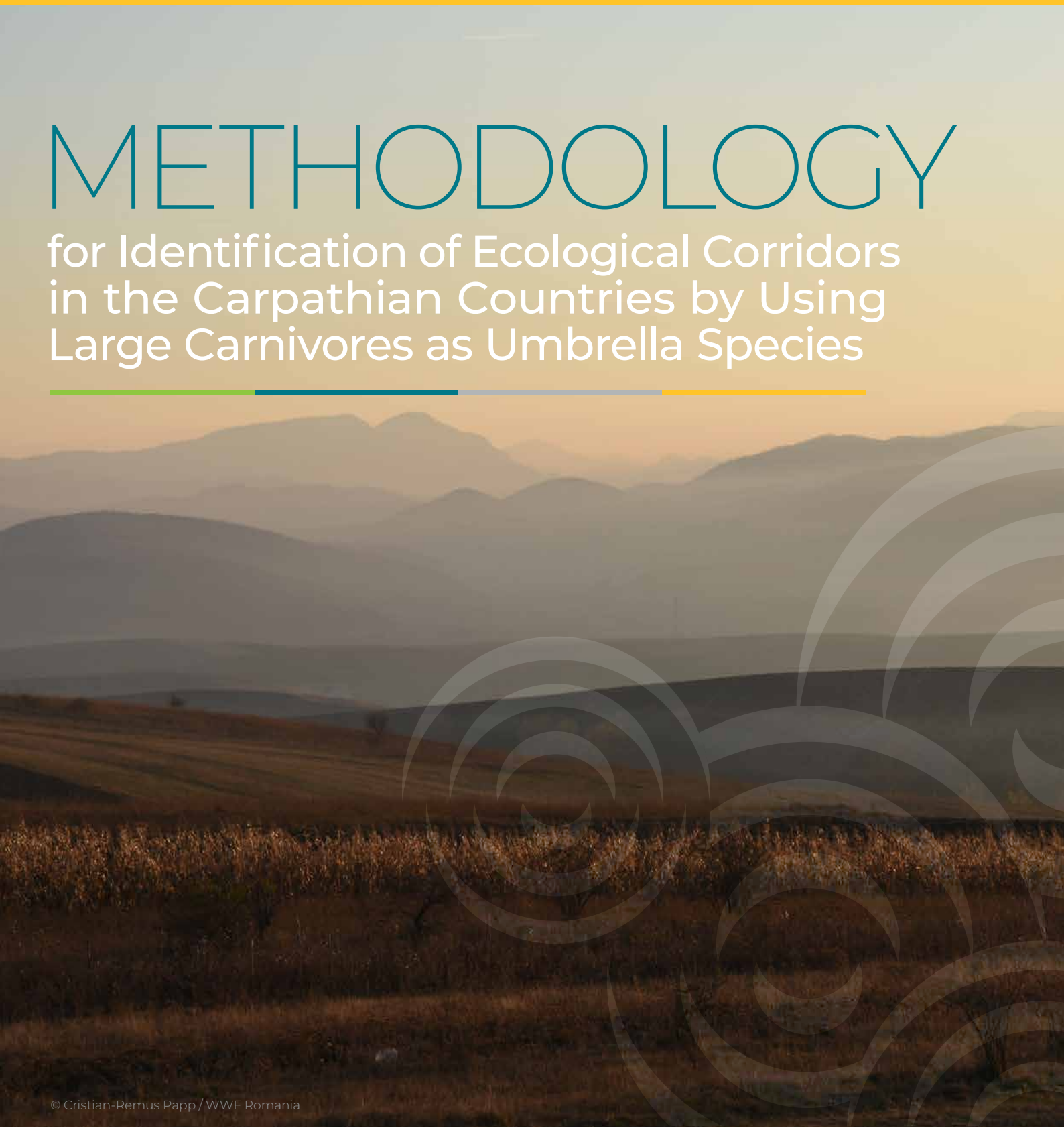
METHODOLOGY

for Identification of Ecological Corridors in the Carpathian Countries by Using Large Carnivores as Umbrella Species



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Methodology for Identification of Ecological Corridors in the Carpathian Countries by Using Large Carnivores as Umbrella Species

Output 3.1

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

Danube Transnational Programme, DTP2-072-2.3

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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"**
- **Guidelines "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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Foreword

The Carpathians – home to humans and wildlife alike

One of the things that make the Carpathian region so remarkable is its diversity. The diversity of nature, authenticity of the culture, and the character of the inhabitants are defining makers of life in this unique mountain range. The Carpathians represent a beautiful home for all of us – people with their history and culture as well as the plants and wildlife that live on the mountain slopes or down in the valleys – striking a fragile balance between the needs of the region's natural environment and the socio-economic aspirations of its human inhabitants.

The Carpathians represent one of the last sanctuaries for populations of large carnivores in Europe. These animals are keystone species of the habitats they occupy, performing a central role for the healthy functioning of these ecosystems and thus, their loss could lead to severe imbalances. The survival and health of large carnivore populations depend on numerous factors. Key among them are the existence of sufficiently large and intact habitats capable of supporting these big animals, and the possibility for individuals to pass freely between such suitable patches of wilderness through a network of green migratory routes. All around the world human activities are placing increasing pressure on these remaining wild areas. Safeguarding and re-establishing the structural and functional connectivity between these ecosystems is one of the most important challenges of the upcoming decades.

One of the core objectives of the Carpathian Convention is to foster the sustainable development and the protection of the Carpathian region. By establishing a dialogue among all relevant stakeholders, regional and national Governments, local communities and NGOs, it seeks ambitious and innovative ways to improve the quality of life in the Carpathians while simultaneously preserving its natural heritage. The maintenance and improvement of ecological connectivity plays a crucial role in the search for this harmonized approach and has been underlined in several key documents [i.e. Carpathian Convention Protocol on Biodiversity[1], International Action Plan on conservation of large carnivores and ensuring ecological connectivity[2]] adopted by the Parties to the Carpathian Convention. The Secretariat further supports numerous past and present regional projects such as BioREGIO, TRANSGREEN, ConnectGREEN and SaveGREEN, which promote the mainstreaming of ecological connectivity in policy and management practices.

Harald Egerer
Head of UNEP Vienna Programme Office - Secretariat of the Carpathian Convention

Striking a balance between socio-economic development and environmental protection requires a harmonized approach based on solid scientific data and methods and responsible spatial planning that considers long-term impacts on a broader scope. We are therefore delighted to introduce this *Methodology for identification of ecological corridors in the Carpathian countries by using large carnivores as umbrella species*. The aim of this document is to enable decision makers and managing authorities to identify key ecological corridors whose preservation is key to the sustainable development of the Carpathians.

The Methodology is an output of the ConnectGREEN project and was developed with the support of project partners from seven countries throughout the Carpathian region and could be replicated and adapted to mountain ranges in other parts of Europe or worldwide.

1 http://www.carpathianconvention.org/tl_files/carpathiancon/Downloads/01 The Convention/Protocols in pdf/Biodiversity Protocol.pdf

2 http://www.carpathianconvention.org/tl_files/carpathiancon/Downloads/02%20Activities/Large%20carnivores/CC%20COP6_DOC9P_Int%20Action%20Plan%20Large%20Carnivores%20and%20Ecological%20Connectivity_ADOPTED.pdf

Introduction


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Green Infrastructure Strategy developed by the European Commission[3] represents a key strategy within the European landscape policies. This strategy aims to ensure that the protection, restoration, creation and enhancement of green infrastructure (GI) 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 to 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 to 2020 aimed to halt the loss of biodiversity and ecosystem services in the EU and to stop global biodiversity loss by 2020. It reflected the commitments made by the EU in 2010, within the international Convention on Biological Diversity. However, more efforts are needed to recover Europe's biodiversity. The new EU Biodiversity Strategy for 2030 (European Commission 2020) plans to improve and widen the network of protected areas and integrate ecological corridors to build coherent Trans-European Nature Network and to develop an ambitious EU Nature Restoration Plan.

The European Strategy for the Danube Region (EUSDR) is a macro-regional strategy, which defines the Danube Region as a major international hydrological basin and ecological corridor with a need of regional approach to nature conservation, spatial planning and water management. This macro-regional strategy sets 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 long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive. The Habitats Directive in its Article 10 emphasizes the importance of the ecological coherence of the Natura 2000 network and encourages the Member states to manage features, which are essential for the migration, dispersal and genetic exchange of wild species.

The 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 the process of adopting the EU rules. Therefore, the Emerald network plays an important role for the Carpathians as well. 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, while adopting the Recommendation No. 16 (1989) of the Standing Committee to the Bern Convention. Its objective is a 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 that the Parties identify and prioritize important areas in order to improve connectivity and 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 climate adaptation, and areas important for keeping ecosystem functioning and

3 COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Green Infrastructure (GI) — Enhancing Europe's Natural Capital, COM/2013/0249 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0249

mainstreaming the biodiversity in sectors such as infrastructure, energy and mining (CBD 2018, COP Decisions 14/8 and 14/3).

Increasing of the area, connectivity and integrity of natural ecosystems is among the four main long-term goals for 2050 of the updated zero draft of the Post-2020 Global Biodiversity Framework[4]. Action-oriented targets for 2030 include a percentage of land areas that should be under spatial planning addressing land use change, retaining most of the existing intact and wilderness areas, and allow restoring a percentage of degraded natural ecosystems and connectivity among them. By 2030 there should be protected at least 30 per cent of the planet through well-connected and effective system of protected areas and other effective area-based conservation measures. We should ensure active management actions to enable wild species of fauna and flora recovery and conservation and reduce human-wildlife conflict.

IUCN WCPA with other partners introduced a concept of an ecological network for conservation as a common standard for global monitoring and database management of ecological networks and ecological corridors. "An ecological network for conservation is a system of core habitats (protected areas, other effective area-based conservation measures (OECMs) and other intact natural areas), connected by ecological corridors, which is established, restored as needed and maintained to conserve biological diversity in systems that have been fragmented". Ecological networks are composed of core conservation units - protected areas and OECMs – connected with ecological corridors. Ecological networks for conservation are more effective in achieving biodiversity conservation objectives than a disconnected collection of individual protected areas and OECMs because they connect populations, maintain ecosystem functioning and are more resilient to climate change. In the context of ecological connectivity, 'connect' refers to the enabling of movement by individuals, genes, gametes and/or propagules (Hilty et al. 2020)[5].

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

The ConnectGREEN is implemented within the Interreg Danube Transnational Programme (DTP). DTP is a funding instrument contributing to the implementation of the EUSDR. Since two countries of the Carpathians (Ukraine and Serbia) are not members of the EU yet, this Programme plays an important role in the implementing the macro-regional strategy within a defined geographical area (Danube region) as it also relates to third countries located in the same geographical area.

The project aims to address the fast and increasing ecosystem and habitat fragmentation in the Danube region and to improve ecological connectivity among natural habitats, especially among the Natura 2000 sites and other categories of protected areas in the Carpathian eco-region of transnational importance.

The ConnectGREEN project developed this Carpathian-wide methodology and based on this identified the ecological network 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 specific management and restoration measures will be developed in a participative way with key stakeholders to safeguard the ecological connectivity in these areas. The Decision Support Tool, created by the spatial planner partners in the project will also support this process by overlapping and analysing a broad range of spatial data and various individual scenarios. Within the ConnectGREEN project, the International Action Plan on Conservation of Large Carnivores and Ensuring Ecological Connectivity in the Carpathians was 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 and was adopted by the parties to the Carpathian Convention. A capacity building programme will be set up for conservationists and spatial planners to contribute to this endeavour and ensure durable outcomes.

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

4 Update of the zero draft of the Post-2020 Global Biodiversity Framework. CBD/POST2020/PREP/2/1. https://www.cbd.int/doc/c/3064/749a/0f65ac7f9def86707f4eaefa/post2020-prep-02-01-en.pdf

5 https://portals.iucn.org/library/sites/library/files/documents/PAG-030-En.pdf

Chapter 1

PREFACE

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This **Methodology for identification of ecological corridors in the Carpathian countries using large carnivores as umbrella species** (further referred to as Methodology) has been developed in a close cooperation of partners within 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 ecological connectivity in the Carpathian eco-region.

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 the results of the project "Complex approach to the protection of fauna of terrestrial ecosystems from the landscape fragmentation".[6]

This Methodology is the first output of the project ConnectGREEN, and enables to identify the ecological network used by large carnivores as umbrella species in the Carpathians.

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 translating the connectivity approach into practice and to consistent territorial protection of the coherent network.

There are two main target groups of this Methodology– i) entities and experts who are going to use the Methodology as a guide, and ii) entities and individuals who are going to use the results of the applied Methodology.

The main target group for whom this Methodology is developed to use in practice is nature protection experts. This Methodology provides the nature protection managers

6 https://eeagrants.org/archive/2009-2014/projects/CZ02-0017

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 shall be tested to identify the wildlife/migration corridors in four pilot areas during the project lifetime. The Methodology will be replicable and adopted accordingly to the needs of countries and regions of the Carpathians and beyond.

The Carpathian region varies in each particular country as regards the occurrence and abundance of the large carnivores, the quality of the ecological network for large carnivores, the scientific knowledge, and 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 conservation 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 a considerably different situation compared to the situation at the borders between the Czech Republic and Slovakia. Nevertheless, economic development and connected urban sprawl are irreversible and it is only a question of short time when the currently "safe" regions get under immense pressure of uncontrolled development. Therefore, the need for existence of such scientific, verified and replicable Methodology, which can provide solid scientific background for decision-making processes, should be accepted throughout the Carpathian countries among both the nature protection and spatial development sector. The results provided by applying this Methodology in the Carpathian countries can significantly contribute to the maintenance and improvement of ecological connectivity. Avoiding the landscape fragmentation rather than the mitigating measures is not only becoming a question of money but a question of ultimate responsibility towards the future generations.

