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Wildlife and Traffic in the Carpathians

Guidelines how to minimize the impact of transport infrastructure development on nature in the Carpathian countries

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Part of Output 3.2 Planning Toolkit

TRANSGREEN Project "Integrated Transport and Green Infrastructure Planning in the Danube-Carpathian Region for the Benefit of People and Nature"

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About TRANSGREEN

TRANSGREEN means a better connected Carpathian region with transport infrastructure that takes nature into account. The project aims to contribute to safer and environmentally-friendly road and rail networks that are being developed in the Czech Republic, Hungary, Romania, Slovakia, and Ukraine. www.interreg-danube.eu/transgreen

Output 3.2 Planning Toolkit consists of the following parts:

- Wildlife and Traffic in the Carpathians - Guidelines how to minimize the impact of transport infrastructure development on nature in the Carpathian countries
- TRANSGREEN Policy Recommendations on integrated road and rail transportation planning in the Carpathians
- State of the Art Report and Gap Analysis in the field of environmentally-friendly transport infrastructure development
- Keeping Nature Connected – Environmental Impact Assessment (EIA) for Integrated Green Infrastructure Planning
- Public Participation – Scheme for an integrated linear transport infrastructure development/ planning
- Tool for registering animal-vehicle collisions

Table of contents

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

FOREWORD

The Carpathian Mountains are an ecological backbone of the Danube region and provide a significant contribution to Europe's green infrastructure. These mountains are composed of fragile ecosystems, which can be seen both as a barrier to transportation or as a vital provider of multiple ecosystem services across our planet. Thanks to the existence of the Carpathian Convention legal framework, it is possible to pursue comprehensive policy and cooperation to guarantee the protection and sustainable development of this outstanding region of global importance.

In the Carpathians, socio-economic changes after 1989 have brought about extremely rapid growth in traffic, which then spurred increased construction efforts. As a result of this, the overall length of motorways in the region quintupled in 25 years and further expansion is expected in the upcoming years as the region demands denser, better and safer transport infrastructure.

The Carpathian Mountains host a very rich diversity of fauna and flora and harbour many ecosystems and species, which are increasingly threatened by fragmentation from infrastructure development. Roads, railways, hydroelectric dams, power lines, as well as intensive agriculture and forestry, all of these challenge the care for the delicate Carpathian mountain ecosystem and the sustainable management of the local natural resources.

The fragile environment of the Carpathian region, due to its mountainous relief, is unique for its high local diversity of habitats and species. For this reason, the loss of habitat can have greater consequences for the wildlife than in other types of landscape. Considering the wildlife connectivity early in the planning process allows to include all relevant perspectives from the beginning and avoids changes or hindrances later on.

An integrated management of ecosystems such as the mountains has the potential to improve the overall management of the natural capital, improving human well-being and the achievement of the adopted sustainable development goals at the same time. A radical shift in thinking about the ecosystem management is needed to provide a more holistic and integrated view of the links between ecosystem service delivery and human needs.

These guidelines are an effective tool for mainstreaming biodiversity into transport planning and development, not only for the benefit of nature but also of our society. In recent years, integrated approaches including concepts of 'green infrastructure' have been successfully tested and implemented in the Carpathians through strategic projects like TRANSGREEN. This has been facilitated thanks to the adoption and ratification of legal instruments like the Protocol on Sustainable Transport to the Carpathian Convention. Green infrastructure addresses the spatial structure of natural and semi-natural areas but also other environmental features which enable citizens to benefit from its multiple services.

Finding appropriate solutions that balance environmental protection with economic growth, while ensuring the most environmentally friendly ways of building, is a key challenge for infrastructure development.

We are approaching a new milestone in designing and planning a modern and well-distributed network of roads and railways in the Carpathians. We are entering an era in which the necessity of co-existence with our natural environment is evident, rather than provoking conflicts with it. The TRANSGREEN Project results show the way towards this co-existence:

- Mitigation hierarchy – avoidance at first, only if it is not possible to avoid building a linear infrastructure in a valuable area, careful planning of mitigation measures is necessary.
- Cooperation between nature conservationists and transport infrastructure planning is of utmost importance from the early planning process.
- Monitoring before and during the construction and during the operational phase is absolutely essential, as well as monitoring performed to learn and improve the functionality of mitigation measures, such as green bridges or other constructions.
- Careful Environmental Impact Assessments are necessary.

These guidelines respect the specifications of the Carpathian region and the value of the unique nature of this region. They give general standards for minimizing the negative environmental impacts of expected transport development in the Carpathians.

These guidelines do not only concern the process of improving the environmental performance of a transport plan on an ad hoc basis. They suggest an innovative and ambitious approach, which considers the importance of an interdisciplinary cooperation between conservation and transportation sectors, in all steps of the transport processes. Today, we still have the possibility to choose the best way to invest and to make decisions for the current and future generations. **Let's do it all together!**

1 Introduction

Development of transportation brings extensive impacts on nature and landscape. When it comes to collisions with vehicles, animal mortality is undoubtedly most visible. However, transportation brings other issues as well, less noticeable at first sight. Motorways and other intensively used arterial roads and major railways create impassable barriers for animals. Such barriers then separate the originally continuous distribution areas into smaller and mutually isolated islands that are no longer able to ensure conditions for long-term survival of populations. This process, called fragmentation of the environment, is more and more becoming a serious threat.

Animal movement through landscape is a basic condition for survival of populations on covering both local daily needs and long term and seasonal demands. Especially long migrations outside of permanent home ranges are of fundamental importance. Dispersion movement of young animals pushed out of the territories of their parents and searching for their own home ranges is known for a large number of species. Sometimes even adult individuals set out for a long journey. In many species, the motivation for this migration has not yet been entirely clarified; however, it is certain that these migrations are crucial for the survival and well-being of the population. Immigration from prosperous parts of the population makes 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, and natural disasters or by anthropogenic impacts. On the other hand, migration makes it possible to discover and occupy new suitable habitats outside of the current distribution area. Immigration and emigration within a distribution area also provide the necessary genetic exchange to ensure that variability of genetic pool is maintained. The fact that individuals or even some small populations may have adapted to fragmented environment is not evidence that contradicts the general requirement for permeable habitats in the long term.

Fragmentation of populations caused by transport infrastructure therefore becomes a key issue for survival of many species. Species inhabiting large areas in relatively small numbers are threatened the most. Large mammals will inevitably belong to the most endangered species. The impact of fragmentation on populations significantly increases under the conditions of climate change, which brings modifications of habitats and by doing so it also shifts in ranges or relocations of both individuals and populations into new areas.

Fig. 1.1 Lynx belongs to species that require extensive areas for their existence. The size of each individual's home range varies between 100-300 km^2. Habitat fragmentation therefore brings a serious threat to its further survival. © Tomáš Hulík

Seriousness of fragmentation caused by infrastructure is also increased by the fact that it is an irreversible process, usually manifesting itself with a delay. Isolated populations still survive for certain time even after negative changes in their habitat have taken place. However, if we start solving the problem when the populations are already declining, it is usually too late for a successful solution.

Fig. 1.2 Fauna passages are an example of measures that aim to minimize the negative impacts of transport on wildlife. © Václav Hlaváč

The Carpathians create an area with exceptionally well-preserved landscape and unique nature within Europe. It is given by varied natural conditions, but also by still traditional use of the landscape. Especially sheep and cattle grazing, practiced here for centuries, contributed to the origin of specific habitats with great species diversity. Compared to Western Europe, the transport network is still underdeveloped in the Carpathians. For this reason, the Carpathians belong to the least fragmented areas in Europe. It is also the reason why thriving populations of all three large carnivore species – the wolf, the lynx and the bear – still occur here.

Rapid development of transport infrastructure has been visible over the last years, especially in the context of most Carpathian countries entering the European Union, and this development is expected to continue as there is legitimate socio-economic demand. This situation means a serious threat to Carpathian nature but also represents a great opportunity to use existing expertise/available know-how in building the transport infrastructure in the Carpathian countries in a way that will not destroy their unique nature.

These Guidelines are one of the outcomes of the project 'Integrated Transport and Green Infrastructure Planning in the Danube-Carpathian Region for the Benefit of People and Nature' (TRANSGREEN project). This initiative represents a particular step towards fulfilling the goals of the Carpathian Convention Protocol on Sustainable Transport in the Carpathians. It is based on the European COST 341 Handbook (Wildlife and Traffic) on avoiding Habitat Fragmentation due to Linear Transportation Infrastructure (Iuell et al., 2003) and other guidelines and handbooks with special focus and adaptation designed to support ecological connectivity in the Carpathians.

Fig. 1.3 The Carpathians represent an area with unique natural value, high biodiversity and scenic beauty. © Václav Hlaváč

Fig. 1.4 Motorways create impermeable barriers that prevent animal movement. Contiguous forest areas are thus gradually divided into small islands that are no longer able to ensure the existence of populations of some animals. © Václav Hlaváč

Fig. 1.5 The Carpathian eco-region spreads across eight countries – Austria, the Czech Republic, Slovakia, Poland, Ukraine, Hungary, Romania and Serbia. © CCBIS 2019

2 Users' Guide

2.1 Part of the TRANSGREEN project

These guidelines are one of the main outputs of the TRANSGREEN project. They are generally aimed at minimizing negative impacts of transport infrastructure development on wildlife in the Carpathian mountain range system and are recommended to be used in combination with other TRANSGREEN outputs:

The State of the art report
presents an up-to-date overview of the current level of knowledge, information and practices in the field of environmentally-friendly transport infrastructure development in the different countries of the Carpathian eco-region.

The Catalogue of measures
describes critical sites, which have been identified in each pilot area, and suggests mitigation measures for improving and securing the permeability of these sites, as they are crucial for animal migration.

The In-depth analysis
provides detailed description of ecological corridors in each participating pilot area and an overview of major policies influencing the construction of transport infrastructure in the pilot areas, along with an overview of the stakeholders who influence the process of infrastructure development.

Policy recommendations for sustainable transportation in the Carpathians
are recommendations for countries working together under the Carpathian Convention, EUSDR and EU. Their aim is to facilitate and promote the implementation of the Carpathian Convention Protocol on Sustainable Transport and findings of the project consortium.

The training package 'Keeping Nature Connected - Environmental Impact Assessment (EIA) for Integrated Infrastructure Planning'
emphasizes the importance of ecological connectivity in relation with the EIA processes and provides information and case studies on how to integrate ecological corridors within the EIA processes, which can enable practitioners and decision-makers to maintain and increase connectivity.

The Guidelines can be used at all levels of sustainable linear transport infrastructure development – from the initial planning and design through the construction to the operation and maintenance.

2

2.2 Main target groups

The Guidelines are written mainly for the following groups of users:

- Transport infrastructure planners and designers.
- Environmental impact assessment specialists.
- Authorities responsible for decisions regarding authorizations for transport constructions at all levels – coming from both the transport and environmental sectors.
- Transport infrastructure building contractors.
- Transport infrastructure operators.
- Biologists and ecologist involved in monitoring the impacts of transport on wildlife.

2.3 How to use the Guidelines

The Guidelines constitute a comprehensive material focused on minimizing the negative impacts of transport infrastructure and traffic on wildlife in the Carpathian region. There are many different aspects and viewpoints in the tackled issue and many topics are connected to each other in more or less expected ways. Despite our efforts to organize the texts in a logical and continuous way, some pieces of information are provided repeatedly, or a given sub-topic is mentioned in two or more associated chapters. Readers are therefore encouraged to use the detailed table of contents to look for specific topics which they are interested in at the moment. The following table including the basic structure of chapters and their short descriptions should also help readers to orient themselves within the Guidelines.

Introduction – wildlife and traffic in the Carpathian mountain range system – why these guidelines are needed	1
Users' Guide – about the guidelines and how to use them	2
Basic Terms – explanation of used terms and abbreviations	3
Effects of Transport Infrastructure on Nature – the ecological impacts of transport infrastructure, primary and secondary effects	4
Particularities of the Carpathian Countries – introduction of the region, characteristics of natural conditions, transport and settlement in the Carpathian mountain range	5
Biota and Ecological Connectivity, Demands of Different Groups of Fauna on Infrastructure Permeability – main habitats and species in the Carpathian mountain range, their demands for connectivity in the landscape	6
Legislative Aspects – European Directives and strategies, relevant conventions, national level legislation in the respective Carpathian countries	7
Basic Steps and Processes for Ensuring Ecological Connectivity within Transport Infrastructure Development – how to apply protection of wildlife and requirements for landscape connectivity during the process of transport infrastructure development	8
Integration of Linear Transport Infrastructure into the Surrounding Landscape – key issues for successful integration of infrastructure into the landscape, with emphasis on factors relevant to minimising habitat fragmentation	9
Fauna Passages and other Technical Solutions – choice and location of mitigation measures according to target species and habitats; overpasses, underpasses, passages for aquatic organisms, joint-use and modified passages; measures to avoid or reduce mortality	10
Ecological Compensation – the use of compensatory measures as the last option in cases when mitigation measures cannot prevent ecological damage or where it is not possible to mitigate; methods and examples	11
Monitoring the Impact of Transport on Nature – guidelines for the design of monitoring programmes and for evaluating the effectiveness of measures; different monitoring methods described	12

2

2.4 Following the IENE principles for sustainable linear transport infrastructure development

Twenty years of exploration in the field of transportation infrastructure and ecology at local, national and international level have resulted in IENE – Infra Eco Network Europe (www.iene.info) - an important knowledge and experience platform covering all phases of linear infrastructure development (Iuell et al. 2003; Roedenbeck et al. 2007; Georgiadis et al. 2015; Van de Ree et al. 2016). In order to use this experience, it is recommended to take into account the following IENE principles for environmentally friendly linear transport infrastructure development (Georgiadis et al. 2018):

I. Strong legal framework: Establishment and strengthening of a legal framework for sustainable linear infrastructure development.

II. Sustainable strategic planning: Sustainable strategic planning for development of any major transportation infrastructure project based on the hierarchy of priorities: avoidance – mitigation – compensation.

III. Ecosystem approach: Ecosystem approach to crossing points of grey and green infrastructure, knowing the values of natural capital and ecosystem services in combination with the 'precautionary' principle.

IV. Any case, a unique case: Establishment of the 'any case, a unique case' approach, taking any problem as a unique problem and always properly evaluating the use of existing solution.

V. Multi-disciplinary cooperation: Establishment of multi-disciplinary cooperation among different professionals such as engineers and environmentalists.

VI. Civil society involvement: Involvement of civil engineer society in the planning phase of linear infrastructure projects.

VII. Polluter pays principle: Implementation of the 'polluter pays' principle, after clarifying the ethical and transparency concerns, by including particular mitigation measures right from the beginning of the planning phase until the tendering and contracting of the building and operating phases.

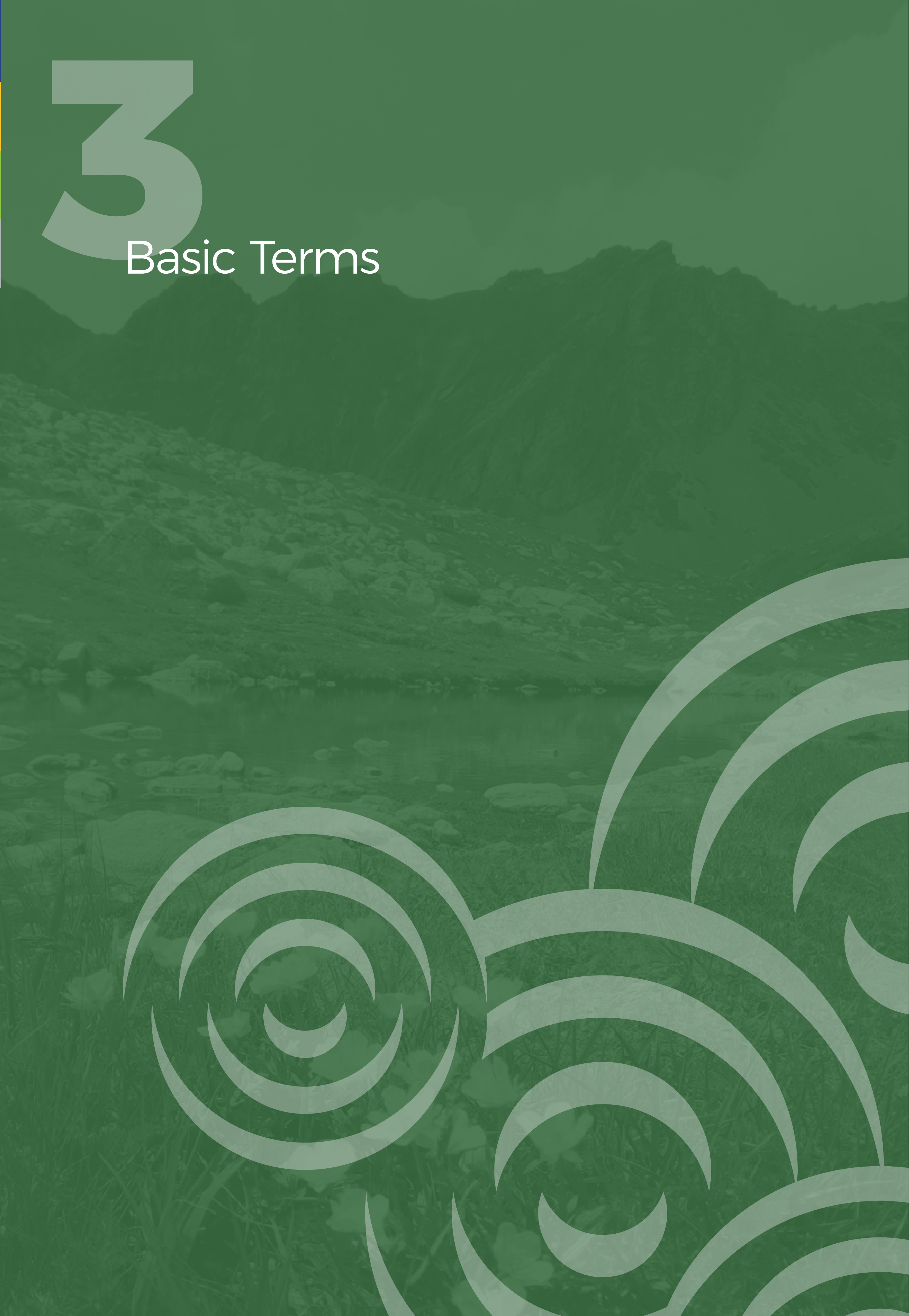
VIII. Long life effective maintenance: Inclusion of maintenance of mitigation measures in the budget of the ordinary program for maintenance of the infrastructures under operation.

IX. Environmental supervision: Inclusion of environmental supervision of technical features of the infrastructure and monitoring of the habitat and wildlife populations' status at all phases of the projects from design to full operation.

X. Culture of learning: Establishment of a culture of learning to build up and support continuous evaluation and exchange of knowledge and experience among the interested, relevant and authorized organizations and state services.

2

3 Basic Terms



Barrier effect	Combination of different factors (technical structures and its parameters, disturbances, fauna mortality) which together decrease the probability and success rate of wildlife crossing the linear infrastructure.
Buffer zones	Peripheral areas intended to enhance the protection of sensitive habitats, e.g. protected sites from the negative impacts of infrastructure such as pollution or disturbance.
Building proceedings	Administrative process that deals with the specifics of planned construction, its design and technical aspects.
Core areas	Areas meeting the habitat and size requirements of target species for their sustainable permanent occurrence and providing them with sufficient food supply, shelter, breeding and dispersal conditions.
Dispersal	The process or result of random spreading of animal young offspring in all directions once they reach maturity.
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 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 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 for animal movement within core areas (including daily movements in search of food, etc.).
Ecological network	Coherent system of natural and/or semi-natural landscape elements configured and managed with the objective of maintaining or restoring ecological functions as a means to conserve biodiversity while also providing appropriate opportunities for the sustainable use of natural resources. Ecological network consists of core areas, corridors and buffer zones.
Ecotone	Transitional zone between two habitats.
Ecotype	Genetically distinct geographic variety, population or race within a species, which is genotypically adapted to specific environmental conditions.
Endemic species	Species confined to a particular region and thought to have originated there.
Expressway	Limited-access arterial road designed for high-speed road traffic but with lower construction standards than the motorway. It is usually characterized by dual carriageway (spatial separation of opposing traffic flows), access only via grade-separated interchanges and with restriction of use for some transport modes (such as bicycles) or for motor vehicles not complying with legal regulation (e.g. minimal design speed). Construction standards and access regulation may vary from country to country.
Fauna passage	Measure installed to enable animals to cross over or under a road, railway or canal without coming into contact with the traffic.

Final inspection	Official procedure that has to take place before the given construction can be used (start its operation phase).
Fragmentation	Transformation of large habitat patches into smaller, more isolated fragments of habitat. Such units then gradually lose the potential for fulfilling their original functions.
Green infrastructure	A strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and to protect biodiversity in both rural and urban settings.
Grey infrastructure	A network of (both existing and planned) linear transport corridors, housing development, mining grounds and other human-induced constructions/infrastructures in the landscape.
Habitat	Assemblage of all biotic and abiotic factors that create the environment of a specific species, population, community.
Home range	Area regularly used by an individual, where it satisfies its basic needs.
Indicator species	Species indicative of (a) some current or historical environmental or historical influence (e.g. lichens can be atmospheric pollution indicators, and woodland ground-flora can be indicative of ancient woodland), or (b) a community or habitat type (e.g. some species can be used to classify invertebrate communities, or are indicative of particular habitats).
Landscape connectivity	The state of structural landscape features being connected, enabling access between places via a continuous route of passage. The physical connections between the landscape elements.
Linear transport infrastructure	Road, railway or navigable inland waterway.
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 migration corridors for species is difficult due to relatively high degree of permeability.
Metapopulation	A set of local populations within an area, where typically migration from one local population to at least some others is necessary to sustain the local population numbers. The metapopulation may have a higher persistence than the single local populations.
Migration	Regular movements of animals outside of their original home ranges. For the purpose of TRANSGREEN and ConnectGREEN projects, the term migration is also applied to other types of animal movement (within home ranges, food searching, dispersal of offspring, etc.).
Migration barrier	Natural or anthropogenic structure in landscape that blocks free movement of fauna.
Migration potential (MP)	Concept that helps with assessing the efficiency of planned fauna passages; MP is defined as the probability of a fauna passage being functional. It is calculated by multiplying the ecological migration potential (MPE) and the technical migration potential (MPT) of the given structure.

Migration route	A geographic route along which certain fauna species customarily migrate.
Migratory/dispersal occurrence	Irregular presence of a species in certain area only due to its migration or dispersal movements, meaning that this area does not have a permanent occurrence of the species.
Mitigation	Action to reduce/eliminate the severity of an adverse impact.
Monitoring	Combination of observation and measurement employed to quantify the performance of a plan, measure or action against a set of predetermined indicators, criteria or policy objectives.
Motorway	Major arterial highway that features: two or more traffic lanes of traffic moving in each direction, separated by a ´central reservation´, controlled entries and exits, and alignment eliminating steep grades, sharp curves, and other hazards (e.g. grade crossings) and inconveniences to driving.
Openness index	The width of an underpass multiplied by its height divided by its length: w x h / l (see also Fig. 3.1 B).
Home range	Area regularly used by an individual, where it satisfies its basic needs.
Permeability (of linear transport infrastructure or landscape)	The ability to let animals safely pass through.
Planning decision	Binding decision issued by relevant authority based on the results of the planning proceedings, it approves a proposed construction intention, given the planned construction is in compliance with all the planning documentation.
Planning proceedings	Administrative process assessing whether a proposed construction of a given type, including its impacts on the surroundings, can be placed into the intended area and whether the construction is in compliance with spatial planning documentation.
Population	Assemblage of individuals of the same species that together occur in a certain area and can interbreed.
Restoration	The process of returning something to an earlier condition or state. Ecological restoration involves a series of measures and activities undertaken to return a degraded ecosystem to its former state.
Roadless (or low traffic) area	Natural or semi-natural area of high conservation value that has no or little traffic and provides multiple ecosystem services.
Ruderal species	A plant species that is among the first to colonize disturbed lands. The disturbance may be natural (e.g. wildfires, avalanches) or a consequence of human activity, such as construction (roads, buildings, mining, etc.) or agriculture (abandoned fields, irrigation, etc.).
Stepping stones	Landscape features allowing short-term survival of animals. They are usually part of wildlife corridors. Stepping stones and 'wildlife corridors' can help connect core areas, allowing species to move between them.
Target/relevant species	Species that are being influenced by landscape fragmentation caused by transport infrastructure. These species are taken into consideration during the planning and implementation of optimization measures.

3

Territory	Area that an individual defends against other members of the same species.
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.
Wildlife overpass	A structure where animal migration takes place above the level of traffic. (Fig. 3.1 A).
Wildlife underpass	A structure where animal movement takes place under the level of traffic. (Fig. 3.1 B).
Zero state	State of a given area before any planned construction starts, which also means without any potential impacts of such construction taking effect.

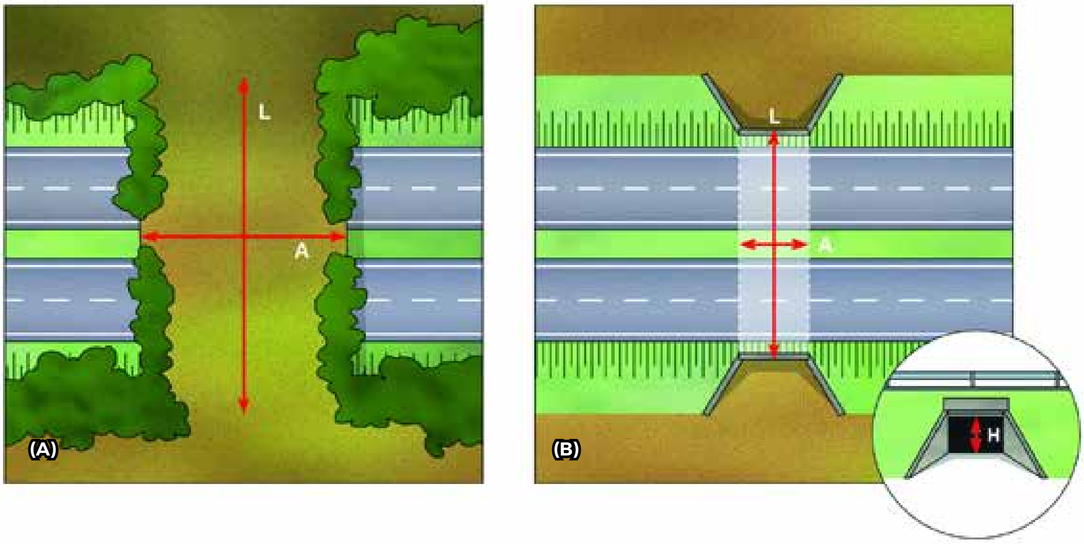


Fig. 3.1 General scheme of a wildlife overpass (A) and a wildlife underpass (B), showing also their basic dimensions (L - length, W - width, H - height). © Spain. Ministry for Ecological Transition. 2016. Technical prescriptions for wildlife crossing and fence design (second edition, revised and expanded) (on line). Madrid: MAPAMA. Illustrations made by Pep Gaspar, ARTENTRAÇ

Abbreviations

CBD	The Convention on Biological Diversity
COST	European Co-operation in the Field of Scientific and Technical Research
DMS	Detailed migration study
EC	European Commission
EEC	European Economic Community
Espoo Convention	UNECE Convention on Environmental Impact Assessment in a Transboundary Context
EIA	Environmental Impact Assessment
EU	European Union
FMS	Framework migration study
HSR	Trans-European high-speed rail
IENE	Infra Eco Network Europe
IUCN	International Union for Conservation of Nature and Natural Resources
NDS	National Motorway Company in Slovakia
OI	Openness index
PEEN	Pan-European Ecological Network
SEA	Strategic Environmental Assessment
SMS	Strategic migration study
TEN-G	Trans-European Network for Green Infrastructure
TEN-T	Trans-European Transport Network
UNECE	United Nations Economic Commission for Europe

4

Effects of Transport Infrastructure on Nature

These Guidelines are primarily focused on motorways, roads and railways. Some recommendations can be applied to inland waterways as well, especially in case of artificial canals that can also create barriers limiting free movement of animals in the landscape. The effects of transport infrastructure on nature are typically divided into two groups: primary (directly bound to the construction and further operation of a given piece of infrastructure) and secondary (effects that do not directly fall into the transport sector but are likely induced by it). The basic categories and descriptions of Iuell et al. (2003) are used in this document, with only a few specifications regarding the Carpathian region. Primary effects are described in Chapter 4.1, secondary effects in Chapter 4.2.

Evaluating the effects of roads and railways on nature must be based on their technical description and on the particularities of different life cycle phases. These facts are mentioned in Chapters 4.3 and 4.4.

4.1 Primary ecological effects

The five main primary ecological effects of transport infrastructure on nature are discussed in the following sections. It is important to mention that these effects very often interact with one another and the resulting synergistic effects may then have even stronger negative impact. Additionally, the overall complex of effects is much more cumulative in case of pairing or bundling of transport infrastructure when roads, railways or canals are sitting close to each other in a parallel way (Helldin and Jaeger 2016, Deshaies 2016, Godart et al. 2016). Such synergies should therefore always be considered.

Loss of wildlife habitat

Habitat fragmentation (the barrier effect)

Fauna traffic mortality

Disturbance and pollution

Creating new habitats on transport verges

4.1.1 Loss of wildlife habitat

4

This is represented by the actual physical loss of natural habitat as it is replaced with or significantly altered by the transport infrastructure. It may seem negligible at larger scales, since roads and associated infrastructure generally take up only a few per cent of the landscape. However, the impact of this habitat loss can hardly be viewed separately from other effects that inevitably follow (disturbance, barrier effect, etc.). Moreover, even the habitat loss itself can be quite serious at a local scale, depending on specific placement of the infrastructure in the landscape and on the affected habitat type and species. The mountain environment of the Carpathian region with high vertical relief segmentation is unique for its high local diversity by frequent changes of habitats with different species. For this reason, the loss of wildlife habitat can have greater consequences here than compared to other types of landscape.

Fig. 4.1 Construction of roads in mountain environment often brings destruction of valuable habitats. Road S52 between Skoczów and Bielsko-Biała, Poland. © Ivo Dostál

case study

Genetic exchange between Hungarian subpopulations and Poľana Mountains is blocked alongside the expressway R2, section Zvolen - Kriváň

Expressway R2, section Zvolen – Kriváň has dramatic negative impacts on the movement of wildlife because of its construction and absence of useful wildlife crossing structures. Nearly the entire section is located on an embankment, which creates a complete barrier for the movement of any wildlife species. Not a single mitigation measure has been implemented. The road section cuts off the valuable Poľana Mountain range from the south of the country and further from Hungary.

Poľana is home to many wildlife species, including the three large carnivores: the brown bear, the grey wolf and the Eurasian lynx in very healthy population numbers. Large predators originating from the Poľana Mts. had a potential to disperse further south of Slovakia and even up to Hungary, but this is nowadays impossible. Vice versa, genetic exchange between Hungarian subpopulations and Poľana is now blocked alongside this section. Sadly enough, even if attempts to reconnect the area again are emerging, the embankment makes the construction of a green bridge nearly impossible.

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Fig. 4.2 Case study: Genetic exchange between Hungarian subpopulations and Poľana Mountains is blocked alongside the expressway R2, section Zvolen - Kriváň, Slovakia. © Michaela Skuban

4.1.2 Habitat fragmentation (the barrier effect)

4

This effect is the consequence of eliminated permeability of roads or railways for animals. Especially roads with high traffic density and high-speed railways are basically impossible to pass for most species, which in turn limits their ability to move around the landscape in search of food, shelter, mating partners, etc. Naturally, all of this negatively affects entire populations and threatens their survival.

The barrier effect can have physical or behavioural character:

- Physical barriers are usually associated with completely fenced roads and railways or very high intensity roads (typical of larger mammals), or with unsuitable surfaces or crossing objects, road verges or a different type of disturbance (typical rather of smaller animals, especially invertebrates, fish, amphibians, and reptiles).
- Behavioural barriers occur mostly in larger species and lie in various avoidance patterns, when animals do not use at all areas near roads or railways or avoid crossing large open spaces.

Possible ways to deal with the negative effects of barriers and habitat fragmentation include careful selection and planning of the route and making infrastructure more permeable for wildlife by means of fauna passages in combination with fencing and barriers, guiding the animals to the fauna passages. Quite complicated from the barrier effect point of view are multimodal transport corridors (two or even more forms of transport infrastructure aligned along the same corridor). Combining barriers in mountain valleys is exactly the typical problem for mountain landscapes and alpine environments. Rivers, motorways, railways and many local roads, coupled with dense settlements, can together make mountain valleys into completely impermeable barriers, which fragment both the mountain environment and the animal populations living on both sides of the valleys.

Fig. 4.3 Fenced roads represent physical barriers for most animal species. © Václav Hlaváč

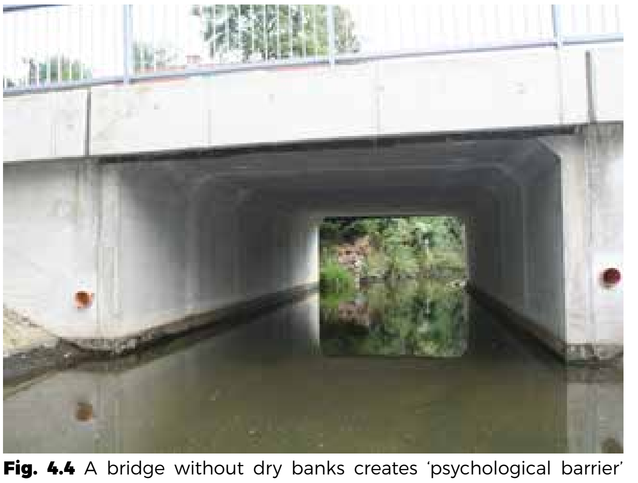
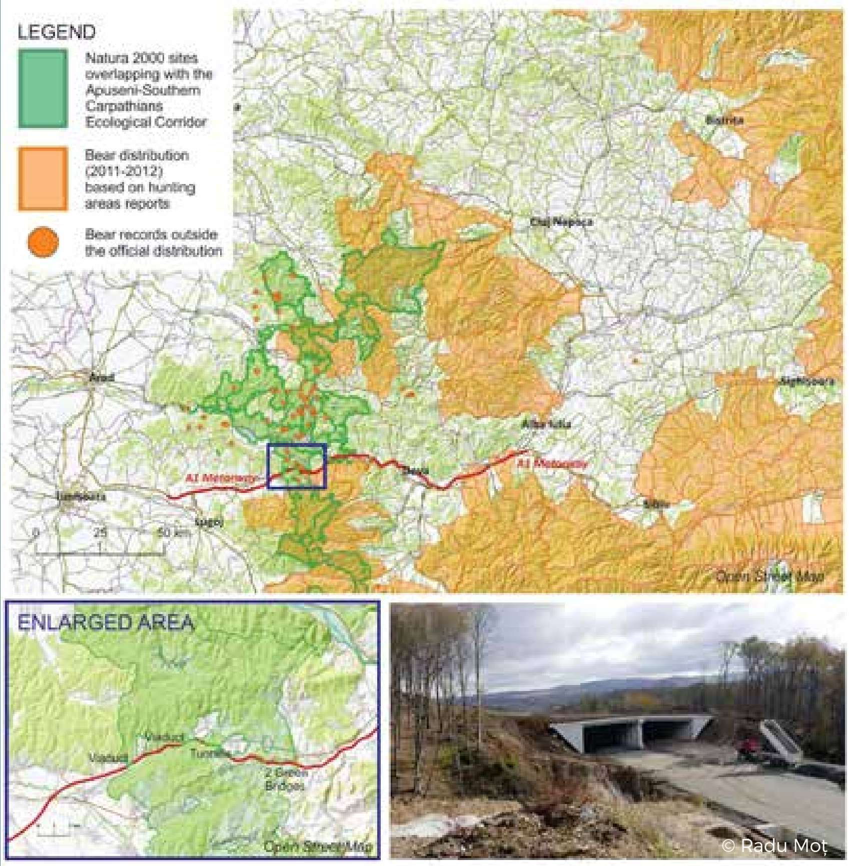


Fig. 4.4 A bridge without dry banks creates 'psychological barrier' for otters, although they are physically able to swim through such a bridge. Experience shows that most otters do not use such underpasses and cross the road instead. © Václav Hlaváč

case study

Safeguarding an important ecological corridor in Romania

The ecological corridor between Apuseni Mountains and Southern Carpathians in Romania was recognized as one of the major connectivity issues in the whole Carpathian Range (Salvatori, 2004) and its safeguarding was highlighted as one of the objectives for the Carpathian brown bear population in the European large carnivore action plan. The A1 motorway unfortunately separates the two main bear ranges. Since the proposed alignment did not intersect the official bear distribution (made based on hunting area records) and the bear presence was not observed in the vicinity of the alignment during the Environmental Impact Assessment studies, the first Lugoj-Deva motorway project did not include adequate mitigation solutions. Such a design of the motorway raised arguments that it will have a major impact on the population connectivity and on Natura 2000 network coherence (the motorway intersects one Natura 2000 site designated especially to ensure the functionality of the ecological corridor). Consequently, the IENE workshop held at Lugoj in 2012 became the first step in convincing stakeholders that a series of mitigation measures is needed and they should be designed in accordance with the regional importance of the corridor. As a result, a revised plan was developed for the Lugoj-Deva motorway section, in which the environmental permit requires bored tunnels, viaducts and green bridges as local-adjusted solutions. Some of them are currently under construction. Since 2013, new records of bears outside the 'official' range have shown that the corridor is used and that there are new areas being gradually recolonized by the species.



The larger map shows the official distribution of the bear and records of bears outside of it, highlighting the need for proper assessment of corridor areas in which adequate mitigation solutions should be implemented, even if large carnivores are not permanently present. The detailed map presents the revised solutions requested by the environmental permit within the ROSCI0355 Podișul Lipovei - Poiana Ruscă Natura 2000 site. The two green bridges are currently being built within this site designated with the specific role to ensure the functionality of the corridor (photo).

Fig. 4.5 Case study – Safeguarding an important ecological corridor in Romania © Radu Moț

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4.1.3 Fauna traffic mortality

Mortality caused by collisions on roads and railways is the most evident and well-known negative impact of transport infrastructure on wildlife. Vast numbers of individuals are killed and injured every year. In common widely spread species traffic mortality is estimated to count for only a small percentage of their total mortality (1-4%). Unfortunately, in case of some more sensitive and rarer species, it can represent much greater proportion (e.g. 40%), which makes it a significant factor possibly threatening the survival of local populations. Such sensitive species include:

- Rare species that move long distances and are forced to overcome transport infrastructure while doing that (e.g. otter, large carnivores)
- Species exhibiting daily or seasonal migratory transfers between local habitats (e.g. amphibians, some ungulate species)
- Birds, especially raptors and owls that are attracted to prey around road verges or by road-kills
- Some species of bats, especially on roads equipped with lighting, which attracts insects and as a result also bats to feed there

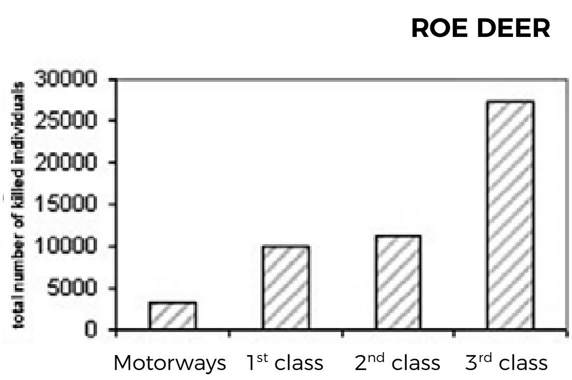
The concentration of fauna casualties on roads and railways in general depends on environmental factors such as temperature, precipitation or time of day, on ecological factors associated with affected species (breeding, dispersal, seasonal migrations, food supply, age and sex of animals, etc.) and also on location, landscape context of the infrastructure, its width, traffic value, as well as crop rotation in its surroundings. Efforts to reduce fauna casualties are typically made for reasons of traffic safety, which involves rather larger species, while smaller ones are often neglected. Proper way to solve this issue is a matter of landscape planning and should not only focus on blocking access of the animals to the infrastructure, but especially on providing safe wildlife corridors and stepping stones, safe passages and guidance to the safe passages. It should also address all relevant species and not forget about the safety of smaller species.

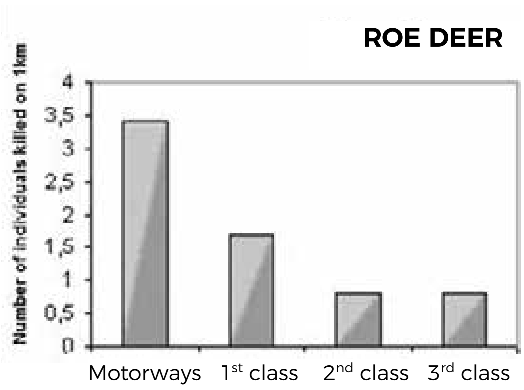
Fig. 4.6 Lynx killed by a car south of Malá Fatra, Slovakia. © Michal Kalaš

case study

Fauna traffic mortality in the Czech Republic

Fauna traffic mortality threatens the existence of many animal species in the Czech Republic. Relative mortality per 1 km of a road is the highest on roads with the highest traffic intensities. However, due to the extent of lower category roads, most animals die on these local roads.





