areas (including daily movements in search of food, etc.).

Ecological network - Coherent system of natural and/or semi-natural landscape elements configured and managed with the objective of maintaining or restoring ecological functions as a means to conserve biodiversity while also providing appropriate opportunities for the sustainable use of natural resources (Bennett 2006). Ecological network consists of core areas, corridors and buffer zones.

Fragmentation (of landscape, habitats, populations) **-** Process, in which continuous landscape is further divided into smaller and smaller units that are mutually isolated, or reduced in area. Such units then gradually lose their potential for fulfilling their original functions. Transformation of large habitat patches into smaller, more isolated fragments of habitat. (https://www.eea.europa.eu/publications/landscape-fragmentation-in-europe). Such units then gradually lose potential for fulfilling their original functions.

Green Infrastructure - A strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and to protect biodiversity in both rural and urban settings.

Habitat - The type of site (vegetation, soils, etc.) consisting of biotopes, where an organism or population naturally occurs - including a mosaic of components required for the survival of a species. Assemblage of all biotic and abiotic factors that create the environment of a specific species, population, community.

Habitat of large carnivores – habitat of the core areas, corridors (including stepping stones) and critical zones for large carnivores

Habitat suitability patches - Areas that are suitable for permanent occurrence of species.

Home range - Area regularly used by an individual, where it satisfies its basic needs.

Land use/spatial planning - Activity aimed at predetermining the future spatial usage of land and water by society. Process of spatial planning with aim of using the landscape resources in a sustainable way, balancing socio-economic and environmental needs and conditions.

Linkage areas - Broader areas of connectivity important to facilitate the movement of multiple species and to maintain ecological processes within two or more neighbouring core areas, where delineating clear wildlife/migration corridors for species is difficult due to relatively high degree of permeability.

Migration - Regular movement of animals outside of their original home ranges. For the purpose of TRANSGREEN and ConnectGREEN projects, the term migration is applied also to other types of animal movement (within home ranges, food searching, dispersal of young, etc.).

Migration barrier –Natural and anthropogenic structures in the landscape which restrain the free movement of the animals.

Natura 2000 - Natura 2000 sites are those identified as Sites of Community Importance / Special Areas of Conservation (SACs) under the Habitats Directive 92/43/EEC, or classified as Special Protection Areas (SPAs) under the Birds Directive 79/409/EEC (amended as 2009/147/EC). Together, the SPAs and SACs designated by the Member States make up the European network of protected sites, Natura 2000.

Permeability (of linear transport infrastructure or landscape) - The ability to let animals safely pass through.

Stepping stones - Landscape features allowing short-term survival of animals. They are usually part of wildlife corridors. Stepping stones and 'wildlife corridors' can help connect core areas, allowing species to move between them.

Target species - A species that is the subject of a conservation action or the focus of a study.

Wildlife - Wild animals collectively; the native fauna (and sometimes flora) of a region; animals and plants that grow independently of people, usually in natural conditions.

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