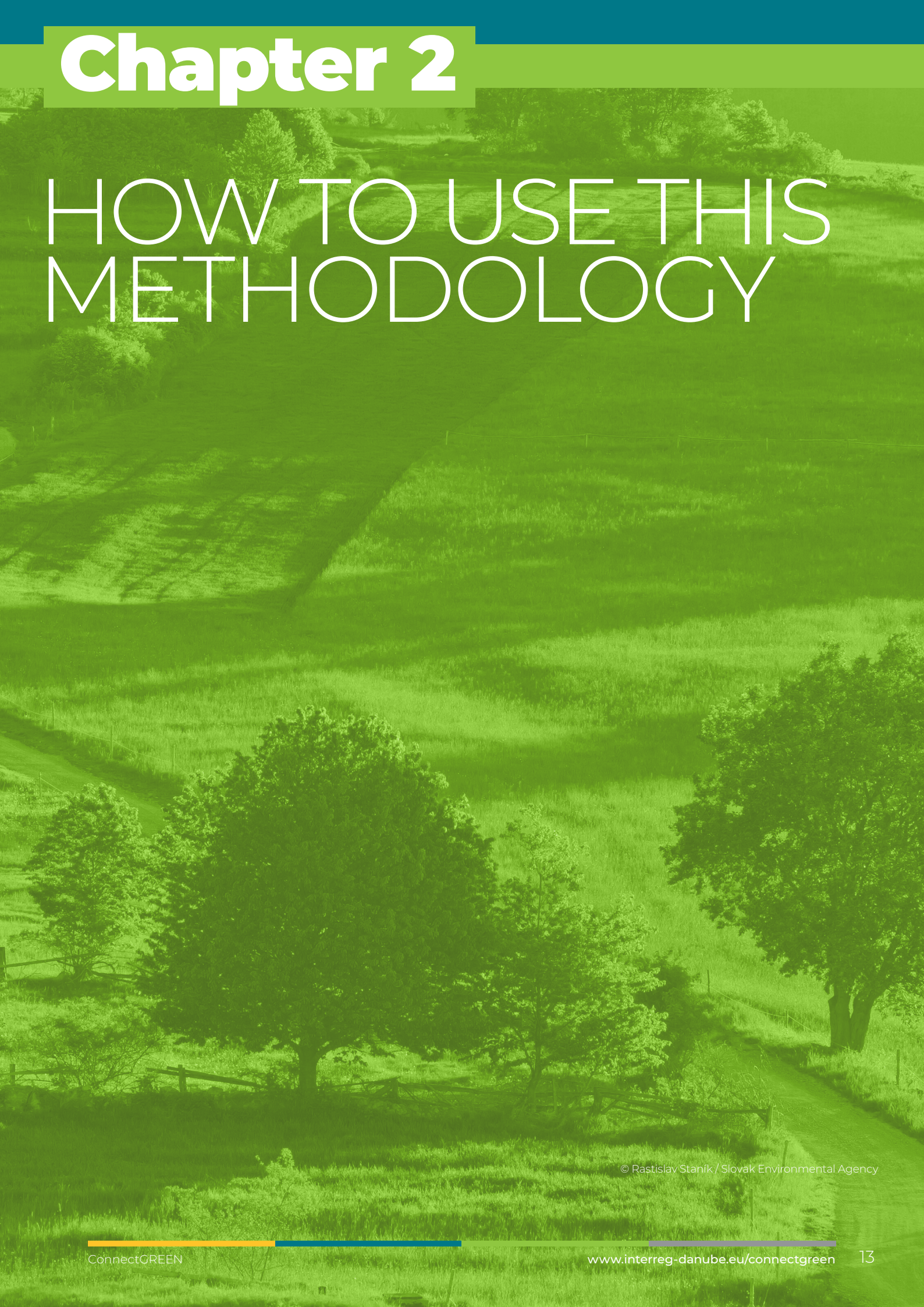
The outputs of the identification process of wildlife/migration corridors based on this Methodology will consist of a set of variable data which can be used in the decision making processes in both spatial planning and management of protected areas at different levels of decision making (local, regional,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

The maintenance of 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 to the further development of the management of wildlife/migration corridors in the Carpathians. Therefore, this Methodology will be interlinked with the follow-up documents, which will be developed during the project implementation, and mainly focused on harmonizing the interests of nature conservation and spatial planning and on an efficient implementation in planning and management of the Carpathians.

The Methodology is embedded as part of the International Action Plan on Conservation of Large Carnivores and Ensuring Ecological Connectivity in the Carpathians into the frame of the Carpathian Convention through its parties.

Chapter 2

HOW TO USE THIS METHODOLOGY



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This Methodology aims to be a practical guide that can be easily used by experts and on the other hand, it has an ambition to become 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 provides information on the topic of the Methodology in terms of the ConnectGREEN project with a specific focus on the practical steps and procedures towards the identification of wildlife/migration corridors of large carnivores. The Chapter 5 *Defining the ecological network for large carnivores* refers to **Factsheets**, which provide detailed description of procedures to be undertaken or respective forms of data collection.

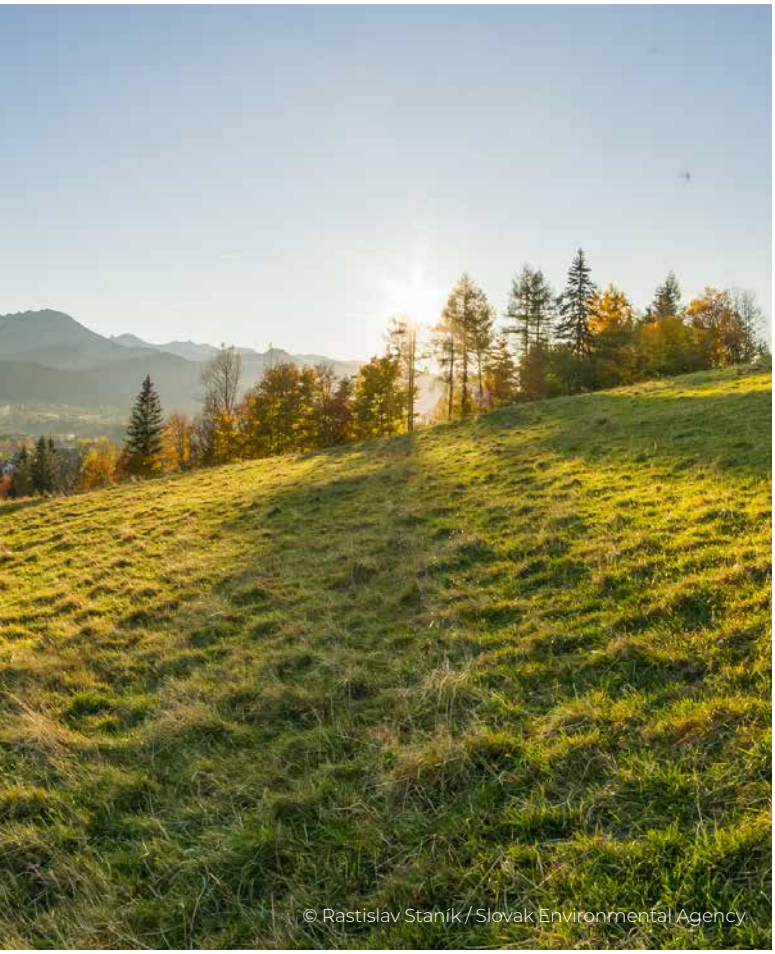
Section 2 - Supporting documentation provides reference material and additional information on topics like connectivity, target species, the Carpathians, main types of barriers, pro-connectivity measures, and monitoring of pro-connectivity measures.

SECTION 1

Chapter 1 – PREFACE refers to the main goals of the Methodology section, describes who the main target group of the document is, 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, and brings information on migration barriers, connectivity measures, and 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 accepting the results provided by the Methodology and real applicability of results in practical life in the field of spatial development.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Chapter 5 – DEFINING THE ECOLOGICAL NETWORK FOR LARGE CARNIVORES represents a crucial part of the document and brings step-by-step instructions for the Ecological network for large carnivores at 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, specifically regarding the 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 – Inventory of 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 over the last decade.

Supporting document 03 – CONNECTIVITY AND FRAGMENTATION provides general basic knowledge on connectivity, fragmentation, corridors and can serve as the 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.

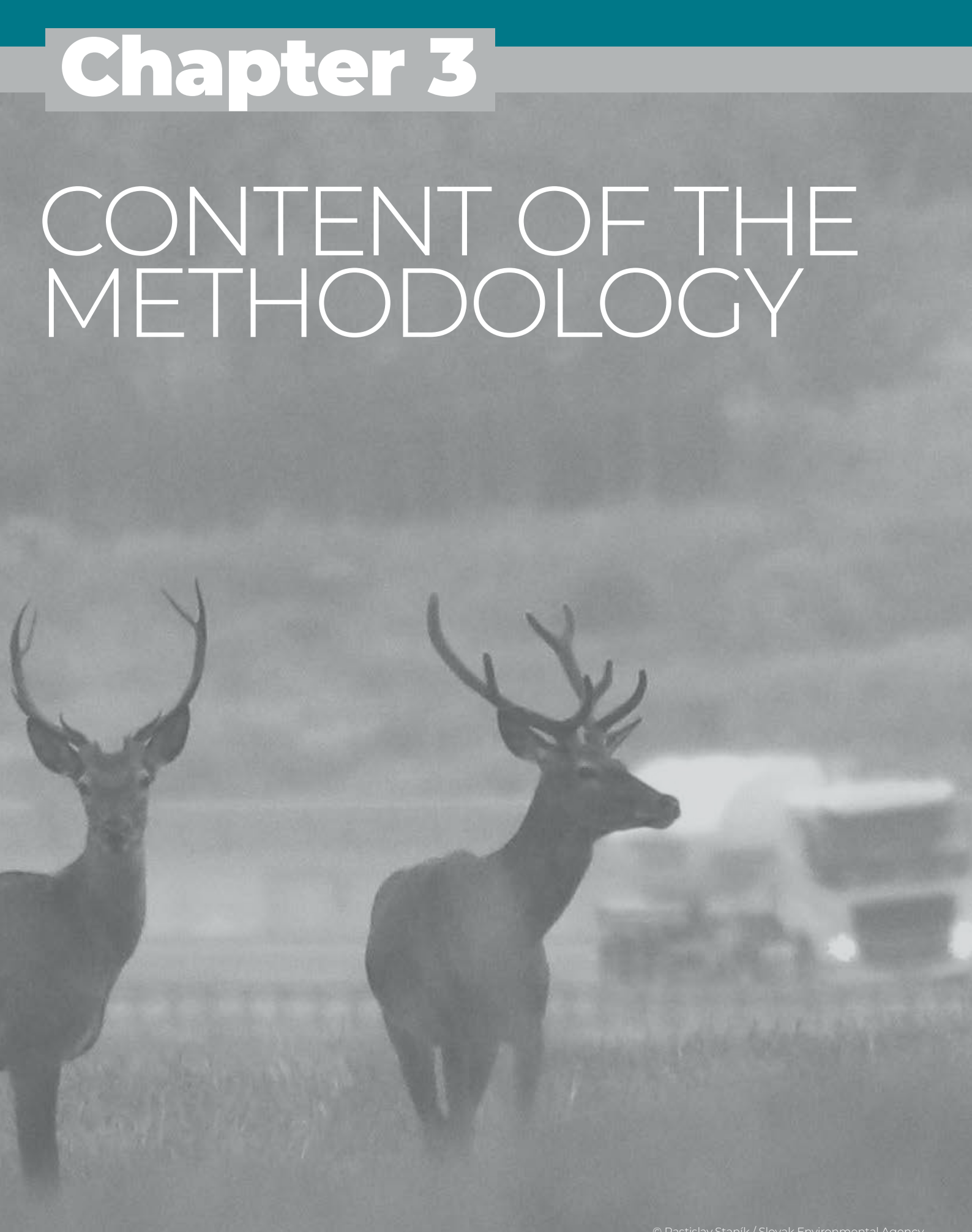
Supporting document 05 – BARRIERS describes main types of barriers for migration of large carnivores and includes the evaluation of particular types of barriers. The principles of evaluation of barriers are reflected in the “mapping sheets (cards)” which were developed for mappers to facilitate the fieldwork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

Supporting document 06 – CONNECTIVITY MEASURES brings the list of possible measures that may 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



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Ecological connectivity is an inevitable condition for the long-term survival 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 terms of nature protection and building of ecological networks is the main tool used to protect ecological connectivity.

Traditionally the corridors have been viewed as linear strips (Jongman & Pungetti 2001) sheltered by a buffer zone. Over the past years however, a more integrated approach of connected spatial structures of biotopes has become justified for the group of large carnivores.

The approach of connected spatial structures was adopted for the Methodology.

(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 a 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 landscape fragmentation are those bound to the well-preserved natural environment, those which have high demands on the size of the home range or whose biology includes regular or occasional migration, especially the three species of large carnivores present in the Carpathians: **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 their ecological requirements since 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 only be efficient if both the home range areas and the migration areas are protected. Large carnivores are so called umbrella species for the forest ecosystem. If we sustain their high ecological demands for 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 may also be used, and mostly data related to the 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 SD04 was taken into consideration while designing the subsequent chapter on defining the ecological network for large carnivores as well as in the particular materials of the Supporting documentation (barriers, species, measures and monitoring). Target species will also be focused on in the practical implementation of this Methodology in the pilot areas e.g. in the 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 barrier types and a variety of their possible impacts on ecological connectivity often do not allow to comprehend all possible variations in the field and to offer simple solutions with general methods of application.

The general knowledge described in detail in the supporting document SD05, however, will create a basis for development of tailor-made adaptations on the local level (in pilot areas as for the ConnectGREEN project), also considering local micro attributes which may influence the impact of the barrier both in individual and cumulative evaluation. These findings will be permeated in both the strategic and 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 ecological network for large carnivores is identified in accordance with this Methodology, 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 the field in different regions over the world; however, it is always considered to be a specific situation regarding the 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 regarding the Connectivity measures, see Supporting document SD06)

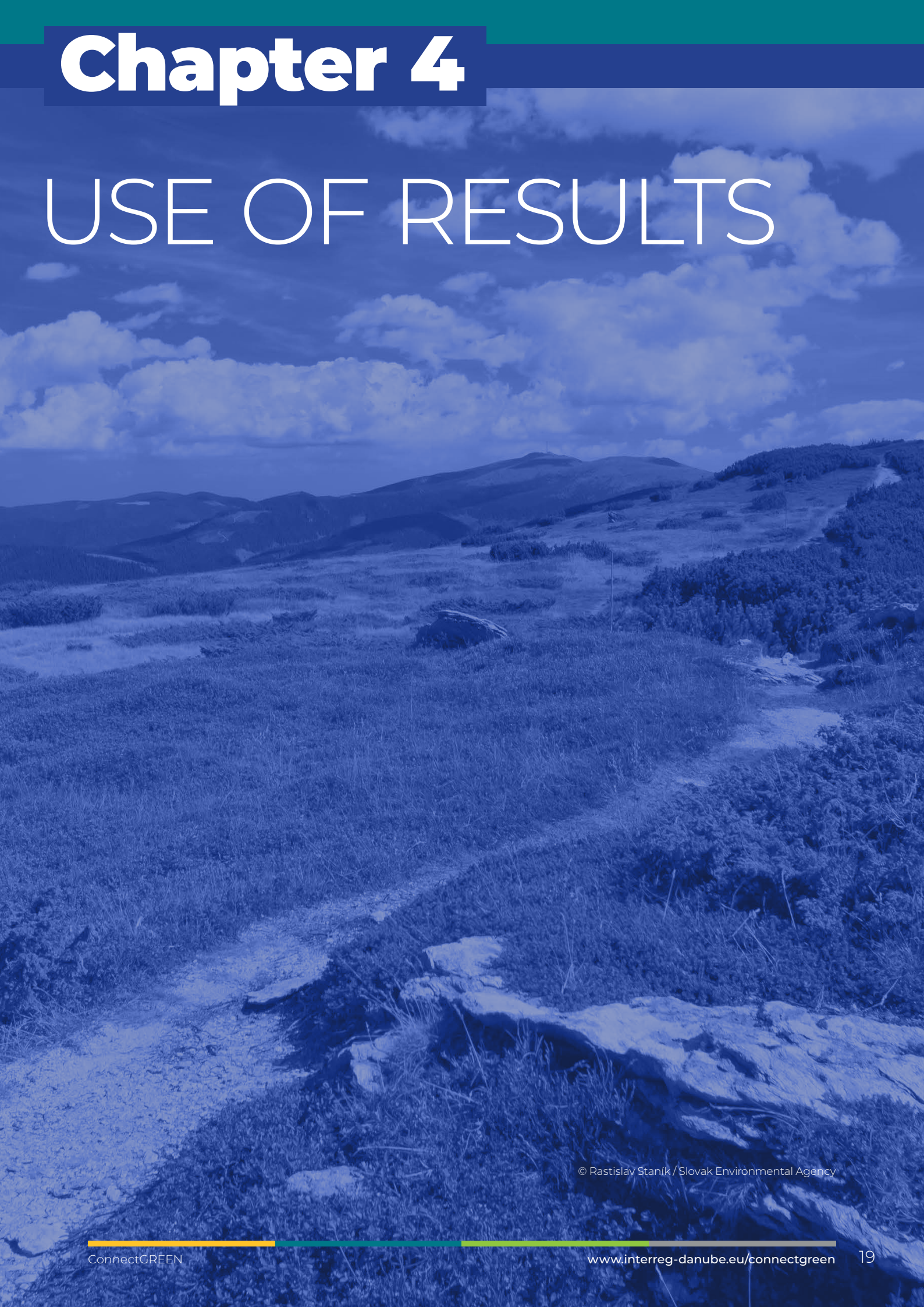
Hand in hand with applied connectivity measures, a proper **monitoring of measures** should be planned and carried out in order to collect the information on effectiveness of these measures. Monitoring of effectiveness provides important feedback and allows for adaptation and fine-tuning of mitigation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

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 considered for the best option to choose in respect to the selected target species.