Estimates of yearly mortality of selected animal species on roads in the Czech Republic

Species	Motorways	1st class roads	2nd class roads	3rd class roads	Total
European hare	14,400	73,600	150,700	327,700	566,400
Marten	8,400	21,200	15,100	5,100	49,800
Hedgehog (both species)	15,100	59,100	115,600	157,000	346,800
Common weasel	3,000	9,100	4,300	11,700	28,100
European roe deer	3,300	10,100	11,300	27,300	52,000
Red fox	2,000	2,400	0	0	4,400
Common pheasant	4,600	4,700	18,100	41,000	68,400

© Václav Hlaváč

© Václav Hlaváč

Fig. 4.7 Case study: Fauna traffic mortality in the Czech Republic. © Hlaváč & Anděl 2008

4.1.4 Disturbance and pollution

The construction and especially subsequent operation of transport infrastructure generates various changes in its surroundings, many of them meaning negative interventions into ecological characteristics of the area and lower habitat quality for local wildlife populations. It is important to point out that mountain environment is more sensitive to disturbances than more common types of landscape. This concerns individual species, individual environmental components (water, soil, etc.), or even the entire alpine ecosystems. The main types of such disturbances are:

- **Hydrological changes** – cuttings and embankments, which may increase soil erosion, drain aquifers or change water regime.
- **Chemical pollution –** various polluting oxides, hydrocarbons, particles or heavy metals are released from motor exhausts. Using de-icing salt in winter causes pollution by sodium and chloride, while contamination by herbicides often occurs during summer road and railway maintenance. Gasoline or other oils can leak out during accidents. All these chemicals then get into and pollute surfaces and groundwater as well as the soil in the surroundings and often cause acidification and eutrophication. That can cause serious disturbance of biological functions in the area.
- **Noise and vibration** – these are impacts inseparably connected to traffic and their intensity, road surface, rail type, topography, surrounding vegetation, etc. Sensitivity of different species to these factors varies; some exhibit strong avoidance of areas disturbed by them.
- **Lighting and visual disturbances** – artificial lighting associated with transport infrastructure represents a problem for several animal groups (birds, amphibians, bats, nocturnal mammals), as it can alter their behavioural patterns (in foraging, breeding, etc.) and can in certain cases even lead to increased mortality.

When evaluating these disturbing effects, it is necessary to distinguish effects from common operation and risks arising from emergency situations. The latter are typically represented by traffic accidents that may be accompanied by leakages of transported chemicals or fires with toxic emissions.

Fig. 4.8 A noise protection wall eliminates the effect of disturbance while also increasing the barrier effect. © Tomáš Flajs

4.1.5 Creating new habitats on transport verges

Besides irreversible elimination of original habitats, road/railway construction also brings creation of new habitats, especially in the form of road verges. Verges are installed and/or maintained with a specific purpose – to protect infrastructure against snow, inhabited areas against noise and light pollution, prevent fire from expanding, prevent traffic accidents (trees on verges are considered to increase the alert level of drivers), or they are represented by vegetation that occupies the adjacent areas of infrastructure and is managed only randomly.

Infrastructure verges can have both a positive and negative impact on wildlife. They could for instance provide filter for noise and light disturbance to species present in the landscape. The two most commonly discussed functions of verges are habitat quality and corridor function. Depending on geographical location, type of infrastructure, slope and width of verges and its exposure to sunshine etc., roadsides and verges can provide important habitats for several species (especially invertebrates associated with a given plant community).

However, when compared to natural habitats, these are typically of lower quality due to disturbance and pollution. Consequently, roadside communities are sometimes dominated by non-native or ruderal species. From this point of view, verge management is extremely important. Planting of native bushes and trees, bush pruning, mowing grassy vegetation and its proper timing or reducing the use of chemicals for weed and insect control can all increase local biodiversity. Different management can lead to significant local abundance of local or non-native species. However, there is evidence that the increased stress induced by traffic is affecting individuals and thus the vitality of local population segments. Hence, the value of intensively managed verges or high-traffic infrastructure as important habitats for native species should be considered with precaution. There are also two sides of the corridor function of verges. They can enhance the movement of species along the infrastructure (observed so far mainly in small mammals, reptiles and insects) and broad verges with low vegetation may reduce fauna casualties by increasing visibility. The negative part lies in the fact that verges can also lead animals to more dangerous crossroads or to urban areas, and that alien species or weeds may spread along the verge corridors even more easily than the native ones.

Fig. 4.9 Appropriately maintained verges form a habitat for invertebrates and reptiles. © Klára Řehounková

case study

The 'Butterfly Highways' project

Transport infrastructure does not only need to be a negative factor with respect to fauna and flora. Under certain conditions, the verges and slopes along a linear infrastructure may represent suitable habitats for many species of native plants and invertebrates, and can even help connect their isolated populations. Possibilities in this topic are being developed, tested and monitored in a project called 'Butterfly Highways', which is currently taking place in the Czech Republic. Its main goal is to develop a comprehensive technological solution for landscaping motorway and road slopes in ways that support biodiversity and at the same time reduce long-term costs for maintenance. Very interesting and promising seems to be a new method of introducing indigenous hemi parasitic plants of the genus *Rhinanthus sp.* on grassy slopes along with planting low-productivity grass-forb mixtures. More about the project at: http://www.motylidalnice.cz/index_EN.html.

A slope with hemi parasitic *Rhinantus* plant near Nová Lhota, the Czech Republic. © Jakub Těšitel

Fig. 4.10 Case study: The 'Butterfly Highways' project. © http://www.motylidalnice.cz/index_EN.html

4.2 Secondary ecological effects

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Secondary ecological effects of transport infrastructure on wildlife are represented by changes in land-use, human settlement or industrial development that originate as a result of new road and railway construction activities. Another important factor is increased degree of human access and disturbance associated with denser transport infrastructure. As these secondary effects fall under the responsibility of many different sectors, not just the transport one, they should always be carefully considered in SEAs and EIAs. Especially careful planning is then needed in case of sensitive habitats or so far undisturbed wildlife areas, because limiting access of people to valuable wildlife habitats may prove very complicated once any infrastructure is built there. Secondary effects of transport infrastructure are often very significant in the mountain environment of the Carpathian mountain range. Building a new transport infrastructure in natural areas brings the development of recreational and sports facilities, as well as new possibilities of industrial use of natural resources. It is therefore necessary to take these effects into consideration while planning the transport infrastructure.

Fig. 4.11 New transport infrastructure often brings further construction to the area. Logistic centre near the city of Nitra, Slovakia. © Michal Ambros

4.3 Impact of particular components of roads and railways

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Road construction contains several components that can have a significant impact on wildlife. This involves more than the road itself. The construction also includes junctions (interchanges), fences, crash barriers, local road relocation, drainage, noise barriers, reservoirs to catch contaminated water, bridges, etc. All these parts must be taken into account when assessing the effects of the construction on nature.

Fig. 4.12 Reservoirs to capture water from motorways are sometimes part of their constructions. When constructed as concrete tanks with vertical walls (A), they form traps for many animals. Optimal solution is to design these capture tanks as natural habitats (B). © Petr Anděl (A) and Martin Strnad (B)

Table 4.1

Individual components of transport constructions and their impacts on nature.

Construction component	Negative impacts, problems to solve
Road	▪ Land occupation and destruction of original habitats ▪ Barrier effect ▪ Coordination and mutual connection of all other components
Junctions (inter-changes)	▪ Land occupation and destruction of original habitats ▪ Optimization of the use of areas inside interchanges from the viewpoint of animals
Bridges	▪ Land occupation and destruction of original habitats ▪ Changes of habitats under bridges ▪ Adjustments of watercourses under bridges – threat to fish migration and reproduction ▪ Overpasses and underpasses for animals ▪ Nesting possibilities for birds and bats
Tunnels	▪ Technology of construction – bored and cut-and-cover tunnels ▪ Temporary land occupation and destruction of original habitats in cut-and-cover tunnels ▪ Tunnel portals and ventilation shafts as point sources of emissions
Road and local way/path reloca-tions	▪ Land occupation and destruction of original habitats ▪ Barrier effect (accumulation with main construction) ▪ Lowering the efficiency of fauna passages
Drainage	▪ Quality of water from the road ▪ Retention ponds as substitute habitats ▪ Runoff settling reservoirs as traps for animals
Adjustments of vegetation	▪ Sufficient anti-erosion prevention ▪ Creation of new habitats (e.g. road verges and insects) ▪ Undesirable draw for animals (ecological trap) ▪ The spread of invasive plant species
Noise barriers	▪ Improving the quiet environment behind the wall ▪ Increasing barrier effect ▪ Risk of higher mortality when using one-sided walls ▪ Higher mortality of birds on transparent walls ▪ Protection of sensitive sites from noise and light pollution
Fences	▪ Preventing animals from entering roads, escape gates for animals trapped within fences ▪ Increasing barrier effect ▪ Placement of fences in relation to vegetation ▪ Maintenance of fences
Other technical components	▪ Using toll gates as passages for squirrels ▪ Placement of traffic signs warning drivers about animal movements
Accompanying objects/ buildings	▪ Land occupation and destruction of original habitats ▪ Risk of cumulative effects together with the road/railway ▪ Necessity to assess the impact on the environment together with the road/railway construction
Construction site facilities	▪ Land occupation and destruction of original habitats ▪ Re-cultivation of affected areas after the construction phase ends

4.4 Life cycle stages of a road and railway

Effects of roads and railways on nature change during their life cycle and therefore all phases must be included in a proper evaluation. From the life cycle point of view, four basic phases can be distinguished:

The main problematic areas related to these phases are listed in the following table:

Table 4.2

Potential problematic areas of road/railway life cycle stages and their impacts on nature.

Life cycle stage	Potential problematic areas
Planning	▪ Quality of routing fundamentally influences future impacts of the road/railway on nature ▪ Availability of data on biodiversity/ecological connectivity
Construction	▪ Destruction of natural habitats ▪ Creation of new artificial habitats, preference for allochthonous / invasive plant species ▪ Re-cultivation of sites after construction ▪ Effect on groundwater and surface water ▪ Mortality of animals at construction sites – protective measures ▪ Noise, emissions and contamination of the environment during construction
Operation	▪ Barrier effect of the road/railway ▪ Mortality of animals on roads/railways, human casualties and damages ▪ Gaseous, liquid and solid emissions from transportation and corresponding contamination of environment ▪ Noise pollution ▪ Contamination of the environment by substances used for summer and winter road maintenance ▪ Both positive and negative effects of new habitats on road/railway verges
Removal	▪ Processing and elimination of waste materials (given the long lifetime period of roads/railways complete elimination is usually not discussed, rather just partial reconstructions)

The road/railway life cycle projects itself into technical and organizational processes of construction planning and it is further discussed in Chapter 8.

5 Particularities of the Carpathians

5.1 Natural conditions of the Carpathian countries

5

The Carpathian Mountains, or the Carpathians, form roughly a 1,500-kilometre-long arc across the Central and Eastern Europe. They cover an area of about 209,000 km^2 and stretch through the territories of eight countries (from west to east and south-east): Austria, the Czech Republic, Slovakia, Poland, Hungary, Ukraine, Romania and Serbia. The Carpathians do not form an uninterrupted chain of mountains, but rather consist of several orographically and geologically distinctive groups with a high structural variety. Their highest range is the Tatras, on the border of Slovakia and Poland, where the highest peaks exceed 2,600 m (highest peak - Gerlachovský štít in Slovakia with 2,655 m a. s. l.).

The region is most commonly divided into three main geographic areas/divisions referred to as: Western Carpathians (covering parts of Austria, the Czech Republic, Poland, Slovakia and Hungary), Eastern Carpathians (stretching through south-eastern Poland, eastern Slovakia, Ukraine, and Romania) and Southern Carpathians (areas of Serbia and Romania). Further subdivisions are used as well, but not consistently in all of the involved countries. The Carpathians, as a whole, form the watershed between the Baltic Sea and the Black Sea and are surrounded by three large plains: the Pannonian basin to the southwest, the plain of the Lower Danube to the south and the Galician plain to the northeast.

The Carpathians are geologically very varied. Their origin goes back to the younger Tertiary, when the first orogeny took place approximately 15 million years ago, on the base layers made of sandstones and slates, at some places also granite, limestone and dolomite. The current profile of the mountains was then finalized during the Quaternary period by shifting of glaciers in the interludes between the glacial periods. The landscape was shaped by volcanic activity as well; its remnants can be found in the Southern Carpathians, in southern parts of Slovakia and Hungary. Typical are also many thermal and mineral waters, especially at foothills in Romania, Slovakia, Ukraine and Hungary.

Fig. 5.1 Tatra Mountains represent the highest mountain range of the Carpathians. Vysoké Tatry, Slovakia. © Barbara Immerová

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With the exception of a few small areas with alpine character, the Carpathians are rather low and forested mountains. Only about 5% of the area lies above the timberline and parts covered in snow all-year-round or glaciers are basically missing (with an exception of only one recently discovered permafrost and glacial area). The climate of the Carpathians is moderately cool and humid, with both temperature and precipitation strongly correlated with elevation. The average annual temperature ranges from more than 10 °C in the Romanian foothills to -2 °C in the Tatras. The amount of precipitation is also quite variable, from more than 1,800 mm per year to 600 mm per year and except for the alpine zone, most of it falls as rain, peaking either in June (in the South) or in July (in the North). Snow cover lasts from less than three months in the foothills to more than seven months in the alpine zone.

The Carpathian landscape has largely been shaped by a long tradition of mountain agriculture and sheep grazing. Human population of the area currently reaches approximately 17 million people, but the traditional practices are gradually being abandoned. Still, the Carpathians contain some of the most intact ecosystems in Europe, which provide important ecological services to human inhabitants and also serve as a habitat for numerous indigenous wildlife species. For many of them, the mountains are also very important as a corridor for dispersal and genetic exchange throughout Europe. This function of the Carpathians is supported by the fact that their southern part represents Europe's largest unfragmented forested area.

Based on elevation, there is typically a well pronounced zonation of the vegetation in the Carpathians, with the following main zones:

- **foothills** (below 600 m, mostly covered by mixed deciduous forests),
- **montane zone** (600–1,100 m in the North and 650–1,450 m in the South, dominated by European beech and silver fir),
- **subalpine zone** (1,100–1,400 m in the North and 1,400–1,900 m in the South, with Norway spruce forests or stone pines),
- **krummholz zone above timberline** (1,400 m in the North-West, 1,900 m in the South, with mountain pine, dwarf juniper and green alder),
- **lush alpine meadows or rocky areas with very sparse alpine vegetation**.

Fig. 5.2 Traditional sheep grazing helps to maintain valuable mountain habitats in the Carpathians. Fagaras, Romania. © Václav Hlaváč

Fig. 5.3 Traditional agricultural practices with a positive impact on mountain habitats and biodiversity are currently being abandoned in most areas of the Carpathians. Banat, Romania. © Václav Hlaváč

Fig. 5.4 Alpine meadows represent high richness of biodiversity. Apuseni, Romania. © Hildegard Meyer

Fig. 5.5 Carpathian old-growth forests are home to a very wide spectrum of species groups. Poloniny, Slovakia. © Tomáš Hulík

Fig. 5.6 The Carpathian population of the brown bear counts approximately 7,200 individuals, which is approximately 42% of the Europe-wide population outside the Russian territory (Chapron et al. 2014). The current findings show a quickly proceeding fragmentation of habitats as the main threat to the brown bear. © Tomáš Hulík

Fig. 5.7 The European bison is a native species to the Carpathians but was completely exterminated in the past. Currently, it has been reintroduced into several areas in Slovakia, Ukraine and Romania. © Tomáš Hulík

However, the species composition and proportion can vary greatly among different local areas of the region and the Bieszczady Mountains in the East lack the subalpine spruce forest zone.

The types of habitats that occur in the Carpathians are also extremely rich and generally high in biodiversity. A study done as part of the BioREGIO Carpathians project in 2011-2013 (Appleton et al. 2014), focused on forest, grassland and wetland habitats, described 9 main different forest types, 6 main ecological groups of high nature value grasslands with 38 different vegetation types, and 7 simplified ecological groups of wetland habitats. Especially rare and unique are for example virgin/primeval and old-growth forests (approximately 300,000 ha, mostly in Romania and Ukraine) or semi-natural dry grasslands, which belong to the most species-rich plant communities in the world and host many endemic species. High biodiversity and a number of rare species of lower plants, lichens and fungi is habitual as well in the Carpathians, especially in association with the old-growth forests and dead wood, but unfortunately not enough is yet known about these organisms.

Regarding animals, the Carpathians are probably best known for large carnivores, which form the largest and most viable populations in Europe. A recent study compiled by Chapron et al. (2014) has indicated the existence of approximately 7,200 brown bears, 3,000 wolves and 2,300-2,400 lynxes in the region, with the highest densities in Romania and Slovakia. In the last decades, golden jackal is occurring as well, as it is in the process of recolonizing many areas of Europe.

Other large mammals, especially herbivores, play an important ecological role and are linked to the presence of large carnivores. The most common ungulates in the Carpathians are roe deer and red deer, chamois occurs in lower numbers and only in certain isolated high mountain areas, and even scarcer is the moose, whose main area of distribution lies in northern Europe. European bison is another animal often associated with the Carpathians, since the only free ranging population of the species exists here. European bison became extinct in the wild in the 1920s and was saved by captive breeding programmes.

5

Currently, populations are being re-established along the Carpathian mountain range in Poland, Slovakia, Ukraine and Romania, with the aim to establish a viable metapopulation of interconnected stocks (Linnel & Zachos 2011). The Carpathians are also one of the last European refuges for the European wild cat, and a nesting range for the golden eagle and other rare raptors. High diversity of other animal groups in the Carpathians (birds, reptiles, amphibians, and especially invertebrates) and plant species associated with the various habitats described above, should not be forgotten either.

Approximately 18% (overall approximately 36,000 km^2) of the Carpathian Mountains are under some form of legal natural protection with more than half of this area belonging to Category V according to the IUCN Protected Area Management Category System.[1] The types of designated protected areas and associated conditions of protection vary among individual countries, with differences given most notably by the current status of the EU membership. Non-EU Carpathian countries (Serbia and Ukraine) preserve biodiversity through national ecological networks, by implementing international agreements (e.g. the Bern Convention that entails designation of sites as part of the Emerald network – a parallel to the Natura 2000 network) and by contributing to the Pan-European Ecological Network (PEEN). EU Member States (the Czech Republic, Hungary, Poland, Romania and Slovakia) have designated sites under the Birds and the Habitats Directives as part of the Natura 2000 network of the European Union. Despite these differences, seven countries cooperate under the Carpathian Convention, which was signed in 2003 and entered into force in 2006, in order to achieve comprehensive policy and guarantee protection and sustainable development of the region. Within the Convention, protected areas larger than 100 ha that have an administration also became members of the Carpathian Network of Protected Areas.

5.2 Transportation infrastructure and traffic in the Carpathian countries

Trade routes have crossed Europe since ancient times. The Carpathian region is located at the crossroads of East–West (from South-Eastern Europe/Asia towards Western Europe) and North–South ('Amber road' Baltic-Adriatic). Therefore, the transport has always played a crucial role in the economic life of the Carpathian region. Complicated orography predetermined the best routes for transport networks. Their directions followed the deep narrow valleys of the main rivers embedded in mountain ranges, which resulted in increased possibility for uniting the infrastructures to create multiple linear barriers increasing the fragmentation level for several terrestrial species. Thus, in this combination, the Carpathians' orography requests an assessment of overall cumulative impacts, also considering the fact that over time, other human activities were concentrated in these favourable positions as well and have gradually formed barriers, which are only hardly permeable for wildlife.

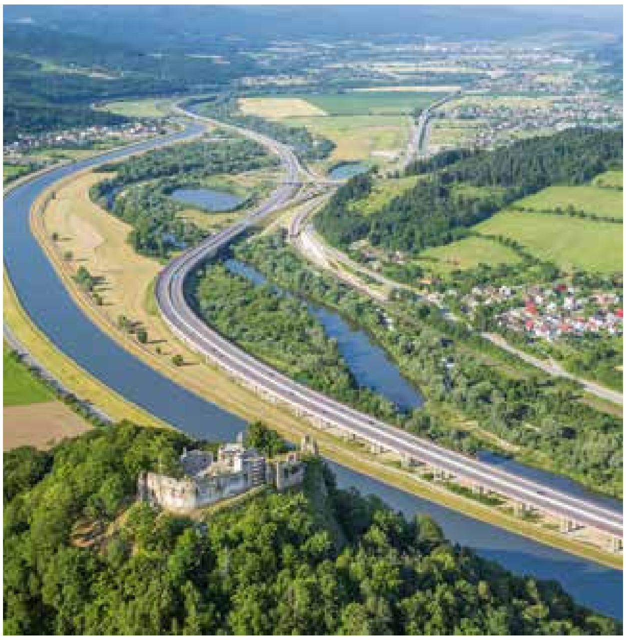

Fig. 5.8 Cumulation of linear structures (artificial canal and motorway) in the Váh valley represents an impermeable barrier for most species. © NDS Archive

[1] 'A protected area where the interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values' (Dudley 2008).

The foundations of transport networks were laid in the mid-19th century, when the major part of the region was under the rule of the Kingdom of Hungary, which designed the modern age concept of the transport network development to improve the economic, social and political profile of the country (Oszter 2017). The rail network reached its peak at the beginning of World War I; however, its influence soon began to slowly decline in favour of the emerging road transport, which took over the role as the main transport system during the 1960s. Its rising importance meant significant increase of motorisation and traffic intensities, which were difficult to be absorbed by the existing road system, especially in the hinterlands of the main cities. The first plans for construction of motorway networks were developed; nevertheless, the construction of motorways in the Carpathian countries continued very slowly. There were only 1,118 kilometres of discontinuous motorway network in operation around 1990 (see Tab. 5.1).

Socio-economic changes after 1989 have brought an extremely rapid growth in traffic, which spurred increased construction efforts. Thus, the overall length of motorways in these countries quintupled in 25 years. Moreover, further expansion is expected in the upcoming years as the region demands

Fig. 5.9 Transport infrastructure in the Carpathians has been changing rapidly in recent years. © Václav Hlaváč, NDS Archive

Fig. 5.10 Socio-economic changes after 1989 have brought an extremely rapid growth in traffic, which has spurred increased construction efforts. A further expansion is expected in the upcoming years . © NDS Archive

denser, better and safer transport infrastructure and the European funding provides a considerable opportunity to decrease the gap compared to Western countries.

One of the crucial transport problems in the Carpathian countries is the long-term unfavourable development of a modal split, with rising road transportation, and the individual automobile transport. The underdeveloped transport network in the Danube-Carpathian region is not designed to meet all rising mobility needs. Mobility challenges at stake consist of multimodality improvement, better interconnections among the modes, and modernisation and extension of infrastructure networks. In this respect, the opportunities rely on the potential to improve the TEN-T Core Network Corridors crossing the region (Maffii et al. 2017). These corridors are shown in Fig. 5.11.

In addition to the TEN-T core network, a notable project of strategic importance is the Via Carpathia transport corridor. It is planned as an international route, leading from the Baltic port Klajpeda (Lithuania), passing through Eastern Poland, Slovakia, Hungary, Romania, Bulgaria to Greece, with some

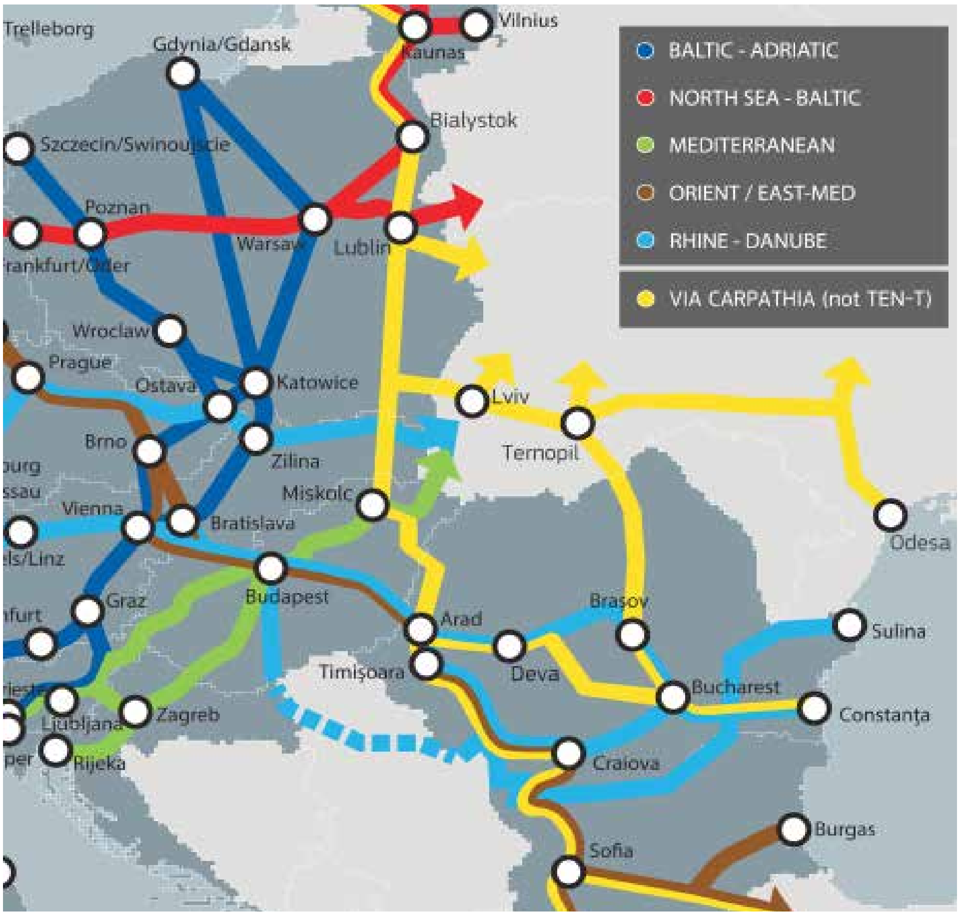

Fig. 5.11 Main transport corridors in the Carpathian area. © EU TEN-T flyer with own drawing of Via Carpathia

branches including the connection between Lviv and Odesa through Western Ukraine. It reaches both the Black Sea and the Aegean Sea. This corridor partially overlaps the existing TEN-T corridors.

The completion of the core transport networks is important to fulfil the goals of the European transport policy (EC 2011). There is a lot to be improved in these corridors – apart from the construction of new infrastructure, major improvements are necessary in sections where the existing infrastructure does not meet technical standards and requires rehabilitation, upgrading or widening measures. The lack of capacity may also occur in specific time periods for high utilisation and nearby urban agglomerations, where traffic is mixed (i.e. long distance, regional and urban).

All five EU-members from the Carpathian countries belong to the states with the worst quality of roads, far behind the EU average. It will be necessary to increase the scale of reconstruction of the existing roads, which may lead to further fragmentation. However, it is also an opportunity to reduce the degree of fragmentation by improving the permeability for wildlife while upgrading the existing roads. The completion of the TEN-T road network continues at a fair speed in Hungary and Poland. Romania has made a significant progress in last years as well. On the other hand, in the Czech Republic and Slovakia, this process is very slow. More information on road networks in the Carpathian countries is available in Fig. 5.12 and 5.13 and Table 5.1.

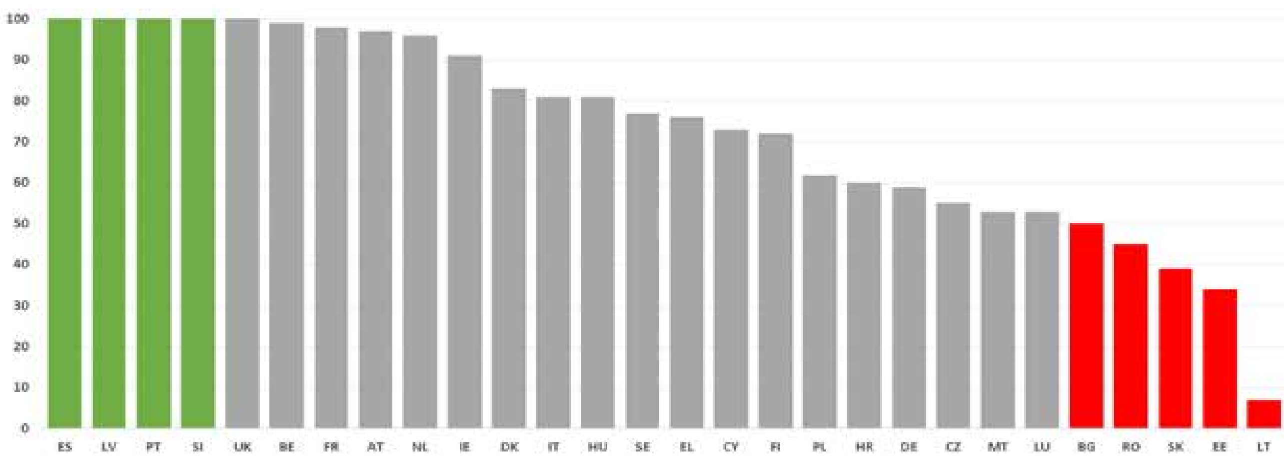

Fig. 5.12 Completion of TEN-T Core Road Network in %, 2016. © EU 2019

Table 5.1

Length of motorway and road network in the Carpathian countries as of January 2016 and the 1990 baseline. (Compiled from MD ČR 2017b; SSC 2017; GUS 2017; Verner 2017; SORS 2017 and Eurostat)

	CZ	SK*	HU	PL	RO	UA	RS
Motorways 1990 [km]	326[1]	192[1]	361	220	113	0	n/a
Motorways [km]	1,223[2]	463	1,481	1,559	747	177	782*
Motorway density [km per 1000 sqkm]	15.51	9.50	15.91	4.99	3.13	0.29	8.85
Expressways [km]	- 2	274	443	1,292	16,859	± 9,000	n/a
National roads [km]	5,807	3,306	30,061	16,442			4,487*
Secondary roads [km]	14,593	3,611	174,599	29,109	35,316	± 7,000	11,392
Tertiary class roads [km]	34,135	10,363		125,092	33,158	± 147,000	29,374
Road network total [km]	55,757	18,031	206,584	173,494	84,333	± 163,000	45,410
Road network density [km per 1000 sqkm]	707.0	367.7	2,210.6	554.9	353.8	± 270.0	513.9

Notes: **CZ**-Czech Rep.; **SK**-Slovakia; **HU**-Hungary; **PL**-Poland; **RO**-Romania; **UA**-Ukraine; **RS**-Republic of Serbia
1 In 1990 Czech and Slovak Republics were Czechoslovakia.
2 Czech Republic included 459 km of expressways into motorway network from January 1st, 2016
***** all data as of January 1st, 2017 unless noted

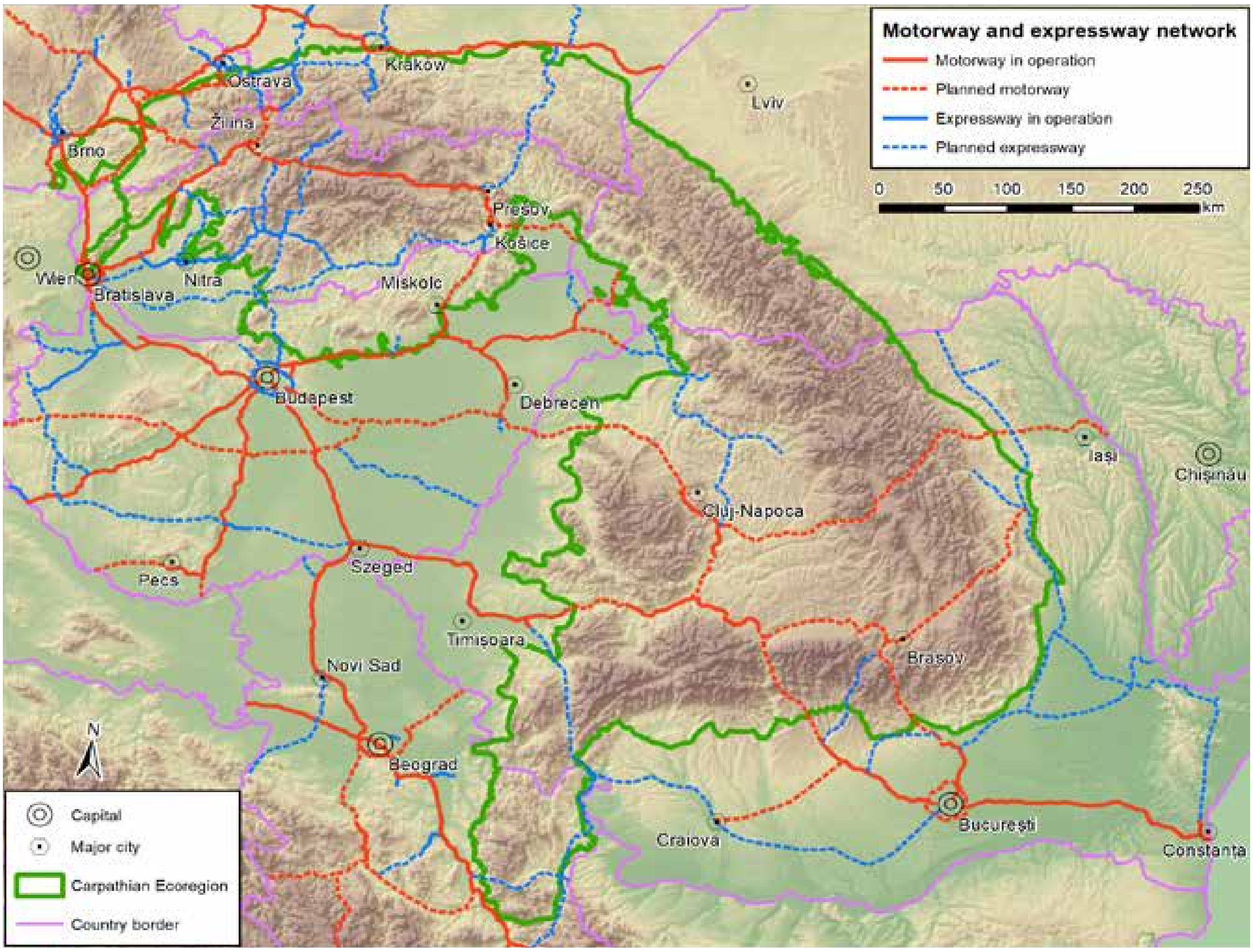

Fig. 5.13 Existing and planned network of motorways and expressways. © TRANSGREEN project, CCIBIS and EEA

Fig. 5.14 The rail network in the Carpathian countries is mostly underdeveloped. © Ivo Dostál

The core railway network is defined by the TEN-T Directive, which sets up the Trans-European high-speed rail (HSR) network and the Trans-European conventional rail network. Most railways in the Carpathian countries are underdeveloped, technologically forgotten in the past. The main lines (mostly those included in the TEN-T network) have been upgraded to increase travel speed up to 160 km/h in the recent years (and probably with an expected increase up to 200 km/h in certain sections). Some basic parameters of railway networks in the individual Carpathian countries are listed in Table 5.2.

Especially the Czech Republic has advanced far and has already completed the rehabilitation of nearly two-thirds of the network of European importance. On the other hand, Romania has just started and completed only about 5% of the network by 2015. These railways are upgraded but still not real HSR lines with speed limits exceeding 220 km/h. These are, however, important for the competitiveness of the railway sector in passenger transportation for long-medium distances from 300 to 800 km (CMC 2013). The Carpathian countries have only just started to think about construction of HSRs. While Hungary recently announced plans to build new connections between Vienna and Budapest, Budapest and Bucharest via Cluj (Bendre 2018), the Czech Republic published a policy document (MD ČR 2017) to open the discussions on the future of HSR. In the cargo sector the most painful problems are the lack of capacity of the major railways, limitations in the transit of main railway hubs and insufficient interoperability due to individual national technical requirements for rolling stock, which are not compliant with common European standards.

Fig. 5.15 Oftentimes it happens that railways do not create impermeable barriers for fauna, but mortality of animals can be quite high in some places. More than 27% of bear mortality caused by traffic in National Park Malá Fatra during the years 1997-2014 (n=29) took place on railways, although traffic intensity on these railways is much lower than on roads in the National Park (Kalaš 2014). Modernization of railways, especially construction of HSR can increase the barrier effect as well as mortality of animals. © Stanislav Ondruš

Table 5.2

Length of railway network in the Carpathian countries as of 2016 (compiled from MD ČR 2017b; ŽSR 2017; INS 2017; Verner 2017 and Eurostat).

	CZ	SK*	HU	PL	RO	UA	RS
Railways [km]	9,564	3,206	7,811	19,132	10,774	± 21,000	3,739
of this electrified [km]	3,236	1,587	3,018	11,874	4,030	± 10,000	1,247
of this double tracked [km]	1,965	1,016	1,250	8,731	2,917	n/a	n/a
Rail network density [km per 1000 sqkm]	121.3	65.4	84.0	61.2	45.2	± 34.8	42.3

5.3 Settlement and traditional life in the Carpathian countries

5

In the territory of the Carpathian countries, two completely different worlds in terms of settlement in rural areas can be seen. Fertile lowlands and hillsides along main rivers in the Outer Carpathian Depressions have attracted inhabitants from prehistoric times and were always the core settlement regions (Hrnčiarová 2009). Ancient empires such as Roman provinces of Dacia and Pannonia, the Great-Moravian Empire or the Empire of Huns developed there. The landscape began to be cultivated for the benefit of agriculture (Demek et al. 2012). The continuous process of intensifying production in these favourable conditions slowly turned landscape into agrarian wastelands, poor in biological diversity with only scattered remnants of nature to be preserved.

The second world is represented by hilly parts of the Carpathian Range, which was – relatively intact by humans for ages – colonized as the last area of Central Europe as late as in the 16th and 17th century. Generally, less favourable conditions forced people to adapt their farming and whole life to the natural conditions. Crop fields are restricted only to the fluvial modelled valleys in lower altitudes, while higher grasslands are suitable for pastures (Hreško et al. 2015). Extensive sheep and goat farming with typical dispersed settlement is widespread across the whole region. Also, forestry is an important part of Carpathians' economy as wood became the main construction and industrial resource in the area. Further changes in landuse are expected as a result of climate changes (Alberton et al. 2017). Although modern age brings a decline in these traditional occupations and ways of living, the preserved patterns of land use, vernacular architecture, handcrafts and cultural heritage still create the image of rural Carpathian regions.

Long narrow valleys of the Carpathians highly impacted the structure of dwellings. Villages of elongated shape were established along mountain streams and due to the lack of suitable space they stretched up to communities several kilometres long. This phenomenon itself then often constitutes a linear barrier with respect to landscape connectivity.

Fig. 5.16 Dispersed settlement of Piatra Fântânele in Pasul Tihuța (Romania) in an elevation of 1,200 m. © Ivo Dostál

Fig. 5.17 Poiana Țapului in Prahova valley (Romania). Linear development with dominating recreational function. © Ivo Dostál

Castles were the base of the administrative structure of Early-Medieval Hungary. The cities emerged significantly later than in other parts of Europe and originated mainly as administrative centres, the crossroads of trade routes or as mining towns. In the period of Industrial Revolution, factories began to concentrate in the cities and attracted labour force from the surrounding mountains. This concentration of workers then caused fast urbanization growth. Accessibility has been the crucial factor for economic development since the mid-19th century.

The turbulent 20th century brought growth of heavy industry and further concentration of inhabitants, due to implemented socialist economy principles. In modern post-socialistic times, the demand for quality of life has increased, causing the process of suburbanization – the rapid expansion of villages in the hinterland of cities, where people sought quiet living in the womb of nature, but with all the conveniences of urban life. The lack of regulation of these processes has caused spatial problems and excessive increase of car traffic in many places.

During the second half of the 20th century recreational functions of landscape were increasingly dominating. First, from the 1950s, there were objects of collective accommodation designed to recreate the working class, later also a high demand for individual recreational facilities began to emerge. The development of recreational potential of the Carpathian communities is also the driving force of construction or expansion of other facilities such as ski-resorts, new cableways, single tracks or off-road trails (Cianga & Răcăşan 2015; Voda et al. 2017). This generally rising intensity of recreation is also related to a low share of permanently occupied houses.

The major trend of a population decline due to work migration is clearly visible especially after the accession to the EU (Cristina et al. 2015) and dwindling rural economy also has an impact on biodiversity. Rare meadow biocenoses are disappearing due to abandonment of originally well managed areas. The original ways of farming are replaced by activities in the field of recreation, although its protagonists can hardly replace the landscape maintenance provided by the native population.

Fig. 5.18 Intensive tourism increases the amount of vehicles in the area and has a major impact on the infrastructure development in these areas. © Barbara Immerová

5

6 Biota and Ecological Connectivity, Demands of Different Fauna Groups on Infrastructure Permeability

6.1 Main types of habitats in the Carpathians with respect to their threat by transport infrastructure

6

The Carpathians represent a biodiversity reservoir for Europe and a 'green-spine' which facilitates dispersion of species and natural re-colonization of some of them into their former distribution areas across the continent. Therefore, fragmentation should be considered at the scale of the whole Carpathian range, not just locally. In this context, linkage areas such as valleys and foothills between mountain areas are of critical importance for ensuring the functionality of the Carpathians as a continental corridor, especially as these linkage areas are also targeted by anthropogenic developments, including transport infrastructure. The main valleys already act as barriers for wildlife due to existing settlements, industrial areas, infrastructure, intensive agriculture, and mineral extractions etc. – all having a cumulative impact. On top of that, new transport infrastructure may be planned in parallel with existing roads and railways, due to lower costs in comparison to mountain areas. For these reasons, special attention must be paid to the linkage areas in the Carpathians when dealing with the issues of landscape permeability.

Building new transport infrastructure threatens different habitats to a different degree and measures aimed at reducing negative impacts of transportation on these habitats will have to be different as well. These differences originate primarily in the spectrum of animal species occurring in given habitats. Each species has

Fig. 6.1 The diversity of natural conditions in the Carpathians is given mostly by varied geological bedrock, high vertical relief segmentation and differing climatic conditions. Many specific habitats with distinctive fauna and flora emerged here due to these factors. Vysoké Tatry, Slovakia.
© Tomáš Hulík

different requirements for connectivity and distinct behaviour with respect to transport infrastructure. However, it is possible to find species with similar requirements on permeability of linear barriers in individual habitats, or to select species that generally represent a wider group with similar requirements (so called umbrella species). Therefore, instead of specific species approach, a more overall ecosystem or landscape approach is necessary.

When dealing with permeability of transport infrastructure, it is useful to define main types of habitats occupied by groups of species with similar requirements. The main habitats from this point of view are alpine and sub-alpine grasslands, forests, dry grasslands and pastures with shrubs, wetlands, watercourses, agricultural landscapes and urbanized areas. Characteristics of these typical habitats and their representative species are described in the following sections.

6.1.1 Alpine and sub-alpine grasslands

This habitat includes all types of alpine forest-free areas, even at altitudes above 1,000 m, which are above altitudinal forest limit or are maintained by sheep or cattle grazing. This type of habitat gradually changes at lower altitudes into forests.

Exactly these ecotone habitats often represent unique communities with the occurrence of both alpine and forest species. alpine meadows and mountain pastures are inhabited mainly by alpine species such as alpine marmot (*Marmota marmota*) and chamois (*Rupicapra rupicapra*).

Typical bird species are for example the golden eagle (*Aquila chrysaetos*), the wall creeper (*Tichodroma muraria*) or the alpine accentor (*Prunella collaris*), and from insects the apollo butterfly (*Parnassius apollo*). Representatives of amphibian and reptile species are the European common frog (*Rana temporaria*) or the viviparous lizard (*Zootoca vivipara*) and the common European viper (*Vipera berus*), which can be met even at high altitudes. Many other species use these areas for migration, especially all species of large carnivores, the red deer (*Cervus elaphus*), etc.

Building transit transport infrastructure in alpine conditions is not very common, but intentions to make mountain sport sites and resorts accessible by traffic can be expected. It is important to keep in mind that alpine environment is always particularly sensitive to any disturbing influences and strong ecological impacts can be expected especially in the case of transport constructions. Therefore, attention should be paid to planning such resorts as well, since ski lifts, related infrastructure and changes in landscape generated by them can have negative impacts on wildlife comparable to a new road. The preferred approach for valuable alpine and sub-alpine grasslands is to be delineated/designated as 'roadless' or 'low traffic' areas.

Fig. 6.2 Transitional habitats between alpine meadows and forests, formed by sparse and low vegetation, are typical for many areas in the Carpathians. Nízke Tatry, Slovakia. © Barbara Immerová

Fig. 6.3 Chamois is a typical inhabitant of the alpine zone in the Carpathians. © Adrian Ciurea

Fig. 6.4 Building holiday resorts always brings development of transport infrastructure into the mountain environment. Jasná, Nízke Tatry, Slovakia. © Barbara Immerová

6.1.2 Forests (mountain coniferous, beech, oak, mixed and alluvial)

Forests belong to the most common and at the same time the most species-rich habitats in the Carpathians. Forests are represented at all altitudinal zones, from lowland floodplain forests through oak and beech forests to mountain spruce forests. The ecological value of forests is influenced by their size, age and species composition and by the intensity of forest management.

Fig. 6.5 Most of the area of the Carpathians is covered by vast forests. © Radu Moț

Fig. 6.6 Large proportion of original forests with high biodiversity is still typical of the Carpathians. © Pavol Polák

Fig. 6.7 The fire salamander is a typical species of submontane deciduous forests. © Václav Hlaváč

Biodiversity of forests decreases with changes in their original structure of woody species and with increasing intensity of economic activities. In this process, rare and threatened species disappear first. Forests are home to a wide spectrum of species from all groups.

Rosalia longicorn (*Rosalia alpina*) and some other invertebrates are typical components of full-fledged natural forests. Typical amphibian species of submontane deciduous forests include the fire salamander (*Salamandra salamandra*) or the yellow-bellied toad (*Bombina variegata*).

The eastern slow-worm (*Anguis colchica*) can be mentioned as a representative of reptiles from forest habitats. Forests are also habitats for many bird species – from passerines or songbirds (order *Passeriformes*) through woodpeckers (order *Piciformes*) to sensitive species such as the western capercaillie (*Tetrao urogallus*) or several species of birds of prey and nocturnal raptors (owls). The mammalian spectrum is very wide as well – small rodents and insectivores, many bat species, animals living in tree crowns such as the red squirrel (*Sciurus vulgaris*) and dormice (the edible dormouse (*Glis glis*), the forest dormouse (*Dryomys nitedula*), the garden dormouse (*Eliomys quercinus*)), the European wildcat (*Felis silvestris*), large carnivores: the grey wolf (*Canis lupus*), the Eurasian lynx (*Lynx lynx*), the brown bear (*Ursus arctos*) and large ungulates. The last listed are represented mainly by the red deer (*Cervus elaphus*). The moose (*Alces alces*) occurs irregularly in northern areas, the European bison (*Bison bonasus*) has been reintroduced into several areas in Slovakia, Ukraine and Romania.

From the viewpoint of building the transport infrastructure, forests constitute a habitat where requirements of the widest spectrum of species needs to be addressed – from amphibians, small and medium-size mammals, through tree-crown species and bats to large mammals, which can also use forests as a migration corridor (see Chapter 6.4). The barrier effect of individual road sections will vary depending on the given forests' habitat value, but also according to the significance of their function as migration corridors – from local to regional.

6

case study

Intensity of traffic affects permeability of local roads for the brown bear

Smaller roads of lower category with intensive traffic can create an impermeable barrier for the brown bear. A study by Skuban et al. (2017) performed in north and central Slovakia confirmed that a traffic volume exceeding 5,000 vehicles per 24 h completely restricted the movement of bears. Bears were more likely to cross during the periods of low- rather than high-traffic volumes, and the crossings occurred primarily at night. Males were able to cross the roads with annual average daily traffic up to 5,000 vehicles per 24 h, whereas females were only able to cross the roads with less than 4,000 vehicles per 24 h.

© Karol Kaliský

© Michal Kalaš

Fig. 6.8 Case study: Intensity of traffic affects permeability of local roads for the brown bear © Skuban et. al., 2017

6.1.3 Dry grasslands and pastures with shrubs

Both natural and secondary (man-made and maintained by extensive grazing) grasslands belong to these habitats. This type of habitat used to be represented to a bigger extent, but substantial part of it has been converted to agricultural land. On the other hand, areas unsuitable for intensive farming often turn into a stage of shrubs and forests as a result of terminating extensive grazing and proceeding succession. Dry grasslands and grasslands with shrubs and trees are typically characterized by high species diversity of plants, invertebrates, but also reptiles and birds. They also benefit from the ecotone effect on the boundaries with neighbouring habitats (forests, rivers, etc.).

Fig. 6.9 Extensive pastures (with lower number of animals per given area unit) with juniper shrubs constitute a habitat with high biodiversity. Koločava, Ukraine. © Václav Hlaváč

Characteristic species of this type of habitats are for example the aesculapian snake (*Zamenis longissimus*), the Balkan wall lizard (*Podarcis tauricus*) or the common spadefoot (*Pelobates fuscus*). Typical mammals are represented by the European ground squirrel (*Spermophilus citellus*), the European hare (*Lepus europaeus*), the steppe polecat (*Mustela eversmanii*), or the golden jackal (*Canis aureus*), and the European marbled polecat (*Vormela peregusna*) at the Southern edge of the Carpathians in Romania. Bird species that occur in dry grasslands and pastures with shrubs and trees and can be affected by transportation infrastructure are low flight raptors such as harriers (*Circus sp.*), owl species or insectivorous birds that follow road lighting like nightjars (*Caprimulgus europaeus*).

Fig. 6.10 The European ground squirrel is a typical inhabitant of dry grasslands. Its populations are decreasing in many areas of the Carpathian region due to changes in land use (intensification of agriculture) and fragmentation is a big threat to this species. © Adrian Ciurea

From the viewpoint of building the transport infrastructure, dry grasslands and pastures with shrubs represent habitats where it is necessary to address requirements of specific species occurring in the areas. It may most often mean ensuring connectivity among communities of invertebrates, which are usually closely bound to local vegetation. From the vertebrates, this will likely concern reptiles and small and medium-size mammals. Especially grasslands with shrubs and trees can have the function of a migration corridor (see Chapter 6.4) for large mammals, but also for invertebrates, bats and other species. In such cases it is also necessary to address the requirements of this group of animals as for migration permeability.

6.1.4 Wetlands

This type of habitat includes springs, marshes, swamps, peatlands, fens, ponds, lakes and man-made water bodies, and wet meadows in the valleys of river floodplains. These are very often areas with exceptionally high biodiversity. Wetlands usually have a great productivity; therefore, substantial part of the original wetlands is now exploited by humans as fisheries or for agriculture.

When looking at the possible placement of transport infrastructure, we must pay special attention to areas that are not economically used or areas where extensive farming does not bring a significant decrease in biodiversity and ecological value. Typical species of Carpathian lowland wetlands are for example the fire-bellied toad (*Bombina bombina*), *Pelophylax sp.*, the European pond turtle (*Emys orbicularis*), the grass snake (*Natrix natrix*), a wide range of water birds and the Eurasian otter (*Lutra lutra*). Wetlands are often an attractive hunting habitat for bats as well.

When planning a new transport infrastructure, it is always necessary to consider such variants in which wetlands are not affected at all. In case this is not possible, priority needs to be given to the aquatic animals, but also to the semiaquatic ones, which migrate along both standing and running waters. That means it is necessary to keep full continuity of the water environment but also of the subsequent terrestrial ecosystems. Another issue to consider is using salt in winter road maintenance approaches. It is an example of secondary effect of transport infrastructure on wildlife, but can have a negative impact especially on wetlands, where the run-off consequently ends up and dissolves. Wet meadows are prone to invasive species expansion and building activities can favour this phenomenon.

Fig. 6.11 Wetlands in larger river floodplains represent areas with exceptionally high biodiversity. It is necessary to avoid impacts on these valuable ecosystems when planning transport infrastructure. Lower part of Sula river basin, central Ukraine. © Andriy-Taras Bashta

Fig. 6.12 European pond turtle is bound to standing or slow-flowing waters. It can be sporadically found on roads near the sites of its occurrence. © Radu Luca Popa

6.1.5 Watercourses

Fig. 6.13 Watercourses are habitats and wildlife corridors for many aquatic and semiaquatic species. When the stream has well preserved natural banks and riparian vegetation, even many terrestrial species move/migrate along the watercourse. Mureș River, Romania. © Radu Moț

Fig. 6.14 The Eurasian otter is bound to watercourses. Although a good swimmer, it prefers streams with natural banks, without technical adaptations. Otters often move for more than 20 km in one night. © Václav Hlaváč

This type of habitat includes all types of watercourses, from small streams to large rivers such as the Tisza or Danube. Watercourses have a different character – from mountain streams with trout to slow-flowing lowland rivers with carp. The ecological value of the watercourses should always be taken into consideration, irrespective if they are in a natural condition or artificially regulated (canalized).

6

Watercourses in the Carpathians are inhabited by a wide range of fish, including species typical for the Danube basin, such as sturgeons or the Danube salmon (*Hucho hucho*). Also, the fauna of small streams with the Eurasian minnow (*Phoxinus phoxinus*), the Ukrainian brook lamprey (*Eudontomyzon mariae*) and the riverine ecotype of the brown trout (*Salmo trutta morpha fario*) is very significant. From the reptiles, the dice snake (*Natrix tessellata*) and the grass snake *(Natrix natrix)* occur often in the proximity of rivers, and in lower reaches also the European pond turtle (*Emys orbicularis*). The Eurasian otter (*Lutra lutra*) moves along the rivers and during the last years also the Eurasian beaver (*Castor fiber)*. A large number of birds are associated with rivers as well; they often use large watercourses as migration corridors or wintering sites. Bats use the surroundings of streams for hunting and cavities in bank trees as hiding places. A line of watercourses with bankside vegetation, especially when surrounded by open agricultural landscape, constitutes an important migration corridor for bats.

In case the transport infrastructure interferes with a watercourse, it is always necessary to keep the continuity of the watercourse for fish species and other aquatic organisms, as well as the continuity of banks for semiaquatic animals. Such crossings often create an opportunity to make a passage even for other species, including large mammals. With watercourse crossings it is also necessary to always consider the movements of birds and bats along the watercourse and to know when plan measures are needed to prevent collisions with vehicles.

6.1.6 Agricultural landscape

6.1.6.1 Landscape mosaic with extensive fields and meadows

This type of agricultural landscape is represented by a varied mosaic of pastures, meadows and small crop fields, patches of woodland, protective verges, orchards etc. It originated as a result of traditional small-scale farming in the Carpathian area. This environment typically has a high diversity of habitats and therefore also high species-richness and relatively good possibilities for the species to move through the different neighbouring habitats.

Fig. 6.15 Small scale farming creates diverse mosaic of habitats and is usually linked with high biodiversity. Unfortunately, traditional farming is now often replaced by intensive farming on large areas. © Ivo Dostál

Unfortunately, the traditional way of farming has been receding in the last decades and the trend continues. Efforts to maintain as much traditional farming as possible or trying to go back to it are therefore very important.

6.1.6.2 Agricultural landscapes with intensive crop fields and meadows

Fig. 6.16 Large-scale approaches and intensification of agriculture lead to a decrease in biodiversity and ecological value of agricultural landscape. © Michal Ambros

In the second half of the 20th century, large-scale approaches and intensification of agriculture started to be applied, which meant a decrease in biodiversity and ecological value of agricultural landscape.

As a result, usually only common and highly adaptable species currently occupy this agricultural landscape. Insect communities are strongly suppressed here (with the exception of several species of field pests) and bird communities are limited as well (the grey partridge (*Perdix perdix*)). Examples of amphibians living in agricultural landscape are the European green toad (*Bufotes viridis*), or the sand lizard (*Lacerta agilis*), typical of areas not used for farming. From mammals it is the common vole (*Microtus arvalis*), which at the same time serves as the food base for 'mice-eating predators', both birds (raptors and owls) and mammals (fox, mustelids). Also, two species of ungulates are able to successfully use current agricultural landscape – the wild boar (*Sus scrofa*) and the roe deer (*Capreolus capreolus*). In general, most species in this type of landscape are strongly influenced by the crops grown in a given year. It means that the occurrence of many species is not natural, but rather a consequence of such choices in agriculture. A specific situation may arise when the agricultural landscape is linked to mountain forests. Some species of large mammals such as bears, the wild boar or the red deer are attracted by the offer of food in the fields (especially maize). At the time of this food abundance, the movement of these species between forest and corn fields can be very common.

Fig. 6.17 The roe deer is a typical species of agricultural landscape. Rut takes place in this species in the summer months – animals move more and become more often victims of traffic. © Václav Hlaváč

Fig. 6.18 Biodiversity of urban environment generally tends to be quite limited, but even here, securing the connectivity among green areas may be beneficial for some animal groups. © NDS Archives

When planning transport infrastructure, it is usually enough to consider the requirements of common species of agricultural landscape. In specific cases, even agricultural landscape can represent a migration corridor for large mammals (see Chapter 6.4). This can happen in a situation where a stripe of agricultural land lies between large forested areas. Careful approach is needed in large scale agricultural plains in which the frequency of culverts or other possible passages for fauna is low. This leads to a lack of mitigation measures and low wildlife permeability. An appropriate system aimed at ensuring effective frequency of mitigation measures is necessary and reconstruction of connectivity at landscape level should be considered as an option here.

6.1.7 Urbanized areas

It is important to consider the particularities of this type of environment when dealing with transport infrastructure going through built-up areas. Towns in the mountain environment often directly neighbour with natural or even wilderness areas, which means that animals come to a close contact with urban environment. Typical of the Carpathians is also location of housing development into mountain valleys, where it creates long, continually built-up areas. Biodiversity of urban environment generally tends to be quite limited but is not to be overlooked. Depending on specific local conditions, some suburban areas can constitute a suitable habitat for different animal groups (e.g. reptiles, amphibians, birds).

In the Carpathians, it is usually possible to exclude the occurrence of large mammals from urbanized areas. However, it is necessary to consider specific situations when for instance large carnivores adapt to food sources in the city surroundings or when a narrow migration corridor remains between settlements and it is important to maintain it (see Chapter 6.4). Movement of birds can be expected even in the city environment, as well as of small mammals in the vicinity of parks. Typical problem of building transport infrastructure in urbanized areas are noise protection walls, as they significantly increase the barrier effect. Glass or other transparent walls mean a danger of collisions for birds and numbers of dead individuals are in some cases very high. The basis for solving this problem should always be an effort to design these walls in a way that they can be noted by the birds early enough – for more details see Chapter 10.4.4.

Lighting is often a problem as well, mostly for bats and especially on roads/paths near different water bodies. In such places, lighting attracts a large number of insects and bats catching the insects can be hit by passing cars.

Moreover, cycle paths built along water streams and marches can be dangerous for snakes and amphibians. Especially snakes are heating themselves on tarmac surface during sunny days and thus can easily become victims of cyclists.

6.2 Demands of various groups (categories) of animals on permeability of transport infrastructure

6

Permeability of linear barriers is often a prerequisite for survival of a whole spectrum of indigenous species. However, ensuring permeability can at the same time result in faster spreading of non-native species. This fact needs to be taken into account while dealing with permeability of landscape. Permeability of a transport infrastructure is also significantly influenced by its fencing. The aim of the fence is to prevent animals from entering the road and improve traffic safety. However, fences also significantly increase the barrier effect of the infrastructure. They should only be built where animals have the opportunity to cross the road/railway using a safe fauna passage. Therefore, it is important to decide between 'do nothing' on infrastructures that are still permeable or 'do everything', which means build both fauna passages and fences.

Major groups of Carpathian fauna and their basic requirements for connectivity and permeability of transport infrastructure are described in this chapter. A detailed overview of the measures and requirements of the species on the passage parameters follows in Chapter 10.2.

From the viewpoint of requirements on connectivity and parameters of fauna passages, the Carpathian fauna can be divided into the groups described in following sections.

6.2.1 Terrestrial invertebrates (especially insects)

Most species are bound to a specific habitat with specific plant species. It is a very diverse group; individual species often have very specific ecology and life cycles. Many species are able to fly as adults, but their ability to overcome longer distances is varied. The further existence of many of these species is currently threatened and fragmentation of populations is a significant issue for them. A dual approach should be applied in relation to transport infrastructure:

- In the case of species with a high degree of protection (i.e. the apollo butterfly, the rosalia longicorn), the goal should be to solve each situation based on the needs and migration abilities of a particular species.
- In the case of habitats with a high invertebrate species diversity, connectivity must be solved at the habitat level in a way that ensures full linkage of habitats on both sides of the transport infrastructure.

Fig. 6.19 Fences prevent animals from entering the roads and improve traffic safety, but they significantly increase the barrier effect. They should therefore only be built where animals also have the opportunity to cross the infrastructure using a safe fauna passage. © NDS Archive

Fig. 6.20 The rosalia longicorn is a typical species of original beech forests of higher altitudes from 200 to 1,000 m above sea level. © Adrian Ciurea

6.2.2 Fishes and other aquatic animals

This group includes not only fish species but also other aquatic animals such as crayfish, dragonflies, freshwater clams, snails and many more. Fishes that inhabit watercourses often move long distances, some even migrate between freshwater and the sea (anadromous fishes – live in the sea and migrate to fresh waters to spawn, catadromous fishes – adolesce in fresh waters and then migrate to the sea to spawn, potamodromous fishes – migrate only within freshwaters to spawn). Free movement through the watercourse in both directions is the condition for existence of most aquatic organisms.

Fig. 6.21 The Eurasian minnow (*Phoxinus phoxinus*) is a common species in mountain streams and rivers. There are many impermeable culverts on small streams, which fragment the habitat of this species. © Stanislav Harvančík

6.2.3 Amphibians

Amphibians represent not a very numerous group that includes so called caudal species (newts, salamander) and acaudal species (frogs). Most amphibians belong to threatened and protected species. This group is specific by reproduction bound to water, where eggs develop, and tadpoles live. Adults then leave the water environment and often live in places quite far away from the places of reproduction. During their migration time, amphibians often must overcome roads and these situations could translate into mass deaths – even thousands of individuals are killed in a short time-period of several days at one place.

High physical activity even outside of the reproduction period is also observed in some species. It is often caused by specific climatic conditions such as night rain after a long period of drought. Moreover, warmed up road after rain can attract insects, and amphibians follow the insects. All these situations can cause high amphibian mortality, which in extreme cases can even lead to extinctions of local populations.

Fig. 6.22. The yellow-bellied toad is a typical inhabitant of mountain areas. It usually reproduces in small temporary water bodies such as tractor tracks or road water drainages, which often become mortality traps for eggs or larvae. © Ionut Iorgu

6.2.4 Reptiles

This is a diverse group that includes lizards, snakes and two species of turtle – the aquatic European pond turtle (*Emys orbicularis*) and the terrestrial Hermann's tortoise (*Testudo hermanni*). Most reptile species are bound to warm grasslands with hiding places (shrubs, fallen wood, rocks or vegetation verges). The common European viper (*Vipera berus*) climbs to the highest altitudes, while the European pond turtle (*Emys orbicularis*) and the dice snake (*Natrix tessellata*) prefer lowland rivers and wetlands. Reptiles usually use the suitable landscape all-around and they typically move only short distances. When a habitat attractive for reptiles is intersected by a road, high mortality can result as they are attracted by warm surfaces. High mortality of reptiles is often detected also on bicycle trails. In case of threatened populations, measures with the aim to prevent reptiles from entering the road and at the same time to navigate them to safe passages are required.

Fig. 6.23 The Aesculapian snake inhabits most often light shrubby slopes. When their habitat is split by a road, these snakes often crawl across the road and become victims of traffic. Special Protection Area Poľana, Slovakia. © Miroslav Jarný

6.2.5 Birds

Birds also represent a very diverse group of species inhabiting all types of environment. All bird species living in the Carpathians are able to fly, so transport infrastructure does not represent a migration barrier for them. However, some small species from forest environment (the goldcrest, some tit species) overcome wide busy motorways only reluctantly and prefer underpasses or overpasses for these situations. Anyhow, many bird species still become victims of traffic. The main factors associated with transport infrastructure and often causing high bird mortality are discussed in Chapters 10.2.5 and 10.4.4.

Another issue that needs to be considered is the impact of winter maintenance on some species (for example the Eurasian siskin). Mass deaths resulting from consumption of salt crystals used in winter road salting have been recorded. It can be solved by using crystals of minimum size or even better by using a saline solution.

However, not all aspects of transport infrastructure always have negative effects. Bridges can for instance serve as nesting sites for birds (the white-throated dipper, the barn swallow, the common house martin, the common kestrel, and the peregrine falcon) and hiding sites for some bats. Nesting of birds on bridge objects can have some advantages for them (nests are not accessible for predators) but can bring some risks as well. Purposeful support of bird nesting on bridges is often problematic and can also conflict with regular technical maintenance. Therefore, it is the best to solve specific cases by an agreement between road (bridge) management and conservationists.

Fig. 6.24 Owls have high mortality on roads, because they often hunt for small rodents on the verges. This Ural owl (*Strix uralensis*) looks out for its prey from electric wiring. © Tibor Sos

Fig. 6.25 Bridges can create good nesting conditions for the common house martin (*Delichon urbica*, visible in the picture) and also for the barn swallow (*Hirundo rustica*). © Andriy-Taras Bashta

Fig. 6.26 The wildcat lives secretly in deciduous and mixed forests. The size of its home range varies based on conditions from 50 to 1,200 ha. © Tomáš Hulík

Fig. 6.27 The Eurasian beaver can become a frequent traffic victim where watercourses or water bodies cross or come close to linear infrastructure. This species, however, can also cause damage to the infrastructure by its own activities (flooded ditches or culverts due to beaver dams, damage to vegetation along the infrastructure or to some parts of the infrastructure itself). © Ladislav Vogeltanz

Fig. 6.28 Edible dormouse inhabits deciduous forests dominated by oak and beech, where it often visits cottages and cabins. They spend most of their lives on trees, so connectivity of tree tops and the entire forest environment is very important for them. © Andryi-Taras Bashta

6.2.6 Terrestrial mammals up to the size of fox and badger

This is a diverse group including small rodents, insectivores, lagomorphs, mustelids, foxes and wildcats. Environmental requirements and the ability to overcome barriers vary in different subgroups; they can be quite specific mainly in species living permanently underground, such as the European mole or species of the *Spalax genus* (mole rats). However, the ability to cross roads differs even in similar species, for example in the European hare or the European rabbit. While the European rabbit lives in burrows, capable of using small culverts, the European hare prefers open spaces and practically does not use small fauna underpasses at all.

Nevertheless, the group in general includes mobile animals that frequently cross roads while searching for food. They usually willingly use even small bridges and culverts, but only under the condition that these constructions have a suitable technical design.

6.2.7 Otter and other semi-aquatic animals

This group includes species that live near water environment and often move along watercourses. Typical representatives are the Eurasian otter and the Eurasian beaver, but many other species move along watercourses as well (the European polecat, the ermine, the European water vole and others).

Although these species can swim and dive, most of them do not use bridges without existing dry banks. Unsuitable bridges then force the animals migrating along streams to cross roads.

6.2.8 Mammals living on trees

The dormouse – all species, the Eurasian red squirrel, and the European pine marten. These animals can use all passages where connectivity of the forest environment is ensured. In addition, in view of their ability to move in the tree tops, they can use special overpasses interconnecting tree tops.

Fig. 6.29 The Daubenton's bat hunts near water bodies and watercourses. It overcomes infrastructure usually via underpasses (bridges over watercourses). © Andryi-Taras Bashta

Fig. 6.30 Most traffic accidents with game species involve the roe deer or the wild boar. Therefore, measures to reduce collisions with game are often focused on these two species. © Václav Hlaváč

Fig. 6.31 The wolf belongs to species with the highest spatial requirements; individuals can move hundreds of kilometres in several days. © Tomáš Hulík

6.2.9 Bats

There are over 40 species of bats in Europe that differ in size but also in their way of life. All species can fly, some of them could overcome long distances high above ground, while others avoid free space and move predominantly in the forest environment. For such species, busy roads create barriers for their movement. For this reason, fauna passages should be solved for this group as well. Lighting along transport infrastructure attracts insects and as a result, some bat species become traffic victims in such places.

6.2.10 Medium-sized mammals (the European roe deer, the wild boar)

These species are widely spread and inhabit both forest and agricultural landscape. While the roe deer are usually restricted to their permanent home ranges, the wild boar often makes long distance moves. The requirements of these two species are considered as a standard to ensure permeability of roads in common landscape.

6.2.11 Large mammals (the red deer, the moose, the European bison, large carnivores)

Three species of ungulates and three species of carnivores are included in this group. The wolf, the lynx and the bear belong to endangered and protected species. As top predators, these animals occupy large areas in very low population densities. Connectivity between different parts of their populations at supraregional scale is crucial for their long-term survival. The wolf is more adaptable but generally the lynx and the bear are closely linked to forested landscapes. The red deer is a widespread species in the Carpathians. It is used as an indicator species; its demands for permeability of landscape are similar to those of large carnivores. The moose is widespread mainly in northern Europe; only individual migrating animals occasionally visit the Carpathian region. European bison was reintroduced in some areas and has locally become a member of the Carpathian fauna again.

case study

Landscape fragmentation (using the method of effective mesh size) and the wolf distribution within Central Europe

Current wolf distribution in Central Europe is related to the degree of landscape fragmentation. The lowland population (Baltic and Central European) uses relatively unfragmented habitat patches in northern Poland to spread westwards. In contrast, the Western Carpathian population is more isolated due to the surrounding fragmented landscape. Recently, there have been no signs of marked expansion beyond the area of the Carpathians and only one documented long-range dispersal event outside of the Carpathians has been documented to date. The arrow depicts the distance and direction of dispersal performed by a male wolf killed on D1 motorway near Jihlava (the Czech Republic) in March 2017.

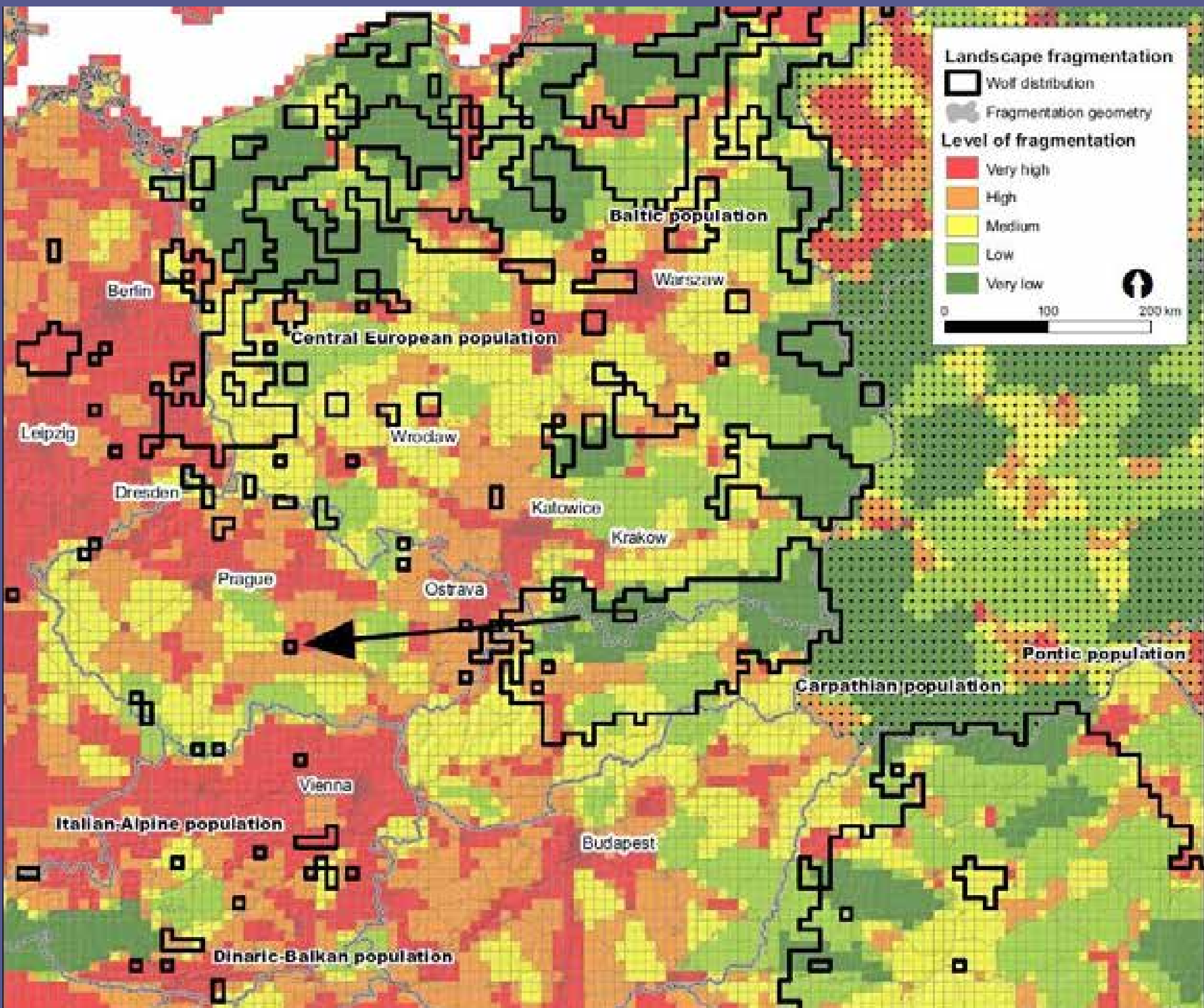

Fig. 6.32 Case study: Landscape fragmentation (using the method of effective mesh size) and the wolf distribution within Central Europe. © Hulva et al. 2018

6.3 Connectivity of different types of habitats

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When planning a new transport infrastructure, it is necessary to ensure connectivity of populations of all species typical for the given habitat and for species which are not permanently present but would use this habitat as a linkage area. Three main questions usually must be addressed while doing so:

- **What kind of fauna passages (with what kind of parameters) to build?** There is already enough experience regarding the use of overpasses and underpasses by different animal species in Europe and in other parts of the world. These issues are described in detail in Chapter 10.

Fig. 6.33 The red deer (*Cervus elaphus*) is a common species in the Carpathians. Its requirements for types and parameters of fauna passages have been found to be similar to those of large carnivores. Therefore, data on the behaviour of the red deer in some passages indicate that the passage is very likely suitable for large carnivores as well. © Michal Králik

- **What should be the density and placement of such fauna passages?** That means how many passages of each category and where exactly in a given road section they should be built. Safe crossings of wildlife corridors with transport infrastructure are very expensive constructions; therefore, it is necessary in general to determine a minimum number of passages that still prevents fragmentation of populations. This is, however, a very complicated question from the biological viewpoint (it is difficult to determine the number of migrating individuals needed to prevent genetic isolation). The efficiency of implemented measures in relation to funds spent is thus always a significant viewpoint. Although environmental effects are often difficult to calculate in simple monetary values, the principles of cost-benefit analysis (including factors such as mitigating human casualties in traffic or adaptation to climate-driven phenomena) can be used for this purpose. It is convenient for practical reasons to set general recommendations for prevention of habitat fragmentation that can be implemented at a reasonable cost (these recommendations are listed further along with individual habitats).
- **How should the fauna passages be integrated into the landscape in order to ensure their functionality?** This question partly covers the previous two but places the emphasis on local conditions (both environmental and human-induced), which always need to be taken into consideration. It means that for each new construction plan, a comprehensive analysis of all factors with possible impacts and their cumulative effects in the given area has to be prepared. The most important factors to evaluate are typically: management of surrounding land (e.g. agriculture, fences and other barriers, forest and water management, mineral extraction, industrial or housing development, etc.). The limits given by the specific conditions of the landscape can also be actively influenced by the creation of different types of structures leading the animals to the passages (tree planting, corridor formation, guiding fences, etc.).

It is necessary to mention the crucial role of spatial planning to take into account reliable information about the future development in the area, because even a perfectly designed fauna passage in a well-chosen spot will not be effective if the wildlife corridor later becomes blocked by unexpected development or if high disturbance occurs from the human activity (see Chapter 6.4).

In order to reach sufficient permeability of transport infrastructure for animals, it is in the first step recommended to verify the possibility of multipurpose use of bridges (culverts) that are originally proposed on the planned route for other uses. Especially culverts, bridges over watercourses, but also crossings of planned infrastructure with forest or field roads offer possibilities to adjust these objects in a way that they can be used as fauna passages as well. It is often possible to increase their functionality to reach very good effects by only slight enlargement of the bridge parameters. This type of solution is always much cheaper than building special passages.

Fig. 6.35 Culverts can – with a suitable design – serve as fauna passages for many animals. Rectangular shape is always the preferred solution. Tube culverts are not an optimal solution, but otters are able to use them at times of lower flow rates. © Václav Hlaváč, phototrap picture

Fig. 6.34 Multipurpose use of bridges is usually the preferred solution in terms of costs. Also, linking functions of fauna passages with bridges over watercourses or with viaducts is suitable. On the contrary, a busy path on a green bridge can cause large mammals to avoid it, which then makes the entire measure non-functional. Poprad, Slovakia. © EUROSENSE s.r.o., 2010

Fig. 6.36 In cases when bridges that could be adapted for use as fauna passages do not exist, special passages must be built to ensure a safe crossing of the motorway with the wildlife corridor. Overpass on D2, Slovakia. © NDS Archive

It is very important to note that the joint use by wildlife and humans brings the risk that sensitive species such as large carnivores will not accept such fauna passage or that they will be used only by particular individuals. Therefore, at a crossing point of infrastructure with known migration corridor of large mammals (see Chapter 6.4), special overpasses (green bridges) or large underpasses (bridge across a valley or viaduct across floodplain) without any human activity are the preferred solutions.

Structures suitable for multipurpose use:

- culverts
- bridges over small streams
- motorway bridges over forest paths/roads
- forest paths/roads leading from above over a motorway/road/railway
- large bridges over rivers or entire valleys
- estacade bridges (viaducts) over floodplain areas

Multipurpose bridges and culverts must be clearly assigned with their permeability function in the environmental permit and their constructive details should be followed. When multipurpose objects cannot sufficiently ensure connectivity for the target species, special objects aiming only for migration of fauna should be proposed. This principle needs to be respected in all types of habitats.

Next section describes recommended approaches to proposing adapted transport infrastructure in different habitat types. Types of passages recommended for a given habitat are discussed, as well as the minimum density of such passages. Listed general recommendations should be taken into consideration as the basic standard, since local conditions and particularities always need to be accounted for in finding the best solution for specific constructions.

It is important to point out that especially large mammals undertake long migrations during which they are not bound to specific habitats. In case a migration corridor of large mammals is identified in an area (see Chapter 6.4), it is always necessary to design suitable fauna passages for these species at the site where the corridor is crossed by a transport infrastructure.

6.3.1 Alpine and sub-alpine grasslands

As is clear from the habitat description, these are exceptionally sensitive ecosystems. Important transport infrastructure should always be planned in a way that these habitats are not affected. If avoiding construction in these areas is not possible, it is necessary to pay special attention to technical solutions and to minimize the impacts on mountain environment. Demands for maximum transport capacity should in this case be always inferior to environmental requirements. This is true for both technical parameters of the road (width arrangement) and choosing its route. Increased attention needs to be paid to integrating the construction into the surrounding landscape. With respect to permeability, it is necessary to address connectivity of entire ecosystems. Sufficient extent of tunnels is an optimal solution in this type of habitat.

Fig. 6.37 In addition to traffic itself, accompanying human activities along roads increase the impact on sensitive mountain ecosystems. Connectivity should always be ensured by a sufficient number of tunnels. Transfăgărășan, Romania. © Blanka Dovrtělová

6.3.2 Forests

Forests in general represent a habitat where permeability must be dealt with for the widest spectrum of animals. It is therefore important to work with all culverts and bridges and to adapt them to multipurpose use. The density and placement of fauna passages are in some groups (aquatic fauna, amphibians, otter and others) given by environmental conditions (crossing with watercourse, crossing of a wetland, etc.).

For most terrestrial forest species, it is crucial to address the question of what is the minimum number of fauna passages that ensures the necessary connectivity and prevents fragmentation of populations. The recommended densities of fauna passages for different groups of animals are listed below. These recommendations are only indicative, local conditions must always be the main criterion for such a decision.

When multipurpose bridges do not reach the listed recommended densities, it is necessary to proceed to building special passages of a given category. It is also necessary to assess whether the multifunctional objects ensure permeability for species with specific requirements (species living on trees, forest species of bats, etc.). If not, special measures for these species should be proposed.

Table 6.1

Recommended densities of fauna passages in a forest habitat:

Animal category	Recommended average distance between functional passages
Mammals up to the size of fox and badger	1 - 2 km
Medium-sized mammals	2 - 5 km
Large mammals: in areas of permanent occurrence	3 – 5 km
Large mammals: outside of permanent occurrence areas	Only on migration corridors or in linkage areas (see Chapter 6.4)

In case a transport infrastructure crosses unique natural forest ecosystem, for example protected natural/old growth/primeval forests, it is essential to ensure a complex connectivity of ecosystems on both sides of the planned road. This can be achieved by:

- sufficiently wide overpass/es that will allow for connectivity of tree canopy growths,
- tunnel/s,
- large bridge/s that overcome(s) an entire valley.