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

Chapter 4

USE OF RESULTS



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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 spatial planning and implementation systems throughout the relevant sectors. This will only be possible if there is:

- Political will/support to prioritize nature protection and connectivity protection in particular, 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 for 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 at the level of the Carpathian Convention.


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- Development and adoption of the Methodology for the identification of wildlife/migration corridors for large carnivores supported by experts from all the Carpathian countries.
- Development of a Guideline for harmonizing the interests between nature conservation and different land uses.

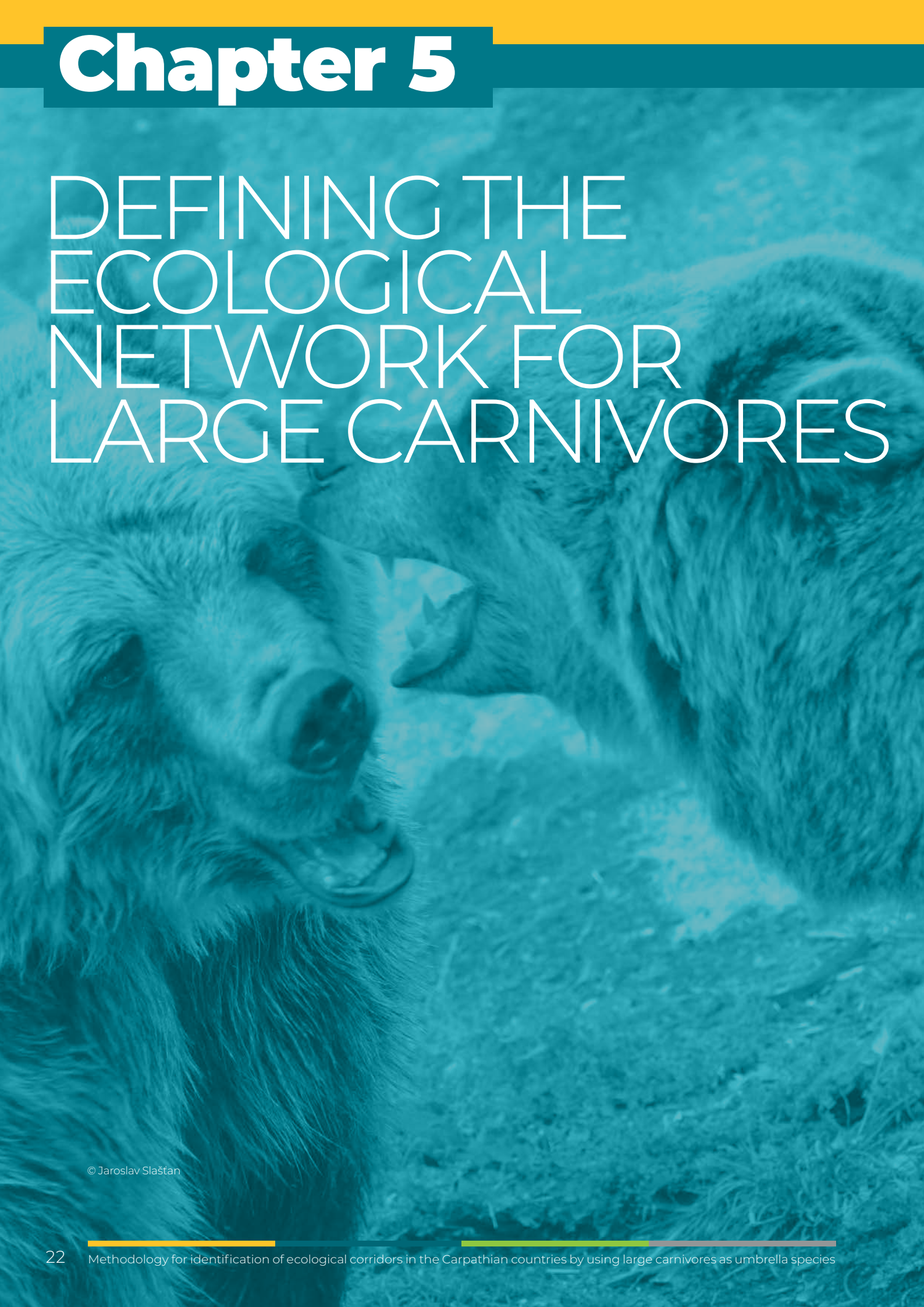
The 14th Meeting of the Conference of Parties to the Convention on Biological Diversity (COP14 to CBD) in Egypt in 2018 underlined the necessity to review and adapt landscape and seascape plans and frameworks (both within and across sectors), including, for example, land-use and marine spatial plans, 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). Connectivity, integrity and conservation of natural ecosystems, their increasing and improvement were also included to the draft goals and targets of the Post-2020 Global Biodiversity Framework of the CBD and its related proposed indicators. This is reflected also in the EU Biodiversity Strategy for 2030 where a need to build a truly coherent Trans-European Nature Network with more and better protected natural areas and set-up ecological corridors is highlighted. To prevent genetic isolation, allow for species migration, and maintain and enhance healthy ecosystems, investments in green and blue infrastructure and cooperation across borders should be promoted and supported (European Commission 2020).

These ambitious, but inevitable plans must be accepted at the international and national levels by politicians and on the other hand must be feasible to implement at 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 the connectivity projects in local and regional real setting, 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 continual 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 a successful employment of the ConnectGREEN project results is the awareness raising among 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.

Chapter 5

DEFINING THE ECOLOGICAL NETWORK FOR LARGE CARNIVORES



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5.1. TERMINOLOGY

During development of this Methodology there was a long discussion within the expert group on the terminology, specifically related to the term **corridor** and the term which should be used for the **expected output** (i.e. favourable and suitable areas + movement/migration zones + critical zones). Experts took into consideration international standards, agreements on the use of terminology with other projects (mainly the TRANSGREEN project) as well as the national acceptance of terminology and the IUCN classification (Hilty et al., 2020).

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

Corridor

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

Ecological corridors – 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 for the movement of a wide range of organisms between high natural value areas.

Migration corridors - allow for 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)

For the purposes of this Methodology, we generally use the term **ecological corridor** when describing the landscape elements that allow 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, mainly with the focus on large carnivores as the umbrella species in the process of defining the ecological network (favourable and suitable habitats of large carnivores, linkage areas, corridors and stepping stones and critical zones) for large carnivores (see below).

Expected output of the project

The output of the process is the map/layer of ecological network for large carnivores in the Carpathians, which consists of favourable and suitable habitats, movement/migration zones and critical zones. Finally, experts of the working group agreed on the term **ecological network for large carnivores**.

It is also necessary to state that even if the terminology in English language can be unified internationally (as agreed for the Carpathian level), the national terminology still remains to be reflected/adapted/kept within the national legislation framework.

This chapter describes a gradual procedure to define the ecological network for large carnivores, both at the Carpathian level and pilot areas level. The subsequent steps are aggregated into logical units with respective partial outputs verified by experts.

To keep the chapter consistent and organized, the detailed information mainly regarding the harmonized procedure in data inventory is described in Factsheets (see page 36), which represent a fixed part of this Chapter.

ConnectGREEN classification including correspondence with IUCN categories

<table>
<tr><th colspan="2">IUCN</th><th colspan="2">ConnectGREEN</th></tr>
<tr><th>CATEGORIES</th><th>MAIN CATEGORY</th><th>SUBCATEGORIES</th><th>SPATIAL LIMITS</th></tr>
<tr><td rowspan="2">Protected Areas
A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values. Preservation is the primary objective.</td><td rowspan="3">Favourable and suitable habitat
Favourable (may include different classes, including optimal) and suitable habitats for long term or temporal occurrence of large carnivores.</td><td rowspan="2">(Relatively) Continuous Favourable Areas (assimilated to Core areas)
It is primarily a natural continuous habitat (usually forested) which meets both qualitative and spatial requirements of particular species for their long-term occurrence.</td><td>area ≥ 300 km²</td></tr>
<tr><td>width ≥ 1 km</td></tr>
<tr><td rowspan="2">Conserved Areas (OECMs)
A geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in situ conservation of biodiversity with associated ecosystem functions and services and where applicable, cultural, spiritual, socio–economic, and other locally relevant values. Delivers the effective in-situ conservation of biodiversity, regardless of its objectives.</td><td rowspan="2">Other Suitable Areas
Relatively continuous habitats which meet qualitative (mostly forested) but not spatial requirements of particular species for their long-term occurrence.
It could be used permanently/seasonally by individuals/small segments of populations, or not used at present.</td><td>10 ≤ area < 300 km²</td></tr>
<tr><td>width ≥ 1 km</td></tr>
<tr><td rowspan="4">Ecological Corridors
A clearly defined geographical space, not recognised as a ‘protected area’ or an ‘other effective area-based conservation measure (OECM or conserved area)’ that is governed and managed over the long-term to conserve or restore effective ecological connectivity, with associated ecosystem services and cultural and spiritual values.</td><td rowspan="3">Movement/ Migration zones
Relatively suitable patches of habitats, which maintain the landscape connectivity by linking favourable and/or other suitable areas.</td><td>Linkage area
A (relatively) large and heterogeneous area connecting two or more favourable or suitable areas; normally includes multiple stepping-stones and corridors, but the latter cannot be clearly defined due to the heterogeneity of the relatively permeable landscape.</td><td>width ≥ 0.5 km</td></tr>
<tr><td>Corridor
A “classic” corridor (relatively continuous and linear-shaped habitat) that connects favourable/suitable areas through a relatively impermeable landscape.</td><td rowspan="2">width ≥ 0.5 km</td></tr>
<tr><td>Stepping stones
Smaller patches of relatively suitable habitats used by individuals as temporary refuges during movements/ dispersals through a relatively impermeable landscape. Might not be easily identified at the Carpathian level (due to resolution for instance).</td></tr>
<tr><td rowspan="2">Critical zones
Zones critical for connectivity (i.e. places where movement/ migration is mainly depending on currently permeable sectors along linear features / infrastructure).</td><td>Critical connectivity sector
A narrow corridor intersected by one or more linear barriers, which are limiting the movement possibilities of the animals within the landscape.
Each situation has to be individually assessed. There might be more subcategories identified at the national or local level, based on the level/magnitude of cumulative effect.</td><td>-</td></tr>
<tr><td>Critical connectivity area
A favourable or suitable area intersected by one or a series of linear barriers, which are limiting the movement possibilities of the animals within the landscape.
Each situation has to be individually evaluated based on the assessment of the permeability of the linear barriers.</td><td>-</td></tr>
</table>


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Ecological network for the target species, i.e. ecological network for large carnivores, is identified in line with the habitat preferences using the latest occurrence data for the Carpathians.

To define the ecological network for large carnivores, the habitat suitability models of the target species and the connectivity model are crucial. The 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 ecological network for large carnivores consists of three main categories:

- Favourable and suitable habitat ((relatively) continuous favourable areas (assimilated to core areas) and other suitable areas).
- Movement/migration zones (linkage areas, corridors and stepping stones).
- Critical zones (critical connectivity sectors and critical connectivity areas).

Within the project, we worked on two different resolution outputs:

A. The level of the Carpathians (subchapters 5.2 to 5.5)

B. Pilot areas (subchapter 5.6)

The Map of Ecological Network was developed using the best available data and information with the aim to create a consistent map at the Carpathian level. The output – the Carpathian map of ecological network for large carnivores – is the basis for further use at the level of pilot areas within the ConnectGREEN project as well as beyond the project's implementation.

The applied approaches/practices in ecological connectivity across the Carpathians may not be fully reflected in the methodology applied at the Carpathian level and this is subject to the adaptation at the **national level**, especially in terms of terminology, management methods etc.

It is recommended that national authorities consider the best available approaches and options on how to accommodate the methodology from the Carpathian level to national circumstances in order to 1) keep the results developed within the Carpathian scope in order to maintain the ecological connectivity at the Carpathian level, and 2) achieve best solutions at the national and local level.

While defining the layer of ecological network for large carnivores, the continuous verification of partial outputs of modelling is necessary to identify disparities in terms of 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 at the level of the Carpathians was conducted by the national/local experts according to their local knowledge via a desktop exercise. The verification of the model at 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 MODELLING

1. Collection and preparation of input data

2. Development of the habitat suitability model

3. Definition of favourable and suitable habitat (assimilated to core areas) and other suitable areas

4. Expert discussion/verification of the layer of favourable and suitable habitats by national and local experts & finalization of the layer

2. CONNECTIVITY MODELLING

1. Preparation of the resistance surface including barriers

2. Connectivity modelling – network of corridors (and linkage areas, stepping stones)

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 ECOLOGICAL NETWORK FOR LARGE CARNIVORES

1. Synthesis of particular outputs – proposal of the map of ecological network for large carnivores

2. Expert discussion/verification of the proposed map of ecological network for large carnivores – national and local experts

3. Finalization of the map of ecological network for large carnivores for the Carpathians

B. PILOT AREA 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

5.2. HABITAT SUITABILITY MODELLING

5.2.1 COLLECTION AND PREPARATION OF INPUT DATA

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

1. OCCURRENCE DATA – all relevant and verified observations (collected within focal regions of the Carpathians over the last 20 years). 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 living individuals or animal carcasses, while 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 shape files or vector layers of open software (QGIS, PostGIS, GRASS, SAGA etc.).