Fig. 6.38 Movement of all animal groups, including all species of large mammals needs to be expected in a forested landscape. This picture shows the European bison crossing a third-class road near Hostovice (district of Snina), Slovakia. © Anna Macková

6.3.3 Dry grasslands and pastures with shrubs

These specific habitats are significant most of all by diversity of invertebrates, reptiles, birds and small mammals. Permeability should be ensured here mostly by adjusted culverts and bridges over small streams and channels. Field-road bridges over motorways can play a very important role. However, a condition for functionality is widening these bridges to get a 2-5 m wide strip of grassland vegetation on both sides of the road. Most steppe invertebrates are bound to specific vegetation types and are therefore not able to use culverts or small bridges. Such multipurpose overpasses can be used by a whole range of steppic species, including invertebrates, also some reptiles, the European ground squirrel, the hare and many others.

In some cases (the Aesculapian snake, the European ground squirrel), special measures preventing animals from entering the road and leading them to suitable passages are necessary.

If a transport infrastructure crossed a unique steppe ecosystem with extraordinary diversity or significant protected species, it would be necessary to ensure a complex connectivity of ecosystems on both sides of the road by a sufficiently wide overpass.

Table 6.2

Recommended densities of fauna passages in habitats of dry grasslands and pastures with shrubs:

Animal category	Recommended average distance between passages
Mammals up to the size of fox and badger	1 - 2 km
Medium-sized mammals	3 - 8 km
Invertebrates and small mammals (the European ground squirrel)	3 – 5 km (adapted overpasses with steppic vegetation)
Large mammals	Only on migration corridors or in linkage areas (see Chapter 6.4)

6.3.4 Wetlands

Typical requirement in these habitats is ensuring permeability for wetland species, especially for amphibians, the European pond turtle, the dice snake, and from mammals for the Eurasian otter. Therefore, main emphasis must be placed on all bridges where transport infrastructures cross water bodies or wetlands. Their proposals need to count with maintaining (or creating) dry banks.

Roads leading on top of pond dams are very dangerous. Amphibians, but often also otters moving along the stream or water body are forced to overcome the dam and frequently become victims of traffic. Solution depends on local conditions; an optimal way is to merge fauna passage for these species with the space assigned for flood flow rate. Another option is to install fencing (barriers) that guides the animals to special underpasses (amphibian passages, otter tunnels, etc.).

The risk of aquatic birds' mortality should also be accounted for when planning transport infrastructure in wetlands. Special measures to prevent mortality in critical places need to be planned. A way of either planting suitable vegetation along the road or installing protection walls can be used, both with the aim to force the birds to fly higher above the passing vehicles.

Fig. 6.39 An otter moving along a watercourse must cross the dam of a fish pond. A road leading to the top of the dam is therefore always a very risky place for otter and other semiaquatic species. © Václav Hlaváč

Fig. 6.40 In case it is necessary to overcome the wetlands, a viaduct is usually an optimal solution. However, protection walls to limit disturbances and prevent bird mortality are essential. Motorway M3, Hungary. © András Szirányi

6.3.5 Watercourses

The priority requirement in this habitat type is always maintaining the migration continuity for all aquatic and semiaquatic animal species. Strengthening the function of bridges as fauna passages is in this case in agreement with increasing demands on the safe dealing with floods. Enlarging the bridges' dimensions is in favour of both functions. Partial widening of a bridge over a watercourse is always a cheaper solution than building a new special passage, therefore it is appropriate to always consider whether the bridge can in a given location fulfil the function of a fauna passage even for other animal groups (for example medium-sized ones and large mammals). A frequent issue of bridges over watercourses is the technical adjustment of the stream bed under the bridge, as it often worsens the passability for aquatic and semiaquatic species. Therefore, the priority in the case of medium and large streams should always be to keep the stream in its natural state. Adjustments are sometimes necessary in case of small streams; however, they should always be solved with the use of natural materials (preferring stone to concrete). Even in the case of technical adjustments it is necessary to maintain minimum jaggedness of the bottom and banks and to keep the passability through both the 'wet' and the 'dry' route. Any vertical steps/barriers, sedimentation sumps, stilling basins etc. must be excluded.

6.3.6 Agricultural landscape

Current agricultural landscape in the Carpathians includes areas with different biodiversity levels. Submontane areas with smaller field units and dispersed vegetation are often inhabited by many species, while intensively used agricultural landscape in lower areas is usually poor in species diversity. Therefore, requirements for permeability of roads/railways for fauna should always be adapted to local conditions. It is in general appropriate to always keep at least the basic passability for common species. The guidance greenery in the surroundings of the passage is an important functional element in this type of landscape.

Table 6.3

Recommended densities of fauna passages in agricultural landscape:

Animal category	Recommended average distance between passages
Mammals up to the size of fox and badger	1 - 2 km
Medium-sized mammals	5 - 10 km
Large mammals	Only on migration corridors or in linkage areas (see Chapter 6.4)

Fig. 6.41 A properly designed bridge across a watercourse allows for free movement of water, semiaquatic and terrestrial animals. Sufficiently wide banks without technical adjustments allow for movement of all animal categories. Moreover, bridges designed in this way are also able to safely convey flow rates during floods, associated with climate change. © Václav Hlaváč

Fig. 6.42 A green bridge can be built even in a flat lowland area where the motorway is at ground level with the terrain. Connecting the bridge to the surrounding terrain however represents a more extensive land occupation compared to a situation where the motorway leads in a notch. Motorway M7, Hungary. © Ábrahám László

6.3.7 Urbanized area

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This is a very specific type of environment, where it is difficult to define general principles of connectivity/permeability. Specific phenomenon of mountain environment is a linear mode of housing development placement, at the bottom of mountain valleys. Continuously built-up zones tens of kilometres long often arise. Important transport infrastructure (roads, motorways, railways) is often placed parallel with such developed housing zones. The combination of housing development, fenced fields and transport infrastructure very frequently create an impassable barrier that separates mountain complexes on both sides of a valley. In this type of situation, identification of wildlife corridors and their protection in land-use planning is of fundamental importance. If a free passage through a linear built-up zone in a mountain valley still exists, it is crucial to respect this wildlife corridor when building transport infrastructure. In cities/towns, depending on local conditions, it is appropriate to address specific local issues such as the protection of birds and bats from collisions with vehicles in places where roads cross the 'urban green infrastructure', or designing 'tree top overpasses' in order to connect parks, etc.

Fig. 6.43 Transparent walls along roads in towns are often the cause of high bird mortality. Formerly used silhouettes of raptors are not a functional protection, so it is necessary to apply a solution that allows the birds to note the barrier in time. © Václav Hlaváč

6.4 Migration corridors for large mammals

As described above, the existence of most species is bound to a specific habitat. However, some species – especially large predators (wolf, lynx, bear) undertake long migrations of hundreds of kilometres. It is clear that during these migrations animals are not able to use their preferred habitat and have to overcome less suitable landscape as well, for example intensively used agricultural landscape.

case study

Lynx migration through fragmented landscape in the Western Carpathians

A lynx named Ludvík was equipped by GPS/GSM collar during a monitoring project carried out in the Protected Landscape Area Beskydy (CZ) in 2013. Its permanent home range comprised of a large forested area on the border between the Czech Republic and Slovakia (red ellipse). Lynx males regularly search for several receptive females during the mating season. Ludvík started a journey from its home range (red ellipse) on March 18, 2013 and in five days it travelled as far as 60 km (measured as a straight line) to the eastern part of the Protected Landscape Area Kysuce, eastward of the city of Čadca. After another seven days, on March 30, 2013, it returned again to its original permanent home range. During this migration, it successfully crossed several busy roads (e.g. a road between the cities of Žilina and Čadca) and it most probably also used a small migration corridor in a continuous urban settlement (point 21.3.2013). The landscape in the Western Carpathian area is already highly fragmented by linear infrastructure and continuous settlement (black lines in the picture). There is an urgent need to protect the last migration corridors in spatial plans as the only possibilities for free wildlife movement in the future.

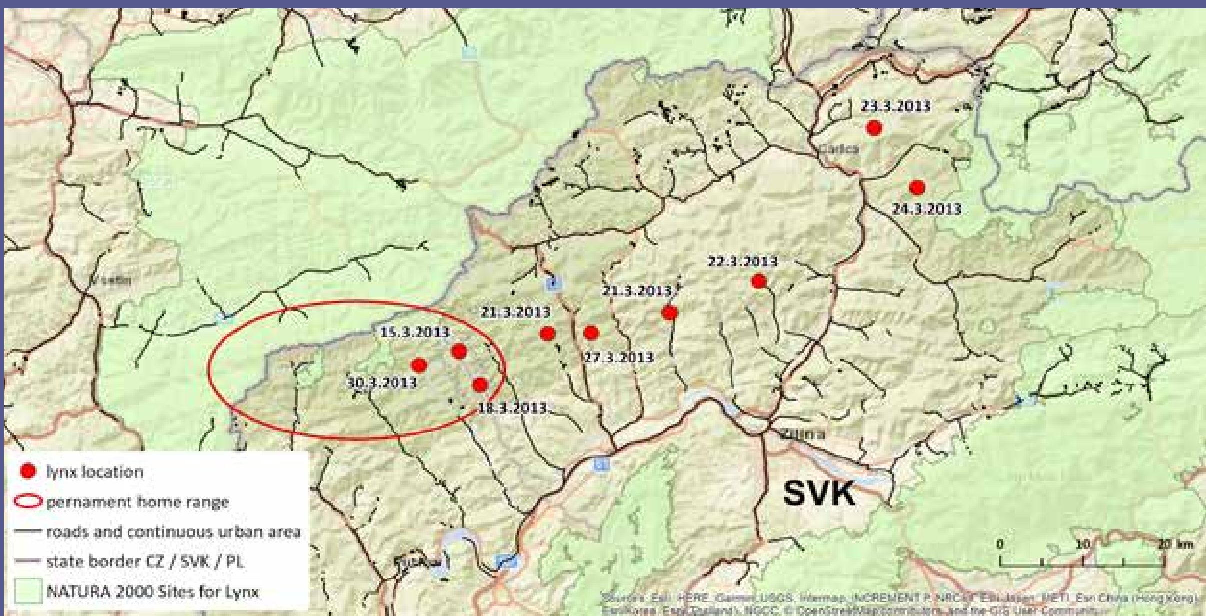

Fig. 6.44 Case study: Lynx migration through fragmented landscape in the Western Carpathians. © Project: Monitoring of large carnivores in SCI Beskydy 2011-2014

Chapter 1 mentions free movement through landscape as the basic requirement for long-term existence of these species. Current landscape unfortunately limits the free movement more and more. Built-up areas, transport infrastructure, recreational and sport resorts and many other human activities all create barriers in landscape that block animal movements. The only approach that can prevent progressive isolation of populations is delimiting migration corridors of large carnivores and ensuring proper protection/management through spatial planning.

If possible, such migration corridors should be delimited in places of original migration routes. Unfortunately, these natural migration paths have often been interrupted in densely populated landscapes and only the remained and very limited passages are available for animal migration in the surrounding impermeable landscape. On the contrary, in still mainly unfragmented regions, it is hard to define clear corridors as animals move more unrestrictedly here. However, even here we can prioritize the necessary crossing sectors or corridors for wildlife.

Migration corridors must be delimited in a way that ensures interconnection of areas of permanent occurrence, possibly even of potential areas of distribution of the target species. As discussed, we are already experiencing the fact that distribution ranges of most species are shifting and/or expanding due to climate change or anthropogenic factors. Without functional corridors, animals are unable to respond to these changes.

Since large mammals belong to typical representatives of the Carpathian nature, migrate over long distances and are umbrella species for many others, the definition of corridors for this group is a high priority in ensuring the permeability of transport infrastructure in the Carpathians. The width of these corridors should optimally not be less than 500 m, in densely populated areas and where overcoming a barrier, it can be narrower. The corridors are delimited primarily on forested lands; however, they must overcome less suitable landscape as well. Places where a delimited corridor crosses a difficult barrier are identified as so called 'critical spots'. These spots are essential for maintaining connectivity. A proposal of special measures to ensure/restore continuity is recommended to be prepared for each critical spot. Ensuring the protection of such delimited corridors in spatial planning is a fundamental task in large carnivore conservation and is a matter of inter-sectoral cooperation. Different legislative procedures can be applied in order to do so in different countries. The goal is nevertheless always the same – ensuring the functionality of migration corridors by protection or restoration of their permeability for large mammals.

case study

Restoration of the last migration corridors in Kysuce – Beskydy (SK - CZ)

Research points to the fact that most original migration routes for fauna have already been irreversibly interrupted in Western Carpathians. To rescue the populations of large carnivores in the area of Beskydy (Natura 2000 site for the wolf, the bear and the lynx) and to secure genetic flow from Slovakia, it is necessary to start with a strict protection and restoration regime for the remaining migration corridors. The results of long-term monitoring in Kysuce - Beskydy confirmed the importance of the area located between the towns of Mosty u Jablunkova (CZ) and Svrčinovec (SK) for migration of large carnivores. Eventually, the construction of two green bridges (one on each side of the CZ - SK state border) has been proposed as a compensation and mitigation measure in order to safeguard the landscape permeability for large mammals. This proposal is a result of great efforts of many stakeholders involved in the protection of this area.

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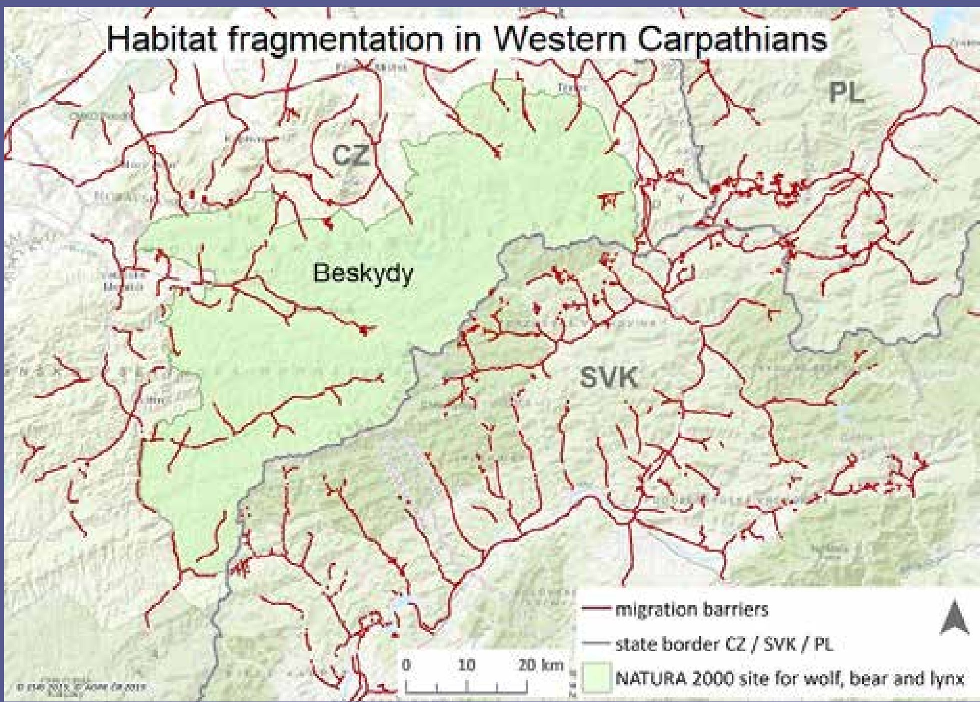

Visualization of the proposed plan for a green bridge near Mosty u Jablunkova (47 m wide) © Planning documentation of Czech Road and Motorway Directorate

On the Slovak side, the site for D3 Svrčinovec green bridge construction has been chosen and its design is being discussed among the relevant stakeholders. Visualization of the proposed plan for Svrčinovec green bridge (80 m wide). © NDS Archive

Fig. 6.45 Case study: Restoration of the last migration corridors in Kysuce – Beskydy (SK - CZ). © Martin Strnad, Václav Hlaváč

6.5 Recommended mutual distances of fauna passages in different types of habitats

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Setting the recommended mutual distance between fauna passages is a complicated expert task. Nevertheless, it is suitable to provide general recommendations within these guidelines that can be used as a standard in proposing transport infrastructure in the Carpathians. The following recommendations take into account the size of local species home ranges but also the existence of migration corridors even for species that are not 'local' to the area. When using these recommendations, it is necessary to keep in mind that certain constructions are implemented in unique local conditions which always must be taken into consideration.

Table 6.4

Recommended mutual distances between fauna passages for main animal categories in different types of the Carpathian habitats.

Type of fauna passage / Type of habitat	Large mammals	Roe deer	Fox, badger	Other types	Recommended proportion of functional fauna passages from the total length of the infrastructure
Alpine and subalpine grasslands	on migration corridors	2-5 km	1-2 km	tunnels, large overpasses and underpasses connecting mountain ecosystems	20-30%
Forests	3-5 km (1) on migration corridors (2)	2-5 km	1-2 km	according to local conditions: tree top overpasses, special passages for bats, amphibians and other groups of species	2-3%
Dry grasslands and pastures with shrubs	on migration corridors	3-8 km	1-2 km	multifunctional or special overpasses for invertebrates, reptiles, ground squirrel - 3-5 km	2-3%
Wetlands	on migration corridors	3-8 km	1-2 km	measures connecting wetland ecosystems, measures for amphibians, the European pond turtle, the dice snake, the Eurasian otter, connecting wetland ecosystems	10% depending on the conditions
Watercourses				measures preventing collisions with birds and bats	100% all watercourses should be kept permeable, dry banks preferably built on both sides
Agriculture landscape	on migration corridors	5-10 km	1-2 km	permeability for aquatic and semiaquatic species	1%
Urbanised areas	on migration corridors		1-2 km	adaptation for other groups of animals	depending on the conditions

(1) - areas with permanent occurrence of large mammals

(2) - areas outside the permanent occurrence of large mammals

Project co-funded by the European Regional Development Fund (ERDF) www.interreg-danube.eu/transgreen

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7 Legislative Aspects

This chapter dedicated to legislative aspects consists of two main sections. Section 7.1 is devoted to several crucial environmental as well as transportation directives and strategies such as the EU Biodiversity Strategy, the Strategy on Green Infrastructure, the European Landscape Convention, the Carpathian Convention, and TEN-T or the Road Transport Strategy for Europe. Section 7.2 contains selected national legislations in the field of nature conservation, transport infrastructure and landscape development.

7.1 European directives and strategies, relevant conventions

7.1.1 Nature and biodiversity legislation and strategies

Nature and biodiversity in the Carpathians are protected through several directives and strategies at the EU level, which must be taken into account when transport infrastructure is being planned, designed, constructed and then gets in operation.

The European Union's international legislation on nature and landscape conservation primarily aims at protecting selected species and habitats of the European interest through **the Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) and the Birds Directive (Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds).** The EU Member States are therefore obliged to implement these directives into their legislation. Ukraine and Serbia, which are not yet members of the EU and at the same time belong to the Carpathian region, have also begun to incorporate this legislation into their national laws.

The Habitats Directive (92/43/EEC) has the following main pillars which are relevant to the implementation of transport infrastructure:

1. Article 3: designation of coherent network of protected sites for selected natural habitats and species mentioned in Annex I. and II. (Natura 2000 sites)

Fig. 7.1 The obligation to define Sites of Community Importance for the wolf, the bear and the lynx applies to all EU Member States with natural occurrence of these species. EU Member States also have an obligation to implement measures under the Article 6 of the Habitats Directive, including the assessment of the impact of plans and projects on Natura 2000 sites where the wolf, the bear or the lynx naturally occur or if they naturally migrate between these sites and the plans and projects could prevent their natural migration.
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2. Article 6: any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives.

3. Article 10: Member States shall endeavour, where they consider it necessary, in their land-use planning and development policies with a view to improve the ecological coherence of the Natura 2000 network, to encourage the management of features of the landscape which are of major importance for wild fauna and flora.

4. Article 12: Member States shall take the requisite measures to establish a system of strict protection for the animal species listed in Annex IV **(strict species protection applied not only in protected sites)**.

case study

Natura 2000 sites for large carnivores and Emerald network in the Carpathian countries

The most important nature protection instrument in habitat and species protection is the network of Natura 2000 sites declared in the EU countries and network of the Emerald sites in the non-EU member states under the Bern Convention. Both networks are complementary and play an important role in large carnivores´ population conservation. Large-scale sites have the function of core areas and small-scale sites function as stepping stones when species migrate through the landscape. The most challenging task for the future is to propose and legislatively also protect the migration corridors (connectivity areas) in between the already declared sites to fill in the gaps which should counteract continuous landscape fragmentation.

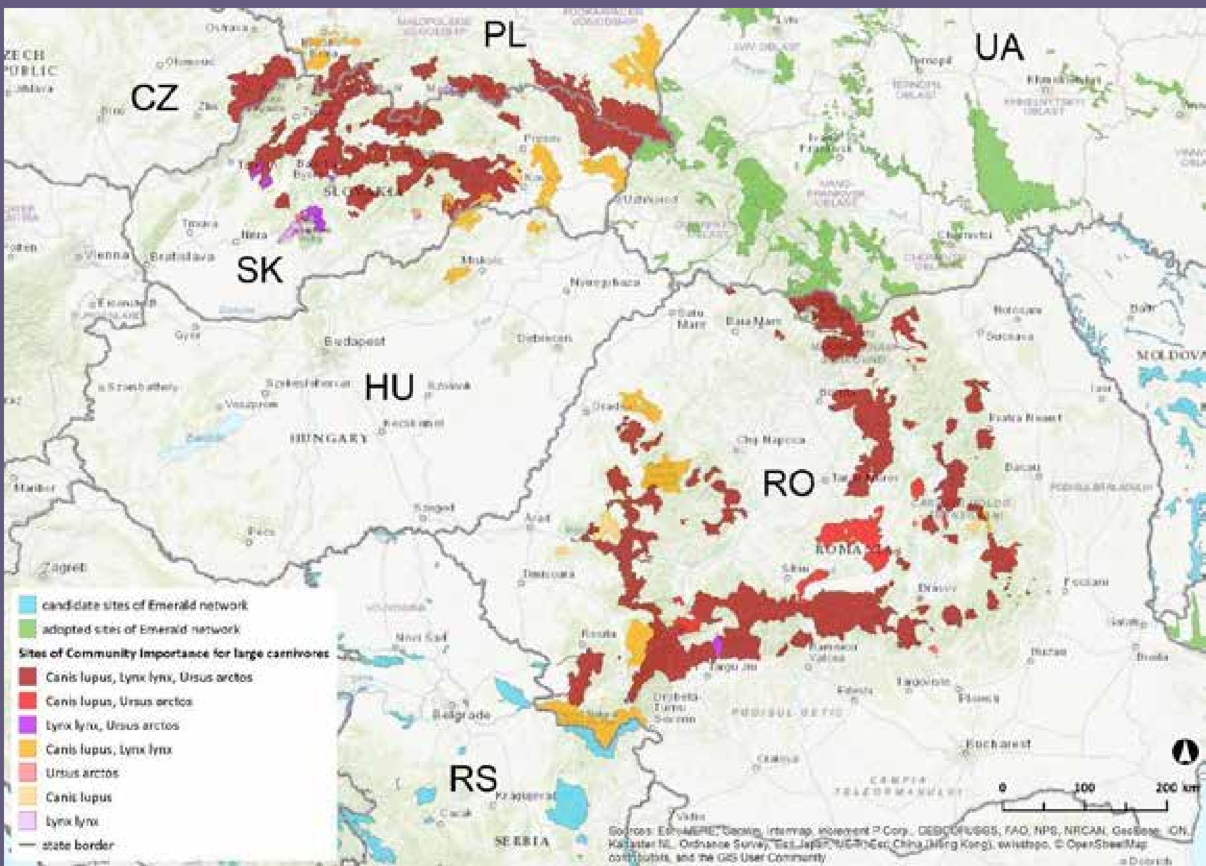

Fig. 7.2 Case study: Natura 2000 sites for large carnivores and Emerald network in the Carpathian countries. © Martin Strnad

The Birds Directive (2009/147/EC) binds all EU Member states to protect threatened bird species mentioned in Annex I. of this directive. The following articles are of the highest importance:

1. Article 3: Member States shall take the requisite measures to preserve, maintain or re-establish sufficient diversity and area of habitats for all the species of birds referred to in Article 1.

2. Article 5: Member States shall take the requisite measures to establish a general system of protection for all species of birds referred to in Article 1.

Bern Convention and the Emerald Network of Areas of Special Conservation Interest

The Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) was the first international treaty that brought European and some African countries together with the aim to protect wild flora and fauna and their natural habitats. One of the main tools of its implementation is establishing an ecological network to ensure long term survival of the species and habitats requiring specific protection measures. Within the EU, Natura 2000 sites are fully compatible with this requirement and thus considered as the contribution to this pan-European Emerald network.

case study

Suspension of the construction work on a motorway during the nesting time of the eastern imperial eagle

The eastern imperial eagle (A) is a threatened species in Europe, very sensitive to disturbance during the incubation period. Thanks to the cooperation between conservationists and the National Motorway Company of Slovakia, the construction in a selected section of the newly built D1 motorway (between Budimír and Bidovce) was repeatedly suspended in years 2017 - 2018 for the time of nesting of this bird of prey (1st February till 31st July). Currently, there is a temporary wall (B) minimizing the disturbances built in this section between the construction site and the nest, at 150 m distance to each side of the nest. This wall will be replaced by a permanent barrier after the nesting period is over, which should make low flights of the eagles above the motorway impossible, and therefore prevent direct collisions.

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Fig. 7.3 Case study: Suspension of the construction work on a motorway during the nesting time of the eastern imperial eagle.
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Regarding the two Carpathian countries that are not yet Member States of the EU: altogether 271 sites have been declared in Ukraine according to the updated list of officially adopted Emerald sites and 61 sites were proposed according to the updated list of officially nominated candidate Emerald sites in Serbia (Convention on the Conservation of European Wildlife and Natural Habitats Standing Committee, November 2018).

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Fig. 7.4 The steppe polecat (*Mustela eversmanii*) is one of the species listed in Annex II of the Bern Convention. One of the important factors that may negatively affect the steppe polecat is lower landscape permeability due to the rapid spread of traffic infrastructure (Csathó & Csathó 2009; Hegyeli 2009). The disintegration of the formerly permeable landscape due to the proliferation of barrier sand roads could result in the isolation of remaining populations by reducing their dispersal or lead to a higher probability of collisions with vehicles (Grilo et al. 2009). For example, road mortality has been identified as a major anthropogenic factor of the European polecat mortality (Blandford 1987; Kristiansen et al. 2007) (Šálek et al. 2013). © Vlasta Škorpíková

At the EU level, two important strategies have been issued in order to enhance the protection of biodiversity. First of all, having regard to the communication from the Commission entitled: Our life insurance, our natural capital: **an EU Biodiversity Strategy to 2020 (COM (2011) 0244)**, which aims at halting the loss of biodiversity and ecosystem services by 2020. The second important EU-wide strategy is the **Strategy on Green Infrastructure**. It promotes the deployment of green infrastructure across Europe as well as the development of the Trans-European Network, so-called TEN-G, equivalent to the existing or planned parts of the European Transport Network (TEN-T).

One of the main conventions related to the topic is the **European Landscape Convention of the Council of Europe**. This convention promotes the protection, management and planning of landscapes and organises international cooperation regarding landscape issues. Another very significant convention in place is the UNECE Convention on Environmental Impact Assessment in a Transboundary Context (**Espoo Convention**), which sets out the obligations of Parties to assess the environmental impact of certain activities at an early stage of planning. It also lays down the general obligation of States to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across boundaries. The application of the Convention to an extended list of activities in areas ranging from transport and energy infrastructure to industrial installations is expected to further strengthen the role of the environmental impact assessment in the Carpathian region.

The Protocol on **Strategic Environmental Assessment (SEA)** augments the Epoo Convention by ensuring that the Parties integrate environmental assessment into their plans and programmes at the earliest stages, and thus help in laying down the groundwork for sustainable development.

The Environmental Impact Assessment (EIA) Directive (2014/52/EU) applies to a wide range of defined public and private projects, which are defined in Annexes I and II. Mandatory EIA refers to all projects listed in Annex I, having been considered to have significant effects on the environment and require an EIA (e.g. long-distance railway lines, motorways and express roads, airports with a basic runway length ≥ 2100 m, etc.). For projects listed in Annex II, the national authorities must decide whether an EIA is needed. This is done by the "screening procedure", which determines the effects of projects on the basis of thresholds/criteria or a case by case examination. However, the national authorities must take into account the criteria laid down in Annex III. The developer may request the competent authority to say what should be covered by the EIA information to be provided by the developer (scoping stage); the developer must provide information on the environmental impact (EIA report – Annex IV); the environmental authorities and the public (and affected Member States) must be informed and consulted; the competent authority decides, taken into consideration the results of consultations.

The Framework Convention on the Protection and Sustainable Development of the Carpathians (Carpathian Convention) was adopted and signed by seven Parties (the Czech Republic, Hungary, Poland, Romania, Serbia, the Slovak Republic, Ukraine) in May 2003 in Kyiv, Ukraine, and entered into force in January 2006. It is the only multi-level governance mechanism covering the entire Carpathian area. Common vision of the Parties to the Carpathian Convention is to pursue comprehensive policy and cooperation in order to guarantee protection and sustainable development of the Carpathians. Several Protocols to the Convention were adopted; most relevant are two of them: 1) Protocol on Conservation and Sustainable Use of Biological and Landscape Diversity; 2) Protocol on Sustainable Transport.

Protocol on Sustainable Transport sets principles for cooperation of the Parties for the development of sustainable freight and passenger transport and related infrastructure in the Carpathians for the benefit of present and future generations with the objective to contribute to the sustainable development of the region while avoiding, minimizing and, where necessary, mitigating and compensating negative environmental and socio-economic impacts of transport and related infrastructure development (Article 1).

One of the most important international multilateral environmental conventions is the **Convention on Biological Diversity (CBD)**. Its objectives are: protecting biodiversity at all levels, sustainable use of its components, access to genetic resources and fair and equitable sharing of benefits from their use. Programs of the Convention's activities include e.g. forest and agricultural biodiversity and the biodiversity of mountain ecosystems. The Aichi Biodiversity Target 5 of the Strategic Goal B is to slow down the process of habitat loss at least by 50%, and also the degradation and fragmentation should be significantly reduced.

Fig. 7.5 The Carpathian Convention is a subregional treaty to foster the sustainable development and the protection of the Carpathian region. © Eleonora Musco

Fig. 7.6 One of the objectives of the Protocol on Sustainable Transport is to minimize the negative impact of transport on nature. The Green bridge Moravský Svätý Ján on D2 motorway (Slovakia) was built to support the restoration of animal migration in the Alpine-Carpathian corridor, which was interrupted by high-level roads and settlements between the Alps and the Carpathian Mountains. © Dušan Valachovič

Fig. 7.7 The Carpathian grasslands, meadows and pastures have rich biodiversity and represent an important food source and habitat for many species. Abandonment, succession and conversion to arable land all contribute to the loss of these valuable habitats. © Ivo Dostál

Other international conventions supporting conservation and management of migratory species, their habitats and migration routes (including the Convention on the Conservation of Migratory Species of Wild Animals and its tools, the Ramsar Convention on Wetlands, the World Heritage Convention) and designated sites of international importance (Ramsar Sites, World Heritage Sites, Internationally Important Underground Sites for Bats) need to be taken into consideration in planning and assessing transport infrastructure.

7.1.2 Transportation legislation and strategies

The Trans-European Transport Network (TEN-T) is a European Commission policy directed towards the implementation and development of a Europe-wide network of roads, railway lines, inland waterways, maritime shipping routes, ports, airports and rail-road terminals. TEN-T is anchored in Regulation (EU) No. 1315/2013 of The European Parliament and of the Council of December 11, 2013 on Union guidelines for the development of the Trans-European transport Network and repealing Decision No. 661/2010/EU. Altogether 4 TEN-T corridors are under consideration in the Carpathian region: the Rhine-Danube, the Baltic-Adriatic, the Orient/East-Mediterranean, and the Mediterranean.

Fig. 7.8 The ultimate objective of TEN-T is to close the gaps, remove the bottlenecks and eliminate the technical barriers that exist between the transport networks of the EU Member States. D1 motorway in Slovakia (in the picture) belongs to the TEN-T network. © NDS Archive

The Road Transport Strategy for Europe is aiming at promoting mobility that is efficient, safe, secure and environmentally friendly.

White paper 2011 is an EU roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. The European Commission adopted a roadmap of 40 specific initiatives for the next decade to build a competitive transport system that will increase mobility, remove major barriers in key areas and fuel the growth and employment.

7.2 National level legislation in respective Carpathian countries

The following chapter contains a summary of most relevant legislation in seven Carpathian countries: the Czech Republic, the Slovak Republic, Poland, Ukraine, Hungary, Romania and Serbia. The legislation relates to:

1. Nature conservation with respect to habitat fragmentation.
2. Transport infrastructure.
3. Landscape development and spatial planning.

For a more detailed description please refer to respective national State of the art report, which was drafted during the TRANSGREEN project.

Fig. 7.9 Habitat fragmentation by transport infrastructure such as roads and motorways is one of the main threatening factors for species survival. However, this phenomenon is not satisfactorily mentioned in legislation of all the Carpathian countries. © Václav Hlaváč

7.2.1 National law on nature conservation that applies to habitat fragmentation

(ecological networks, wildlife corridors)

Legislation related to nature conservation in the Carpathian countries is summarized in Tables 7.1 and 7.2 Neither ecological network nor landscape connectivity is explicitly stated in the Constitution of respective countries. The Czech and Slovak Republics have the specific tool of territorial system of ecological stability in their laws on Nature and Landscape Protection. The nature protection law in Poland contains a general obligation to maintain ecological processes and their stability. The same law in Hungary contains general provisions for creating/implementing ecological corridors and networks. Romanian Government Ordinance 57/2007 regulates the regime of protected areas, conservation of natural habitats and of wild flora and fauna. Ukraine and Serbia have special law or decree, respectively, related to ecological network.

Table 7.1

Nature conservation related legislation in the Czech Republic, the Slovak Republic, Poland and Ukraine.

	Czech Republic	Slovakia	Poland	Ukraine
Ecological network/ connectivity in the Constitution	None	None (ecological balance/active care of the environment)	None (sustainable development)	None (ecological security/balance)
Legislation	Law No. 114/1992 Coll. on Nature and Landscape Protection - Territorial System of Ecological Stability	Law No. 543/2002 Coll. on Nature and Landscape Protection - Territorial System of Ecological Stability	The Nature Conservation Act of 16 April 2004 (maintain ecological processes and ecosystems' stability)	Law of Ukraine on Ecological Network of Ukraine, 24 June 2004 (territorial system, created with the aim of improving conditions for the formation and renewal of the environment)
				Law on Protection of Natural Environment, 25 June 1991
				Law on Natural Protected Areas of Ukraine, 16 June 1992

Table 7.2

Nature conservation related legislation in Hungary, Romania and Serbia.

	Hungary	Romania	Serbia
Ecological network/ connectivity in the Constitution	No (biodiversity protection)	None	No (protection of natural heritage and limitation to land use due to environmental protection)
Legislation	The Act No. 53 of 1996 on Nature Protection - contains general provisions for creating/ implementing ecological corridors and networks	The Law on Environmental Protection (No. 195/2005)	Decree on the Ecological Network, 102/2010 (ecologically significant areas and ecological corridors of international importance)
		Emergency Government Ordinance No. 57/2007 regarding the regime of protected areas, conservation of natural habitats and of wild flora and fauna	Law on Nature Protection, 2009

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7.2.2 National law on transport infrastructure

(road safety, prevention of animal collisions with vehicles, mitigation measures for habitat fragmentation, animal migration)

Transport related legislation in the Carpathian countries is summarized in Tables 7.3 and 7.4.

All Carpathian countries, both EU and non-EU Member states (Ukraine and Serbia) have already adopted the most significant Acts on Environmental Impact Assessment (SEA/EIA), which regulate the procedures and processes of selected projects, including the linear infrastructure. Technical rules for building fauna passages to allow safe animal movement across linear infrastructure have been approved in the Czech Republic and Slovakia. Ukraine has State Construction Norms and Ecological Requirements for motorways that should be updated. Majority of the countries have its own strategy for road/railway development and national road safety strategy which should be applied in the most appropriate way to ensure free animal movement as well as human safety.

Fig. 7.10 Transportation can be a barrier that causes population isolation of selected species. On the other hand, animals crossing the roads, especially ungulates can influence the traffic safety. © Mária Apfelová

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Table 7.3

Transport related legislation in the Czech Republic, the Slovak Republic and Poland.

Czech Republic	Slovakia	Poland
Act No. 100/2001 Coll. on Environmental Impact Assessment	Act No. 24/2006 Coll. on Environmental Impact Assessment (SEA, EIA)	Act on Making Available Information about the Environment and its Protection, the Public's Participation in Environmental Protection, as well as on Environmental Impact Assessments of 3 October 2008
		The Act of 13 April 2007 on preventing the damages to nature and their compensation
Technical Conditions of the Ministry of Transport TP 180 "Fauna passages for reinsurance of the motorways and roads for wildlife"	Strategic Transport Development Plan of the Slovak Republic up to 2030 – Phase II	Act on Special Rules for the Preparation and Implemetation of Investments in the Field of Public Roads, 10 April 2003
		Transport Development Strategy until 2020 (from the perspective until 2030), 22 January 2013
National Road Safety Strategy 2011-2020	National Road Safety Plan of the Slovak Republic 2011-2020	Program of Construction of National Roads for the years 2014-2023 (with a prospect until 2025), 4 September 2015
		National Road Safety Programme 2013-2020

Table 7.4

Transport related legislation in the Hungary, Romania, Serbia and Ukraine

Hungary	Romania	Serbia	Ukraine
Government Decree 314/2005 (XII.25.) on Environmental Impact Assessment	Ministerial Order No. 135/2010 for Approving the Methodology for Environmental Impact Assessments for Public and Private Projects. Order No. 225/2006 regarding lists of plans and programs requiring environmental assessment procedures provides the areas of application of Government's Decision 1076/2004 on the establishment of a procedure to evaluate the environmental effects of plans and programs carried out by institutions and companies.	Law on Environmental Impact Assessment, 2004	Law on Environmental Impact Assessment, 23 May 2017
			Law on Strategic Environmental Assessment, 20 March 2018
Act No. LIII of 1996 on Nature Protection - Sec. 7, Subsec. 2, Para. g) Transport routes shall be constructed considering wildlife corridors and not disturbing them.		Law on Strategic Environmental Assessment, 2004.	State Construction Norms (DBN B.2.3-4:2007). Motorways, 2007
			Branch Construction Norms (GBN B.2.3-218-007: 2012).
	The Master Plan for Transport in Romania 2030		Ecologic Requirements to Motorways, 2012.
			Law on Transport, 10 November 1994
Hungarian Transport Policy	National Strategy for Road Safety for the period 2016-2020	Law on Public Roads, 2005	Law on Railway Transport, 4 July 1996
			Law on Automobile Transport, 5 April 2001

7.2.3 National law on landscape development and construction

Landscape development related legislation in the Carpathian countries is summarized in Tables 7.5 and 7.6. All Carpathian countries have their own building and land-use planning laws, which do not contain proper definition of landscape permeability and ecological network preservation. The most crucial thing is thus the introduction of the nature and landscape protection topic into the spatial planning procedures. Presently, the protection is based either on strict species or territorial protection (specially protected sites e.g. national parks, nature reserves, Natura 2000 sites). It is necessary to enhance both public and governmental awareness to protect ecological corridor functions (e.g. free animal movement through landscape) and be aware that these functions represent ecosystem services for the future.

7

case study

Implementation of migration corridor for large mammals into the Jablunkov city spatial plan

The area represents an important migration corridor that connects populations of large mammals in the Beskydy Mountains with other populations in the Western Carpathians. It is, however, also an area with an increasing density of residential development.

In recent years, this migration corridor has been incorporated into the local spatial plan in order to protect it from further development. At the same time, measures on the transport infrastructure have been implemented to ensure the permeability for migrating animals (estacade bridge on the 1st class road I/11 - point 1 in the map) and places where the corridor passability is limited - so called critical spots (for example point 2 in the map) - have been identified. A plan of measures to improve the corridor permeability has been elaborated for each critical site.

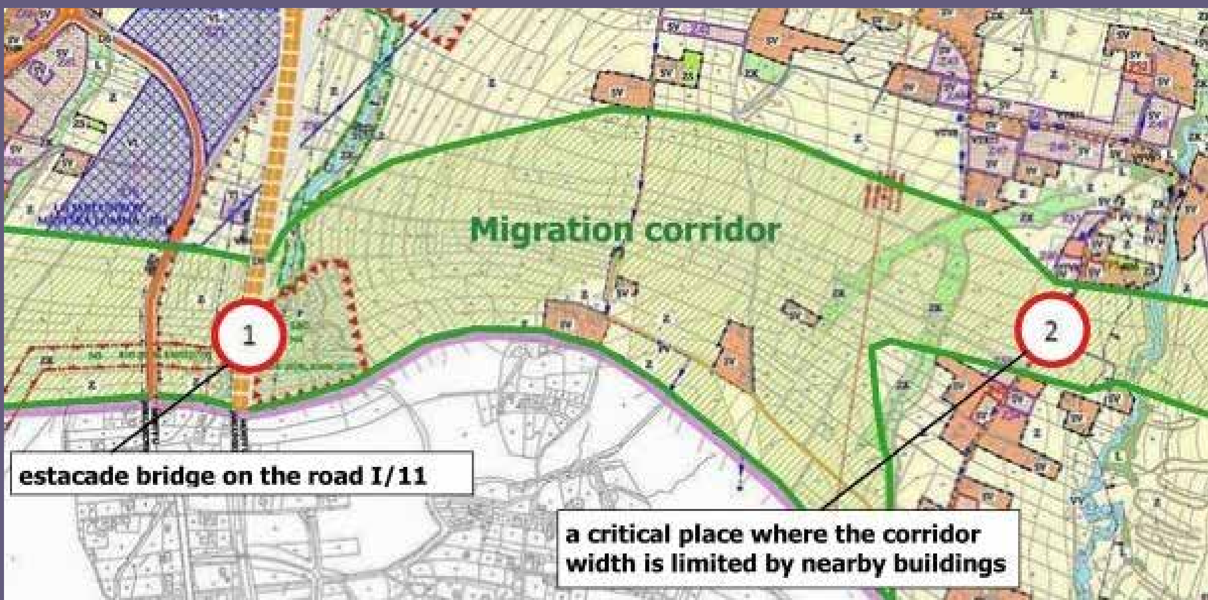

Fig. 7.11 Case study: Implementation of migration corridor for large mammals into the Jablunkov city spatial plan. © Martin Strnad

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Table 7.5

Landscape development related legislation in the Czech Republic, the Slovak Republic, Poland and Ukraine.

Czech Republic	Slovakia	Poland	Ukraine
Act No. 183/2006 Coll. on Land-use Planning and Building Code (Building Act) - sustainable development of the territory and public interests, including the protection of nature and the landscape	Act No. 50/1976 Coll. on Land-use Planning and Building Order (Building Act). The obligatory conditions for the execution of the construction shall be assured or determined; the protection of public interests, particularly human health and the environment.	Building Law of 7 July 1994. The Act is to provide guarantees included in provisions of environmental protection law.	Law on Regulation of Urban Planning, 17 Feb. 2011. Land use and spatial planning is regulated by specialized legislative acts and provisions contained in environmental legislation.
		Act of 27 March 2003 on Spatial Planning and Land Development.	Law on the General Planning Scheme of the Territory of Ukraine, No. 3059-III of 7 February 2002 (the Planning Scheme Law)
Decree No. 500/2006 Coll. on Spatial Analytical Documents, Spatial Planning Documents and on the Means of Registration of Spatial Planning Activities (Sub-category 36b - biotope of selected specially protected species of large mammals)	Act No. 330/1991 Coll. on Land Reform. The purpose of land reform is rational spatial organization of land ownership in given area in accordance to the demands of environment, development of territorial system of ecological stability and functions of agricultural landscape.	The Long-Term National Development Strategy (DSRK), MP of 2013. 121.	Law on Planning and Construction, No. 1699-III of 20 April 2000
		Spatial Development of the Country (KPZK 2030) (MP of 2012.252)	Law on the Basis of Urban Construction, No. 2780-XII of 16 November 1992

Table 7.6

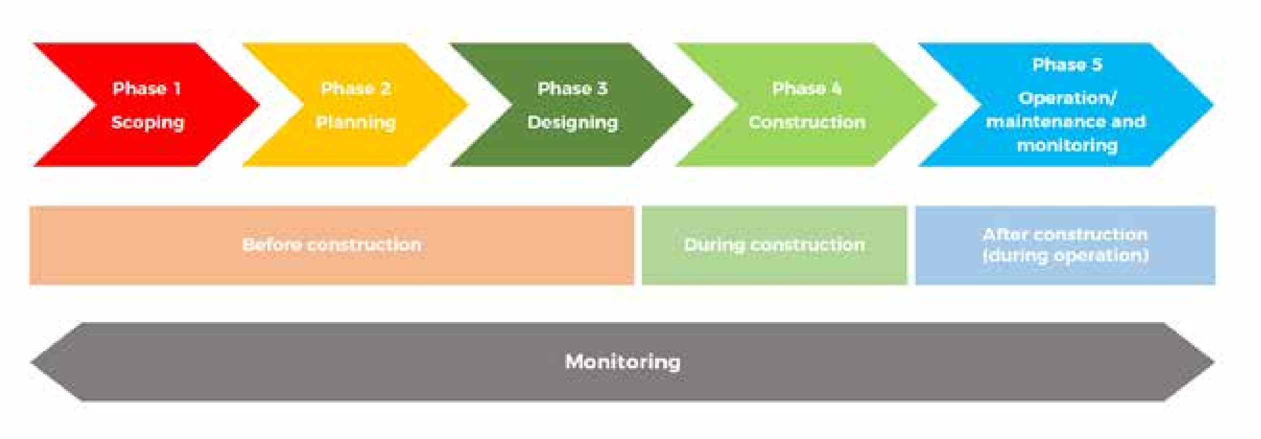
Landscape development related legislation in Hungary, Romania and Serbia.

Hungary	Romania	Serbia
Act on Spatial Planning and Development (1996. XXI.). In case of transport infrastructure, electricity or other energy channels are planned through an ecological corridor, the nature conservation authority must define conditions and/or prescribe extra mitigation activities for land users (Sec. 9, Subsec. 6).	Law No. 350/2001 regarding the territory arrangement and urban planning, with subsequent completions and modifications. Ministerial Order no. 19/2010 for approving the methodological guidelines on the appropriate assessment of the potential effects of plans and projects on protected areas of Community interest.	Law on Planning and Construction, 2009
Act No. XXVI. of 2003 on National Spatial Plan defines the zones of the National Ecological Network (core area, ecological corridor, buffer zone). These zones were harmonized with the Pan-European Ecological Network - related category system in 2009.		The Strategy for Spatial Development 2009-2013-2020. The point 115 of the Strategy reads: Ecological connectivity shall significantly affect the concept of spatial development of the Republic of Serbia. This comprehends enabling the sustainability of the organic connection of natural systems and subsystems as well as key natural elements.
The National Framework Strategy on Sustainable Development for the period of 2012–2024	The Territorial Development Strategy of Romania 2035	

8 Basic Steps and Processes for Ensuring Ecological Connectivity within Transport Infrastructure Development

8.1 General principles

Planning and preparation of transport infrastructure is a long-term process. Proposals are specified in stages from transport policies and delimiting main transport corridors through route selection and evaluation of variants to the final detailed project of implementation. In general, each new construction of transport infrastructure goes through several phases which can be described by the following scheme:



Nevertheless, it is important to emphasize that these phases are not strictly separated. Preparing transport constructions is a continuous process with progressive specification. Specific processes take place in individual phases of preparation and each concept has to go through these processes in order to get to the next phase. Many of these processes are given by international legislation and are performed as mandatory in all the Carpathian countries. This is represented mainly by two directives of the European Union regarding the assessment of impacts on the environment: Strategic Environmental Assessment (SEA Directive 2001/42/EC) and Environmental Impact Assessment (EIA Directive 2014/52/EU). Processes of landscape and spatial planning differ in individual Carpathian countries according to their national legislations. Planning decision and building permit are typically included in the standard process of preparation and planning.

It also needs to be pointed out that the European directives relating to SEA and EIA deal with assessment of impacts on the entire environmental area. According to Article 3 of the Directive: EIA shall identify, describe and assess in an appropriate manner, in the light of each individual case, the direct and indirect significant effects of a project on the following factors:

a) population and human health;

b) biodiversity, with particular attention to species and habitats protected under Directive 92/43/EEC and Directive 2009/147/EC;

c) land, soil, water, air and climate;

d) material assets, cultural heritage and the landscape;

e) the interaction between the factors referred to in points (a) to (d).

This chapter aims – as a follow up to the European legislation – to describe in more detail different tools that should lead to protection of biodiversity, especially the ones that will allow to avoid fragmentation of habitats as a result of building linear transport infrastructure. At the same time, the main goal in solving the impacts of transportation on nature is to always do so in a hierarchical way: avoidance, mitigation, compensation.

In order to reach these goals, it is necessary to assert requirements on wildlife protection in all phases of the long process – from the level of policies and strategic decisions all the way to detailed project for implementation of the construction and to operation and maintenance. For this reason, the individual phases are described here in detail and the corresponding processes, as well as tools that should be used to reach the given goals.

Nine specific tools (T1 – T9, see also Table 8.1) to apply ecological requirements are described in this chapter. Their use is recommended for individual preparation phases and related processes, so that the requirements to minimize environmental fragmentation are applied in a complex way in the entire process of preparing the construction. The time frame of using these tools can in each country be slightly different. However, it is very important that all of them be implemented, because they include the entire process in its complexity, from transport concepts all the way to getting the feedback. This is the only way to achieve effective protection of fauna and ecological connectivity.

It is important to emphasize that the purpose of this chapter is not just to summarize used approaches, but first of all to recommend optimal processes and tools to reach given goals (= to effectively avoid, mitigate and/or compensate the impacts of transport infrastructure on wildlife and to ensure sufficient connectivity in landscape for relevant groups of species).

Table 8.1 lists the main phases of transport infrastructure planning and preparation and processes that take place in these phases. Specific tools (T1 – T9) that need to be used in order to ensure the protection of fauna and ecological connectivity are mentioned for each phase as well. Chapters 8.2 to 8.6 provide a detailed description of individual phases and present the corresponding tools in the form of tables. Chapter 8.7 briefly looks at the specifics of different types of transport infrastructure constructions and Chapter 8.8 attempts to review the most important aspects of this topic.

One of the newly introduced tools is a **migration study**. Assessing the impacts of a plan or project on landscape permeability in general stems from the EIA Directive, the term ‘migration study’ simply assigns the content specific to this evaluation. It is a simplified working term for an expert material that is prepared at different levels of the planning process (strategic migration study at SEA level, framework migration study at EIA level, detailed migration study at the level of designing and building permit). A ‘migration study’ contains evaluation of spatial requirements of animals in the area of construction, their demands on permeability of linear barriers and proposal of measures to ensure sufficient permeability. While strategic migration study (T1) identifies issues from supra-regional viewpoint (conflicts between important green and grey infrastructure), framework migration study (T3) already solves density and basic types of fauna passages and detailed migration study (T5) is devoted to exact parameters and design of all measures.

Table 8.1

Overview of basic phases, corresponding processes and recommended tools

	Phase	Key topics	Processes	Tools
SCOPING	Transport policies	Transport concepts, analysis of the above-regional conflicts with protected areas and main migration corridors	SEA	Strategic migration study, map of protected areas, Natura 2000 (Special Protection Areas, Sites of Community Importance, Natura 2000 habitats), core areas and main migration corridors for target species, important and protected Species Action Plans and their distribution, etc. (T1)
SCOPING / PLANNING	Delimiting a transport corridor	Delimiting and survey of a wider transport corridor, selecting basic conflicts with protected areas and main migration corridors, starting a biological survey	SEA	(T1)
PLANNING	Route selection	Assessment of proposed variants, basic proposal for placement and type of fauna passages, detailed biological survey, monitoring program	EIA	Biological survey (T2) Framework migration study (T3)
DESIGNING	Detailed project	Solving details in placement of fauna passages, technical parameters, surfaces of bridges and areas under them, connection to the surroundings, means of spatial protection of migration corridors	EIA Planning proceedings Building permit	Monitoring program (T4) Detailed migration study (T5) Incorporation of migration corridor(s) near fauna passage(s) into spatial plan (T6) Monitoring before construction (T4) Plan to protect biota during construction (T7)
CONSTRUCTION	Construction	Minimizing impacts on natural habitats, prevention of animals entering the construction site, building time schedule, protecting surrounding habitats of fauna from contamination and disturbance	Ecological construction supervision Final inspection	Ecological supervision (T8) Monitoring during construction (T4)
OPERATION	Operation and maintenance	Assessing the effects of infrastructure operation and maintenance on fauna, functionality of mitigation measures (underpasses, overpasses), contamination and disturbance on habitats of fauna, animal mortality		Monitoring after construction, monitoring the impacts of operation (including maintenance) on fauna (T4) Post-project analysis (T9)

8.2 Transport policy, delimiting transport corridors

SCOPING	PLANNING	DESIGNING	CONSTRUCTION	OPERATION

8

Phase characteristics

National transport policy is a basic document that predetermines the development of transportation for the long-term perspective. It is based on socio-economic needs and determines the representation of individual transport modes, proposals for building new roads/railways and their categories. Such materials also ensure the interconnection of projects with neighbouring countries and with the European Transport Network, for example TEN-T.

The national transport policy is a strategic document which always has to go through the SEA process before it is approved. Within the SEA process the transport policy must also be compared with conceptual materials of nature protection and the issue of habitat fragmentation has to be incorporated as well.

Main transport corridors are delimited based on the transport policy. Transport corridors are initial resources for incorporating a transport proposal into spatial planning, especially at national and regional levels.

A **transport corridor** constitutes a linear structure between the beginning and the end of a planned proposal. After the transport corridor is approved, variants for final route selection are searched for in this area (see Chapter 8.3). Placing transport corridors into spatial plans is a basic step to check the proposal with respect to protection of fauna and landscape connectivity.

Strategic Environmental Assessment (SEA) is an evaluation process. **Strategic migration study** (T1) is recommended to be an obligatory part of SEA.

Mutual interaction between spatial planning and road preparation does not end at the 'strategic' level; it will be repeated in the next phase while selecting the final variant.

Data on protected areas and priority species according to both the European and national legislation (Natura 2000, national parks, natural reserves, etc.) are commonly available, but a **complex elaboration regarding the entire ecological network and securing its cohesion,** mutual interconnection of protected areas in the landscape and delimiting of long-distance migration corridors and linkage areas for some species of large mammals are often missing. The network of core areas and migration corridors of large mammals are currently under preparation as part of the ConnectGREEN project and it will be available for the entire Carpathian region. Well prepared network of green infrastructure (focused on protected areas, Natura 2000 sites, core areas and main migration corridors for target species) is therefore an important resource material for identification of conflicts with the planned 'grey infrastructure' within SEA. Avoidance of the most important protected areas and limiting conflicts with migration corridors can be solved at this level. This analytical map also called **strategic migration study** (SMS) is therefore listed here as the first tool (see Table 8.2).

Table 8.2

Basic description and characteristics of the recommended tool 1 - Strategic migration study

Tool: SMS - Strategic migration study (T1)
A. Goal
To prepare a resource material for the analysis of problems between the planned transport corridors/constructions (grey infrastructure) and natural areas (protected areas, Natura 2000 sites, core areas of target species) and long-distance migration corridors of some species (green infrastructure).
B. Placement in the process
A phase of transport policies, studies for selection of transport corridors. SMS is recommended to be an obligatory part of Strategic Environmental Assessment (SEA).
C. Initial resource materials
Natura 2000 network, national register of protected areas, protected or umbrella species action plans, migration corridors of large mammals, surveys themselves, etc.
D. Principles
▪ Migration corridors for large mammals have to connect the places of permanent occurrence continually without an interruption and they need to have a long-term sustainability. ▪ SMS is worked out in cooperation of a zoologist and a designer of the technical part or of the spatial plan with the author of SEA documentation. ▪ Preparing a categorization of the area of interest with respect to wildlife migration. ▪ Checking in advance for places where migration barriers could potentially emerge.
E. Note
An example of delimiting migration corridors based on the habitat approach is given in Case study 8.1. SMS is a part of the SEA and is focused on the issue of permeability of landscape for animals.

case study

8

Map of habitats of the selected protected species of large mammals in the Czech Republic

The map of core areas and migration corridors of protected large mammal species in the Czech Republic (the lynx, the wolf, the bear and the moose) serves as the resource material usable for identification of conflicts between transport corridors and the requirement to ensure ecological connectivity in the process of SEA. The core areas are delimited as areas meeting the requirements for permanent occurrence (reproduction) of at least one of the target species. The minimum size of a core area is 300 km^2. The core areas are mutually interconnected by a network of migration corridors in such numbers that sufficient functional linkages between individual parts of the populations are still ensured. The width of migration corridors is at least 500 m (it can only be narrowed down at critical spots).

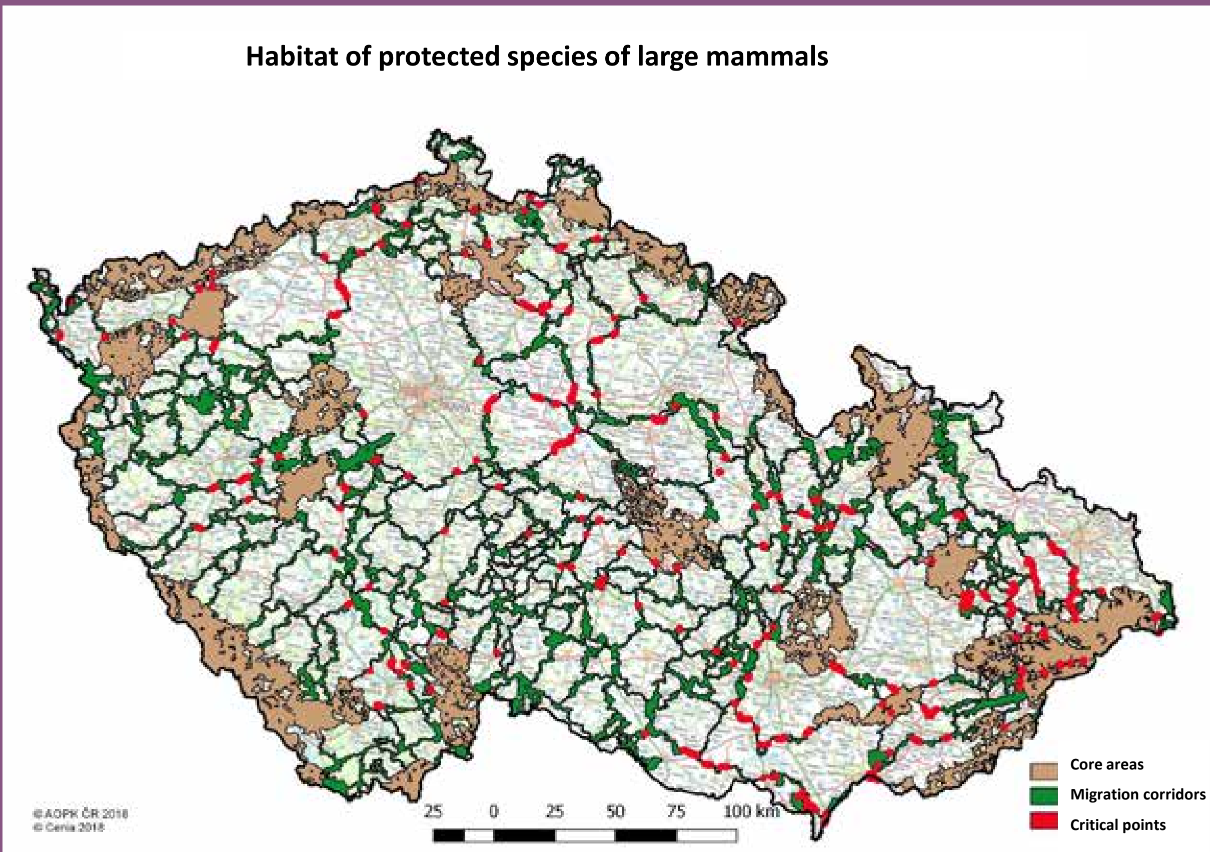


Fig. 8.1 Case study: Map of habitats of the selected protected species of large mammals in the Czech Republic. © The project Complex Approach to the Protection of Fauna of Terrestrial Ecosystems from Landscape Fragmentation in the Czech Republic

8.3 Route selection

SCOPING | PLANNING | DESIGNING | CONSTRUCTION | OPERATION

8

Phase characteristics

This is a key phase which determines the final impacts of a road/railway on fauna and landscape connectivity. The decision about the final route should always be based on evaluations of more variants of solution. This evaluation of variants is in some countries part of the EIA assessment, while in other countries, the process of EIA is carried out for the already selected variant. EIA deals with the environment in a complex way and therefore is devoted to a wide spectrum of natural elements (population and human health, biodiversity, land, soil, water, air, climate, material assets, cultural heritage, landscape, and the interaction among all of the above factors) and in final decisions then makes compromises between impacts on these individual elements of the environment. Requirements on minimizing the fragmentation must always be applied in the phase of route selection and must be taken into account during the selection process.

Starting a **biological survey** (T2) focused on the impacts of the proposed infrastructure on fauna, flora and ecosystems is recommended in this phase. Beginning the biological survey in the form of screening the whole area of the transport corridor prolongs the time of data acquisition and allows for a subsequential survey of the individual variants in a better quality. Similarly to other preparation modes it is necessary to implement the biological survey in a stepwise manner (screening of transport corridor, survey of route variants, survey of localities). The survey has to be focused on all target habitats and groups of species (see Table 8.3).

The **framework migration study** (T3) is a recommended tool that should be used to put into effect the requirements to limit fragmentation in the phase of route selection. It is designed in analogy to other environmental components (acoustic study, dispersion study, study of impacts on human health, etc.). It is a complex material that summarizes the given issue from the initial analysis of starting state, all the way to the proposal of measures. Framework migration study is based on an intensive field survey (see Table 8.4).

Fig. 8.2 Biological survey on the impacts of the proposed infrastructure on fauna has to be focused on all target habitats and groups of species. Biological survey regarding large carnivores is usually done by phototraps and collection of signs of species occurrence (e.g. footprints/tracks or remnants of prey), or when available also by telemetry research. © Jerguš Tesák

Table 8.3

Basic description and characteristics of the recommended tool 2 - Biological survey

Tool: Biological survey (T2)
A. Goal
To find out the real occurrence, population state and migration routes of the target species, distribution of selected habitats and to work out an overall background material for selecting the final alignment, for proposals of mitigation measures and for proposal of follow-up monitoring. The whole survey should be done in a complex ecosystem approach (besides fauna also flora and ecosystems are assessed).
B. Placement in the process
Considering the variability of natural conditions, it is necessary to carry out the survey over a longer time period (minimum of 1 year, optimum 3-5 years). The recommended incorporation into the process (subsequently following phases with permanently increasing specification of the results): a) Phase of transport corridors' assessment – screening survey of the entire corridor. b) Phase of route selection – basic survey of all proposed variants (part of EIA). c) Phase of preparing the planned decision – detailed survey of localities in the final alignment. Biological survey is followed by monitoring purposefully focused on observing the impacts of transportation on biota. Biological survey is the responsibility of investor.
C. Initial resource materials
Distribution maps of habitats, results from previous surveys, research from literature, databases of data occurrence of target species.
D. Principles
▪ Survey has to be directed at all defined target groups of animals (11 groups) and selected habitats (7 basic types, see Chapter 6). ▪ Biological survey has a mutli-disciplinary character and individual taxonomic groups must be elaborated by corresponding experts. ▪ Survey of the habitat distribution – distribution map of target habitats should be updated. If there is a good reason, more detailed classification and division of habitats into lower units (for example categorization of forest habitat) should be carried out. In case a habitat is substantially heterogeneous with regard to preservation and natural quality, it should be categorized, and its most valuable parts should be delimited. Results need to be compiled in the form of map resources. ▪ Specifying the list of representative species – based on the literature research and analysis of habitats. ▪ Specifying the distribution areas of representative species and their main migration routes, delimiting migration corridors at local level. ▪ Specialized surveys of occurrence and migration of endangered groups (for example amphibians, reptiles). ▪ Where relevant for selected species, carry out an assessment at population level (population size, trends in natality and mortality, links to surrounding populations – source and sink populations). ▪ Background information for proposal of follow-up monitoring is one of the resulting outputs.
E. Note
Biological survey at the EIA level always includes a botanical survey as well, covering the total biodiversity and landscape approach on habitats' connectivity. This is not further described here given the focus of the guidelines.

Table 8.4

Basic description and characteristics of recommended Tool 3 – Framework migration study

Tool: FMS - Framework migration study (T3)
A. Goal
The goal of FMS is to prepare a complex material on the issue of protecting fauna and landscape connectivity for the process of EIA. It should assess overall permeability and acceptability of the proposed variants and set basic placement and types of fauna passages and other protective measures.
B. Placement in the process
The study is carried out at the level of EIA process. It is the responsibility of investor.
C. Initial resource materials
FMS integrates technical, biological and spatial resource materials. To basic ones include: technical documentation used in EIA phase, map of green infrastructure, strategic migration study, biological survey, local and regional plans, map resources regarding individual habitats and species' distribution, results from field surveys, statements of state authorities to SEA process or other relevant proceedings.
D. Principles
▪ Based on all available data (occurrence of target species, identified animal movement/migration corridors, existing spatial plans, etc.) and field surveys, the FMS works out a detailed local map containing data on animal distribution and movements: known migration corridors, landscape migration supporting elements (forests, watercourses, etc.) and migration threatening elements (settlements, transport and industrial infrastructure, planned construction, etc.). This map then becomes a background material for evaluating individual variants and for determining all places that have to be solved with respect to permeability. ▪ FMS assesses all proposed variants with respect to impacts on fauna and landscape connectivity, including measures necessary to be implemented in order to ensure permeability. It determines basic placement and type of fauna passages, fencing and other measures (selection of places of fauna passages is described in greater detail in Chapter 10). ▪ FMS carries out selection from proposed variants with respect to protection of fauna and landscape connectivity in two steps: a. It determines variants that are completely unacceptable even in the case of implementing certain measures. This is an essential step from the EIA process viewpoint, because there are usually preferences for different variants as the most suitable ones for various components of the environment. Any variant marked as completely unacceptable from the standpoint of just one component of the environment should not be implemented b. It determines an optimal variant from the ones considered acceptable and ranks also the rest of them based on the level of acceptability. This then forms background material for the final selection of recommended variant in the EIA process with respect to the environment as a whole. ▪ The author of FMS takes part in the final variant selection together with other experts from the authorized team. ▪ Besides the placement and type of fauna passages, FMS also determines basic proposal of accompanying measures (for example guiding vegetation adjustments, fencing, barriers for amphibians, solution of area under a bridge, and others). Technical and ecological viewpoints should be considered equally important. Detailed procedure of proposing these measures is solved in the Detailed migration study. ▪ FMS works out a basic proposal for a monitoring plan, which is further presented as a separate methodological document. ▪ FMS prepares a basic proposal of areas that should be protected in the spatial plan as part of migration corridors and surroundings of fauna passages. This proposal is further specified after definitive route placement and is released as a separate methodological document. ▪ FMS prepares a proposal of conditions and measures for fauna protection during the construction phase. These conditions should be included in the final EIA statement. ▪ FMS is worked out by a zoologist together with a designer.
E. Note
When the EIA is worked out in the phase before a detailed project (study assessing different variants), all requested technical conditions should be presented as framework ones, because in subsequent steps of the project preparation, parameters of objects are changed with further specification of the route. Exact object parameters are indicated in detailed migration study and in the planned decision.

case study

Framework migration study – motorway D35 (CZ)

A framework migration study assesses the permeability and overall acceptability of the proposed motorway route in terms of animal movements through landscape. It is part of the Environmental Impact Assessment (EIA). It proposes basic measures for all the relevant animal categories, location and dimensions of all wildlife passages, fences, barriers, and other objects. The example below is from the planned motorway D35 (Hradec Králové – Olomouc) in the Czech Republic, which continues as a national road to the Carpathians. The design of measures for mammals and amphibians is partly demonstrated in the scheme.

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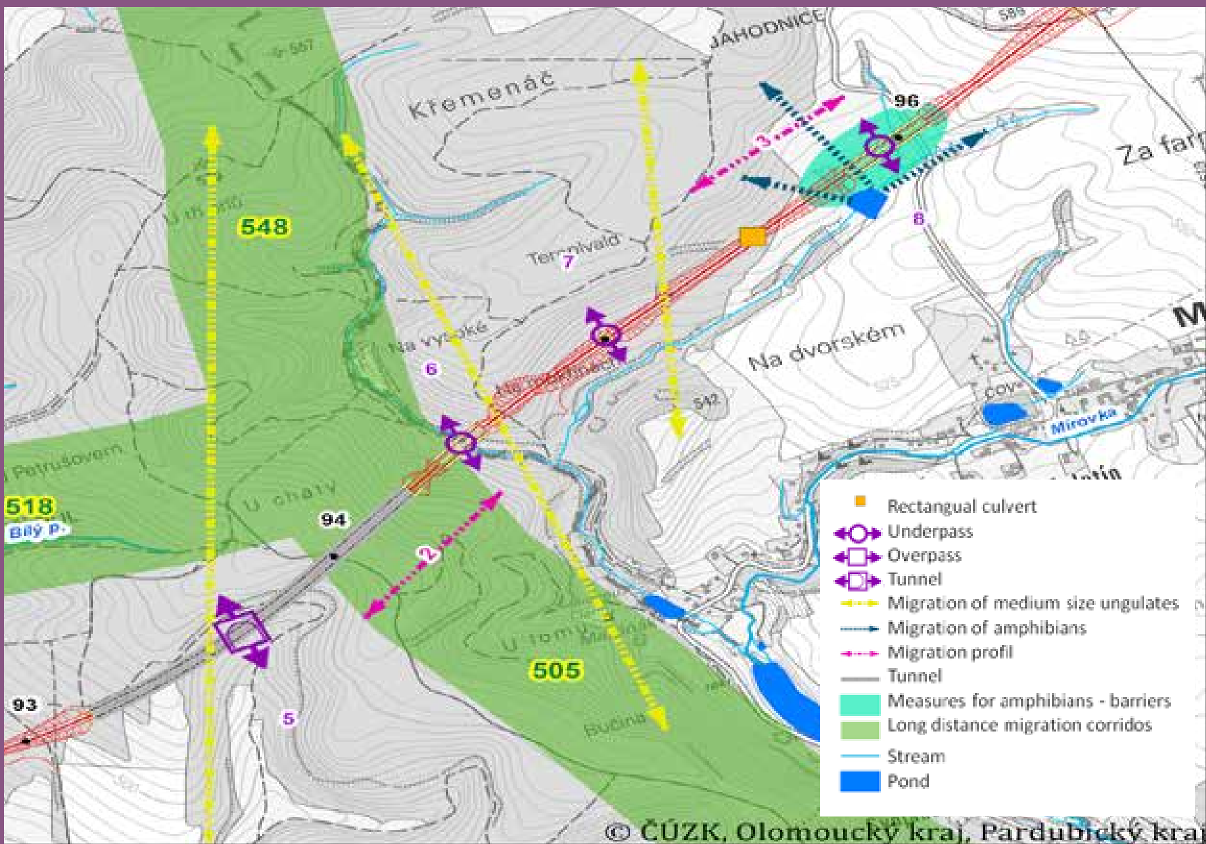

Fig. 8.3 Case study: Framework migration study – motorway D35 (CZ). © Petr Anděl

8.4 Preparation of a detailed project

SCOPING | PLANNING | DESIGNING | CONSTRUCTION | OPERATION

Phase characteristics

The phase of detailed project preparation comes after selecting the final route variant. It usually happens in several steps, in which the detail of solution gets greater and greater:

a) Documentation for decisions on the placement of the building.

b) Documentation for building permit – base for building permit proceedings.

c) Documentation for construction work – base for selection of a contractor.

It should be emphasized that in different construction types and based on different national legislations, the number of these steps can vary. They can be either joined together or others can be added. However, this is not crucial for the methodology of minimizing the impacts of transportation on fauna and landscape connectivity. The entire phase of detailed projects' preparation is characterized by two main facts:

- Continuous specification of documentation and solving details.
- Gradual processing of comments from administrative authorities – conditions relating to the protection of all environmental elements (nature and biota, water, soil, forest, air, etc.) are being specified during this phase of preparation. For this reason, more individual proceedings can be conducted at the same time for one construction.

Besides technical side of the project in operation, organization of construction has to be evaluated (means of future construction, access routes, temporary land occupation, construction site facilities, temporary landfills of materials, parking for construction machinery, etc.). All these activities can affect the environment, including the fauna and landscape connectivity, and have to be assessed in sufficient detail. In practice, this is firstly possible in this phase, when specific solutions are known. A time schedule of construction work is created as well, which also has potential effects on the biota (cutting down vegetation, bird nesting, migration routes of amphibians, etc.).

Monitoring program (T4) is an essential tool that is recommended to be prepared within the process of EIA and should be established in all phases of a transport project (before construction, during construction and during operation) (see Table 8.5). Monitoring program has to be part of EIA documentation and the final statement. In practice however, this resource material is often missing or is worked out insufficiently. The monitoring process is described in detail in Chapter 12 and aims to predict, approve and improve ecological permeability of the transport infrastructure.

Decreasing involvement of ecologists into road/railway preparation is often the unfavourable aspect of this phase. After the SEA and EIA steps, where the influence of experts on the environment is high, it often happens that they are not invited to further cooperate in the phase of a detailed project. Consequently, many approved conditions to protect the biota are gradually limited or even left out. An effective tool to solve all the above-mentioned facts is **detailed migration study** (T5) (see Table 8.6).

In the decision-planning phase, the route of future road/railway is definitively fixed in the area. It is then step by step put into individual local plans. Meanwhile, it is also necessary to solve the protection of migration corridors and places in the surroundings of fauna passages by means of spatial planning from inappropriate construction and other interventions that could limit their functionality. This is a very important fact, which is often not sufficiently addressed in legislation.

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Nevertheless, it is necessary to make an effort to provide this protection. The tool designed to help with it is the **incorporation of the migration corridor near the fauna passage into the corresponding spatial plan** (T6). A very important prerequisite for using this tool is opening the communication with relevant local stakeholders from the environmental, agricultural, forestry or water sectors, because spatial planning is typically the responsibility of local/regional authorities and the success of the incorporation depends a lot on discussions with these groups (see Table 8.7).

Monitoring activities (T4) start in the phase of project preparation, namely three-phase monitoring of the state of biota. It has to begin optimally 3 years before the start of construction works, in order to sufficiently capture the 'zero state', including the consideration of seasonal variability. Monitoring is described in detail in Chapter 12.

Usually the phase of construction can cause the greatest direct negative effects on habitats, plants and animals. For this reason, conditions aimed at minimizing these negative effects have already been formulated in the EIA process and subsequent proceedings. In order to comply with these conditions in reality, it is necessary to work out a comprehensive, detailed **plan to protect biota** (T7), which should be completed before the construction phase starts. The construction contractor needs to have a plan of protective measures available as detailed as other parts of the construction. Localities that must not be affected by the construction have to be precisely defined and clearly marked, placement of temporary barriers for amphibians and temporary fencing has to be solved, full-grown trees protected by barriers, etc. (see Table 8.8).

Table 8.5

Basic description and characteristics of recommended Tool 4 - Monitoring program

Tool: Monitoring program (T4)
A. Goal
To create a comprehensive concept of gaining relevant data regarding the impacts of implemented road/railway on fauna and landscape connectivity and regarding the effectiveness of fauna passages as a resource for feedback in the form of post-project analysis.
B. Placement in the process
Basic proposal of monitoring plan is worked out in the EIA phase and has to be part of its final statement. In further steps of planning and building permits, the monitoring plan can be partially updated and has to be included in binding conditions of corresponding proceedings. Monitoring plan and the monitoring itself are the responsibility of investor, monitoring plan and resulting reports are approved by nature protection authority.
C. Initial resource materials
Biological survey, framework migration study.
D. Principles
▪ Detailed analysis of monitoring issues, recommended methods and periods are described in Chapter 12. ▪ Monitoring is a mandatory part of preparing the operation of a new road/railway and can be methodologically divided into 3 basic types: a. Monitoring the state of biota – so-called three-phase monitoring (before construction, during construction, during operation). b. Monitoring the impacts of transportation – during construction and during operation. c. Monitoring effectivity of implemented measures – fauna passages, fences, etc. ▪ Individual types of monitoring mutually complement each other, and all three types should always be carried out in the needed extent on new road/railway constructions. Where relevant, a combination of monitoring the state of biota with monitoring abiotic factors (contamination, noise, imissions) is recommended. ▪ Monitoring program sets for each type of monitoring: list of localities, list of assessed species, recommended monitoring methods, time schedule. ▪ Monitoring forms background material for the elaboration of a comprehensive post-project analysis, which then becomes basic feedback tool for optimization of measures in construction of roads/railways.
E. Note

Table 8.6

Basic description and characteristics of recommended Tool 5 - Detailed migration study

Tool: DMS - Detailed migration study (T5)
A. Goal
To propose the final detailed technical solution of all measures to protect fauna and landscape connectivity and to check other parts of prepared construction from this point of view. DMS forms an overall background material for statements of administration authorities and for preparing the organization of the construction.
B. Placement in the process
This is the phase of preparing a detailed project. DMS should be included in all levels of project documentation that are being elaborated in this phase (documentation for decisions on the placement of the building, documentation for building permit, etc.). DMS is the responsibility of investor.
C. Initial resource materials
The basic initial resource materials include: framework migration study (FMS), statements of administration authorities (first of all from the EIA process, but also according to component laws), technical project documentation of a given level, biological survey, eventually its further additions, field surveys, etc.
D. Principles
DMS especially solves the following points: ▪ Comparison of proposed state with requirements coming out of the EIA process and other proceedings. ▪ Definitive placement and detailed technical solution of fauna passages (including details such as surface adjustment of the object, solution of the area under a bridge, vegetation adjustments near the object, means of conveying a watercourse, installation of hiding spots for small animals). ▪ Detailed technical solution of fencing, guiding barriers, permanent and temporary barriers for amphibians and reptiles, ensuring continuity with the surroundings. ▪ Detailed solution of measures to protect birds and bats (non-transparent noise protection walls, vegetation adjustments on overpasses, etc.) . ▪ Checking the effects of other technical objects of the construction (noise protection walls, drainage ditches, sedimentation and balancing ponds, protection of slopes against erosion, vegetation adjustments, accompanying constructions). ▪ Proposals to optimize vegetation adjustments of slopes, using road verges for increasing biodiversity (especially of invertebrates). ▪ Preparing materials for plan to protect biota during construction. ▪ Preparing materials for incorporation of migration corridor(s) near fauna passage(s) into spatial plan. DMS is worked out by a zoologist in cooperation with a designer.
E. Note
The detail and exact content of a DMS will differ based on the level of project documentation, at which it is being prepared.

case study

Detailed migration study of the R4 expressway, section Ladomirová - Hunkovce

The Environmental Impact Assessment for this section was done in 2000. The permeability of transport infrastructure for fauna was at that time solved insufficiently. For this reason, the company HBH Projekt prepared a detailed migration study in 2016 with the aim to specify the requirements of fauna for permeability of this expressway. The study was elaborated in a close cooperation of ecologists with engineers and designers and was based on the local spatial plan. Compared to the previous solution, adjustments of the originally proposed bridges were suggested in a way that the bridges can also serve as fauna passages. Based on the study, for example bridge 209_00 has been widened by 95 m in a way that allows for migration of all animal species, including large carnivores.

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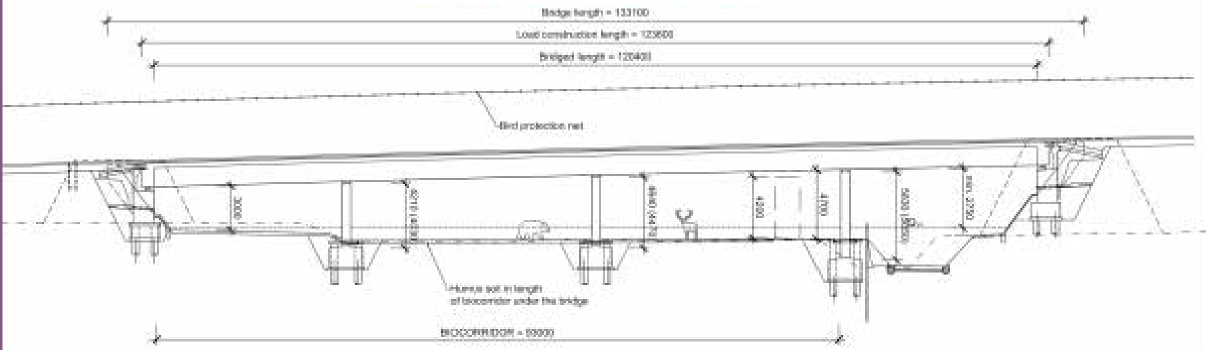
Final proposal adjusted according to the recommendations from the detailed migration study



Original proposal (before detailed migration study)

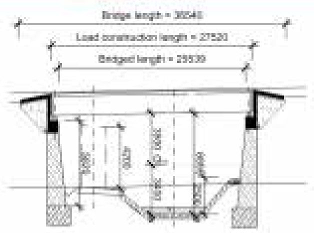


Fig. 8.4 Case study: Detailed migration study of the R4 expressway, section Ladomirová - Hunkovce. © Michal Králik, HBH Projekt, Ltd.