(Factsheet 01 –Availability of occurrence data, Factsheet 03 – Mapping/collecting occurrence data)

2. ENVIRONMENTAL VARIABLES – are essential inputs for habitat modelling. All relevant data on both natural and human conditions of the landscape are collected for the whole region of the Carpathians. These include the following datasets:

2.1. Abiotic factors – source data on topography (digital elevation model) have to be collected together with other datasets related to it (vertical heterogeneity, solar radiation index) using specific tools of spatial analysis (focal statistics, moving window technique, etc.).

2.2. Habitat factors – represent the most influential variables in the model. Combination of Global Land Cover data (pixel size 300 m) and Corine Land Cover data (pixel size 100 m) should be used. Generalized land cover layer as well as derived data on landscape structure (even e.g. density of forest edges, when applicable) has to be involved as inputs into the model.

2.3. Anthropogenic factors – the last group of environmental variables cover the human influence and the level of anthropogenic transformation of the landscape. Open Street Map (OSM) has to 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 are 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 a 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 (Romportl et al. 2013).

In case of the "only presence data", the most widely used approach is the MAXENT (Maximum Entropy Modelling) (Philips, 2017), based on complex statistical evaluation of the relationship between species occurrence and environmental factors. The most important outputs of the model include raster of habitat suitability and several graphs showing the 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 at the level of the Carpathians

5.2.3 DEFINITION OF FAVOURABLE (ASSIMILATED TO CORE AREAS) AND SUITABLE HABITATS

The habitat suitability model is a key input for several sequential analyses – definition of patches of favourable and suitable habitats and

connectivity modelling. (Relatively) Continuous favourable areas assimilated to core areas represent primarily natural continuous (usually forested) habitats, which meet both qualitative and spatial requirements of the target species for their long-term occurrence. Other suitable areas represent relatively continuous habitats which meet qualitative (mostly forested) but not spatial requirements of particular species for their long-term occurrence. Both are defined according to the habitat quality and spatial requirements of target species. A proper literature review and expert discussion are needed for setting the thresholds within a large and heterogeneous region such as the Carpathians. A system of favourable and other suitable areas for long-term or temporal occurrence of large carnivores provides the basis for the final connectivity model – these areas will be interconnected by wildlife/migration corridors. The minimum size should be at least 300 km2 for (relatively) continuous favourable areas assimilated to core areas (see the classification table), respectively, at least 10 km² for the other suitable areas.

Remark: The elevation/altitude and slope parameters are not fully considered in the context of the Carpathians to be highly influential for the movement of large carnivores across the landscape. This is actually not a real impediment for the wolf or even lynx, while for the bear it is questionable (bears or their tracks were spotted on some of the highest peaks). Considering this, in the current model, we make an abstract of the "high peak" elevation parameters in order to avoid the creation of unnecessary isolated impermeable isles. Otherwise, the parameter would indicate a real physical fragmentation (as in the case of man-made fragmentation) and would have an adverse effect on the consistency of the map and the situation in the field.

Output of the step 5.2.3: Proposal of the layer of favourable and other suitable habitats at the level of the Carpathians

5.2.4 EXPERT DISCUSSION/ VERIFICATION OF THE LAYER OF FAVOURABLE AND OTHER SUITABLE HABITATS BY NATIONAL AND LOCAL EXPERTS & FINALIZATION OF THE LAYER

Output of the habitat suitability model and the proposal of the favourable and other suitable habitats will be checked by the core project team experts and adopted according to their expert knowledge. Experts will mainly consider 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 (orthophoto maps, land-cover data, etc.). The adopted model should be sent to national and local experts and discussed within consultation workshops. After verification and eventual modification, the final version of the layer of favourable and other suitable habitats shall be prepared.

Output of the step 5.2.4: Final layer of the favourable and other suitable habitats verified at the national level

5.3. CONNECTIVITY MODELLING

5.3.1 PREPARATION OF THE RESISTANCE SURFACE INCLUDING BARRIERS

Resistance surface represents the resistance of various landscape segments that more or less influence the movement of animals within the landscape. The resistance surface is like a 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 thus 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 with permeable barriers (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, STEPPING STONES)

The connectivity model interconnects particular favourable and other suitable habitats 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, or Resistant Kernel. The method applied in this Methodology is an innovative tool of Circuitscape (McRae et al., 2008) built on the principle of electricity conductance. In terms of landscape ecology, it concerns an interlinkage of particular favourable (assimilated to core areas) and other suitable habitats based on resistance surface.

The favourable and suitable habitats behave like (electric) current sources and the surface is composed of parts of landscape that have different resistance to movement (like different electric resistances). The tool finds ways between each favourable and suitable habitat with the lowest resistance to movement. So-called voltage maps are then the key inputs for the 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 should be sent for verification to the national/local experts and discussed. Based on their local expert knowledge, the national/local experts complete the draft of the connectivity model. According to their comments and recommendations, the final layer of corridors will be prepared.

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

Remark:

As the connectivity modelling has certain limitations caused e.g. by the scale of modelling, heterogeneity of the area, insufficient data coverage in different areas etc., the inputs of experts based on local knowledge at this stage of the process of the ecological network map creation for large carnivores can be decisive as it regards the final quality of the map.

Example:

Valleys are an important segment of interconnection of mountain ranges. In recent decades, however, valleys are becoming impermeable or less impermeable for large carnivores because of dense built-up areas. If there are two long mountain ranges merged at a certain area point during the modelling, 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 meet the criteria for a corridor even if the model did not display them. Thus, the inputs of national/local experts with detailed local knowledge and data will play a crucial role in identifying the (still) permeable locations between (within) built-up areas.

5.4. CRITICAL ZONES

5.4.1 IDENTIFICATION OF BARRIERS AND CRITICAL ZONES

Identification and classification of basic barriers in the movement of large carnivores and **potential** critical zones is based on GIS modelling. The potential critical zone is identified in places where the movement/migration is mainly dependent on currently permeable sectors along linear features/infrastructure.

Output of the step 5.4.1: First draft of critical zones at 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 the 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 the information gained from the national experts, the connectivity model at the level of the Carpathians will be properly adjusted including the critical zones.

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

5.5. DEFINITION OF THE ECOLOGICAL NETWORK FOR LARGE CARNIVORES

5.5.1 SYNTHESIS OF PARTICULAR OUTPUTS – PROPOSAL OF THE MAP OF ECOLOGICAL NETWORK FOR LARGE CARNIVORES

Based on the verified data – favourable and other suitable habitats, movement/migration zones, and critical zones, the first draft of the map of ecological network for large carnivores at the level of the Carpathians will be created.

Output of the step 5.5.1: The map of ecological corridors for large carnivores – first draft

5.5.2 EXPERT DISCUSSION/VERIFICATION OF THE PROPOSED MAP OF ECOLOGICAL NETWORK FOR LARGE CARNIVORES – NATIONAL AND LOCAL EXPERTS

The proposal of the map of ecological network for large carnivores will be verified by using independent occurrence data sets acquired by telemetry and/or by systematic monitoring or by-chance observations. Secondly, national and local experts are to verify the proposal.

Output of the step 5.5.2: The verified map of ecological network for large carnivores at the national level

5.5.3 FINALIZATION OF THE MAP OF ECOLOGICAL NETWORK FOR LARGE CARNIVORES FOR THE CARPATHIANS

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

Harmonization of the national maps of ecological network for large carnivores – a unified shape of the output layer – model output (rasters of 500x500m and GIS inserts of local experts) should be made.

Output of the step 5.5.3: The final map of ecological network for large carnivores at the level of the Carpathians

5.6. DEFINITION OF THE ECOLOGICAL NETWORK FOR LARGE CARNIVORES FOR THE PILOT AREA

Based on the final map of ecological network for large carnivores developed for the Carpathians in the step 5.5.3 (see above), the **ecological network for large carnivores for the pilot areas** will be defined. The process will include both desktop and field verification of (i) movement/migration zones and (ii) the verification of critical zones in respect to real permeability. The results of the verification will be transposed to the final map of ecological network for large carnivores for the pilot areas.

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

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 the 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 ecological network for large carnivores will be specified based on few rules (Anděl et al., 2010). Among such rules/criteria we include:

- Presence of designated protected areas
- Presence of military areas (according to national regulations)
- Respect of landscape elements which support the movement/migration of large carnivores
- Borders of favourable habitats are led outside the settlements
- Borders of favourable habitats are lead outside the arable land
- Adjusted forest units will be added to the favourable habitats (not separated by a noticeable barrier in the movement of large carnivores)
- Borders are delineated in regional context of the landscape

For the delineation of the continuous areas of favourable and suitable habitat (assimilated to core areas), the functional differences of the identical landscape elements in diverse ecological contexts are also 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, etc.).

5.6.1.2 Desktop verification of critical zones

During the "desktop verification phase", the potential problems with delimitation of ecological network for large carnivores will be identified. The majority represents potential critical zones (corridors intersected by linear features/infrastructure – highways, railways, cumulative effect of barriers, etc.).

These identified localities will be the 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 also recommended that consider the future development plans and expected impact on modelling scenarios be considered.

Output of the step 5.6.1: List of localities that will be subjects of verification in the field

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 movement/migration zones.

For the verification of corridors, linkage areas and stepping stones, the real detailed field mapping of the pilot areas will be conducted with the focus on the corridor permeability (barriers) 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 landscapes, such as:

- Motorways, roads and railways – may include technical structures which may either prevent or 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 apparent from the description above, most of the landscape features with a barrier effect will include linear transport infrastructure and fencing. An ArcGIS online application Survey123 was developed for easy recording of such data, and mappers can also use "mapping cards" for each type of the barrier. Both methods facilitate the fieldwork and enable to get standardized high quality data 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 to develop such measures.

Verification of barriers

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 in the movement/migration 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. It is highly probable that the field mapping will reveal new critical zones that could not be identified while only using existing datasets for the modelling of ecological network for large carnivores.

The mapper will go through the movement/migration and assess the potential barriers and questionable landscape elements. 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 the definition of critical zones.

1. Whichever C1 barrier is critical and leads to definition of critical zones.

2. Cumulative effect of a barrier – whichever barrier classed as C2+C2, C2+C3+C3, C3+C3+C3 etc. leads to the definition of critical zones.

For the verification of both corridors and barriers it

is decisive that mappers be experts with a 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, due importance should be given to selecting qualified persons.

Mapping of occurrence of the target species

Targeted field mapping of the presence of large carnivores and possibly other mammals as well (red deer, roe deer, wild boar, etc.) will be organized to detail the delineation of the favourable and other suitable habitats for the target species as well as to determine the more accurate corridors used by the target species for their movement or dispersal. The field mapping may be carried out through different monitoring methods including photo-trapping cameras, snow or mud tracking, tracking and mapping of signs of presence during spring and autumn seasons, etc.

Mapping of small green landscape structures

The pilot area scale may benefit from better knowledge of presence 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 the Carpathian-level modelling due to the scale (pixel size) but may be vital for the correct delineation of corridors on the pilot area scale. That being the case, digitalization of such landscape features based on aerial photos combined with their field verification may be necessary. This will be specifically 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 shall be recorded by the mapper and transported to the GIS layer.

5.6.2.2 Field verification of critical zones (critical connectivity sectors and areas)

Based on the final map of ecological network for large carnivores developed for the Carpathians (see above step 5.5.3), the potential/proposed critical zones are identified as places where movement/migration mainly depends on currently permeable sectors along linear features/ infrastructure (see step 5.4.2 above). The potential critical zones defined at the Carpathian level are further discussed and verified by expert discussions. These potential critical zones need to be verified in the field.

A descriptive form of a critical zone is 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 suggestions 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.

Field mappers should be properly educated and experienced with a strong scientific background, mapping experience and knowledge of local conditions.

Outputs of the step 5.6.2:

- ***Layer of barriers – line geometry, standardized attributes (Survey123, mapping cards)***
- ***Layer of barriers – polygon geometry, standardized attributes (Survey123, mapping cards)***

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 layer of ecological network for large carnivores (developed in step 5.5.3) shall be updated. The collected data will be transferred into the final layer of the ecological network in the pilot area.

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

Output of the step 5.6.3: Maps of the ecological network for large carnivores for pilot areas

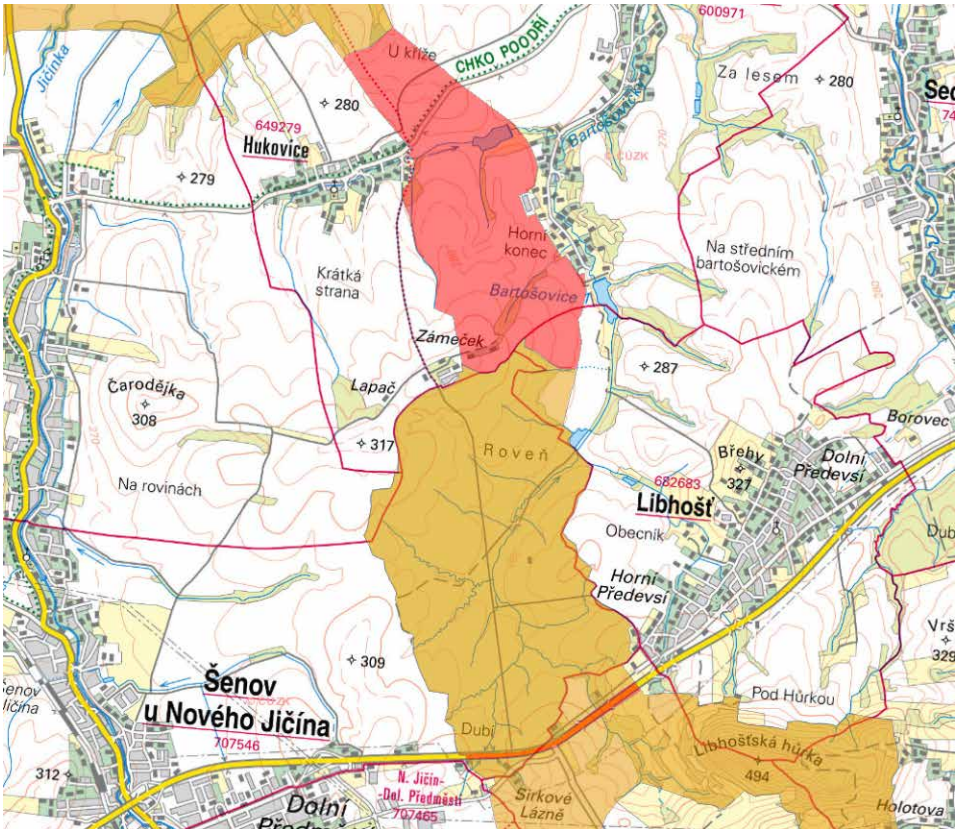

Fig. 01.