Table 8.7

Basic description and characteristics of recommended Tool 6 - Incorporation of migration corridor(s) near fauna passage(s) into spatial plan

Tool: Incorporation of migration corridor(s) near fauna passage(s) into the spatial plan (T6)
A. Goal
To ensure protection of migration corridors in the surroundings of fauna passages in spatial plans, to prevent changes in land use that would limit the access of animals to the fauna passages.
B. Placement in the process
Proposal regarding this issue is being prepared already at the SEA level (permeability of supra-regional migration corridors is solved in SMS), further at the EIA level (local migration corridors and placement of fauna passages are solved in FMS) and consequently in DMS. The final form is bound to definitive placement of construction including fauna passages in the phase of decisions on the placement of the building. The proposal is the responsibility of investor.
C. Initial resource materials
Strategic, framework and detailed migration studies, local and regional plans, statements and declarations of administration authorities to the EIA process and other proceedings according to particular laws.
D. Principles
▪ Incorporation of migration corridor(s) near fauna passage(s) into spatial plan has to be solved simultaneously (within the same phase) with incorporation of approved building permit for incorporating the infrastructure into the spatial plan. ▪ Proposal of zones to be protected is worked out in the form of one comprehensive material set, which sums up and unifies all earlier presented requirements for protection of fauna passages and migration corridors from devaluation of habitats by construction or transformation in the future. ▪ Proposal of zones to be protected is elaborated for individual localities and is presented with maps in the scale corresponding to the scale of the given spatial plan. ▪ Communication with local stakeholders connected with spatial planning (e.g. environmental services, forestry services, agricultural authorities, water services, local agricultural federations, hunters) is essential. ▪ Text of the report contains a proposal for required regulations. ▪ The proposal is worked out by a zoologist in cooperation with an expert on spatial planning.
E. Note
Although the legislative support for this protection is in many cases very weak, it is necessary to have one separate comprehensive material set available to gradually work with. Additionally, there are many cases of effective mitigation measures taken on roads and railways, but insufficient spatial planning and land use of the surroundings, which of course negatively influences the overall ecological connectivity. Since the general spatial planning is not the responsibility of investor or the operator of the transport infrastructure, involvement of appropriate stakeholders and support of cross-sectoral cooperation on securing the functionality of the migration corridors is of vital importance.

case study

Importance of spatial planning – a bad example from the Czech Republic

During the EIA assessment for the planned R6 motorway construction, a migration corridor for large mammals crossing the planned motorway was identified. A green bridge was therefore designed at the crossing point. However, the migration corridor was not incorporated into the local spatial use plan. The local community decided to build up the whole area south of the new motorway. In 2006, a new stretch of motorway, including the new green bridge, was completed. However, the migration corridor for animals has been completely interrupted due to the newly developed area, and the costly green bridge was suddenly useless as a result.

© Mapy.cz © Mapy.cz

Fig. 8.5 Case study: Importance of spatial planning – a bad example from the Czech Republic. © Václav Hlaváč

Table 8.8

Basic description and characteristics of recommended Tool 7 – Plan to protect biota during construction

Tool: Plan to protect biota during construction (T7)
A. Goal
To work out a detailed plan of technical and organizational measures for minimizing negative impacts of construction on natural habitats and wildlife.
B. Placement in the process
Plan to protect biota during construction is usually elaborated within the EIA process, but sometimes also in later phases of preparation (e.g. documentation for building permit or detailed implementing documentation).
C. Initial resource materials
Set conditions in previous proceedings (planning, building, EIA, expert background materials from FMS and DMS, field surveys). Technical project documentation at given levels.
D. Principles
▪ The plan solves specific measures to protect habitats and fauna during construction. It has to be worked out in cooperation with a designer and a zoologist. ▪ Division of the plan into building sections and the detail of drawing documentation have to be at the same level as in other objects of the construction. ▪ A list of localities where measures will be implemented, basic characteristics of the measures and their exact spatial specification (drawing in documentation) is worked out for each building section. ▪ Extra attention is paid to the surroundings of fauna passages. ▪ Additional information is used – for example a list of specially protected species that can be expected near the construction site, methodology on how to proceed in case they enter the construction site. Examples of measures: ▪ Temporary fencing of valuable localities as a protection from construction activities – drawing of placement, length and type of fence. ▪ Protection of selected full-grown trees by wooden barriers. ▪ Barriers against amphibians entering the construction site – drawing of placement, length and type of barriers. ▪ Estimated number of traps – for each trapping locality including preliminary placement (by a drawing in a background map) and a working mark. ▪ Localities for transfer of animals – must be approved by nature conservation authority. ▪ Time schedule of construction activities must take species protection into account– for example the migration of amphibians, nesting period of birds etc.
E. Note

8.5 Construction

SCOPING | PLANNING | DESIGNING | CONSTRUCTION | OPERATION

Phase characteristics

Plan to protect biota (T7) mentioned in the previous chapter is followed by a control system of its compliance, implemented during the construction phase. It can be carried out at the level of contractor (internal check), investor (as the contracting authority) and administration authorities. Generally, the investor is fully responsible for meeting all environmental requirements. The investor is responsible for the whole construction in face of the administration authorities, which have to regularly check whether the set environmental obligations are met. It is therefore in the investor's interest to implement the construction in compliance with the set conditions. This control activity is marked as **ecological supervision** (T8) (see Table 8.9).

The investor can influence the quality of carried out work already in the selection of the construction contractor, where experience and equipment of contractors in the field of environmental measures can be set as one of the selection criteria. Ensuring special work, according to some national legislations possible to only be carried out by an authorized company (for example transfers of specially protected species), also belongs to this phase. The contract between the investor and the constructor should from the beginning include costs for possible extra technical improvements, whose need is demonstrated by monitoring results.

Monitoring activities (T4) are going on during the construction phase in compliance with plan of monitoring, which means three-phase monitoring (phase of construction and monitoring the impacts of construction activities).

Fig. 8.6 Temporary barriers are used to prevent amphibians from entering the construction site. In such cases animals should be directed to a suitable passage or have to be captured and transferred to appropriate environment. © Naturaservis, Ltd.

Table 8.9

Basic description and characteristics of recommended Tool 8 – Ecological supervision

Tool: Ecological supervision (T8)
A. Goal
Ecological supervision is performed by a professionally qualified person who oversees the compliance with the interests of nature protection during the entire time of construction all the way to its final inspection. This person is responsible for the compliance with the conditions laid down by the nature conservation authority and is controlled by that authority. Main objective is to minimize negative impacts on the environment during construction.
B. Placement in the process
Phase of construction implementation. Ecological supervision is part of technical supervision of the investor.
C. Initial resource materials
Plan to protect biota during construction, project documentation for conductor of the construction and other building documentation.
D. Principles
The following belongs to the main functions of ecological supervision: ▪ Checking proper implementation of all measures in the plan to protect biota during construction. ▪ Coordinating construction activities that could have negative effects on biota (for example time schedule of tree felling). ▪ Monitoring the occurrence of specially protected animal species in the area of the construction site and ensuring their rescue transfer if needed. ▪ Keeping a detailed documentation about all captures and rescue transfers. The documentation should contain a list of found species, numbers of individuals, means of capture and transfer, description of both original and substitute location. ▪ The right to stop activities of the construction company for a necessary time period in case specially protected species are urgently endangered by the building activities.
E. Note

8.6 Operation and maintenance

SCOPING | PLANNING | DESIGNING | CONSTRUCTION | OPERATION

Phase characteristics

Operation phase is the final stage and its time period is in the order of tens of years. During this phase, the construction influences its surroundings by noise, emissions from combustion processes, scattering salts and other substances used in maintenance. At the same time, all measures to protect fauna and landscape connectivity should stay functional. For practical reasons it is good to divide this time period into an initial phase and a subsequent period.

The first 3–5 years can be considered the initial phase of operation. This period sometimes includes a testing (or temporary) operation, in which some technical details are still being finished and defects found during the final inspection are being fixed. Nevertheless, it is already possible to detect first operational experience with implemented measures. The third phase of **monitoring** (T4) is carried out intensively in this phase (monitoring the impacts of transportation on fauna in operation phase), as well as monitoring the effectivity of implemented measures (for detailed description of these tools see Chapter 12).

Post-project analysis (T9) is a recommended tool to ensure the feedback. This mechanism, generally declared in the EIA directives, has in practice been used only very sporadically. The operation period for which a post-project analysis should be worked out is a compromise between the need to gather sufficient representative data from monitoring and the effort to gain feedback and experience for other constructions as fast as possible. Preparation of a post-project analysis is recommended here after 3-5 years of operation (see Table 8.10).

Fig. 8.7 Monitoring the effectivity of fauna passages brings an important feedback on whether proposed measures serve their purpose. The extent of monitoring and used methods have to be planned within the monitoring program (T4) preparation. © Michal Králik, camera trap picture

Further monitoring, even after the compilation of a post-project analysis, serves its purpose, because a number of effects, especially at the population level, can become evident only after a longer latent period. The question of extent and financing of post-project analysis currently lacks unity in the Carpathian countries. Nevertheless, it represents a fundamental tool to improve involved procedures and to limit negative impacts, therefore it is recommended here as part of the standard solution.

Table 8.10

Basic description and characteristics of recommended Tool 9 – Post-project analysis

Tool: Post-project analysis (T9)
A. Goal
To summarize in one complex document the basic experience with implementing the construction and with the road/ railway operation, including protection of fauna and landscape connectivity. The main purpose of the report is to serve as background material for the investor, administration authorities, designers and public and to use the gained experience in other constructions. In case the post-project analysis reveals that some conditions set in the associated building permit have not been met (e.g. a non-functional spare habitat for amphibians or a green bridge not used by fauna), it should focus on searching for the reasons for this situation and when it is still possible to improve it, it should propose additional measures for such improvements.
B. Placement in the process
The operation phase of a construction prepared approx. 3-5 years after the start of operation. The analysis is the responsibility of investor.
C. Initial resource materials
Statements of administration authorities on the EIA process, planned proceedings, building permit and final inspection. Technical documentation in its last valid version. FMS and DMS, original biological survey, results of three-phase monitoring of the state of biota, monitoring the impacts of construction during construction and during operation, monitoring the efficiency of implemented measures.
D. Principles
▪ The analysis evaluates separately the following basic range of issues: a. Procedural component – respecting and fulfilling the conditions given in the statements of administration authorities. b. Impact on selected representative species – changes in populations from construction preparation to its operation. c. Impact on landscape connectivity – state and changes in migration corridors. d. Contamination and disturbance of the surrounding fauna habitats– changes in the concentrations of the indicator substances in soils, biota, water, impact of noise or light, etc. e. Change in surrounding habitats – means of ensuring protection of migration corridors and the surroundings of fauna passages. f. Effectivity of proposed measures – results from monitoring and experience with object maintenance. ▪ For each range, according to given possibilities, the entire time period from preparation through construction all the way to operation of the construction should be assessed. ▪ For each range, a detailed analysis of the given issue is carried out and specific measures are proposed for application in other constructions. ▪ The obligation to elaborate a post-project analysis has to be set already in the EIA statement and repeated in other subsequential proceedings. ▪ Proposal of monitoring plan for another time period should be developed and submitted to discussion.
E. Note
It would be purposeful in large motorway constructions to work out an analogical post-project analysis immediately after finishing construction. It would shorten the time for getting the feedback and using the new findings from the construction phase.

8.7 Approach to the specifics of individual types of transport infrastructure

The specifics of individual constructions need to be considered when using the above-mentioned tools. For example, in the case of building lower class roads, it needs to be considered that such constructions usually do not represent a migration barrier, especially on low traffic roads; however, the main problem is high mortality. This is similar in the case of low traffic railways, where mortality is again the key issue. The barrier effect should be considered and solved in the case of high-speed tracks, where its impact is comparable to the fenced motorways.

Special importance and attention have to be paid to the types of transport project development described in the following sections (8.7.1-8.7.4).

8.7.1 Upgrading of existing roads/railways

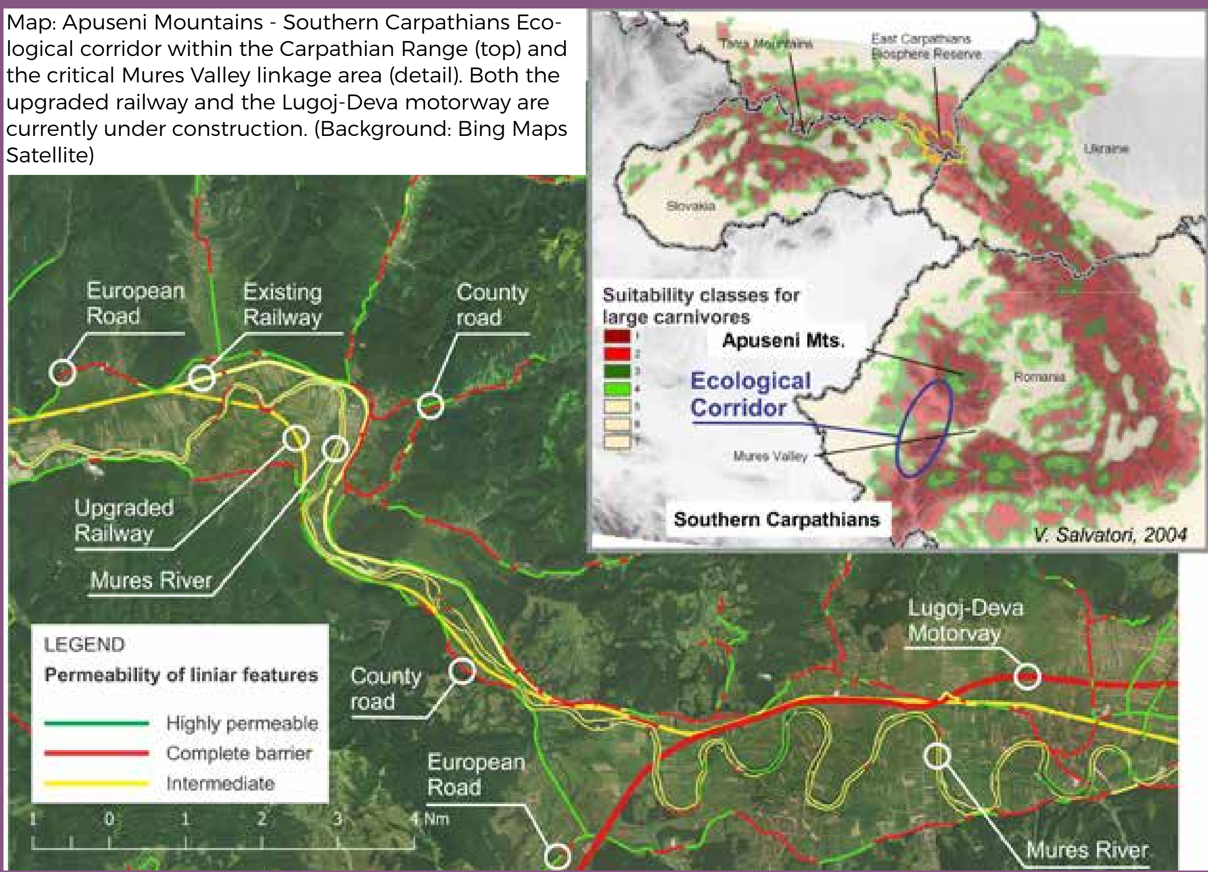
This represents a specific situation. Using the above-mentioned tools depends on the extent of the upgrade. Some upgrades can include measures to increase speed or slight widening of an existing road, others represent extension from a two-lane road to a four-lane motorway, or from a single-track to a multi-track railway. It needs to be decided based on the extent of the upgrade and according to the law, which processes will take place (SEA, EIA, planning decision, building permit). Given the processes, the corresponding tools then have to be used.

In case of upgrading and especially when ecological connectivity was not incorporated at the planning and design stage of the original road/railway, a defragmentation approach shall be adopted that will maximize the permeability for wildlife under the current status of the alignment, its changes and the surrounding landscape and habitats.

case study

Mapping structural permeability of linear features in Romania

The importance of the last ecological corridor between the Apuseni Mountains and the Southern Carpathians in Romania (map, top) was shown in a study done by Salvatori (2004), using large carnivore habitat suitability assessment and pointing out the Mures river valley as a critical area due to further expected anthropogenic development in the near future. An assessment of structural permeability of linear features (including linear transport infrastructure) followed up in this area in 2010. It focused on large mammals and was based on quantitative assessment of structural components (embankments, gutters, parapets, fences, adjacent buildings, underpasses, vegetation verges), assessed in the linkage area of the Mures valley. The resulting permeability maps of the linear features (map, detail) were then used to identify the critical areas for connectivity (obligatory passageways, corresponding permeable sectors, cumulative impact areas) and to implement adequate measures (maintain existing permeability, mitigate barriers, prevent vehicle-fauna collisions, etc.). Based on the assessment, several new Natura 2000 sites have been designated in order to ensure proper connectivity, and it also helped to direct mitigation measures to the most relevant places within the area (more details are provided in the TRANSGREEN Catalogue of measures for Arad-Deva pilot area, including the information on a new methodology developed and used for the purpose of such assessment (Moț 2015 -18)).



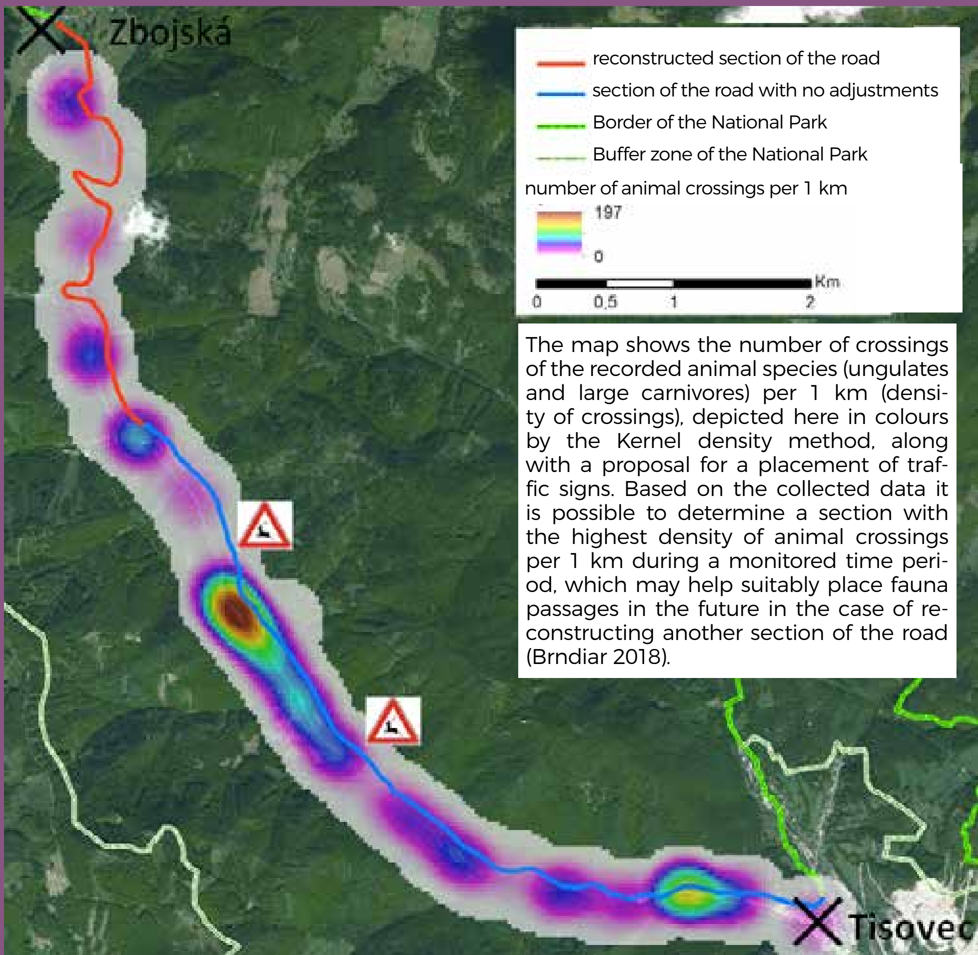
Map: Apuseni Mountains - Southern Carpathians Ecological corridor within the Carpathian Range (top) and the critical Mures Valley linkage area (detail). Both the upgraded railway and the Lugoj-Deva motorway are currently under construction. (Background: Bing Maps Satellite)

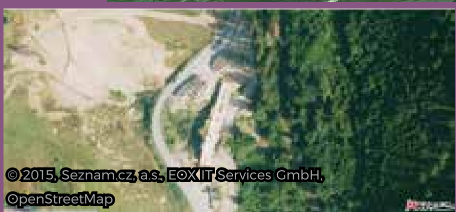
Fig. 8.8 Case study – Mapping structural permeability of linear features in Romania. © Radu Moț

case study

Reconstruction of the lower 1st class road I/72 between Pohronská Polhora and Tisovec, NP Muránska Planina (Slovakia)

The reconstruction of the road I/72 in general improves traffic safety and allows for the increase in speed of traffic. On the other hand, it also increases the barrier effect of the road for fauna. In cooperation with the Administration of National Park Muránska planina, mitigation measures to improve the permeability of the road for animals were suggested for four corridors. For two of them, the measures have been implemented, as shown in the enclosed pictures.





A) Near the locality of Zbojská, part of the old road has been removed, the curve has been softened and a bridge on pillars has been built in order to secure the permeability for animals. © EUROSENSE, s.r.o

B) Building of a new bridge on pillars – the corridor is partially functional. It is necessary to plant guiding vegetation under the bridge and in its surroundings. © Drahoš Blanár

C) Different underpasses for amphibians have been built in several places. © Drahoš Blanár

Fig. 8.9 Case study: Reconstruction of the lower 1st class road I/72 between Pohronská Polhora and Tisovec, National Park Muránska Planina, Slovakia. © Jaroslav Brndiar, Jerguš Tesák

Some important points regarding the upgrades:

- Even roads/railways of lower classes have to be assessed. For instance, a bad bridge on a local road can in certain situations cause high mortality of otters, which can in turn threaten the local population.
- Additional construction of a fence or a protection wall can fundamentally affect mortality (both in positive and negative way) and the barrier effect of the road/railway. For this reason, a migration study at corresponding level should always be performed in these cases. Construction of a fence or a protection wall on an existing road can result in the need to build new fauna passages.
- The impact of an upgrade from a two-lane road to a four-lane road is comparable to the impact of building a new motorway, so all available tools must be used in such a situation.
- The extent of assessment should take into account characteristics of habitats, through which the assessed infrastructure leads.

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8.7.2 Planning double or pairing transport infrastructure

When a new road/railway, or more often a new motorway/high speed railway is selected to be constructed in a parallel line with existing linear infrastructure, the cumulative impact on connectivity from the pairing transport infrastructure alignments has to be studied and the overall mitigation or compensation measures have to be implemented. Considering the fact that the parallel alignment always significantly worsens the permeability of a given area for fauna, building a new infrastructure can raise the necessity to implement certain measures even on the original route. On double or pairing infrastructure, a parallel system of mitigation measures is required, estimating the overall complex needs for connectivity and avoiding high mortality at potentially dangerous points.

Valleys in the Carpathian region very often give the basic landscape background for transport infrastructures, which usually follow the river lines. Such cases bring the need to evaluate the rivers as well – especially if their banks are technically adjusted – as another barrier for animals.

Fig. 8.10 Construction of a motorway parallel with road of lower category, railway or a river channel creates multiple barrier effect. © NDS Archive

8.7.3 Building fauna passages on existing roads/railways

A special case is represented by building fauna passages on existing roads/railways. Such proposals should always be based on migration studies, and the incorporation of migration corridor(s) near fauna passage(s) into spatial plan is a necessity as well.

Fig. 8.11 Green bridge near Moravský Svätý Ján (Slovakia) was built during operation of existing motorway D2. The original motorway was completely impermeable in a long section; in this place it crosses the Alpine-Carpathian wildlife corridor. © Václav Hlaváč

8.7.4 Fencing of existing roads/railways or building protection walls

Fencing of existing roads is often done in order to decrease the number of collisions with fauna. However, from the animal perspective, fencing fundamentally increases the barrier effect of the road. When solving the issue of fencing, it is necessary to mention that the construction of the fence itself is not subject to permission of authorities (different approaches exist in different countries). Therefore, a situation can arise, when a fence is being built without an official statement of nature protection authority, which can have fatal consequences for fauna. Data on what species in which places and in what numbers cross the unfenced road are in general necessary when placing a fence on existing roads. Fencing can be allowed only if sufficient permeability of the road for fauna is ensured in the given section (this is usually ensured by appropriate fauna passages or at least by using warning systems for drivers in places where the fencing is to be interrupted).

8.8 Recapitulation of ensuring protection of wildlife in the process of preparing linear transport infrastructure

The topic of wildlife protection and avoiding habitat fragmentation in building transport infrastructure has not been solved very systematically or conceptually. Relating requirements are often applied first in the late phases of preparing transport constructions, when it is often too late for satisfying solutions.

In order for the requirements on fauna protection to become part of standard procedures, an overview of tools that need to be used in individual preparation phases of transport infrastructure has been prepared. Table 8.11 provides a simplified summary.

Table 8.11

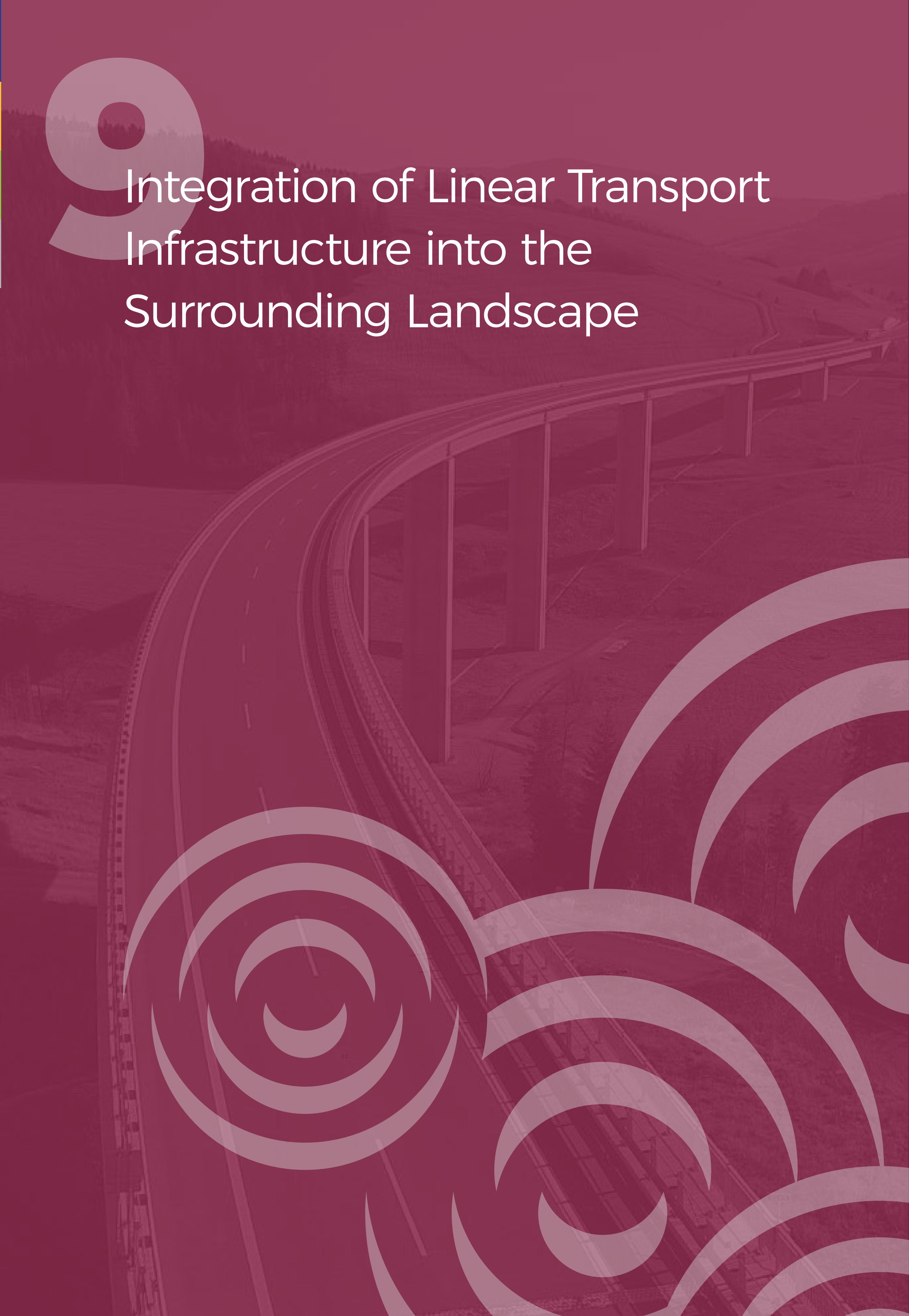
Using individual tools in relation to preparation phases and ongoing processes

Topics	Phases of investment preparation and implementation		
	Transport policy	**Delimiting transport corridors**	**Route selection**
Processes	SEA	SEA	EIA
Map of green infrastructure	National level	Regional level	Local level
Complex documents – migration studies	Strategic migration study determining conflicts of green and grey infrastructure	Strategic migration study (framework migration study)	Framework migration study
Biological survey		Screening of the entire corridor	Basic survey of all variants
Placement of fauna passages and other measures	Determining conflicts of green and grey infrastructure	Identification of conflict areas	Framework placement and setting the types of fauna passages
Incorporation of migration corridor(s) near fauna passage(s) into spatial plan			Basic proposal
Protection of fauna during construction			Basic principles
Monitoring program			Basic proposal
Monitoring the state of biota (three-phase)			
Monitoring the impacts of operation			
Monitoring the effectiveness of proposed measures			
Post-project analysis			

8

Phases of investment preparation and implementation		
Detailed project	**Construction**	**Operation and maintenance**
Planning proceedings Building proceedings	Construction supervision Final inspection	
Detailed migration study		
Detailed survey of final variant		
Exact placement and setting technical parameters of fauna passages	Implementation	
Proposal of zones to be protected and their incorporation into spatial plan	Implementation	Checking validity of implementation
Plan of protection	Implementation of the plan Ecological supervision	
Final form	Implementation of monitoring	Implementation of monitoring
Before construction, null state	During construction	During operation
	During construction	During operation
		During operation
	After finishing construction	After 3-5 years of operation

9 Integration of Linear Transport Infrastructure into the Surrounding Landscape



Route selection for a road or railroad and its incorporation into the landscape is a fundamental step from the viewpoint of final impact of the construction on nature and landscape. For this reason, it is very important to pay special attention to this phase of the preparation. Procedural part of this issue, relationships to investment preparation phases, spatial planning and evaluating the effects on the environment (EIA/SEA) are described in Chapter 8. This chapter provides general recommendations for route selection in different types of landscape (9.1) and preferred design solutions for particular technical components (9.2).

9.1 Alignment – recommendations for different types of landscape

Route alignment of each infrastructure has to respond to local topography and intended type of the infrastructure and should use available engineering elements to minimise habitat fragmentation and to ensure maximum possible connectivity both below and above the infrastructure. It is possible to set certain basic recommendations for the selection of the best route of a planned road and it is good to respect them in certain specific types of environment. These recommendations are listed in the following sections.

9.1.1 Responding to ridges and valleys

Fig. 9.1 Cumulation of barriers in a mountain valley near Hronská Dúbrava, Slovakia. © Peter Urban

A good alignment in a hilly landscape should ideally be both well incorporated into the surroundings and allow for free movement of animals. Solutions ensuring both aspects are therefore preferred; however, the two requirements unfortunately often contradict each other. Probably the most common alignment is leading a road at the bottom of a valley. That is usually not problematic regarding the incorporation into the surrounding landscape, but brings difficulties searching for suitable places for effective fauna passages. Moreover, the barrier effect of a new road planned with this alignment typically cumulates with the effect of the already existing barriers. These can be first of all dense linear housing developments along a watercourse in length of several kilometres and also roads or railways already passing through the area. Such accumulation of old and new barriers often leads to a complete elimination of permeability of long infrastructure stretches and to prevention of animal movement perpendicular to the axis of the valley.

The greatest danger is represented by impermeable housing development and infrastructure, and the only possible tool to solve this issue is spatial planning. Within the spatial plans, it is necessary to protect empty spaces between villages, as well as empty spaces inside the built-up areas of villages and not to allow building new houses in such gap sites. This is a very complicated issue from both the legislative and social viewpoint. It constitutes a fundamental task for migration studies to recognize such critical points in time (before or at the latest during spatial plans' preparation) and to propose protection of available passages.

From the viewpoint of road planning/preparation it is necessary to consider the following aspects:

- Leading the route away from the valley bottom more to the slopes, so that immediate cumulative effect of barriers is limited. This solution is often more demanding technically and economically but is also advantageous, with regard to impacts on human inhabitants. A disadvantage is that often more extensive interventions to natural habitats are needed.
- Linkage of passages in the housing development and fauna passages on the road – mapping of all potential passages through the housing development in the valley should be carried out and an effort should be made to connect them to fauna passages on the road as much as possible.
- Attention needs to be paid to crossing points of the infrastructure with small creeks or small vertical valleys – a system of functional wildlife underpasses should be created instead of constructing small culverts only designed for hydrological purposes.

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In general, following a valley bottom may be a satisfactory alignment only under the conditions that the severance of watercourses and other linear features is avoided or minimised and connectivity between both sides of the valley is maintained.

Alignment that follows the foot of a major ridge is a good option as far as incorporation into the landscape is concerned, since it enables the infrastructure to remain hidden from view. Even minor ridges offer opportunities for sensitive alignment. This type of alignment may also bring some benefits to wildlife, for example lower noise levels or reduction of disturbance from vehicle lights. However, its barrier effect can be very strong and similar to the alignment following a valley bottom, therefore care must always be taken to provide sufficient and safe fauna passages.

Where infrastructure rises or follows the side of a valley, the intrusion can be significant. In such situations, earthworks need to be properly sited and designed. Major earthworks can be avoided by following the contours high up the valley side. Split carriageways and restored graded-out slopes can be effective design solutions. Care must be taken not to grade out slopes where valuable habitats or species may be present.

Fig. 9.2 A road leading along a steep mountain slope represents an impassable barrier due to cuttings and embankments. © Ján Kadlečík

Fig. 9.3 Leading a road higher along a hillside allows for good solution of permeability for animals (e.g. viaducts over smaller side valleys), but has a disadvantage in impacting new natural areas. D3 Svrčinovec - Skalité, Slovakia. © NDS Archive

9.1.2 Alignment in flat landscapes

Many different habitats can be present in flat landscapes. Alignment in this type of environment should be sensitive to landscape scale and context and consider the necessary connectivity of habitats for the species that inhabit them. Some of the main general principles to be followed are:

- Leading a route at ground level with local terrain for good incorporation into the surrounding landscape. At the same time, existing topographical features should be used as much as possible, since alignments respecting local drainage or vegetation are often the best.
- Steep, intrusive embankments should be avoided.
- Viaducts should in general be preferred as they maintain connectivity for species.
- Habitat fragmentation should be minimized by integrating crossing points for target species. Good solutions in flat landscapes may be smaller but well-designed passages, for example culverts with dry ledges or badger or amphibian tunnels in low-level embankments.

Fig. 9.5 Rectangular culverts suitable for passage of mammals up to the size of fox and badger are relatively easy to build on infrastructures in flat landscapes. © Lukáš Poledník

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- Flat landscapes, particularly wetlands, are often of high nature conservation value. In case crossing such an area is unavoidable, a viaduct should be the proper solution, as it minimizes land occupation and soil disturbance and allows passage for animals.
- In case a new alignment will cross a known migration corridor of large mammals, the situation can be solved by a properly designed green bridge.

Fig. 9.4 Alignment of a motorway in a flat landscape at ground level with the surrounding terrain is not very disturbing visually but gives only limited possibilities for incorporating effective fauna passages. © Tibor Sos

Fig. 9.6 Viaducts in general are doing a good job at minimizing the fragmentation and negative impacts on the habitats under them. The biggest viaduct in the Middle Europe on the M7, Köröshegy, near the Lake Balaton, Hungary. © András Weiperth

Fig. 9.7 When necessary, it is possible to allow for movement of large mammals even in flat landscapes – by means of green bridges. It however requires larger land occupation to merge the overpass with the surrounding landscape. © Václav Hlaváč

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9.1.3 Crossing valleys

Infrastructure can be carried across valleys on embankments or viaducts. Viaducts have environmental advantages subject to the choice of the appropriate crossing point. Viaducts are suited to narrow, steep-sided valleys as they minimise land take and fragmentation and enable species movement. Embankments are suited more to wide shallow valleys as they can maintain some degrees of connectivity through the use of appropriately sited and dimensioned culverts and underpasses and offer more scope for green planting.

Fig. 9.8 Viaducts are usually better options to cross valleys than embankments because they allow for free movement of animals and partly maintain connectivity of habitats as well. Aciliu viaduct on A1 motorway (Bucuresti - Nadlac) in Romania, Sibiu County. © Tibor Sos

9.1.4 Crossing watercourses

The basic principle in conveying a road over a watercourse is to maintain in maximum possible extent the natural state of the stream bed and stream flow and of the bank vegetation. The means of conveying watercourses radically influences the possibility to use the object for animal movement as well. In general, following this basic principle together with a proper design (appropriate for the type of infrastructure, size of the watercourse and needs of the animal species present) can usually provide a good solution. This approach is at the same time completely in line with the requirement to safely manage the passage of extreme flood waters, which are expected more frequently in the future due to climate change.

Local materials should be employed within a site-specific design. It is important to ensure that animals can climb out of rivers, streams and ditches and therefore steep banksides and concrete elements should be avoided. Where it is absolutely necessary to use them, exit steps or inset shallow slopes should be provided. Nature conservation opportunities include planting of particular species associated with the water environment, e.g. willow species, or creation of special features such as nesting opportunities for birds, dry ledges and other bankside elements for small mammals.

Fig. 9.9 Properly designed bridge over a stream with dry banks that allows for movement of most animal groups. © Lukáš Poledník

9.1.5 Crossing natural sensitive areas

When infrastructure is planned near sensitive areas of high natural value, the first principle applied should always be avoidance. If complete avoidance is not possible, then a comprehensive evaluation of wider area of interest should be performed in order to set priorities, compare several variants and select the one with minimal negative impacts. Such an assessment requires a lot of input information and looks at the habitat quality from many different viewpoints (e.g. classification according to Natura 2000 network, classification according to the national legislation, function and category of potential wildlife corridors, occurrence of protected species, representation of the given habitat within the area of interest and within a broader region, state of the given habitat as far as its vitality and long-term prospects, etc.). As a result of this, the assessment should provide a map of habitats in the area, including their categorization based on quality. This map then forms the basis for deciding about the final alignment. In this decision, several criteria besides the habitat quality need to be considered as well:

- Size of land occupation and its proportion to the entire area of interest.
- Potential fragmentation and its effects (separating the locality – e.g. leading the route on the side or in the middle).
- Impact on core areas (in case the locality is not homogeneous in its quality).

Protection of habitats represents only one viewpoint in the selection of possible variants, therefore it is necessary to always search optimal solution in relation to all environmental elements.

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Fig. 9.10 Wetlands represent very sensitive areas with great biodiversity. In such valuable habitats efforts should be made to completely avoid any kind of interventions. © Barbara Immerová

9.1.6 Alignment in urban and suburban landscapes

Urban and suburban landscapes usually have strongly anthropogenic character with elements of industrial, transport and housing infrastructure dominating natural elements. The basic principles for leading a route in such areas are:

- To lower the impacts on human inhabitants (e.g. the reduction of noise and air pollution). Nevertheless, this does not mean ignoring the impacts on nature.
- To minimize interventions into smaller and less preserved natural elements, which would in other landscape types remain unnoticed, but have their relevance in this case. These are smaller forest patches, minor streams, trees and shrubs and all other elements belonging to so-called green infrastructure.
- Not to increase the probability of entering towns by large and medium-size mammals, and adequately to this adjust the solutions of migration objects.

Fig. 9.11 Construction of a motorway can also interrupt connectivity of green areas in cities. Securing this connectivity among green urban areas is important for many small species. Motorway D1 in Považská Bystrica, Slovakia. © NDS Archive

9.2 Design solutions of particular technical components

The following sections are devoted to selected most frequently used infrastructure components and give recommendations on how to best design them in order to minimise negative impacts of transport infrastructure on wildlife.

9.2.1 Earthworks: cuttings and embankments

Cuttings and embankments are components that in general help with the route alignment. When well-designed, they can also be used to better integrate the infrastructure with natural landforms or even provide opportunities for various habitats to be created. The following aspects should be considered:

- **Integration into the landscape** – this is usually done by grading out of earthworks to suitable slopes, which also ensures efficient use of materials. In certain areas, irregular cuttings (e.g. in woodland changing with rough pasture) or false cuttings (especially in gently undulating ground) could represent good solutions, in others rock outcrops can be created as most appropriate. It is also beneficial to round off the tops of cuttings to a gentle profile or to use terracing to break up the sides of deep cuttings to overcome their visual dominance (which brings structural stability and facilitates the establishment of vegetation as well).

Fig. 9.12 Terracing stabilizes the slopes of deep cuttings and creates micro-habitats for several plant and animal species. © Václav Hlaváč

- **Elimination of disturbing effects** – this usually goes together with good integration into the landscape, which often brings reduction of noise, light, pollution and other negative effects of transport infrastructure on fauna as well.
- **Traffic safety** – there are several safety issues to consider: proper design of cuttings and embankments always must contain escape routes for people in case of emergency, should effectively stop especially larger animals from crossing the infrastructure and also needs to secure potential falling stones or other material on steeper cuttings.

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Fig. 9.13 Steep slope secured by a catch fence or wire mesh against falling stones. These measures are sometimes necessary to stabilize slopes, but at the same time they represent a reinforcement of the barrier effect and the destruction of road verges as natural habitats. If possible, a more gentle solution should be preferred. R2, Zvolen, Slovakia. © Miroslav Jarný

- **Maintenance** – keeping all infrastructure elements functional and in a good state is absolutely essential. For this reason, regular maintenance and its practical needs always must be taken into account in advance.
- **Ecological importance** – earthworks and other infrastructure edges can in case of good design and care become interesting habitats and host various plant and animal species. Examples include rock exposures in upland areas, rich xerothermic communities or habitats with native grasses or bushes. Respecting the local natural character and appropriate management and maintenance are all very important.

Fig. 9.14 Properly maintained road verges can create valuable habitats for butterflies and many other species. Lower Austria. © Jana Niedobová

9.2.2 Junctions and roundabouts

Highway junctions and roundabouts can be wildlife traps or islands and are very intrusive unless well sited and designed with earthworks at a scale appropriate to minimise the impact of any signs, gantries, lighting and overhead crossings. They should be designed to avoid fragmentation with good connections above or below the carriageways as is appropriate for the species native to the area. Connectivity between the segments of a major interchange may be important for the movement of fauna and can be achieved using culverts or tunnels. These passages must be combined with fencing with exits for large mammals.

Fig. 9.15 Infrastructure junctions always comprise a significant land occupation. In their design, it is necessary to avoid destruction of valuable communities and creation of ecological traps for animals that are drawn by attractive habitats inside the junctions or for migrating animals that follow motorway fencing and can be pushed to dangerous places. Junction near Vrútky, Slovakia. © Tomáš Flajs

9.2.3 Tunnels

Although expensive, tunnels may be the best design solution to protect high-value landscapes, but also a desirable solution from engineering point of view compared to extensive excavations. There are two basic methods of tunnel construction: (A) bored tunnels and (B) cut-and cover tunnels.

Bored tunnels allow sites of high nature conservation value to remain undisturbed and are least damaging environmentally.

Fig. 9.16 A) Construction of the bored tunnel Višňové on motorway D1, Slovakia. B) Construction of a cut-and-cover tunnel - green bridge near Moravský Svätý Ján, Slovakia. © NDS Archive

Cut-and-cover tunnels may be more appropriate for sites of lower conservation interest, but where maintaining connectivity between habitats is desirable. The reuse of the original soils should be considered if they can be stripped and stored in a way that minimises compaction and loss of structure. The soil profile should be constructed to match the adjoining profile in order to reproduce the hydrological characteristics as well as the physical structure and chemical properties of the original substrates. Where the cut-and-cover tunnel is to be used by a range of fauna, the natural vegetation type for the species' habitat should be planted over the tunnel and on the approaches.

9.2.4 Water management (drainage)

The main goals of water management are:

- To safely drain precipitation water from a road.
- To control integration of this water into the surrounding environment, so that no damage to property, nature or water resources is caused.
- To create conditions for the capture of polluted water in case of accidents.

Associated water management features (drainages, ditches, retention reservoirs) have to be built in a way that ensures suitable integration into the landscape, no formation of barriers or traps for animals and if possible, also improved conditions for fauna in the surroundings.

Fig. 9.18 Culverts of larger diameter should always be adapted for passage of fauna under a motorway as well. The outflow is in this case technically arranged in a way that completely eliminates the possibility to use the culvert as fauna passage. In addition, it can create a deadly trap for small animals (amphibians, small mammals) trying to pass through. © Václav Hlaváč

Fig. 9.17 A small retention reservoir becomes a trap for many small animals when water level drops. It would be suitable to design such reservoir as natural or at least with one inclined wall, so that escape of animals is possible. D1, Czech Republic. © Petr Anděl (A), Václav Hlaváč (B)

Fig. 9.19 Massive concrete trough for drainage of precipitation waters from a motorway is very disturbing as far as landscaping is concerned, and it does not allow using culverts as fauna passages. Such a solution also represents a trap for smaller animals that have no means of leaving the trough. © Ivo Dostál

9.2.5 Fencing and barriers

Fences and walls may have serious barrier effects as well as a significant effect on the appearance of the road in the landscape. Their use should be restricted to locations where they are absolutely necessary (effective reduction of fauna mortality and improvement of traffic safety is expected). Technical and other details regarding these components are given in Chapter 10 (section 10.4.1).

Fig. 9.20 Fences in general prevent animal mortality but increase barrier effect of the infrastructure. © NDS Archive

9.2.6 Vegetation adjustments

Vegetation adjustments are a common part of road/railway project preparation. The means of implementation is based on natural conditions in a given area, first of all on climate and characteristics of natural vegetation. For this reason, the species composition of used plants and other parameters of planting will be quite different in each region.

Vegetation adjustments constitute a new ecological element in the landscape. Their relations to the surrounding habitats are complicated and may even be opposing from the viewpoints of various organisms or traffic. The effect of vegetation adjustments can therefore be both positive and negative. Proposing such adjustments must be based on local conditions and should optimize their functions.

Vegetation adjustments are supposed to serve the following basic general functions:

- **Biotechnical function** – stabilization of slopes to prevent from sliding, protection of soil on slopes from water erosion. Technical solutions are needed especially for anti-erosion protection on longer slopes of embankments and cuttings immediately after the road construction is completed. This includes technical grassing of slopes, as succession is very slow in this case.

Fig. 9.21 Vegetation planting is often done with the purpose of slope stabilization. However, these bush or tree covers can create an attractive habitat for many species, including large mammals. When the vegetation is planted in the area between a fence and a road, it can tempt animals into the dangerous fenced space. © NDS Archive

- **Influence on conditions of operation** – changes in microclimatic conditions (increase in humidity, limiting climatic extremes), improvement of health conditions (reduction of dust, noise, etc.), increasing traffic safety (optical leading, capturing vehicles out of control, protection from glares from oncoming vehicles, limiting undesirable climatic effects – for example gusty winds, etc.). At the same time, however, trees planted too close to a road can mean greater danger in the case of traffic accidents.
- **Landscaping (aesthetic) function** – integration into the landscape, improving road appearance, positive effect on landscape character, etc.
- **Biological and ecological function** – increasing landscape stability, creating optimal

volume of biologically active matter, incorporation into the ecological network of the landscape, support of biodiversity, compensation of negative effects of transportation, etc.

The last point is crucial from the viewpoint of biodiversity conservation and therefore several comments are added here:

- Suitability of certain type of vegetation adjustments depends mostly on surrounding habitats. Cuttings and embankments are always more sun-exposed and drier than surrounding habitats and often host xerothermic vegetation of high ecological value. For this reason, in general, it is advisable to prefer natural succession over artificial planting, where possible.
- Thanks to their steppic character, embankments and cuttings represent migration routes for thermophilic species along the road/railway. This phenomenon is also supported by regular management (grass mowing) of verges by the road. Verges sometimes constitute suitable habitats for many invertebrate species and reptiles.
- Road verges can also pose environmental threats. They can create corridors for spreading of non-native species. If vegetation along roads is attractive for some species, the high concentration of animals can bring increased mortality. When setting up or maintaining road verges, these risks need to be taken into account, and minimized as much as possible.

9

Fig. 9.22 Road verges are one of the major pathways for the spreading of invasive plants. This risk can be reduced by proper maintenance. This picture shows the invasive Japanese knotweed (*Fallopia japonica*) on the right side. In this case, the road maintenance should arrange for disposal of this species and prevent its further spreading. © Tomáš Flajs

- Keeping an empty verge near the road is also advisable regarding the risk of collisions of vehicles with animals (especially ungulates). It increases lookout conditions and makes it easier for both drivers and animals to react better.

Fig. 9.23 Road verges with high vegetation decrease lookout conditions for both drivers and animals, which can increase the probability of an accident. © Michal Ambros

- Fruit trees growing near the roads create important ecosystems for many species and improve the aesthetic value of the landscape. However, fruit trees can also create attractive feeding spots for some animals, which can influence the frequency of animals crossing the road. Therefore, planting fruit trees near roads with higher traffic intensity should be carefully considered, as they may cause higher mortality of animals.
- The slopes of embankments and cuttings often include also rocks or stony rubbles that can be suitable habitats for reptiles and invertebrates. Such partial spots should remain untouched to the maximum possible extent.
- For traffic safety reasons it is not recommended to plant trees that could in adulthood fall on the road after a wind gust.
- When leaving space for natural succession of xerothermic vegetation, it is necessary to continuously implement suitable maintenance (cutting of shrubs and trees).
- Proposal of vegetation adjustments must be solved also in relation to road fencing. Vegetation adjustments in open agricultural landscape with lack of trees and bushes often represent attractive hiding spots for animals. It is not recommended that trees and bushes be planted in the fenced area (between the road and the fence). Animals have in this case strong motivation to break the fence and to get dangerously close to traffic.

Fig. 9.24 High vegetation between a motorway and a fence attracts animals, because it is often the only vegetation in intensive agricultural land. If the fence is damaged, animals can easily be trapped between the fence and the motorway. Likewise, the fence behind trees is not visible from the motorway, so damage is not detected and repaired in time and the risk of collisions between cars and animals is even greater. © NDS Archive

- Proposal of vegetation adjustments should be based on the usage of original tree and shrub species corresponding to given pedological and climatic conditions (especially in rural areas). Where possible, natural tree and shrub regeneration can be an optimal way to achieve the ecological functions of verges. It is necessary to avoid planting of invasive alien species.

10

Fauna Passages and Other Technical Solutions

This chapter describes individual technical measures proposed to decrease the barrier effect of transport infrastructure and the risk of collisions between vehicles and animals and to lower the disturbing effects of traffic on fauna (Chapters 10.3, 10.4, 10.5). When dealing with these measures, it is also very important to look at the requirements of particular groups of animals on permeability of fauna passages (Chapter 10.2). For this reason, the same issues are described here from two viewpoints: first based on the requirements of individual species groups and then systematically according to different types of fauna passages and other measures. Both of these viewpoints partially overlap each other and create a combination matrix, in which some important pieces of information may be mentioned repeatedly.

10.1 General approach

10.1.1 Classification of measures to reduce barrier effect and animal mortality

Measures to reduce barrier effect and animal mortality can in general be divided into several groups:

- Measures allowing safe crossing of infrastructure for animals (fauna passages).
- Measures preventing animals to enter infrastructure (fences, barriers).
- Measures warning animals of transport infrastructure or of approaching vehicles.
- Measures warning drivers about approaching animals or about accident risk sectors (warning signs, speed limitation, warning systems based on animal detection).

All these measures are discussed in more details in the following Chapters (10.3 – 10.5), Table 10.1 provides basic classification of fauna passages used in the respective chapters for easier orientation within them.

10.1.2 General principles for proposing measures

The following general principles should form the basis for proposing measures to reduce barrier effect of roads, motorways and railways and should be applied to specific local conditions:

- The efficiency of a proposed measure is the function of ecological conditions and technical solutions. Required efficiency of a proposed measure can be reached only when both main requirements are met at the same time: (i) suitable ecological conditions and (ii) suitable technical solutions. It is a logical and completely essential prerequisite, demanding equal attention to be paid to both technical solutions and characteristics of close and wider surroundings. This has a relation to the next principle. More details are in Chapter 10.1.3.
- Individual approach. Taking into account the complexity of the relationship between fauna and transport infrastructure, individual approach to each measure should be the basic principle for their proposals. All general recommendations always need to be applied to specific local conditions. More details are in Chapter 10.1.4.
- Combination of fauna passages and fences or other barriers. Reducing negative effects on fauna can be best accomplished by simultaneous combination of (i) measures allowing fauna to pass (fauna passages which reduce isolation of populations) and (ii) measures preventing fauna to access the infrastructure (fencing which lowers animal mortality). A suitable ratio of both types of measures should be determined in a migration study based on local conditions.
- Solving long-term sustainability of measures. With all the proposed measures, the question of their long-term sustainability arises. It involves not only the technical lifespan of the objects, but changes in the surroundings that can radically limit or even completely

Table 10.1

Basic classification of fauna passages.

Fauna passages	Wildlife overpasses	Bridges over roads	Green bridges
			Multi-purpose overpasses
			Tree-top overpasses
		Tunnels	Bored tunnels
			Cut-and-cover tunnels
	Wildlife underpasses	Bridges on roads	Viaducts
			Underpasses for large and medium-sized animals
			Modified and joint-use underpasses
		Underpasses for small animals	Culverts
			Special passages (otter/badger/amphibian tunnels)
		Passages for fishes and other aquatic organisms	

cancel the functionality of fauna passages (for example building of new housing and industrial infrastructure). It is therefore essential in implementation of large special fauna passages to ensure spatial protection of both close and wider surroundings. This represents the very fundamental task of integrating the issues of fragmentation into spatial planning at landscape level (see also strategic migration study, Chapter 8.2).

- Economic optimization of proposed measures. An important criterion in proposing measures is cost-efficiency. It is good to know it does not only involve the investment funds themselves, but also indirect effects on the environment (extraction of materials, transportation, power consumption, etc.). On the other hand, costs should also be calculated for wildlife-related accidents and for impacts of climate change related phenomena (if we extend a bridge across a watercourse to fulfil the function of a fauna passage, such a bridge will also allow to carry out the flood flows).

10.1.3 Complex approach to proposing technical measures

In the case of large and costly measures, such as special fauna passages, it is necessary to apply a complex approach, which lies in proper assessment of ecological and technical conditions, including conditions of the surroundings. Main factors from these categories that should always be evaluated are listed in Table 10.2, together with closer specification/explanation.

Required final classification of a fauna passage with respect to overall potential efficiency for migration is important in evaluating the permeability of entire motorway/railway sections. Nevertheless, it is important to point out that the overall assessment of migration potential is not the arithmetic mean of ecological and technical element. In case one of the components is unsatisfactory, the entire fauna passage is unsatisfactory, even if the second component is excellent. Although partial subjectivity is involved in each classification, it is a very important figure for ensuring optimal permeability of roads and railways.

Table 10.2

Evaluation of fauna passages

Factors	Characteristics
Group: A. Ecological conditions	
Habitat	Habitat type, its closer specification, quality assessment
Target animal group	A group of animals for which the passage is made, significance and state of migration route, its long-term perspectives
Secondary animal groups	Groups that can also use the passage, significance and state of their migration routes
Supporting elements for migration	Landscape structure, watercourses, forests, scattered green areas, ecotones, morphological shapes (ridges, valleys), etc., perspectives on sustainability
Disturbing elements	Roads, railways, field and forest paths, cycling paths, tourism, settlement (including individual houses), cottages, industrial and agricultural premises, fenced grounds etc., danger of spreading in the future (territorial plans), land use plans, other (hunting facilities, etc.)
Group: B. Technical parameters	
Type of passage	Overpass/underpass
Type of construction	Basic description according to passage type
Dimensions	Width, height, length, openness index (according to passage type)

Factors	Characteristics
Group: B. Technical parameters	
Conveyed elements	Watercourse, field and forest paths, etc., placement in the passage, technical solution
Type of surface	Natural, artificial; soil, grassy, etc., placement of paved surfaces when conveying roads
Vegetation adjustments in/on the passage	Solution of planting, species composition, placement
Hiding places for animals	Type and localization of hiding places, shelters (stones, logs, branches etc.)
Protection from disturbances	Noise-protection embankments and walls, height and material of the walls, barriers for vehicle access
Group: C. Adjustments of surroundings	
Fencing	Length and means of fencing the road/railway in relation to the passage
Vegetation adjustments on the road/railway	Species composition and solution of vegetation adjustments on the road/railway as they are linked to the passage
Terrain adjustments outside of the road/railway	Partial terrain adjustments (levelling off the terrain, terrain walls, etc.) with the aim to better connect the passage to the surroundings
Guiding structures outside of the road/railway	Planting vegetation, connecting landscape structures to the passage
Keeping disturbing elements away from the road/railway	Ground walls, vegetation belts
Group: D. Overall evaluation	
Ecological conditions	Overall assessment of ecological conditions, narrative evaluation + classification on the scale: excellent – above average – average – under average – unsatisfactory
Technical solution	Overall assessment of technical solution; narrative evaluation + classification using the scale: excellent – above average – average – under average - unsatisfactory
Conclusion	Overall assessment of potential migration efficiency of the passage; narrative evaluation + classification using the scale: excellent – above average – average – under average - unsatisfactory

-

10.1.4 Rules for placement of fauna passages

Placement of fauna passages should be done within migration studies (Chapter 8). The following can be mentioned as the main principles:

- Permeability of a given section is addressed for all animal groups. Their basic classification and description are given in Chapter 6.2.
- Basic approach lies in implementing a sufficient number of passages for all involved animal groups. Required frequency of passages is discussed in Chapter 6.5. The values represent only a framework and have to be adapted to local conditions.
- Each object under or over a built infrastructure should be considered as potential fauna passage.
- When proposing measures, objects planned on the route for conveying watercourses, valleys, local roads, etc. should be used with priority and be optimized, when necessary, for fauna passages. Only when the permeability of a given section is still insufficient, supplementary new special fauna passages will be proposed.
- Placement of fauna passages on defined migration corridors, whose long-term sustainability should be protected by legislation or spatial planning, is evaluated in a special way. In this case it is always necessary to implement suitable fauna passage and to reach its maximal optimization.

Fig. 10.1 Bridges over watercourses can easily be adjusted in a way that allows animals to use them to safely overcome a road. It is necessary to keep natural banks that fluently continue in the surrounding terrain. © Václav Hlaváč

10.2 Parameters of fauna passages and other technical measures according to the requirements of particular groups of species

10

This chapter follows up on Chapter 6.2, which provides the characteristics of individual groups of species, their mobility and requirements for connectivity of populations. This section describes the requirements of individual groups of Carpathian fauna for types and dimensions of fauna passages.

10.2.1 Terrestrial invertebrates

As already described in Chapter 6.2.1, this is a broad group with very different mobility, ability to overcome barriers and with a diverse dispersal strategy. In general, however, it holds true that most terrestrial species without the ability to fly overcome transport infrastructure only when connectivity of their habitat is ensured.

Overpasses

An optimal solution for invertebrates is sufficiently large overpasses providing the same soil, light and precipitation conditions as on both sides of a given road/railway. In such a case, a full connection of habitats can be reached, including vegetation, to which invertebrates are often bound. It can be said that overpasses with the dimensions of green bridges (minimum width of 40 m) ensure good conditions for connectivity of populations of a whole spectrum of invertebrates. Multi-purpose overpasses created by widening of bridges where forest or field paths cross above the road can provide a solution ensuring connectivity for at least part of involved invertebrates. It is sufficient when the path is widened on each side by a strip of vegetation at least 2-5 m wide. In forest sections, one needs to count with planting such a strip with woody plants (or at least bushes), in agricultural landscape or in areas of dry grasslands and pastures with shrubs, a strip of grass with similar species spectrum as on both sides of the road should be enough. These multi-purpose overpasses are not yet a commonly used solution. Nevertheless, they have been built for example in Germany and their efficiency has been verified. It should be emphasised in this point that such measures can be useful for other species groups as well (small terrestrial mammals up to the size of foxes, dormice, squirrels, bats, birds and others). With low construction costs such measures can become an important element in ensuring the permeability of transport infrastructure for fauna.

Fig. 10.2 A multi-purpose overpass over a double-track railway Prague - Brno (Czech Republic) is 7 m wide and 35 m long. Grassy stripes on the sides are used by a broad spectrum of invertebrates. Thanks to a clay surface the overpass is regularly used by the roe deer, the hare, the fox and many other species of small vertebrates, including the sand lizard. Similar bridges over motorways are used only exceptionally, because the disturbance coming from traffic is much more intense there compared to a railway. © Václav Hlaváč

Underpasses

Large underpasses – meaning motorway bridges overcoming entire valleys at a sufficient height – have similar function as large overpasses (green bridges). Also, in this case, growth of vegetation is possible and habitats on both sides of the motorway can be connected. Unfortunately, in smaller motorway bridges, light and precipitation shadows already have some effect under the motorway, which does not allow for full growth of vegetation. The usability of such bridges for invertebrates then quickly drops. Yet, even small motorway bridges (or even culverts) can be used by some species, mostly by fast moving ones such as beetles from the *Carabidae* family. It is obvious that setting minimum parameters of underpasses for such a diverse group is impossible. Nevertheless, one can state that the larger the openness index of an underpass and the more natural (less technically adjusted) the space under the bridge, the broader the spectrum of invertebrates that are capable of using it.

10.2.2 Fishes and other aquatic animals

When a transport infrastructure crosses a watercourse, it is always essential to keep the bi-directional migration permeability. An optimal solution is to maintain the watercourse under the bridge in a natural state, completely without technical modifications. If for some reason this is not possible, it is at least necessary to maintain the same water depth and the same speed of water flow as in the follow-up sections. Vertical steps or similar barriers cannot be created by any means! It is also necessary to emphasize keeping natural river beds and banks. The use of tube culverts always must be excluded – even in the case of small streams when they are inhabited by aquatic fauna (fishes, crayfish, etc.). Rectangular culverts are usually a better alternative that enables to ensure the continuity of the watercourse from the aspect of fish migration. A plate-shape bottom profile is recommended for rectangular culverts. This shape ensures a sufficient water depth in periods of drought and at the same time creates a gradual transition between aquatic environment and dry banks. That brings diversification of conditions and allows for migration of wider spectrum of species.

If a migration barrier in the form of a weir is present on a watercourse, special fish crossings are the solution (see Chapter 10.3.2.5).

Fig. 10.3 A vertical step on an outflow from a culvert causes a migration barrier for fishes such as the common minnow or the brown trout. © Václav Hlaváč

10.2.3 Amphibians

Amphibians get into collisions with transport infrastructure during spring migration to places of reproduction, but also during the migration of adults and juveniles back to their terrestrial habitats. Under certain conditions, higher mortality can occur even further away from these migration paths. Amphibians move mostly through humid environment along watercourses, therefore all bridges over watercourses including culverts should be made permeable for amphibians. From this perspective, it is optimal to maintain the stream and its banks in the natural state without technical adjustments. If strengthening the banks is necessary, it is better to use a stone paving rather than simple concrete (juvenile amphibian individuals are not able to overcome longer distances on the concrete paving because their bodies dry up on this substrate too quickly). Completely unsuitable for amphibian migration are bridges (culverts) with running water without dry banks. In case of technical adjustments to streams it is always necessary to make the stream bed with a plate shape with slight bank slopes. Tube culverts are usually not the optimal solution for amphibian migration. The reason for this is the absence of dry, walkable banks and in long culverts of small diameter, and also lack of light. Only tube culverts of larger diameters are acceptable, unless water permanently flows through them (see Chapter 10.3.2.4). In such culverts the layer of sediments often creates a natural bottom that is completely suitable for the movement of amphibians. It is, however, generally necessary to always prefer rectangular culverts that constitute an optimal solution for amphibians.

Fig. 10.4 The common toad is the most frequent target species when solving the issue of amphibian migrations over roads. Tube culverts are acceptable for this species only when there is enough light inside and the bottom is covered by washed off material. More on this topic can be found in Chapter 10.3.2.4. © Jaromír Maštera

Fig. 10.5 A rectangular culvert is always a better solution for amphibians than a tube culvert. The surface of the underpass is very important for amphibians; a stone pavement is a suitable solution. © Václav Hlaváč

Vertical steps, sedimentation sumps on the inflow or stilling basins to moderate water energy under the culvert outflow all constitute a fundamental problem for amphibians. These technical elements often completely eliminate access of amphibians to the culvert; sometimes they even form deadly traps with no means of escaping. Many cases of large numbers of amphibians and other small animals dying in a sedimentation sump on the inflow of a culvert have been recorded.

Fig. 10.6 Sumps at the entry or exit prevent amphibians from using such a culvert for migration. Such solutions can moreover create fatal traps where tens of amphibians die. © Václav Hlaváč

If no suitable bridge or culvert exists in the place of important amphibian migration, it is possible to overcome the transport infrastructure by a special passage – amphibian tunnel (see Chapter 10.3.2.4).

In case the road permeability cannot be sufficiently ensured between terrestrial habitats and places of reproduction, an alternative solution is possible: to build new wetlands for reproduction on the 'terrestrial habitat side' of the road, so that amphibians do not have to cross the road.

10.2.4 Reptiles

Considering the fact that most reptile species use all parts of their suitable habitats, it is not easy to find the right place for a fauna passage. Moreover, many species directly search for sunny places without vegetation and crossing a road on top of its surface is actually more natural for them than using a shady underpass. For this reason, fauna passages for this group always must contain guiding barriers as well which prevent the reptiles from entering the road and lead them to constructed passages. At the same time, the barriers need to be proposed regarding the capabilities of particular species. While a 40 cm tall vertical wall will be sufficient for tortoises, the Aesculapian snake or some lizard species will require a significantly more demanding construction of the barrier.

Overpasses

Overpasses constitute the most suitable solution for most reptiles. However, an important condition is direct continuity to the used habitat and a suitable vegetation cover on the overpass. Overpasses of the green bridge type (width of 40 m or more) are an optimal solution, but even narrow overpasses are sufficient when at least grassy vegetation and some hiding opportunities (stones or tree branches, etc.) are present.

Underpasses

Represent a suitable solution especially in species bound to aquatic environment (the European pond turtle, the dice snake, the grass snake, etc.). It is always essential in this case that the watercourse including its banks remains in the natural state with minimum technical adjustments. Requirements are very similar to those of amphibians. Utilization of passages is in xerophytic species limited by lack of vegetation, hiding places and with culverts also by lack of light. Clearly only sufficiently large bridges without technical adjustments underneath and covered by vegetation can be fully functional. With smaller bridges, the function of vegetation needs to be replaced by placement of elements that create hiding opportunities and allow reptiles to overcome otherwise unsuitable environment. Correctly proposed guiding barriers will always be the key factor in the case of smaller underpasses.

case study

Special barrier to prevent the Aesculapian snake mortality in the Czech Republic

The Ohře river valley in north-western Czech Republic hosts an isolated population of the Aesculapian snake (*Zamenis longissimus*) on a very small area (only cca 10 km^2). The snakes inhabit – among other habitats – also close vicinity of the main road leading through this area (E442/I/13) along the Ohře river (A), as its sides provide good shelters thanks to many dry stone walls. During a study done in 2005-2007, the mortality of Aesculapian snakes on the road was observed and individuals were captured and marked with ventral scale clipping in order to reveal their movements. Recaptures detected regular seasonal movements of the snakes between post-hibernation, spring (mating), summer (egg-laying) and pre-hibernation sites, quite typical of their life cycle. These movements often required crossing the main road (detected in 13 out of 24 recaptured individuals). Most recorded mortality incidents on the road regarded juvenile or sub-adult snakes (78% of found road-kills). These results pointed out to the fact that in contrast to juveniles with no experience, adult individuals in the area are able to successfully cross the road by using old underpasses, present in several places as remnants of a historical path at a distance of approx. 200 m (B). In order to stop the high detected juvenile mortality, a special barrier was consequently built in the most risky section of the road (C), which guides the juveniles to the same underpasses that are used by adults. After some small adjustments required during the first year of its operation, the barrier proved to be fully functional and the juvenile mortality was almost completely eliminated. Nevertheless, regular checks and repairs of the barrier remain a necessity.

Fig. 10.7 Case study: Special barrier to prevent the Aesculapian snake mortality in the Czech Republic. © Photos by Zamenis, z.s., Source: Musilová et al. 2010

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10.2.5 Birds

Birds are a group for which typically no special fauna passages are constructed. Nevertheless, the requirements of birds should be considered when fauna passages for other animal groups are built. Especially important are bridges over watercourses. They need to be of sufficient capacity so that birds bound to streams such as the common kingfisher, the white-throated dipper, or the grey wagtail can fly under the bridge. The minimum size of a bridge which birds are willing to fly through can be – similarly to mammals – roughly expressed by the openness index. The value of this index should not be lower than 1 for the above mentioned species, larger bridge dimensions will allow its use by a wider species spectrum.

Fig. 10.8 Birds such as the common kingfisher, the white-throated dipper, or the grey wagtail are able to fly under a bridge with the openness index of at least 1-2. Height is also important; it should be minimally 2 m. In case of bridges with smaller dimensions birds typically fly over them and often become traffic victims. © Václav Hlaváč

Transport infrastructure and traffic itself, however, threatens birds by many other means. Road mortality is an issue for many species; dangerous are especially the following situations:

- Crossing of transport infrastructure with a bird migration corridor.
- Transport infrastructure impact on a wetland.
- Attractive (fruit-bearing) low vegetation on both sides of a road (resulting mortality of smaller species then often causes a higher mortality of birds of prey as well).
- High concentrations of small rodents in road edges (especially owls are susceptible).
- Concentration of insects near road lights can attract nocturnal insectivorous birds (European nightjar).
- Roads or other infrastructure elements equipped with different types of protection walls, especially when transparent material is used – this topic is discussed separately in Chapter 10.4.4.

Fig. 10.9 Birds of prey such as this lesser spotted eagle become victims of traffic most often in a situation when they collect other killed animals from roads. Brestov pri Humennom, Slovakia. © Anna Macková

Transportation also represents a significant disturbance for many bird species. For example, some waterfowl or raptor species are sensitive to it. If a transport infrastructure gets in the proximity of nesting sites of these species, it is possible to eliminate visual and noise disturbances by suitably proposed protection walls. However, each such situation needs to be especially evaluated, since protection walls always have some negative effects as well (increasing the barrier effect for some species, aesthetic impact on landscape).

10.2.6 Terrestrial mammals up to the size of fox and badger

This is a group with a typically high mobility, with different environmental requirements and with different ability to overcome the barriers. Usability of individual types of fauna passages is summarized below:

Overpasses

Field and forest paths leading over a motorway. These bridges are usually used as fauna passages only very rarely, but still some species can use these overpasses, for example the fox, the hare or the wildcat.

Underpasses:

Culverts – when suitably constructed and placed they are used by most species with the exception of underground insectivores, the hare and the wildcat.

Bridges up to 5 m wide – when suitably constructed and placed they are used by most species with the exception of underground insectivores and the hare.

Bridges wider than 5 m – are used by all representatives of this group, their use by underground insectivores will depend on the means of compacting.

Fig. 10.10 Overpasses for field and forest paths constructed with asphalt or concrete surfaces are not used by animals. Overpasses with grassy stripes on the sides are sometimes used by the hare, the stone marten or the fox. Disturbance by traffic in the case of a motorway constructed below is a limiting factor for most animals. © Václav Hlaváč

Fig. 10.11 Bridges over small watercourses are also used by species that are not directly bound to the watercourse habitats such as the European pine marten. © Václav Hlaváč, photo trap picture

Field and forest paths leading over a motorway and widened by a green strip on both sides. Here, the range of species able to use such passage is significantly broadened. All species of this group are capable of using this overpass – see Fig. 10.18 in Chapter 10.2.8.

Green bridges - All species of small mammals (except semiaquatic ones) use these measures.

As mentioned in the summary above, some species can use even small passages such as culverts (insectivores, small rodents, rabbits, mustelids, and foxes). From this viewpoint, rectangular culverts are more suitable than tube culverts. Also, material of the culvert plays a role – stone and concrete are generally more acceptable for animals than steel or plastic constructions.

Problematic are also sedimentation sumps on the inflow or stilling basins to absorb the energy of water on the outflow. These measures can limit the entrance of animals into the culverts; sometimes they even create traps for small fauna. There is generally a sufficient density of culverts on motorways and railways that can ensure the migration of this category of animals. However, an important condition is that they are constructed while considering their use as fauna passages. In case the permeability is not sufficient for a certain species, it is possible to build a special passage such as a 'badger tunnel' – see Chapter 10.3.2.4 It is also necessary to emphasize that some species (for example the European hare) do not use culverts and small bridges. Hares on the other hand commonly use bridges, where an unpaved field or forest road goes above a motorway. Most other species do not use such narrow bridges. If the requirement to ensure a fauna passage is taken into consideration when building a bridge over a motorway, it is helpful to slightly widen the bridge and plant a strip of bushes on both of its sides. This measure can create a functional overpass for a much wider spectrum of species.

10.2.7 Otter and other semiaquatic animals

Animals from this group often migrate along watercourses, so it is important that all bridges over streams be permeable for them. Although these species can swim and dive, most of them do not use bridges without existing dry banks. Unsuitable bridges then cause the animals migrating along streams to cross roads. A fundamental requirement in order to ensure permeability and limit mortality of this group of animals is represented by sufficiently wide dry banks under all bridges where the transport infrastructure crosses a watercourse (see Fig. 10.12).

Bridges where the watercourse has natural banks without technical adjustments on both sides are the preferred solution. If maintaining natural banks is not possible, it is acceptable to create dry banks from a stony paving. It should be emphasized here that the banks under the bridge need to have direct continuity to the stream banks in the bridge surroundings. Unfortunately, in many cases, this condition is not met. Animals migrating along the watercourse then cannot enter the bank under the bridge and are again forced to cross the road.

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Fig. 10.12 Dry banks at least 40-50 cm wide under small bridges and culverts constitute a fundamental measure for otters as well as a wide spectrum of other species. © Václav Hlaváč, photo trap picture

Fig. 10.13 In the case of bridges without dry banks it is possible to create additional "animal ledges." The natural continuity of the "path" to the stream banks must be maintained. © Václav Hlaváč

When a watercourse with the occurrence of otter crosses a transport infrastructure via an unsuitable bridge or culvert, a satisfactory solution can be a parallel 'otter tunnel' with a diameter of 30 cm (see also chapter 10.3.2.4).

Road sections where the road goes on top of a water reservoir dam or over a dam that splits apart, two reservoirs are highly dangerous as well. In order to limit the mortality rates, it is often necessary to build special passages in the dam. Using the tunnels by animals should be enhanced by landscaping or by special fencing, guiding the animals to the passages. Another issue for this animal group are long waterfront walls in combination with weirs or lock chambers. Such constructions often create migration barriers on watercourses. Animals are forced to go around these places and often must cross roads while doing that.

Fig. 10.14 In case it is not possible to adjust an unsuitable bridge as fauna passage, a parallel otter tunnel can be additionally created. It is recommended that terrain modulation or guiding barriers be used in order to help the animals find the entry. © Lukáš Poledník

Fig. 10.15 A weir in combination with vertical walls on both sides of a watercourse in a town, forces animals such as otter or beaver to walk around such a place. The animals then often have to cross roads while going around such barriers. © Václav Hlaváč

10.2.8 Mammals living on trees

Special passages for this group are based on connecting tree crowns on both sides of a road/motorway. The main principle is a system of ropes with a shelter to hide from predators. The efficiency of such measures is still being verified, but it can represent relatively cheap and highly efficient measures.

There is so far no practical experience with this type of passages in the Carpathian countries. However, many examples from other fields showing good efficiency of such measures do exist (for example with the dormice). A good solution for this group can be adaptation of small bridges over motorways (bridges for unpaved roads). If such a bridge was slightly widened and a row of bushes was planted on both sides, a functional passage even for species living in tree crowns would be ensured. Moreover, such a bridge would be of multifunctional use – it would be used by smaller mammals (up to the size of fox and badger), small birds, bats and many other animals as well.

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Fig. 10.16 Example of a special passage for mammals living on trees: a gantry over the A12 motorway (Utrecht - Arnhem, near Wofheze, the Netherlands) adapted for use by the pine marten. The gantry contains a "walk-path" and thick ropes connect it at both ends to the edge of the nearby forest. Use by the species has already been proven by a phototrap. © Jan Willem Burgmans, Heijmans Infra

Fig. 10.17 A forest path over a motorway widened by stripes of bushes on both sides allows for the connection of forest environment for many species including mammals living on trees, small birds or bats. It represents a very affordable measure with a strong effect. Dresden, Germany. © Václav Hlaváč

10.2.9 Bats

Some bat species even fly in great heights, while others, first of all small forest species, follow tree structures during their flight and avoid open spaces. Several research studies show that these species almost never overcome a motorway by simply flying, but rather use either overpasses with vegetation or sufficiently large underpasses. A good enough solution might be for example both-sided rows of bushes on a bridge where an unpaved road overcomes a motorway.

Fig. 10.18 A forest path over a motorway widened by stripes of bushes serves as a fauna passage for small bat species. However, this overpass can be used by a broad spectrum of other animal species as well. Germany. © Václav Hlaváč

Higher mortality is usually recorded in places where a road/motorway crosses a watercourse with bankside vegetation. If bats use the bank vegetation as a migration corridor, it is obvious that they are forced to overcome the road in this place. Helpful in reducing mortality can be either a bridge with a sufficient capacity (bats fly under the road), or high enough walls on the bridge, so that the bats fly over the road high enough above the passing vehicles (it is necessary to count with the height of lorries as well). Another factor to always consider regarding bats is lighting, as it attracts insects and bats then use the surroundings for feeding. Especially lighting along roads near water bodies can cause high bat mortality. It is also important to mention the positive effects of transport infrastructure – bats often use construction fissures and openings in bridge structures as their hiding places. Building bridges offers the opportunity to create such hiding places on purpose, either as part of the bridge construction or additionally by installing special boxes. Creation of such measures must be accepted in terms of construction and future maintenance.

10.2.10 Medium-sized mammals (the European roe deer, the wild boar)

These species are widely spread and inhabit both forest and agricultural landscape areas. The group is much more demanding than smaller mammals (up to the size of fox and badger) when it comes to using fauna passages. Due to that, the roe deer and the wild boar cover up the requirements of much broader animal spectrum. Requirements to ensure the permeability for these species represent a usual standard in a landscape without the occurrence of large mammals (the red deer, the Eurasian moose, large carnivores).

Overpasses

- Field and forest paths leading over a motorway – it has been proven by monitoring that these bridges are usually not usable as fauna passages for this group.
- Field and forest paths leading over a motorway and widened by a green strip on both sides – these bridges can be (with a suitable design) used by this group of species (see Fig. 10.18 in Chapter 10.2.8).
- Green bridges – represent an ideal fauna passage for this group.

Underpasses

- Culverts – are not usable for this group of animals.
- Bridges up to 5 m wide – are used by this group only exceptionally.
- Bridges wider than 5 m – are in case of suitable design used by this group. Width is not the only important factor. It has been verified that it is usually possible to express suitability of a bridge by openness index of its passage – see Table 10.4 in Chapter 10.3.2.2.

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Fig. 10.19 Green bridges represent an ideal solution for most animal categories. Medium sized mammals such as the roe deer use even overpasses that are not planted with bushes. However, usability of such overpasses for mammals such as the red deer or large carnivores is limited. Czech Republic, D1, Suchdol. © Friends of the Earth, Czech Republic

Fig. 10.20 The roe deer usually use underpasses with openness index greater than 1. This underpass under a railway is 5 m wide, 3 m high and 15 m long (OI = 1). © Václav Hlaváč, photo trap

10.2.11 Large mammals (the red deer, the moose, large carnivores, the European bison)

These species use large areas in less populated densities. They are mostly rare and protected; fragmentation of their environment can cause their extinction in vast areas. Long movements and migrations in distances of hundreds of kilometres are typical of this group. At the same time, these animals are sensitive to disturbances and have the highest requirements for parameters of fauna passages. It is always necessary to deal with several specific issues when ensuring permeability of transport infrastructure for these species. First of all, it is determining density of passages which will be sufficient for a long-term survival of the species. This issue is often questioned for the efficiency of the fauna 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 green bridges, are often subject of discussions. Recommendations vary in different areas, which can be partly caused by distinct environmental conditions and different behaviour of animals in these areas. Another important factor that must be taken into account in the case of large mammals is traffic safety, since collisions with these animals are very dangerous for drivers.

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Ensuring permeability through transport infrastructure for this group will be different in areas with permanent occurrence of the target species (route interferes with home ranges of the animals), and in areas where these species only irregularly pass through. In areas of permanent occurrence, sufficient density of passages needs to be planned, so that original home ranges are not disrupted. In areas where only migratory/dispersal occurrence is expected, it is necessary to define migration corridors in the landscape, their importance (of local, regional, national, transregional level) and to propose fauna passages in the most suitable places (with respect to functionality) of crossings between transport infrastructure and the migration corridors. The use of fences and other leading structures is very important to improve the function of fauna passages for large mammals, as well as managing functionality of migration corridors at landscape level.

Technical parameters of passages are always an essential question in this group of animals. It does not concern just parameters, but type of construction, used materials and other factors as well. Detailed description of individual types of passages and their recommended solutions are given in Chapter 10.3.

Fig. 10.21 A wolf captured by a photo trap under a viaduct.
© Michal Králik

10.3 Fauna passages

10.3.1 Wildlife overpasses

Wildlife overpasses are structures where animal migration takes place above the level of traffic. Many types of wildlife overpasses exist. Central width of an overpass is a basic technical parameter for assessing potential acceptability for animal migration (see Fig. 3.1. A). The requirements of individual groups of species vary significantly. Overpass width may vary from approximately 5 to 100 m (longer overpasses are considered tunnels).

The following chapters divide wildlife overpasses into: (i) green bridges (single-purpose wildlife overpasses where the function of animal movement prevails) and (ii) multi-purpose overpasses (overpasses that are also used to convey a field or a forest path).