A typical conduction of a 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 the figure it is between critical zones, minimum width of corridor 500 m, etc. – more information in Anděl et al., 2010). First critical zone (up) is characterized by two main barriers – non-forest area and settlements. The second one is characterized by four lane roads.

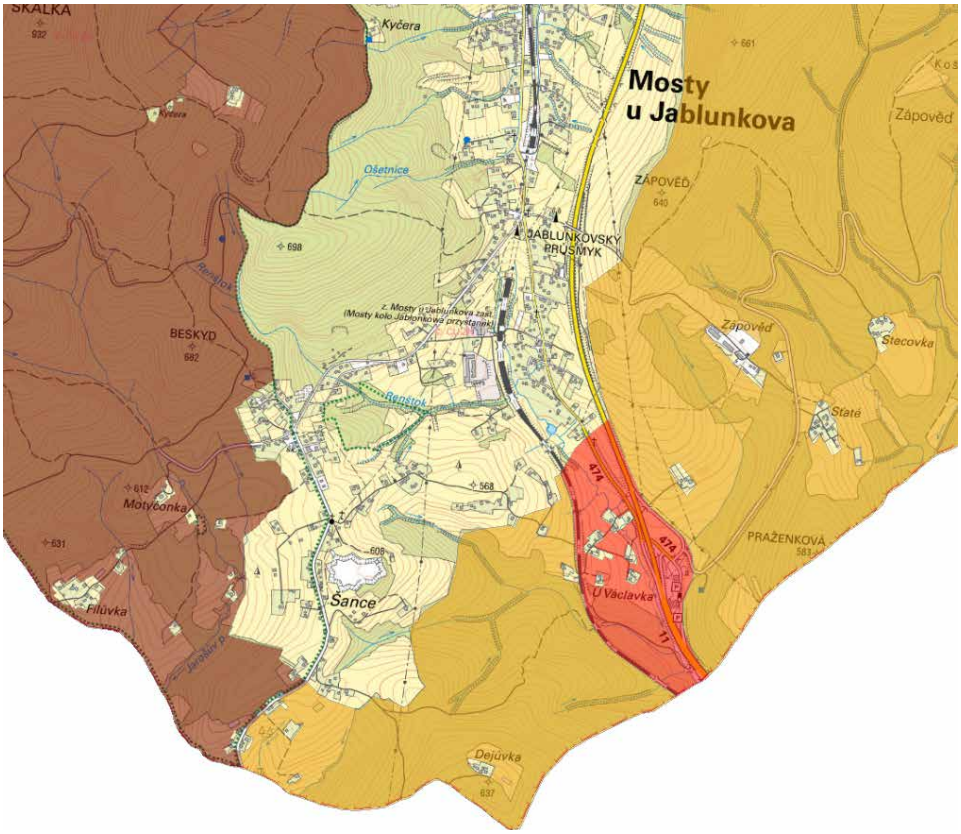

Fig. 02.

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

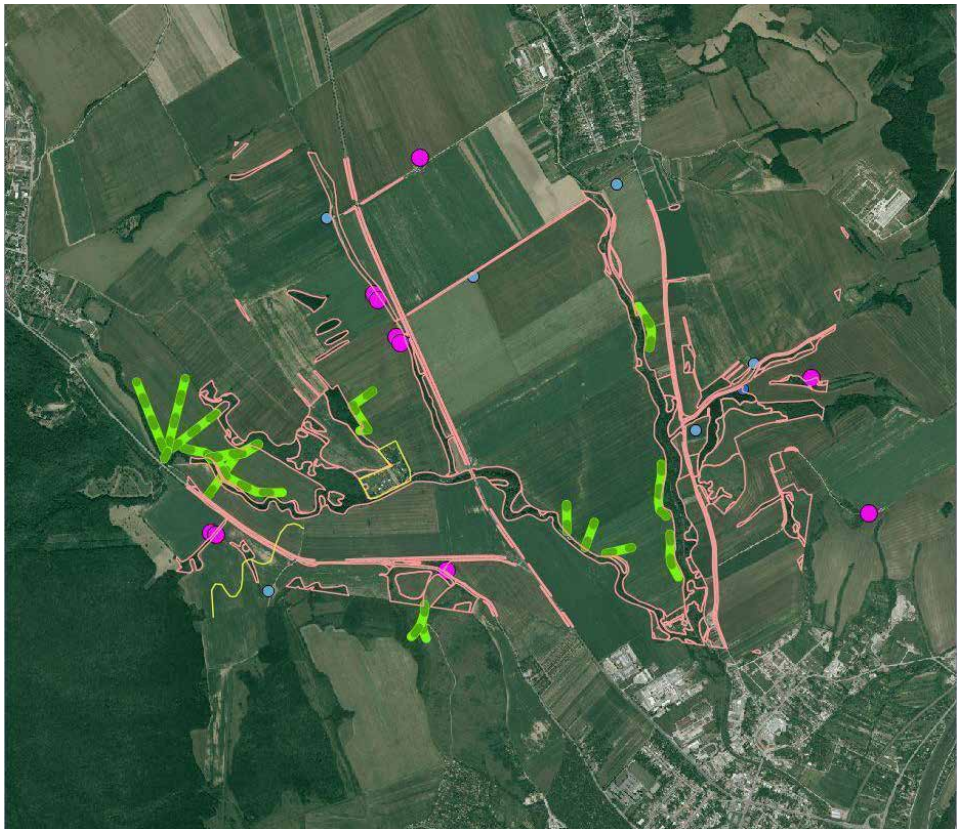

Fig. 03.

Example of data sets obtained through field mapping. Animal presence data include point occurrence of various species (blue and violet points) and movement/migration 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.

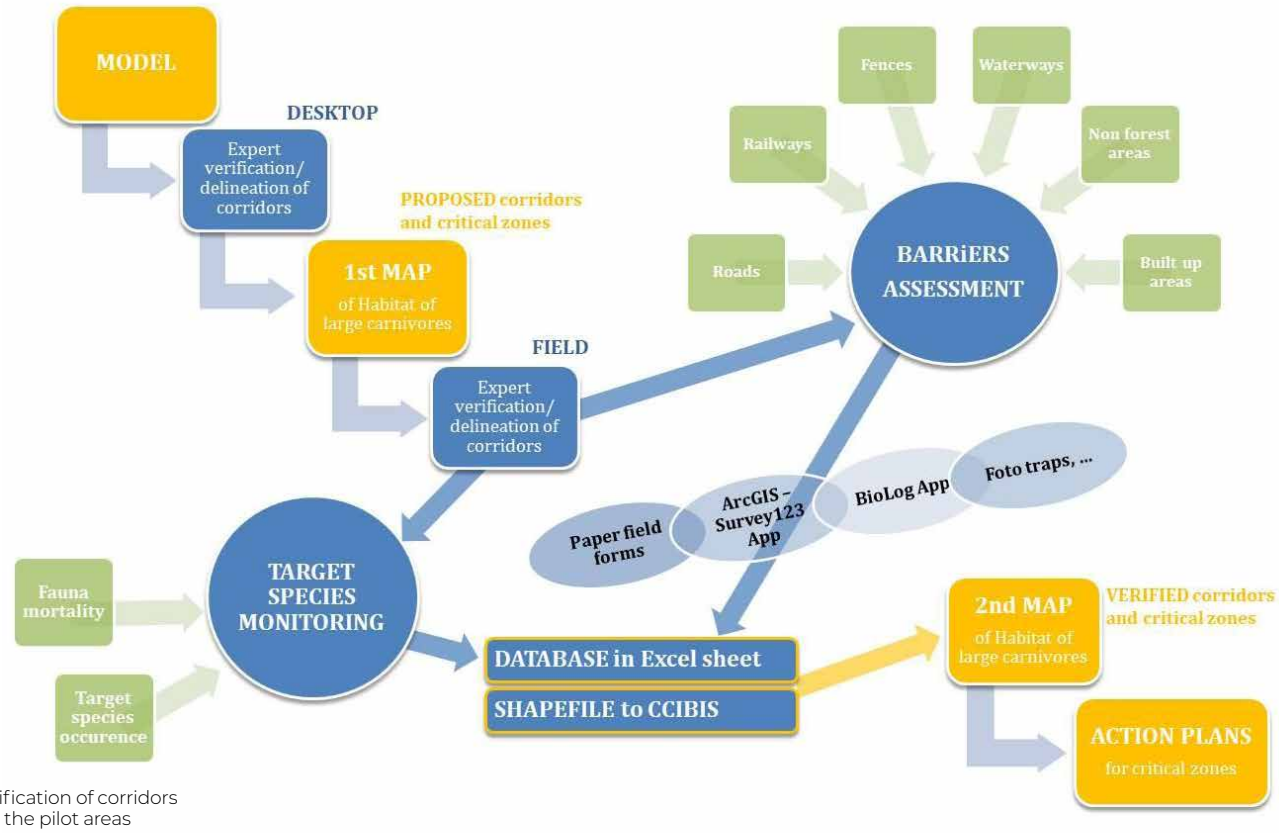

Diagram 01

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

Factsheets

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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

Factsheet 1

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 like wolf, lynx and bear, also the data for red deer are used.

Data of occurrence					
Species	**Type**	**Spatial scale**	**Availability**	**Owner**	**Specific**
Wolf	Telemetry	National	Free		Date/time of sample
		Regional	License		Genetic data
		Local	Not available/private		
	By chance	National	Free		Date/time of sample
		Regional	License		Genetic data
		Local	Not available/private		
Others/note:					
Lynx	Telemetry	National	Free		Date/time of sample
		Regional	License		Genetic data
		Local	Not available/private		
	By chance	National	Free		Date/time of sample
		Regional	License		Genetic data
		Local	Not available/private		
Others/note:					
Bear	Telemetry	National	Free		Date/time of sample
		Regional	License		Genetic data
		Local	Not available/private		
	By chance	National	Free		Date/time of sample
		Regional	License		Genetic data
		Local	Not available/private		
Others/note:					
Red deer	Telemetry	National	Free		Date/time of sample
		Regional	License		Genetic data
		Local	Not available/private		
	By chance	National	Free		Date/time of sample
		Regional	License		Genetic data
		Local	Not available/private		
Others/note:					

Factsheet 2

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	Land cover	National	Free		
		Regional	License		
			Not available/private		
	Forest density	National	Free		
		Regional	License		
			Not available/private		
	Digital elevation model	National	Free		
		Regional	License		
			Not available/private		
	Vertical heterogeneity	National	Free		
		Regional	License		
			Not available/private		
Others/note:					
Barriers	Infrastructure	National	Free		Road classes/railway
		Regional	License		Traffic intensity
			Not available/private		Planned construction
	Settlement	National	Free		Intensity of built-up areas (imperviousness)
		Regional	License		
			Not available/private		
Others/note:					

Factsheet 3

Collecting of occurrence data

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

An excel sheet was created in order to record 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 the Standards for monitoring 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 4

Inventorying barriers in corridors and critical zones (field)

Purpose of these Factsheets is to provide standardized forms and procedures 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 also be recorded to a 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/stone
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/stone
C - Concrete
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˚

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
M - Meadow
AL - Arable land

Orientation (in relation to the corridor)
L - Longitudinally to 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 landa

Orientation (in relation to the corridor)
L - Longitudinally to 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

Percentage 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

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
Ecnr	ecoduct (without road)
Ecur	ecoduct with unpaved road
Ecpr	ecoduct with paved road
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	Longitudinaly 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: .....
Date: .....

Organisation: .....
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
Ecnr	ecoduct (without road)
Ecur	ecoduct with unpaved road
Ecpr	ecoduct with paved road
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	Longitudinaly with the corridor (180°)
P	Perpendicularly to the corridor (90°)
D	Diagonally to the corridor 45°

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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 kindergarden
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	Longitudinaly 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
W	wineyard
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	Longitudinaly with the corridor (180°)
P	Perpendicularly to the corridor (90°)
D	Diagonally to the corridor 45°

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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

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Factsheet 5

Assessment of critical zones

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

Mappers in the field will fill in this standardized form in order to bring a complex picture of the area. A holistic view during the assessment is necessary; a mapper thinks about causes and consequences and besides describing the 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 the definition of Biotope of selected specially protected species of large mammals in the Czech Republic[7].

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

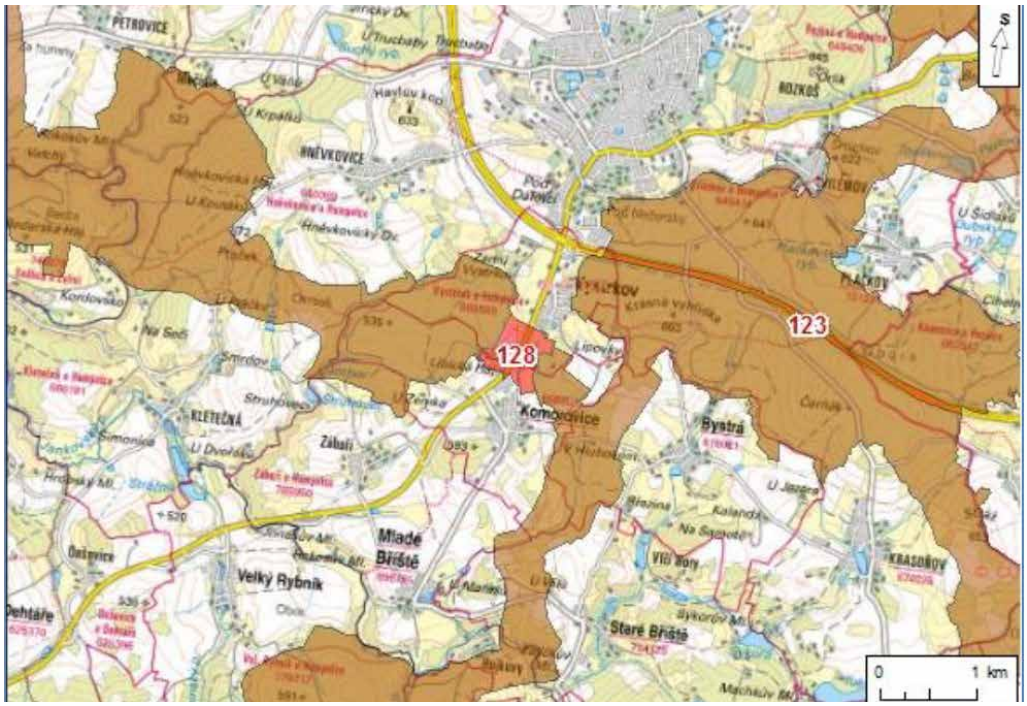
Descriptive form of a critical zone

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:

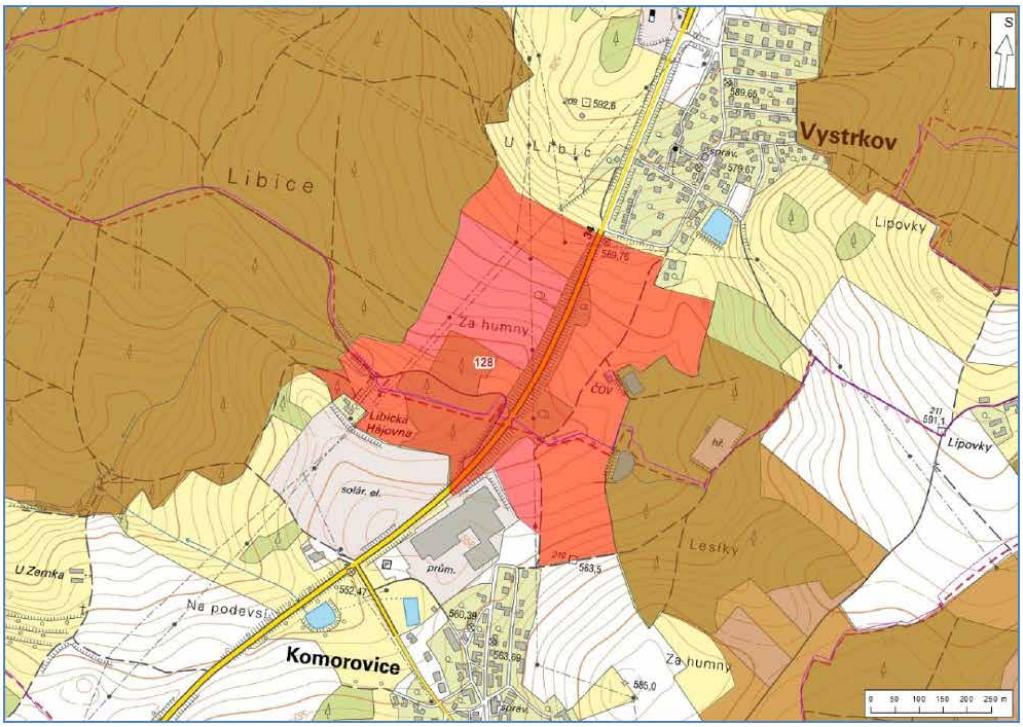
1. Map 1 : 50 000 including corridor delineation



© Anděl Gorčicová / EVERNIA

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

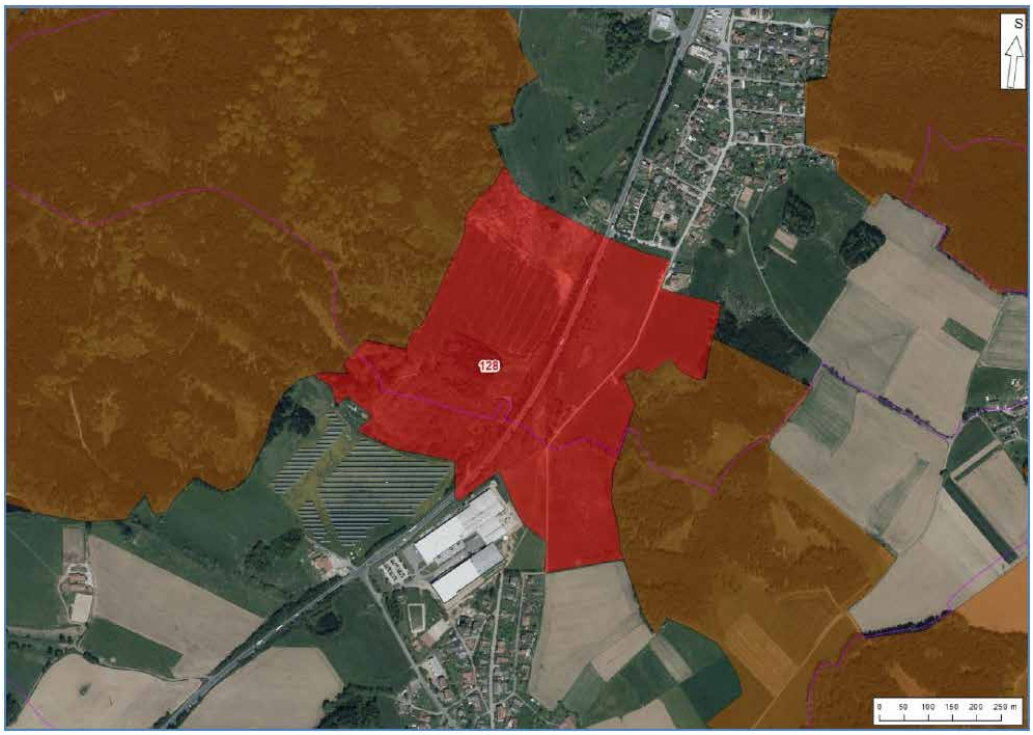
2. Detailed map 1 : 10 000. Including delineation of corridors (In CZ use ZM10)



© Anděl, Gorčicová / EVERNIA

3. Detailed orthophoto map 1 : 10 000

» Delineation of corridors
» Real migration paths used by animals (missing in this photo)



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4. At least 3 descriptive photos

© Ivo Dostal, Czech Transport Research Centre

Supporting documentation


© Dragana Milojkovic

SD 01
Introduction to the Carpathians

SD 02
Previous projects and initiatives

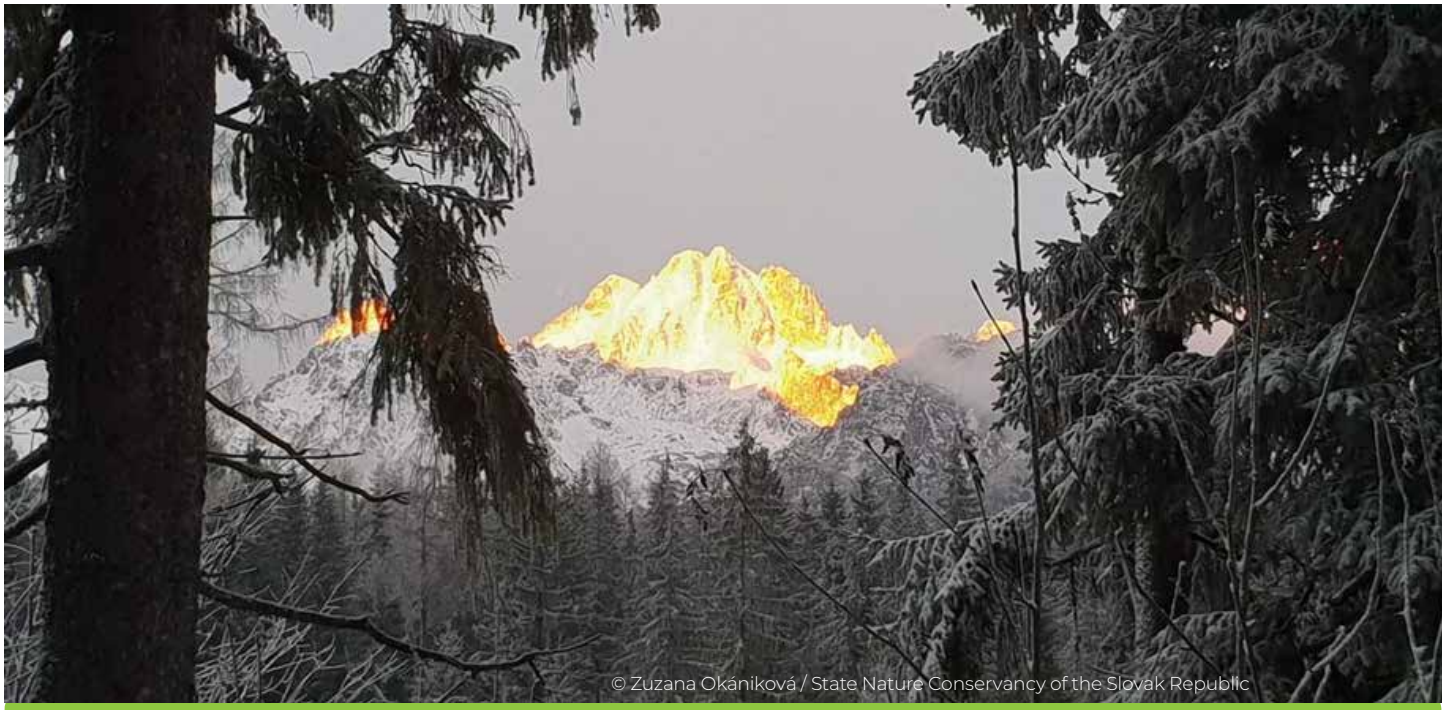
SD 03
Connectivity, fragmentation – background information

SD 04
Target species

SD 05
Barriers

SD 06
Measures for securing the connectivity

SD 07
Monitoring of the connectivity measures



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SD01 Introduction to the Carpathians

THE CARPATHIANS

The Carpathians are the longest and most rugged mountain range in Europe (Kadlečík ed., 2016). The Carpathians stretch across eight countries – the Republic of Austria, the Czech Republic, the Slovak Republic, the Republic of Poland, Hungary, Ukraine, Romania and the 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 provides 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. Rapid development of the region over 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 the continuity and connectivity of habitats and species, the cooperation of contracting parties in developing an ecological network in the Carpathian Mountains and the 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 the 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 by the Secretariats of both Conventions. Several projects have been developed and implemented over the last decade, in order to facilitate the implementation of these principles.

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 (the Czech Republic, the Slovak Republic, Romania, the Republic of Poland, and Hungary) designated their sites to the Natura 2000 network. The Emerald network (Bern Convention) also plays an important role in building the ecological network throughout Europe.

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

SD02 Previous projects

There are various programmes run within 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 the Danube River basin) focused on the improvement of ecological connectivity and prevention of landscape fragmentation.

The ConnectGREEN project takes over the best results and best practices from previous or parallel implemented relevant projects and seeks to progress towards the conceptual solutions for both nature protection and spatial planning at 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 ConnectGREEN project is interlinked with.

BioREGIO

The project of *Integrated management of biological and landscape diversity for sustainable regional development and ecological connectivity in the Carpathians*[8] (implemented between 2011 and 2014) facilitated the 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 built on the GIS model and completed by site visits in the pilot areas (Köck et al., 2014). The Habitat Suitability Model was used while applying the ArcGIS 10.0 tool Corridor Designer, allowing for the assessment of habitat quality for the selected species. This model serves as a basic layer on which the most probable corridors (least cost paths) for species migration were identified. Once the suitability model was created, the 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 the ArcGIS 10.0 tool Linkage Mapper. The tool identified adjacent core areas and created maps of least-cost corridors between them. The result of how these tools were applied is a network of least-cost pathways. The resulting value of each grid cell expresses the level of connectivity between core areas and indicates which routes encounter more or fewer features facilitating or impeding dispersal for the umbrella species in the study area (Favilli et al., 2013). Within the project, the analysis was conducted for several species, including Eurasian lynx, grey wolf, brown bear, Eurasian otter, western capercaillie, chamois and European hare. Habitat suitability models were produced for each 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 that ought to be protected (Köck et al., 2014).

8 *http://www.bioregio-carpathians.eu*

TRANSGREEN

The TRANSGREEN project[9] (*Integrated Transport and Green Infrastructure Planning in the Danube-Carpathian Region for the Benefit of People and Nature*; January 2017 - June 2019) contributed 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 contributed to improved plans and security planning for transport infrastructure projects while taking green infrastructure into account, and deepened the coordination and cooperation of relevant stakeholders. Practical solutions for an environmentally friendly and safer transport network in the Carpathians were elaborated and implemented within the project.

COREHABS

The COREHABS project[10] (*Ecological corridor for habitats and species in Romania*) is located all over the territory of Romania and includes both territories inside and outside the protected areas. The project identified, analysed and promoted ecological corridors nationwide. The project included the development of methodologies to establish ecological corridors, including the designation criteria for them, identification of critical areas and the training of specialists for their better management and monitoring. The COREHABS project provided effective mechanisms for identifying, evaluating, monitoring and managing the connecting elements (corridors, areas of passage, etc.), while enabling the development of a coherent network of the protected areas.

ECONNECT

The ECONNECT[11] project (*Restoring the web of life*) was striving towards an ecological continuum across the Alps. Therefore, besides the 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 not only considered the purely naturalistic aspects (e.g. 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 paid to the regions high in biodiversity value, in order to establish and increase the links between them and towards other neighbouring eco-regions (e.g. the Mediterranean or Carpathian regions).

AKK - THE ALPINE-CARPATHIAN CORRIDOR

The aim of the AKK projects[12] was to safeguard the ecological connectivity between the Alps and the Carpathians within the CENTROPE region. The projects strengthened the conservation management for the protected areas along the Alpine-Carpathian Corridor and neighbouring habitats. The strategy was to secure migration and genetic exchange among wildlife populations through construction of eco-ducts (green bridges) over motorways in Austria and Slovakia, creation of suitable habitat patches or stepping-stones for migrating animals and through increased public awareness (Valachovič, 2015).

JECAMI

JECAMI is a framework – *Joint Ecological Connectivity Analysis and Mapping Initiative*[13] JECAMI is a web application based on Google Maps API, built by the Swiss National Park to help users analyse the connectivity and barriers of the landscape and to assess an area based on very specific criteria. The application was initially created using version two of Google Maps API in 2010, and recreated using Google Maps API v3 in 2014. JECAMI incorporates a set of methodological ecological connectivity approaches. The tool is enhanced by exhaustive documentation on data and methodology, as well as geo processing tools, which allow the user to analyse certain areas in detail or calculate a path of a specific animal across its habitat. In order to stimulate discussion on structural and functional connectivity, JECAMI allows for a

9 *http://www.interreg-danube.eu/approved-projects/transgreen*

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

11 *http://www.econnectproject.eu/cms/?q=homepage/en*

12 *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*

13 *https://www.jecami.eu; https://www.alpine-space.eu/projects/alpbionet2030/en/home*

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.

COMPLEX APPROACH TO THE PROTECTION OF FAUNA OF TERRESTRIAL ECOSYSTEMS FROM LANDSCAPE FRAGMENTATION IN THE CZECH REPUBLIC

The primary objective of the project[14] 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 a way that allows their practical application in urban planning, especially as underlying analytical documents for urban planning. When this objective is reached, it 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 landscape connectivity, both by informing the general public about this issue and by improving the decision-making processes thanks to the presentation and providing access to the resulting methodological materials to professionals and state administration.

TERRITORIAL SYSTEM OF ECOLOGICAL STABILITY (TSES) IN SLOVAKIA

The landscape planning approaches in Slovakia began in the 1980s with the introduction of the LANDEP (Landscape Ecological Planning) methodology, which represented an integrated approach to optimize the landscape structure and composition, aiming for the balance between socio-economic activities and natural conditions, thus ensuring sustainable use of natural resources. Currently, the elaboration of Territorial System of Ecological Stability (TSES)[15] 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 TSES 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.

TERRITORIAL SYSTEM OF ECOLOGICAL STABILITY (TSES) OF THE CZECH REPUBLIC

The Territorial System of Ecological Stability has a long history in the Czech Republic as well[16]. 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 that maintain a natural stability. In addition, the issue has also been included in the country's spatial planning legislation, i.e. the Building Act. From the viewpoint of spatial planning, the TSES is one of the natural limits of land use within the particular territory, which has to be identified and considered during the spatial planning procedure. Therefore, the TSES acquires a general obligatory character within the process of approving the land-planning documentation. In practice, the ecological network should also be considered when elaborating proposals for comprehensive land consolidation/re-plotting and the Forest Management Plan.

THE ECOLOGICAL NETWORK HUNGARY NÖSZTÉR PROJECT

As an implementation of the EU Biodiversity Strategy 2020, the NÖSZTÉR project

14 https://www.ochranaprirody.cz/druhova-ochrana/ehp-fondy/ehp-40-fragmentace-krajiny/
15 http://www.sazp.sk/zivotne-prostredie/starostlivost-o-krajinu/zelena-infrastruktura/uzemny-system-ekologickej-stability-uses.html
16 https://www.mzp.cz/cz/uzemni_system_ekologicke_stability

(KEHOP-4.3.0-15-2016-00001)[17] aims to map the entire Green Infrastructure (GI) and its elements in Hungary. Within the 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 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.

HARMON: HARMONI-ZATION OF GREEN AND GREY INFRASTRUCTURE IN DANUBE REGION

The aim of the project[18] 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. The project aimed to contribute to achieving the TEN-G (Trans-European Network for Green Infrastructure) goal.

The primary deliverable of the project was the document: Moț, 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.*

ECOLOGICAL CONNECTIVITY IN THE DANUBE REGION[19]

The main output of the project is the study "Ecological Connectivity in the Danube Region"[20]. The objective of this study is to implement the EU strategy on Green Infrastructure within the area of the EUDSR and thus 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 Basin was analysed, mainly the spheres of connectivity at land, water and air. The study provides a sound foundation of 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 elaborating particular 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 of the status quo regarding projects and national objectives in the individual states in the Danube River Basin; overview of cooperation among countries; overview of 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 specific measures and projects; overview of similar experience 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 et al., 2018).

GUIDELINES FOR CONSERVING CONNECTIVITY THROUGH ECOLOGICAL NETWORKS AND CORRIDORS

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

The Guidelines for conserving connectivity through ecological networks and corridors were finalized and published in 2020 (Hilty et al., 2020)[21] to help guide the global shift in conservation practice from that of individual protected area conservation to that of large landscape in the context of jurisdiction, terminology, to provide clarity about the purpose of ecological networks for conservation and to define the physical spaces that work in connecting protected and conserved areas. The Guidelines will help the planning, decision-making, and management of ecological network conservation.

17 http://www.termeszetvedelem.hu/kehop-430-15-2016-00001
18 http://www.interreg-danube.eu/Seed Money Facility project: HARMON
19 Danube Transnational Programme, Danube Region Strategy
20 https://nature.danube-region.eu/the-study-ecological-connectivity-in-the-danube-region/
21 https://portals.iucn.org/library/node/49061


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SD03 Connectivity and fragmentation

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 yearly 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 for extended transport networks and crucial changes in land use may increase the risk of landscape fragmentation, limiting the dispersal and 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 that require large habitats, have low occurrence density 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 does not only foster 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., 2013). 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 piece of landscape is well interconnected when organisms or natural ecological/evolutionary processes can readily move across 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. The ones commonly used in conservation science are four major types of connectivity (Worboys et al., 2010):

- Habitat connectivity – connecting patches of a suitable habitat for a particular species or species group,
- Landscape connectivity – connecting patterns of vegetation cover within 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 on a larger scale.

Ecological connectivity can be regarded from a structural or functional perspective. Structural connectivity describes the shape, size and location of features within 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 & Jodi, 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 the spatial planning processes. Nonetheless, functional connectivity has to be considered as far as 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 the originally well-connected habitats and has several ecological effects on nature, among the most important being the 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 a 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 animals and vehicles also represents a very significant negative effect to biodiversity caused by economic development. Direct mortality depends on several factors, roads density including. The number of animals killed on roads and rails is reaching such high values that it is endangering the survival of local populations or even of some sensitive species in particular parts of Europe. Traffic safety for people as well as material damage both play an important role in searching for long-term and efficient solutions.

Fragmentation is a dynamic process, generally human-induced that divides natural environment into more or less disconnected fragments, thus reducing its original surface area. It also affects the physiology, behaviour and movement patterns of many plant and animal species (Debinski & Holt, 2000). It is a process linked to a 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 and begin to be apparent, it is usually too late. The landscape is already irreversibly altered and corrective measures are either financially too demanding or totally impossible.

Fragmentation of originally coherent and continuous areas into isolated islands can have fatal consequences on the population survival in a long-term perspective. Fragmentation of land mostly impacts the species that inhabit protected natural areas, have considerable requirements for the 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 built-up any further.

To understand fragmentation as the 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 principal aim;
4. Green and Grey Infrastructure as the main crossing point and conflict areas;
5. Sustainability as the primary objective; and,
6. Avoidance and Mitigation as the main solution (*the mitigation hierarchy includes avoidance – mitigation – compensation as the basic three options. However, and especially when avoidance is selected to avoid intersect an important/protected area by TLI, 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 of 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 to the development of TLI are 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 remain.
2	Habitat fragmentation	Main cause of the problems	The lack of genetic exchange is caused by the habitat fragmentation in 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

The 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 areal models 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 a way that intensively used areas are balanced by natural zones that function as coherent, self-regulating units. The approaches 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 on 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 important for 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.

It is well established that ecological connectivity cannot be only limited 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 to consider connectivity on a larger scale, but it is fundamental to act at local scale, because the loss of local connectivity also has 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, 2017).

MIGRATION

Animals need to relocate for three different reasons:

a) Daily movement in search for food, shelter, and breeding partners. To do 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 the animals overcome the 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 known.

What we know for sure is that the migration of these species across the 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 the necessary exchange of genes among individual sub-populations, which helps to sustain genetic variability and good conditions for populations.

CORRIDORS TERMS

Due to the different reasons and character of animal locomotion, 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 a 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 a 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).
- IUCN Guidelines (Hilty et al., 2020) define an ecological corridor as a clearly defined geographical space that is governed and managed over the long-term to maintain or restore effective ecological connectivity, and has its detailed explanation.

The terminology used in the context of connectivity and corridors in particular, 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 the national level is bound to legislation and there is no justification to interfere and change.

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

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

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

Within the projects of TRANSGREEN and ConnectGREEN, a definition was adopted 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 for the movement of a wide range of organisms between high natural value areas.
- **Migration corridors** – allow for animal movement (both regular and irregular) between areas of their permanent distribution (core areas).
- **Movement corridors** – allow for 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 connect 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, in order to forage, facilitate the dispersal of juveniles or encourage the re-colonisation of “empty” habitat patches
- Facilitating seasonal migration
- Permitting genetic exchange with other local populations of the same species (although this only requires very occasional contact in general)
- Offering opportunities for individuals to leave a habitat that is degrading or an area that is under threat (which may become increasingly important if the climate change proves to have a serious impact on ecosystems)
- Securing the integrity of physical environmental processes that are vital to the requirements of certain species (such as periodic flooding)

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 of when wildlife movement is no longer 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 the function of corridors is crucial in transport project implementation when implementing the mitigation hierarchy avoidance is the priority in case roads and railways are planned to intersect protected areas. This alternative demands that the choice of mitigation be implemented 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:

- 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 & 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 closer to the sense of linkage areas wider perspective.

SD04 Target species

In most mammal populations, under normal conditions, there is always a part of the population that does not keep within 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 to the survival and well-being 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 provide 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 wear (*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 for home range size is large and comprises usually hundreds of square kilometres. Their core, a 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 behaviour 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 rates, 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, with more than 8,000 bears across Romania, Slovakia, Ukraine, Serbia and Poland. Bears are important management indicators (umbrella species) for a number of other wildlife species (Linnel et al., 2007).
Reproduction and social behaviour	The breeding season is between May and June and the mother bear gives birth to 1-3 cubs (350-400 gr each) during her 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 up to two years of age. After bears reach sexual maturity (4-6 years of age in females), they start to explore suitable territory overcoming longer distances, mainly during the breeding period. They mark the large territory by urine (effluvium signs) and by bark exfoliating (visual sings). Bears belong to long-lived species; they live over 30 years in the wild (Nowak, 1999).
Food	Bears are typical omnivores. The main part of their diet composes of roots, buds, seeds and forest fruits (like berries, plums, cherries, wild pears etc.), and also insects like ants, honey from the bee nests and herbivores. The food composition varies by the season and natural food supply in the environment. At higher altitudes, they tend to consume more meat.
Role in ecosystems	As the brown bear consumes a large variety of fruits and seeds, it contributes to the dispersal of plant species, and while it also consumes fresh carcasses, it prevents the 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. Over the last decades in Romania and Slovakia, bears have penetrated lower altitudes of the beech and oak forests with sufficient food supply during the season (Findo 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 a 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 quiet places for day sleeping and foraging areas demands local movements on a daily basis and implies the crossing of the ecotone zone between forested and agricultural ecosystems by using corridors. The needs resulting from this daily movement determine the status of possibilities to cross artificial barriers as roads, especially when they are constructed in the zone of ecotones, which is a common practice in ranges with extensive valleys as in the Carpathians. The home ranges may vary significantly (40 - 400 km^2 in the Carpathians) and depend on the density of the population, anthropogenic limitations (roads), etc.
Migration	Migration behaviour of the bear variably depends on geographical areas, and even individuals have different migration behaviour patterns. Although the bear is bound to the undisturbed forest habitat, during the migration it is also tolerant to open areas with an ability to overcome anthropogenic barriers (roads, fences). There are seasonal migrations – bears following an abundant food resources, or to denning sites, female with cubs exploring adjacent territories not overlapping with dominant males, and dispersals of juveniles. The migration distance depends on the favourability of habitats, sex, bear density in the area and the age of individuals. The bear is able to overcome tens of kilometres in one day and occupy a large area during the migration process.
Main threats	Brown bears have a low reproductive rate and are very vulnerable to human-caused mortality, habitat changes and landscape fragmentation. Motorways represent the most significant barriers to the bear. Although road-kill accidents do not pose a threat for preserving this species, the planning of motorways in the Carpathians should consider the large habitat requirement of the Carpathian brown bear. Additional labelled threats, such as poaching or a decrease in suitable habitat space due to people expanding may increase the risk of conflicts with this species and have to be investigated locally. As for the wolf and the lynx, a management plan encompassing the whole of Carpathians 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 60s and 70s of the last century, the grey wolf population decreased significantly in Europe; however, the population nowadays 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 5,000 individuals (Linnell et al., 2007).
Reproduction and social behaviour	The grey wolf belongs to canines and is capable of a social family life, being organised in pack all year round. The dominant leading pair – alpha male and female usually have a privilege for reproductive advantage. The oestrous of the wolf female lasts 5-7 days a year, usually occurring between December and February. The female grey wolf breeds 1-11 cubs in a well-hidden place. The pack is mainly composed of sub-adults and young individuals 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 aggressive conflicts within the pack take place in the breeding season while splitting packs usually determines the need for dispersal behaviour of newly 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 protects actively from other packs and marks the area by urine and faeces. The grey wolf lives in the wild for 10 years. The sexual maturity occurs at age of two years and at this stage, they usually start to leave the family territory and migrate to new territories abundant in food and habitat quality.
Food	The wolf is a true generalist with opportunistic tendencies as for the food available in its habitat and is very adaptive with regards to the food scale. In the Carpathians, the grey wolf mainly preys on ungulates, occasionally also smaller vertebrates or carcasses.
Role in ecosystems	The grey wolf is the apex predator instinctively 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 and similarly to the bear consuming carcasses it 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 predominance in the mountain areas. In general, the wolf prefers low settlement density areas with decreased level of land use and 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 environmental requirements for 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 their adaptation ability, wolves can also inhabit areas with lower forest coverage rate with sufficient wetlands, meadows and pastures. Wolves are very sensitive to anthropogenic factors during the breeding season. 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 km² (Anděl et al., 2010).
Migration	In contrary to the breeding season when their tolerance to human factors is critical, wolves increase this tolerance against barriers while migrating and are able to overcome roads, non-forest areas, even the ones close to human settlements, although primarily in the nighttime or early morning hours. When leaving the pack, wolves overcome much longer distances as their common movement distance, whereby the males and females dispose of equal potential for long-distance migration. There are, however, many differences between populations and individuals in their ability to overcome migration barriers in terms of habitat quality and food availability. While migrating, wolves are able to cross tens or even hundreds of kilometres (e.g. a distance 200 km in 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 in some countries only (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 habitat and survival of wolves. 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 to drastic habitat changes and 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 the 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, and Austria.	
Occurrence and dispersal	Lynx prefers large mountain forests; nowadays it also penetrates forest areas of the hill landscape. During migration, the requirements for forest areas decrease substantially, 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 of approx. 150 – 250 km², even larger in males (Hlaváč & Anděl, 2001). Males and females live separately for the most part of the year; they only 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 regarding males. The territory of the male covers several female ranges. The oestrus of the lynx female lasts 1-3 days and the ovulation is only induced after several mating episodes with the male. The Eurasian lynx gives birth to 2-3 cubs, with a high rate of cubs' mortality (50 %). Young lynx offspring leave their mother at the age of 8-10 months; males reach sexual maturity at 33 months, female at 21 months.
Food	The lynx primarily feeds on ungulates. The main prey is represented by the roe deer, the red deer, the European hare and the wild boar, sometimes small vertebrates, foxes, 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 the mountain and sub-mountain areas. The remote rugged terrain places with a supply of refugees serve as the resting areas. 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 1,500 m a. s. l. with home ranges between 100 and 3,000 km². Lynx also inhabits lowland areas – as long as there is a big and relatively old forest complex present.
Migration	In spring, the young offspring leave the mother's territory family range and may migrate long distance in their search of the suitable territory. The migration distance differs by individuals; however, the males may have to migrate longer distances to find territories unoccupied by a dominant male, while female juveniles are tolerated in the adjacent areas by their mother and, females prefer to stay in close vicinity of the mother. The requirements for the quality of the forest habitat decrease during the course of the migration process; nevertheless, the high forest coverage is still essential (mostly 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 to hunters for roe deer and it is an attractive hunting trophy. 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	
The 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 for
Hungary	» Highly secured by Protecting Act: 13/2001. (V.9.) KöM directive about the 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 by 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 (as amended) » 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 the entire year only within 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 16 January until 31 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, 7 February 2002. The law establishes the 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

SD05 Barriers

1. MAIN TYPES OF BARRIERS

Migration barriers are generally referred to as natural and anthropogenic structures within a 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 the barrier effect and the barrier type.

Barrier strength is defined as its resistance, whereas permeability represents the contrary quality. As for 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 for 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 viewpoint, may be perceived as definite. By contrast, certain fences constitute a temporary obstacle and may still be managed consequently. Thus, when environmental impacts are still under assessment, it is crucial to consider whether or not 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, (especially altered) rivers and water areas, etc.)

Permeability of 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 of higher and lower classes (including different purpose roads such as touristic/cycling roads) and railways. These linear barriers intersect the landscape and in essence have two negative impacts on 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 road type and transport intensity in combination with the status and distribution of local wildlife population. In general, despite the lower transport intensity on the lower class roads, the total mortality is higher on the lower class roads given by a higher total number of kilometres of this road category and due to the higher number of attempts to cross these not-completely-fenced roads. On the contrary, a unit relative mortality (e.g. 1 km of the road) is highest on the highways because of high traffic intensity (Anděl & Hlaváč, 2008).

Barrier effect is more obvious on fenced highways or on higher-class roads and highways. On the other hand, unfenced lower class roads with high volume of traffic operate as “alive” vehicle fences, thus have a stronger barrier effect because in some sections they are almost impermeable 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 impact of the 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.). This negative impact is accentuated by their irreversible character. As long as such objects exist, it is hard to find any practical measure that could make the barrier permeable for fauna (Anděl et al., 2010). As far as migration of the large carnivores is considered, 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. The 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 inconstant). In general, large carnivores have a better ability to overcome barriers in the form of various fences than the ungulates, which in the case of electric fence barrier often suffer a conditional psychological block that prevents them from overcoming the barrier. Another important factor is the durability (permanency) of the installed fence. Fences installed in pastures are usually removed or at least disjoined after the grazing period. Fences only represent only a potentially temporary barrier. This is a certain advantage compared to some other barrier types as the fences serve as a relatively easily removable barrier with low cost removal (Anděl et al., 2010). In case of fences, the landscape permeability measures can be considered.

Water courses and other water bodies

Water bodies facilitate the migration of species across a landscape and create one of the most important structures in the ecological network

within a landscape. Watercourses and water bodies form a 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, although 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, these 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 thus animals avoid them. This again induces the creation of further territorial barriers for migration or spreading out of the target species. With regards to the species connected to 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 in order to recognize the scale of the problem of reducing ecological connectivity globally on a 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 pose a significant obstacle. This barrier type is mainly considered for the cumulative barrier effect.

2. ASSESSMENT OF BARRIERS

Practical assessment of barriers should consider 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 on the species of interest, location, technical solutions, wildlife/migration corridor, other concurrent environmental and landscape qualities, etc. The barrier importance is not only the question of its dimensions. An otherwise functional wildlife/migration corridor may be completely discontinued by a wall surrounding a fence or by a single family house. These types of barriers represent rather simple spots in the landscape and cannot be assessed merely based on the map analysis. Each barrier in a wildlife/migration corridor has to be addressed individually and directly on the spot and its effect has to be evaluated in an overall cumulative impact in case multiple barriers happen to exist. General maps of migration barriers are more of an indication importance and allow to determine potentially threatened locations.

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

1. **C1 - Critical impermeability**
2. **C2 - Middle impermeability**
3. **C3 - Low impermeability**
4. **P - Permeable**
5. **PF - Fully permeable**

This critical rate of barriers (C/P) is given by the technical parameters and also by combination of partial barriers that separately would not present a significant threat to the connectivity. Each crossing of the biotope with a barrier is evaluated individually based on the specific data for the particular location as well as for the individual species. Categorization of barriers in the matrix serves as a supportive tool for mappers. In order to determine the 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 might 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 to wildlife/migration corridors, highways and road network in particular. This barrier effect is determined by a combination of the following three factors: (i) the existing 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 the case of planned roads, an avoid fragmentation approach has to be adopted, while in the case of existing roads a defragmentation approach needs to be implemented to recover the ecological permeability of wildlife/migration corridors. If the pairing or parallel development of existing and new roads is at stake, cumulative impacts need to be considered while taking the appropriate mitigation measures. The assessment of the barrier effect itself focuses on the technical solution and traffic flow (with a retrospective evaluation of the route) in locations where roads cross the Habitat suitability patches (core areas and stepping stones – see chapter 5).

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

Highways, expressways and other roads (mostly multi-lane) characterized by multi-lane high intensity traffic and accompanying technical measures (fences, noise walls, etc.) are considered as important obstacles. Sometimes also a road with a single lane but with high traffic intensity is considered as a significant barrier. Other categories of roads (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, at a specific time during the day, the permeability might be better and in some locations the traffic on the weekends can decrease significantly, thus the average data should still 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 constructing a 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 a critical point. In such case, the corridor is evaluated as permeable for a group/s of species, depending on the object's characteristics.

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 vehicles 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)

Railways

Similar to 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 in 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.

Railways acting as a primary migration barrier are relatively rare in the project area. It concerns railways with accompanying technical elements (abutment walls, steep embankments, etc.). Traffic intensity on rails in the Carpathians is not so high as compared with 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 a technical solution in sites 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.

Water objects represent a 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 the cumulative barrier in the landscape.

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)

Matrix 3 - Classification of watercourses and other water bodiesby their permeability for large mammals		
Class	**Size of water body**	**Technical solution on banks structure / Technical parametersof 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)

Fences

Since fences vary enormously in type and application, 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) a permeable distance between two fenced areas, (ii) technical parameters of the fence.

Fences have a similar barrier effect as settlements. For instance, fenced hunting areas, munition stocks and similar zones with high fences are considered as impermeable barrier. The pastures fences, however, can in certain cases be highly permeable and even dismantled in the non-use period. The use of the electric fences depends on the character of the land

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)

and connecting type of the land use, 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 a 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 the assessment of 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 kilometres long and consists of intensively managed arable land is considered as a 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 courses.

Settlements/built-up areas

Urban built-up areas are generally considered as a 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 unfavourable 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.

Settlements (living areas, commercial and industrial zones, etc.) represent an impermeable anthropogenic barrier. The only way to overcome this barrier is to pass

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)

it at 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 hill-foot settlement. Many studies, however, showed/proved that large carnivores are quite tolerant during the migration season. The threshold values for barrier effects are shown in the Matrix 6. A similar problem related to settlements is represented by potentially developing areas, which are to be considered as a future impermeable barrier.

2.2 The cumulative effect of barriers

Individual barriers may have a cumulative effect. High density of at least 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 in 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 locations, areas that pose a more potential threat as a whole should be identified. With the support of habitat modelling, core areas and critical points at the national level can be illustrated in maps providing an overview of land fragmentation/connectivity at the national and supranational levels.

The categorization of barriers described in the 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 a brief description of barriers concerned:

- HIGHWAYS – highway, high-speed roads and multi-lane 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

The permeability of a barrier is not only influenced/determined by the possibility of crossing. A number of other disturbing anthropogenic processes contribute to the barrier effect (light, noise and smell from the traffic, human activities in the vicinity of settlements, etc.) with very difficult quantification of their influence. The extent has not been proven yet to which particular stress factors influence the migration of species. It is assumed that the resistance of migrators is a reaction to the overall effect of migration barriers. Note that species ethology and behavioural ecology may play an important role 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.

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

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

SD06 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, in order 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 such as infrastructure,

energy and mining (CBD COP14 2018, Decisions 14/8 and 14/3).

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

The main risk of linear transport infrastructure primarily is represented by the fragmentation of large carnivore populations and direct mortality of animals. The fragmentation mitigating measures, however, are often contraindicative for measures preventing mortality (e.g. fences). It is therefore necessary to combine the measures (e.g. fences) with a sufficient number of overpasses or other mitigation objects to support 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 the risk of collisions between vehicles and animals and also to lower the disturbing effects of traffic on fauna.

Large carnivores occur in large areas with 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 kilometres 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 the permeability of transport infrastructure for these species. First of all, it determines the density of passages which will be sufficient for a long-term survival of the species. This issue is often questioned as for the efficiency of the wildlife passages. With small population abundances, the frequency of using the passages is often low, which tempts to view 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 a frequent discussion topic. Recommendations vary in different areas, which can partly be caused by specific environmental conditions and different behaviour of animals in these areas. Another important factor that needs to be considered in the case of large mammals is the traffic safety, since collisions with these animals are very dangerous for vehicle passengers.

Measures to reduce the 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 INFRA-STRUCTURE (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 further 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.

The 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 the

ecosystem level. This requires the simulation of the habitats on either side of the infrastructure on the overpass, considering vegetation and environmental factors such as the soil type, humidity, temperature and light. This for example means that the connection between forests requires at least elements of similar forest habitat on the overpass. Wildlife overpasses also naturally 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 in 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 the barrier effect.

This measure, although not overly costly, has so far been overlooked, and is of real importance especially in flat agricultural landscape lacking 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 for the connection of entire ecosystems and are thus 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 especially suitable 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 a limiting factor for some groups of species (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 by the indication of Openness Index (O. I. = Width * Height / Length). The higher the OI, the more effective the underpasses are in wildlife permeability.

Adoption of the bridge objects in the phase of project/construction documentation development can lead to construction of fauna passages that also fulfil criteria 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 essential importance in reducing the barrier effect of roads. The basis lies in keeping a strip with natural surface for migration.

B.1 MEASURES PREVENTING ANIMALS TO ENTER INFRA-STRUCTURE

Fences

Fencing limits animals to enter a road, and is currently the principal 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 the case of lower category roads, fencing is recommended only in critical places with high risk of collisions between vehicles and animals. Fencing increases the barrier effect of the road and thus 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-the-top overhang 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 entering 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 entering the communication from one side 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 pose a complete barrier for all terrestrial animals.

Non-transparent screens

Noise barriers built of concrete, wood or other material represent complete barriers for animals. In natural environments, they must therefore be combined with fauna passages. This has also needs to be considered 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. This way they completely isolate the road verges from the surrounding habitats. For small animals, especially invertebrates, they are thus a more complete barrier than fences. No experience exists as for 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 do not 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 of 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 constructed.

B.2 MEASURES WARNING ANIMALS OF TRANSPORT INFRASTRUCTURE OR OF APPROACHING VEHICLES

Artificial deterrents

Artificial deterrents aim to keep mammals away from roads or railway lines. This group of measures

includes the ones that modify the behaviour of animals so that they are able to spot the coming vehicle or train soon enough. These measures are primarily targeted at deer. Various systems exist based on optical, acoustic or olfactory work principle. 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., 2019).

B.3 MEASURES WARNING DRIVERS ABOUT APPROACHING ANIMALS OR ABOUT ACCIDENT RISK SECTORS

Warning signs and warning systems with sensors

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

- Wildlife warning signs should only be placed where there is a high risk of collisions, because the more widespread they are, the less attention people pay 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 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 have proven to be less effective.

Increasing visibility

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

This primarily includes cutting down trees and bushes in the immediate surroundings of the communication, so that drivers can spot 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 – a grassy belt is usually left on the sides. Lower category roads 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 helps animals avoid these areas. However, lighting has negative effects on other species such as insect and bats; therefore, this measure cannot be generally recommended.


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SD07 Monitoring of the connectivity measures

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

Monitoring methods described below represent a list of possible methods and this list 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 is a complementary project to the TRANSGREEN project. Within the TRANSGREEN project was developed a Guideline of "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 with 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 the subject of evaluation and common methods of monitoring related to the animal group "large carnivores".

The subject of evaluation consists of:

- 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 in snow and mud
- Phototraps and cameras
- Direct observation (bear – long-term network of observation places in 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 – a 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 ecosystems as well as 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 – a peripheral area 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.

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 – a 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 viewpoint of an individual, a species, a population or an association of these entities, for the 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 corridor – a clearly defined geographical space that is governed and managed over the long term to maintain or restore effective ecological connectivity (Hilty et al., 2020).

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

- **wildlife corridors** - allow for the movement of a wide range of organisms between high natural value areas
- **migration corridors** – allow for animal movement (both regular and irregular) between areas of their permanent distribution (core areas)
- **movement corridors** – allow for animal movement within core areas (including daily movements in search of food, etc.)

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

Ecological network for conservation – a system of core habitats (protected areas, Other Effective Area-Based Conservation Measures OECMs and other intact natural areas), connected by ecological corridors, which is established, restored as needed and maintained to conserve biological diversity in systems that have been fragmented (Hilty et al., 2020).

Ecological network for large carnivores – ecological network consisting of three main categories:

- Favourable and suitable habitat ((relatively) continuous favourable areas (assimilated to core areas) and other suitable areas)
- Movement/migration zones (linkage areas, corridors and stepping stones)
- Critical zones (critical connectivity sectors and critical connectivity areas)

Fragmentation (of landscape, habitats, populations) – a process, in which continuous landscape is further divided into smaller and smaller units that are mutually isolated, or reduced within an area. Such units then gradually lose their potential to fulfil 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 designed and managed to deliver a wide range of ecosystem services and to protect biodiversity in both rural and urban settings.

Habitat - a 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, and community.

Habitat suitability patches – areas suitable for permanent occurrence of species.

Home range – an area regularly used by an individual, where it satisfies its basic needs.

Land use/spatial planning – an activity aimed at predetermining the future spatial usage of land and water by society. Process of spatial planning aimed to use the landscape resources in a sustainable way, while 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 a 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 also applies 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 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 EU 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 a 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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Danube Transnational Programme
ConnectGREEN

ConnectGREEN DTP2-072-2.3

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

Project partners:

Romania: WWF Romania (Lead Partner) · National Institute for Research and Development in Constructions, Urban Planning and Sustainable Spatial Development · Piatra Craiului National Park Administration

Austria: WWF Central and Eastern Europe

Czech Republic: Nature Conservation Agency of the Czech Republic · Silva Tarouca Research Institute for Landscape and Ornamental Gardening

Hungary: CEEweb for Biodiversity · Hungarian University for Agriculture and Life Sciences (formerly Szent Istvan University)

Slovakia: Slovak Environment Agency · The State Nature Conservancy of the Slovak Republic · Slovak University of Technology in Bratislava – SPECTRA Centre of Excellence of EU

Serbia: Institute of Architecture and Urban & Spatial Planning of Serbia · National Park Djerdap

Associated Strategic Partners

Czech Republic: Ministry of the Environment · Ministry of Regional Development of the Czech Republic

Hungary: Bükk National Park Directorate

Romania: Ministry of Environment of Romania

Serbia: Ministry of Agriculture and Environmental Protection of the Republic of Serbia

Slovakia: Ministry of Transport and Construction of the Slovak Republic

Ukraine: Ministry of Ecology and Natural Resource of Ukraine

Austria: Danubeparks – Danube River Network of Protected Areas

France: Alpine Network of Protected Areas – ALPARC

Montenegro: Parks Dinarides – Network of Protected Areas of Dinarides

Pilot Areas

1. Piatra Craiului National Park – Bucegi Nature Park (Romania)
2. Apuseni-SW Carpathians (Romania) / National Park Djerdap (Serbia)
3. Western Carpathians (Czech Republic – Slovakia)
4. Bükk Natiaonal Park (Hungary) / Cerová vrchovina Protected Landscape Area (Slovakia)

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