A separate chapter is devoted to special measures for small mammals living in tree crowns – tree-top overpasses.

10.3.1.1 Green bridges

General description and targets

Green bridges are structures built with the purpose of allowing animal movement and migration. They are usually built over a road with several lanes and/or high-density and fast-driving traffic, over high-speed railway lines or over the combination of both. They are a costly but effective means for minimising, at least locally, the fragmentation effect of transport infrastructure for all terrestrial animal groups. Their main goal is to mediate the migration of the broadest possible spectrum of species, which typically also requires simulating habitats on either side of the infrastructure on the overpass (taking into account vegetation and environmental factors such as the soil type, humidity, temperature, or light) and connecting them as fluently as possible.

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Fig. 10.22 General scheme of a green bridge. Such a fauna passage must always be equipped with barriers that eliminate noise, light and other disturbances, vegetation should be situated mostly along the sides, whereas the middle of the structure should stay open. © Spain. Ministry for Ecological Transition. 2016. Technical prescriptions for wildlife crossing and fence design (second edition, revised and expanded) (on line). Madrid: MAPAMA. Illustrations made by Pep Gaspar, ARTENTRAÇ

Technical solution

Suitable dimensions of green bridges always depend on other local factors: ecological conditions in the surroundings and the overall technical design, including elimination of disturbing effects. The key decisive factor should be the main target group of species for which the green bridge is being designed. These groups include:

- Medium-sized mammals – local movements/ migration through landscape are involved, local populations prevail; common purpose is to reduce mortality in sections of frequent animal crossings over the road. Recommended central width is 10–20 m.
- Large mammals – it is important to distinguish what kinds of animal movements/ migration are expected at the concerned locality. The recommended width is 20–40 m in the case of local migration and 40–80 m in the case of a locality that is part of a significant long-distance migration.
- Ecosystems – conveying entire ecosystems assumes that ecological conditions on the overpass will be in their final state similar to those on both of its sides. This measure is typically proposed only in very valuable ecosystems that are divided by the given road/ railway. The width of these green bridges is usually proposed above 80 m.

Within the mentioned ranges, a rather greater width is usually chosen in the following cases:

- Wth increasing length of the overpass (there is a difference between an overpass above a two-lane or a four-lane road).
- Where a forest or field path is led over the overpass.
- In places with worsened ecological conditions in the surroundings (partial disturbance, less suitable habitats, etc.).

Green bridges can have different ground plan shapes – from common rectangle through various partial means of guiding on the edges, to a funnel-shape. The significance of guiding increases especially in narrower and longer structures.

Fig. 10.23 When correctly placed and well technically designed (vegetation, disturbance elimination), green bridges can be intensively used by medium-sized mammals even with a width of 10 m. Luxembourg. © Václav Hlaváč .

Fig. 10.24 Funnel shaped green bridge may be 40 m wide at the entrances, but only 10 m wide in the middle. This solution means financial savings without a significant influence on functionality. The picture shows the same overpass as in Fig. 10.23 in Luxembourg. © Václav Hlaváč

Table 10.3

Approximate functionality of green bridges for different animal categories.

Interval of width of green bridge / length of tunnel (m)	Functionality for small size mammals (fox, badger)	Functionality for medium sized mammals (roe deer, wild boar)	Functionality for large mammals (red deer, large carnivores)	Functionality for ecosystems
10 - 20	Very Good	Good	NO/Blockage	NO/Blockage
20 – 40	Very Good	Good	Minimum	NO/Blockage
40 – 80	Very Good	Very good	Medium	Minimum
80 – 100	Very Good	Very good	Good	Medium
100 – 200	Very Good	Very Good	Very Good	Good
Above 200	Very Good	Very Good	Very Good	Very Good

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Integrating a green bridge into its surroundings

A) Surface

Conditions on a green bridge can unfortunately never be the same as in the surroundings. Since it is not possible to keep the original soil horizons, there is no direct connection to groundwater, the thinner soil layer is often exposed to freezing, etc. However, in general, the conditions on a green bridge and in its immediate surroundings are similar enough (light exposure, precipitation, soil type) to allow for connection of habitats on both sides of the infrastructure.

Main principles regarding surface and vegetation include:

- Recommended depth of soil: 0.3 m (grass) – 1.5 m (trees).
- Basic requirements for vegetation: growth in extreme climatic conditions (stress from drought – often a limiting factor for survival of plants, exposure to overheating in summer, freezing from both the top and the bottom in the winter and to permanent excessive ventilation), resistance to damage by animals using rather bushes than trees.
- The vegetation should be preferably established from local plant species (local seed mixtures, local bushes, etc.), avoid planting and spread of invasive alien species.
- Preference of bushes: for technical reasons (weight of soil layers, risk of disrupting bridge construction by roots). Trees can be recommended in large green bridges designed for conveying ecosystems or only at the boundary between the bridge and its surroundings, where better pedological conditions exist.
- Subsequent care for the plants and grassy surfaces should be minimized, further development should be left to succession as much as possible. Fencing the plantings is not suitable, mowing grass in the first few years is completely undesirable.

Main principles for spatial arrangement of planting:

- Thickening the edges: plantings should be substantially thickened along the edges of the green bridge, so that its centre is protected from disturbances from traffic as much as possible.
- Lower density of plantings on the plain: the middle of the plain should on the other hand not be so thick, so that even large animal species can pass through without trouble and can visually make sure that there is again safe landscape behind the bridge.
- Approximately in the middle of the green bridge, a free slightly meandering belt about 3–10 m wide should be left, in which it is possible to overlook from one side of the bridge to the other (for monitoring purposes).
- Preference for planting in varied groups as opposed to planting in lines.
- Combination of planting with using natural succession surfaces, especially in less nutritious places (without the cover of topsoil) and in case there is no need for quick integration of vegetation.

Other adjustments to the surface of a green bridge have a significant value for its function as well. This especially means using dead wood in all forms (tree stumps, lying trunks, heaps of branches). Using stones is also significant, either in the form of piles, stripes or using individual large stones. It is very important that the surface of the green bridge is not flat/even. Its modulation together with placing dead wood and stones contributes to creating a spectrum of microhabitats which allows the bridge to be used by a broad spectrum of species. Suitable placement of these elements can also ensure that the green bridge is not used for illegal crossings of terrain cars or motorcycles.

Fig. 10.25 A green bridge with suitable management. Dead wood and planting of bushes on the sides were used during construction and subsequent succession led to a good natural connection to the surrounding environment. France. © Václav Hlaváč ,

Fig. 10.26 Dead wood on a green bridge creates microhabitats for tiny animals and at the same time forms a barrier against undesirable crossings by off-road cars or motorcycles. © Václav Hlaváč

B) Surroundings

The following aspects relating to the immediate surroundings of a green bridge should always be considered:

- Green bridges are meant to be in use for a long time. Engineering works are developed for a period of 50 to 100 or more years. Safeguarding a corridor which allows access to the green bridge must follow a similar time frame and should be part of spatial planning at local and regional scales. A proper maintenance plan should be developed.
- No development that reduces the functioning of the green bridge (housing, local roads, industrial areas) should be permitted.
- Hunting should be avoided on a green bridge and in its surroundings (approx. zone of 0.5-2 km).
- No parallel paths or roads should lead in the immediate surroundings of a green bridge, as they can block the entrance to it especially for smaller animals.
- Access to a green bridge for animals cannot be blocked even temporarily by fences, wood dumps or other activities.
- Measures guiding animals towards a green bridge are of fundamental significance. This is true especially for guiding fences along motorways. Suitably placed planting of woody plants can serve as a guiding structure in areas outside of forests.

Disturbance elimination

Disturbances from the surroundings can be eliminated on a green bridge by building protection walls on its edges (best on the outer edge), especially on narrower structures. The walls protect not only from the noise, but also from artificial lighting and visual contact. Recommended height of the walls is 2 m; walls from non-transparent material should be used. Suitable bushes and climbing plants should be planted on the inside of the wall.

Terrain embankments are also advisable. Good barriers should be created along the outer edge of the green bridge and should continue further along the road/railway.

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Fig. 10.27 Fencing fluently connected to the protection walls (full railing) is guiding animals which follow the motorway fencing to the entry of a green bridge. D1, Czech Republic. © Václav Hlaváč ,

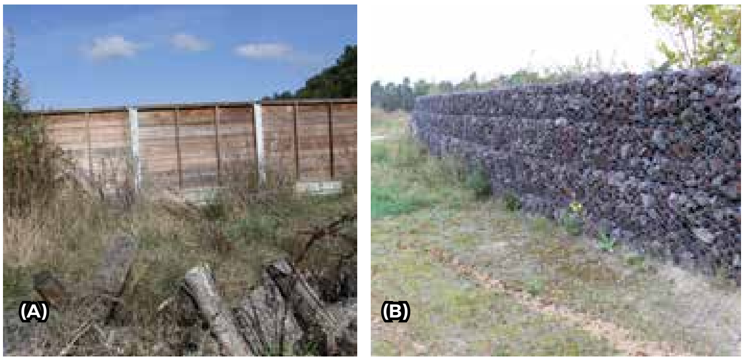

Fig. 10.28 Protection walls effectively reduce disturbances on green bridges. They can be made of wood (A), plastic, or in the form of stone walls (B). Stone walls have disadvantages in higher costs and greater load on the bridge, but also advantages in unlimited lifespan and creating new habitats (for example for reptiles). © Václav Hlaváč

10.3.1.2 Multi-purpose overpasses

General description and targets

Multi-purpose overpasses are usually represented by wildlife overpasses over which also a field or a forest path is led. Nevertheless, there are also overpasses where the traffic function (conveying a field or a forest path over a motorway) is primary. If such overpasses are widened and adjusted, they can also – at least partially – serve as overpasses for wildlife. These bridges are usually covered with concrete, asphalt or tarmac and are hardly used by animals. By simple addition of an earth-covered strip an improvement can be achieved. Such earth-covered or vegetated strips are used by invertebrates, small vertebrates, carnivores and occasionally by ungulates. They favour the dispersal of animals. Overpasses adjusted in this way can significantly contribute to reducing the barrier effect.

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

Fig. 10.29 A multi-purpose overpass with a local path, where the main purpose is to allow animal movement. When well implemented, this solution is suitable for small and medium-sized mammals, but large mammals often do not accept it. Multi-purpose overpasses are completely undesirable in places where infrastructure crosses a long-distance migration corridor. Písek, Czech Republic.
© Václav Hlaváč

Fig. 10.30 A bridge for a forest path over a motorway was in this case widened by 2 m on each side and the new strips were planted with bushes. Disturbances are eliminated by protection walls (full railing). Such a multi-purpose overpass can be used by smaller mammal species (up to the size of fox or badger), but also by small birds, bats, tree top species, etc. Germany. © Václav Hlaváč

Technical solution

Creating a multi-purpose overpass from a common bridge over a road is based on adding strips for animal migration on one or both sides of the roadway. Considerable variability of solutions lies in the possibility to combine one-sided or both-sided designs, different strip widths and its surfaces (unpaved, grass, bushes, and trees). Two types can be chosen:

A multi-purpose overpass with grassy strip

- Both-sided alignment of the strip, width 1–2 m.
- Grassy surface or at least not paved (sand, dirt), depth of needed soil approximately 30 cm.
- Full railing from non-transparent material.
- This is a relatively simple solution that increases the migration of invertebrates, amphibians, reptiles, small and sometimes even medium-sized mammals.

A multi-purpose overpass with woody plants

- Both-sided (or at least one-sided) alignment of the strip, width 2–5 m.
- Strip divided into a grassy part (0.5–1 m) follows up on the road and part with woody plants (follows up on grassy strip in the direction towards railing).
- Trees with guiding function are planted on both sides of the overpass (in places with still natural soil depth). Bushes are planted along both edges of the overpass. Neither a deep soil layer nor a higher load capacity of the construction is required by this solution.
- Full railing from non-transparent material, height min. 1 m, optimal 2 m.
- This is a type of bridge that makes the movement of small songbirds and bats easier (especially where the infrastructure has interrupted natural landscape structures such as avenues, forest edges, etc.). It is also used by invertebrates, reptiles, amphibians, small and medium-sized mammals including mammals living in tree crowns.

Integrating a multi-purpose overpass into its surroundings

A) Surface

Solution of the overpass surface can vary quite a bit depending on the selected technical design. Two possibilities are described above. The following is an example of asymmetrical arrangement: the road is placed on one side of the bridge and the migration strip on the other side. Vegetation adjustments can be done as follows (described from one protection barrier to the next):

a) Dense strip of bushes and climbing plants by a noise-protection wall to deflect traffic.

b) Field and forest path with natural, only compacted surface (no coarse gravel and asphalt).

c) Strip of bushes or stones to mark the boundary to the field or forest path.

Fig. 10.31 Non-transparent full railing was installed on this bridge with a forest path for disturbance elimination. However, the asphalt surface is completely unsuitable for animal movement, therefore this solution is in general insufficient. Czech Republic, D1 near Jihlava. © Václav Hlaváč

Fig. 10.32 A multi-purpose overpass like this has only a limited use for fauna. Suitable hiding places and microhabitats for small animals are missing, similarly, to bushes for larger animals. The need for hiding places is increased by the fact that the animals do not see a safe habitat at the other side of the overpass. © Václav Hlaváč

d) Grassy space for migration, disengaged planting of bushes in groups.

e) Dense strip of bushes and climbing plants by a noise-protection wall on the side of the overpass. Widths of the strips depend on the overall width of the overpass. Minimum width of the strip is 2 m, optimal 5 m.

B) Surroundings

Since a multi-purpose overpass is usually of smaller dimensions, it is even more important to connect it to guiding landscape structures in the surroundings. It is significant especially in overpasses designed for birds and bats. These animals often follow avenues, forest edges, scattered green vegetation and other structures and it is good to connect them to the migration strips on the bridge as much as possible.

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It is recommended to follow up on the overpass with a fence as a guiding element for small and medium-sized mammals. In places with the occurrence of amphibian migration, the lower part of the fence should be solved as a barrier for amphibians.

Disturbance elimination

A protection wall from non-transparent material should be built on both sides of the bridge. Minimum height is 1 m, optimal 2 m.

10.3.1.3 Tree-top overpasses

This type of measure is aimed at species living on trees (dormice, squirrel, etc.). Squirrels or pine and stone martens easily cross roads and railway lines and fences are not obstacles for them. Where traffic is heavy this may cause high traffic mortality. Edible and garden dormice on the other hand rarely descend to the ground and prefer to cross roads at points where the branches of trees get close to each other.

These species are generally capable of using different types of underpasses and overpasses, but these objects are often not constructed in sufficient density that would match the requirements of this group. Special simple measures termed tree-top overpasses can contribute to decreasing mortality on roads. They are made of a system of ropes equipped with a cover from predators. Low costs can represent an advantage of these measures, but their efficiency is still to be verified.

These objects are typically constructed in forested areas with high population densities of the target species (dormice, squirrels, martens) or in areas of high mortality. They can be of good use also in urban areas where individual elements of city/town green infrastructure need to be connected.

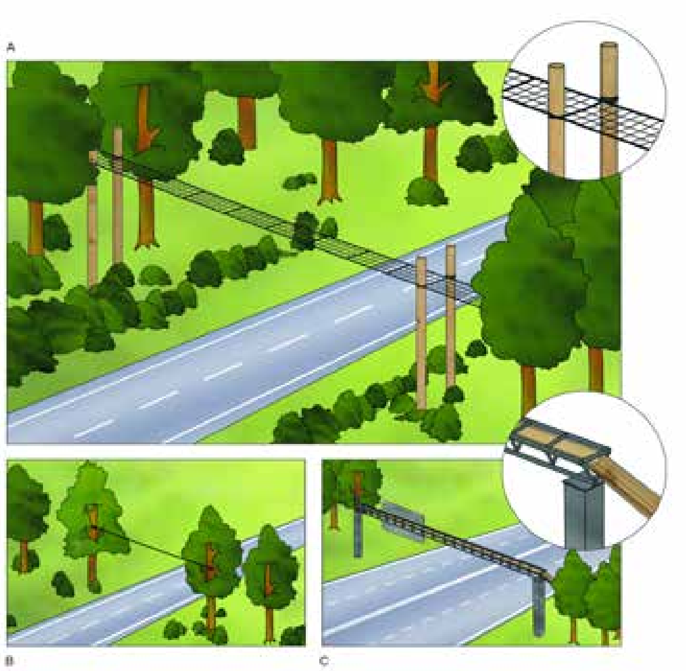

Fig. 10.33 Possible designs of tree-top overpasses. © Spain. Ministry for Ecological Transition. 2016. Technical prescriptions for wildlife crossing and fence design (second edition, revised and expanded) (on line). Madrid: MAPAMA. Illustrations made by Pep Gaspar, ARTENTRAÇ.

10.3.2 Wildlife underpasses

Wildlife underpasses are all structures where animal movement takes place under the level of traffic. Several types of underpasses are described in the following chapters, from large bridges (viaducts) to culverts for small fauna or special structures for certain animals. Passages for fish and other aquatic organisms are mentioned separately as specific objects.

10.3.2.1 Viaducts

General description and targets

Viaducts 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 a possibility to suitably integrate the object into its surroundings. Thanks to these parameters, they allow for the connection of entire ecosystems and are therefore suitable for migration of all species groups, from invertebrates to large mammals.

Technical solution

Technical solution should be based on specific situation of a given place. These objects are usually sufficiently permeable for animals and there is no need to optimize them. In the case of overcoming valleys with valuable ecosystems it is necessary to select a construction technology that does not directly affect the valley.

Integrating a viaduct into its surroundings

- The basis is keeping the surfaces as natural as possible (soil, grassy vegetation), as well as the surrounding vegetation.
- Watercourse should be – whenever technically possible – left in its natural state (stream bed, banks), including natural bank vegetation.
- There should be no obstacles for animals to pass through under the viaduct. It is necessary to regularly check for a free passage.

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Fig. 10.34 Viaducts over entire valleys serve as fauna passages for most species, including large mammals. They can under good conditions allow for connection of the entire ecosystems. Czech Republic. © Václav Hlaváč

Fig. 10.35 When a viaduct has a split construction, the surface under the bridge has enough light and precipitation for the growth of vegetation. That allows for a better connection of habitats. On the other hand, the overall width of impacted area is greater compared to a unified construction, which is also true for noise intensity under the bridge. Hungary. © Václav Hlaváč

10.3.2.2 Underpasses for large and medium-sized animals

General description and targets

These are special bridges constructed for the movement and migration of medium-sized and large mammals. They usually interconnect known traditional migration routes of animals (determined in migration studies). They are suitable especially in mountain areas, in places of crossings with watercourses or where the road is led in an embankment. There is usually not enough light and water under these objects for vegetation to grow, which for some species groups is a limiting factor (mostly invertebrates). A shorter height may be less suitable for birds or bats.

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Technical solution

As far as animal migration is concerned, noise disturbance is another very important factor besides the dimensions of passages.

First of all, the bridge dimensions depend on the main species group for which they are designed. The width and height are evaluated, as well as the length of the underpass. Table 10.4 shows probability of bridge usage in relation to its dimensions for medium-sized and large mammals.

Fig. 10.36 Special underpasses for large mammals are built in places where a motorway crosses a migration corridor. D1 motorway, Bělotín, Czech Republic © Martin Strnad

Fig. 10.37 Behaviour of animals near underpasses makes it evident that they register the noise caused by the passing vehicles (bearings of the bridge plate) - (A). Therefore, while constructing new bridges, it is always necessary to choose a solution that minimizes noise under the bridge. Noise under a bridge is best eliminated when there is a layer of soil between the bridge construction and the road/railway (B). However, this solution always brings under comparable conditions a reduction of the bridge dimensions as well. © (a) by Friends of the Earth Czech Republic, photo (b) by Nature Conservation Agency of the Czech Republic

Table 10.4

Probability of bridge usage in relation to its dimensions (dimensions of an underpass are shown in Fig. 3.1 B)

OI interval	Example of dimensions	Functionality for terrestrial mammals up to the size of fox and badger	Functionality for medium-sized mammals (roe deer, wild boar)	Functionality for large mammals (red deer, moose, large carnivores)
0.1 – 0.7	3 x 2 : 30	Minimal	NO/Blockage	NO/Blockage
0.7 – 1.5	10 x 3 : 30	Medium	Minimal	NO/Blockage
1.5 – 2.0	13 x 4 : 30	Good	Medium	Minimal
2.0 – 4.0	20 x 5 : 30	Very good	Medium	Minimal
4.0 – 8.0	30 x 6 : 30	Very good	Good	Medium
8.0 – 40.0	50 x 20 : 30	Very good	Very good	Good
Above 40.0	70 x 25 : 30	Very good	Very good	Very good

OI = openness index: w x h / l (the width of the underpass multiplied by its height divided by its length)

Dimensions: width x height: length (in meters)

The probability of bridge usage increases with a greater openness index up to the boundary when dimensions are no longer the limiting factor (ideal stage). From the cost effectiveness viewpoint, it is usually good to oscillate somewhere around the average value.

The dimensions always must be based on a specific local situation. Larger dimensions from the provided range should be selected in the case of conveying a migration corridor of regional importance and in places where surrounding ecological conditions are not ideal. On the contrary, in places with no disturbances and with suitable natural habitats on both sides of the underpass, even bridges of smaller dimensions fulfil their role effectively.

Integration into the surroundings

- There is minimum vegetation under the bridge due to the lack of light and water, but it is still advisable to support vegetation growth whenever possible.
- It is good to install hiding spots for animals under the bridge.
- Suitable is to plant vegetation attractive for animals near the entrance to the object.
- No obstacles to animal movement should be present under the bridge.

Disturbance elimination

When noise-protection walls are installed on the bridge to block noise and light from the traffic, they must be designed in a way that they do not constitute a risk for birds flying through.

10.3.2.3 Modified and joint-use underpasses

General description and targets

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

Dimensions

Recommended width of these objects is 10 m minimum. However, it always depends on specific conditions and the level of disturbance. Some field or forest paths can be used by humans only very rarely, and migration of local populations well adapted to local conditions can successfully take place even in a small underpass.

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Fig. 10.38 Natural surfaces significantly improve the functionality of a wildlife underpass. A protection wall contributes to better utilization by fauna as well, thanks to disturbance elimination. A transparent wall has to be secured against bird injuries. The Czech Republic. © Nature Conservation Agency of the Czech Republic ,

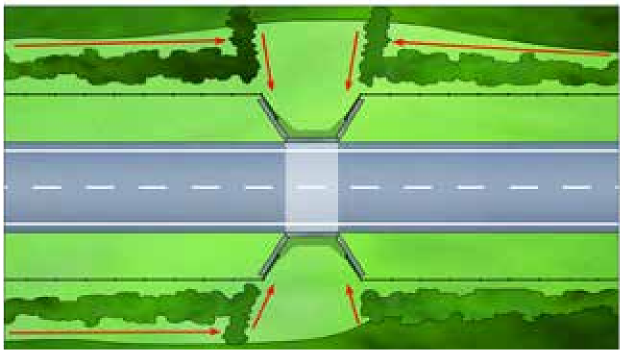

Fig. 10.39 Usability of wildlife underpasses for fauna is improved by planting trees or bushes by the entrances. This diagram shows a suitable distribution of vegetation on approaches to the underpass, which should help with guiding animals towards the entrances. © Spain. Ministry for Ecological Transition. 2016. Technical prescriptions for wildlife crossing and fence design (second edition, revised and expanded) (on line). Madrid: MAPAMA. Illustrations made by Pep Gaspar, ARTENTRAÇ
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Integration into the surroundings

- Planting bushes and trees at the entrance to the underpass is desirable.
- Traffic interference including noise from bridge plate bearings needs to be minimized.
- Special attention needs to be paid to bridges over watercourses (see the following section).

Importance of bridges over watercourses

Large number of objects in landscape is constructed for the purpose of conveying watercourses. The means of conveying watercourses significantly influences the possibility of using it for animal migration. This issue involves thousands of bridges on roads of all categories and fundamentally influences not only aquatic species, but also amphibians and smaller mammals, especially the otter. It is in many cases of significance even for medium-sized and large mammals. For this reason, it is necessary to deal with this issue not only on new roads and motorways, but also in the case of reconstructing bridges in general on the entire road network. On lower-class roads, bridges and culverts are often the only places where measures to reduce animal mortality can be applied.

The main principles that must be applied in the case of bridges over watercourses, so that they function well also as fauna passages, are as follows:

- If technically possible, a strip minimally 10 m wide on each side of the watercourse should be left.
- Keeping natural banks is essential (ideally on both sides of the watercourse), as passing animals need natural surface. If this is not possible, at least some kind of dry banks with minimum width of 0.5 m must be maintained or created under the bridge on both sides of the watercourse.
- Transition between the watercourse under the bridge and its surroundings should be overall as smooth as possible, the same holds also for the transition between dry banks and their surrounding terrain.
- Existing impassable bridges can be improved by installing a special ledge 40-50 cm wide. If the ledge is made of wood, lifespan of approximately 10 years should be expected and after that it has to be restored.
- No vertical steps higher than 10 cm should be created in the stream.
- Stream profile needs to be solved in a way that ensures sufficient depth for fish migration in the middle even at times of low flow rates.

Fig. 10.40 This underpass with a forest path does not represent a suitable passage for fauna. Dimensions w = 6 m, h = 5 m, l = 33 m (OI = 0,9) are insufficient for large mammals, medium-sized mammals such as the roe deer or the wild boar use such underpasses only when disturbances are eliminated (protection wall along a motorway, limited human activities). The Czech Republic, motorway D1. © Václav Hlaváč

Fig. 10.41 Bridges over small watercourses represent an important element in ensuring the connectivity. If they have sufficiently wide dry banks on both sides of the watercourse, they are used by a broad spectrum of animals up to the size of badger. © Friends of the Earth, Czech Republic

10.3.2.4 Underpasses for small animals

General description and targets

Bridges and culverts designed primarily for hydrological purposes play a crucial role in ensuring the permeability of roads for small animals. They are typically crossings of infrastructure with small watercourses or just drainage solutions for the precipitation water. These underpasses are fundamental for ensuring the permeability of roads for small mammals (size of fox, badger, but even smaller ones), amphibians and reptiles. An essential requirement in planning and constructing bridges and culverts is to take into consideration that it needs to fulfil both functions – hydrological one and that of a fauna passage. Bridges and culverts should be designed in a way that meets this requirement. It is important to emphasize that often only small and both financially and technically modest adjustments are needed in order to reach good solutions. Where this is not possible, especially in places with higher mortality rates or higher migration pressure, installation of special underpasses for migration should be done. There is a wide range of fauna passages that can be divided based on the particular type of construction. In general, bridges (underpasses wider than 2 m), culverts (underpasses less than 2 m wide) and special underpasses for selected animal groups can be distinguished.

Bridges over small watercourses

There exist many types of bridges that differ in size, shape, construction style and the material used. In order to ensure the permeability for animals, the same basic principles as described above for larger bridges must be applied.

Fig. 10.42 Different types of bridges over small watercourses are very well usable as fauna passages for small animals. Dry banks at least 0.5 m wide allow the movement of a broad spectrum of species up to the size of badger. The banks should be made from stone pavement and concrete should be avoided, because it does not allow migration of amphibians (risk of drying out). © Václav Hlaváč

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Culverts

Culverts can be divided based on their shape (rectangular, tube, muzzle) and can be made of various material (concrete, stone, steel, plastic). In order to ensure the permeability for animals it is always necessary to consider the following recommendations:

- Rectangular culvert (see Fig. 10.43) is in general more suitable for animal migration than circular profile, it is preferred by a wider spectrum of species (for example amphibians). Rectangular culverts have greater bottom width and brightness with the same height, washed off material naturally settles on the bottom and animals can then more easily move on it. Rectangular culverts are also more suitable if greater water flow or even flooding can be periodically expected.
- Similarly to other animals, the usability of an underpass for amphibians is decided mainly by its length and dimensions of the entrance. Recommended dimensions for different lengths of an underpass are listed in Table 10.5.
- Culverts of a greater diameter (1.2 – 1.8 m) are more universal and usable by a larger species spectrum.
- Bottom should optimally not be made of concrete (depends on the gradient – sediments settle at the bottom in the case of low gradient, which forms a good substrate for animals).
- An adaptation in the form of creating a dry bank can significantly improve usability of culverts as fauna passages (see Fig. 10.44).

Fig. 10.43 Rectangular culvert is a good solution for amphibians, reptiles and mammals up to the size of fox or badger. © Lukáš Poledník

Fig. 10.44 Usability of culverts for animals can be increased by creating a dry concrete bank which allows for the movement of terrestrial animals. © Václav Hlaváč

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Table 10.5

Minimum size requirements of amphibians for different construction types depending on the length of the tunnel (= the width of the road).

Topics	Minimum clear sizes for tunnel lengths from				
Construction type	<10 m	<20 m	20-30 m	30-40 m	40-50 m
Rectangular tunnel (clear width, clear height)	0.70 m; 0.70 m	1.0 m; 0.75 m	1.5 m; 1.0 m	1.75 m; .25 m	2.0 m; 1.5 m
Pipe (diameter)	0,5m	1.0 m	1.4 m	1.6 m	2.0 m
Dome-shaped (half circle) (clear width, clear height)		1.0 m; 0.7 m	1.4 m; 0.7 m	1.6 m; 1.1 m	

- For amphibians, guiding barriers always need to be used and the culvert has to be free of obstacles.
- Gradient: the bottom of a culvert needs to be done in a single gradient, so that permanently flooded places do not arise. It is necessary to consider the possibility of flooding the culvert while designing it.
- No barriers can be placed near the entrance to the culvert.
- In case of fencing a road, the inflow and outflow of a culvert must always be outside of the fenced area (see Fig. 10.45).

Parameters of underpasses generally must respect ecological requirements of species. In small vertebrates, size of an underpass is usually not the issue, but rather their unsuitable design – for example permanent water flow in culverts, absence of hiding spots, unsuitable materials and technical solutions (creating traps in the form of shafts, barriers in the form of steps, etc.).

Fig. 10.45 If the entrance into a culvert is on one roadside outside of a fenced area and on the other roadside inside of the fenced area, animals using such an underpass stay trapped between the fences and the road. In case both entrances are inside a fenced area the underpass cannot be used by animals at all. © Václav Hlaváč

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Fig. 10.46 Examples of inappropriate solutions. Culverts where the entrance is technically designed in a way that prevents the animals from entering. © Lukáš Poledník - A) and D), Václav Hlaváč - B), Jitka Matoušová - C)

Otter and badger tunnels

Culverts for otters (otter tunnels) are used as a supplement to impermeable bridges and culverts or in order to make pond dams with roads on top permeable. They are concrete pipes with a diameter of 30 cm placed above the water level. Suitable terrain modelling, low walls, or in an extreme case even guiding fencing can be used to lead the animals into the culvert.

In areas with high population densities of badgers it is advisable to place badger tunnels in the frequency of every 200 – 400 m. Badgers use regular migration routes within their territories, so these need to be mapped in a migration study and culverts should then be placed as close to these routes as possible. Special fences on both sides of roads are needed for badgers – length depends on a specific situation (sometimes 10 m to both sides from the entrance to the culvert are enough, sometimes it is necessary to fence the entire area, especially places with food sources near the road). Fences for badgers should have small openings/holes (25 x 50 mm). They should be buried deep enough, so that the badger cannot dig under them. It is also possible to fix the fence to the ground.

Amphibian tunnels

Most amphibian migrations take place under bridges and via suitable culverts – principles of their solution have been described earlier in this chapter. Nevertheless, it is sometimes necessary to look for a solution in places with no such suitable bridge or culvert. In this case a special passage – an amphibian tunnel - should be built. This measure is usually suitable only on narrow roads of lower category. It is a passage of rectangular cross-section, covered from the top with bars (these must have dimensions allowing for a smooth passage of vehicles) in order to ensure enough light in the passage. Many prefabricated types are available, and their efficiency has been sufficiently verified in practice. There are currently also many studies and expert literature available, therefore it is advisable to solve every case individually in cooperation with specialists. However, a necessary condition is always the construction of guiding barriers that prevent the migrating amphibians from entering the road and lead them to safe passages. These barriers can be built as temporary or permanent (see Chapter 10.4.2). Their type, length and placement should always be solved by an expert in this field.

Fig. 10.47 Otter tunnels are a suitable solution in places where a bridge is impassable for otters or where transport infrastructure is led on top of a pond or reservoir dam. © Lukáš Poledník

Fig. 10.48 An amphibian tunnel is a good solution for overcoming narrow roads of lower category. Barriers guiding animals to the passage are a necessary condition for proper functionality. © András Weiperth

10.3.2.5 Passages for fishes and other aquatic organisms

Requirements of fish for the permeability of bridges and culverts are described in Chapter 10.2.2 Ensuring these requirements is a basic demand in designing all bridges over watercourses. Culverts should be adapted for fish migration always when the conveyed watercourse is inhabited by them (it is not necessary in case of periodic watercourses).

Occasionally, a vertical step in a watercourse can arise also as a result of its crossing with a transport infrastructure. Therefore, to be complete, this type of measure is briefly described as well. Technical measures that serve fish and other aquatic organisms in overcoming a vertical step in a watercourse are called fish crossings. Fish crossings are typically designed for the fish to overcome weirs or reservoir dams.

There are many different types of fish crossings, depending both on watercourse character and fish communities, whose migrations are expected at the given section. This represents measures that are given a lot of attention in many countries and large amounts of expert literature are available.

A fish crossing can generally be solved as a bypass, or it is sometimes possible to place it directly into the stream bed. Regardless of the selected type it is always important to maintain longitudinal gradient. According to the monitoring results from many countries, the slope for salmonid fish species should be minimally 1:25, for all other species then 1:30 or more moderate. It is always necessary to alternate places with greater gradient and places with calm deeper water where the fish can rest. Proposal for a fish crossing must always be solved in a close cooperation with biologists.

Fig. 10.49 A fish crossing in the form of a bypass – in order to overcome a weir 1.3 m high, it was necessary to create a fish crossing with a total length of 40 m. The Czech Republic. © Bohumila Jermlová

Fig. 10.50 A fish crossing near Lyon, France, where a vertical step on a watercourse was created as a result of a road construction. The fish crossing is placed directly in the watercourse and is used by the entire fish spectrum inhabiting the stream. It is also used by otters. © Václav Hlaváč

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10.4 Avoiding and reducing animal mortality

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Mortality of animals on roads represents probably the most visible impact of traffic on wild fauna. Millions of individuals are killed on roads every year and even more than that are injured. Road mortality concerns practically all animal species including birds and insects. Collisions with large mammals, especially ungulates, are also very dangerous with respect to the road safety. It is therefore necessary to deal with measures in order to lower mortality rates and increase traffic safety. Basic measure in this respect is fencing or constructing barriers (Chapters 10.4.1 and 10.4.2), complementary are for example vegetation adjustments or artificial deterrents (Chapter 10.4.3), transparent protection walls should be made visible for birds (Chapter 10.4.4). Other measures – warning signs or detection systems (Chapter 10.5) are aimed at drivers instead of the animals, but their purpose is the same – to avoid or at least reduce mortality of fauna and contribute to traffic safety.

Fig. 10.51 When an otter following a watercourse meets an unsuitable culvert or bridge it is forced to cross the associated road. Mortality on roads directly threatens survival of this species in many European countries. © Václav Hlaváč

10.4.1 Fencing

General description and targets

Fencing helps limit the entry of animals on an infrastructure. It is currently the main measure used to reduce animal mortality on roads and railways. On the other hand, fencing increases the barrier effect of transport infrastructure and therefore it is always necessary to combine it with fauna passages. In such cases fences then guide animals to fauna passages. Fences are usually built along motorways, in the case of lower category roads fencing is only recommended in critical places with a high risk of collisions between vehicles and animals.

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

- Sufficient height – animals must not jump over the fence.
- Suitable size of mesh – animals must not crawl through the mesh of the fence.
- Suitable anchoring – animals must not crawl under the fence.
- Suitable termination – it should be designed in a way that prevents animals from going around the fence and getting on the road. Fences should therefore be terminated, for example by bridges or by a built-up area. Fencing at these points (bridge abutments, junctions, etc.) needs particular attention, so that gaps for fauna are avoided.

- Intact construction – animals must not crawl through gaps or damaged parts of the fence
- Placement on both sides of a road – animals that get onto the road from one side but cannot leave the road on the other side have to return. This increases the risk of collisions with vehicles.
- Escape possibility for confused individuals (escape ramps or one-way escape gates).

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

Fig. 10.52 Fencing interrupted by a connection to a forest path. This first-class road was fenced because of a high number of collisions with animals. Unfortunately, due to several exits of connected forest paths the fencing is not continuous. The number of accidents in the observed section increased even more after the fencing was installed, because the passing animals were getting inside of the fenced area without a possibility to escape. © Václav Hlaváč

Location

Placement of fencing should be decided in a migration study, which evaluates not only critical points from the animal mortality viewpoint, but also overall permeability of the road, selection of fauna passages and interconnections of fauna passages and fences.

Fences should take up the least possible amount of usable environment, which means they should be placed as close to the road as possible. However, traffic safety and road maintenance must be taken into consideration. If the road is led in the notch or in the embankment, it is recommended that the fence be placed within the road proximity with respecting approximately 5 m wide belt for maintenance. When the fence is located at the edge of notches or embankments, attractive habitats often arise between the road and the fence and tempt animals into this dangerous space. Similarly, shrubs and trees that are attractive to animals should not be planted in the area between the fence and the road but should be planted outside the fenced area.

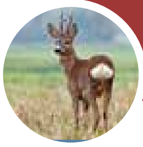
Fig. 10.53 A correctly placed fence. Trees and bushes represent an attractive habitat for a whole range of species; therefore, they should stay outside of the fenced area. It is also easier to check the functionality of fences placed in this manner than compared to fences placed at the edge of a cutting or an embankment. © Václav Hlaváč

Construction types

- Classic fences consist of mesh (stainless material) attached on posts (suitable are metal, wooden).
- Electric fences are expensive and require frequent checks and maintenance. They do not provide solution for long sections; they can be installed locally in places with higher risk of collisions with rare species. They can be installed temporarily on new roads with the aim to change the existing migration habits of the occurring species.

Dimensions

Proper dimensions of fencing are determined based on target species:



Size of the roe deer, the wild boar:
minimum height of 1.5 m, optimum 1.6 – 1.8 m

Size of the red deer (the moose, the fallow deer):
minimum height of 2.2 m

Size of the bear:
minimum height of 3 m, including an overhang of 0.8 m on top with negative angle to stop the bears from climbing, horizontal mesh 1.5 m wide on the ground connected with the vertical one to deter bears from digging

- Height must be adapted to terrain (different in notch and embankment).
- In areas with regular snow cover the minimum height must also be maintained in winter.
- In areas where the lynx or the wildcat belong to target species it is necessary to design fences with a barrier against climbing over (inclined roof on top of the fence with a width of 50 cm).
- Badgers, foxes, otters, or even wild boars can crawl or dig under the fence or lift it. This can be prevented by embedding the fence at least 30 cm underground.
- Denser mesh is recommended for the bottom third of a classic fence. Mesh size (dimensions horizontally x vertically): 50 mm x 150 mm for the lower third, 150-200 mm x 150 mm for the rest of the fence.

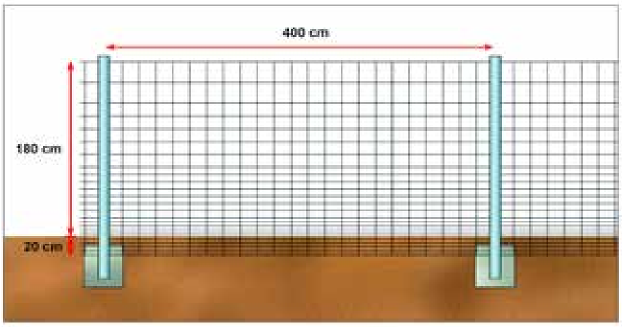


Fig. 10.54 Design of a fence for large and medium-sized mammals with denser mesh at the bottom. © Spain. Ministry for Ecological Transition. 2016. Technical prescriptions for wildlife crossing and fence design (second edition, revised and expanded) (on line). Madrid: MAPAMA. Illustrations made by Pep Gaspar, ARTENTRAÇ

case study

Fence design for protection of bears (example from Greece)

Although new motorways often include mitigation measures such as tunnels, viaducts and underpasses, it is still necessary to prevent animals from entering the infrastructure. Construction of fences is absolutely essential, especially for large animals such as the bear. Positive results have been recorded for example in the case of fences installed on the Egnatia Motorway in Greece. Their total height is 3 m (including an overhang of 0.8 m on top) and the end is made in a negative angle to stop the bears from climbing. There is also a 1.5 m wide horizontal mesh on the ground, connected with the vertical mesh to deter the bears from digging. More information on this type of bear fences is available from Egnatia Odos SA, Mrs. Niki Vumvulaki, e-mail: nvum@egnatia.gr.

Fig. 10.55 Case study: Fence design for protection of bears (example from Greece). © Lazaros Georgiadis/ARCTUROS

Other general recommendations

- Regular checks and maintenance of fences are absolutely necessary. Fences with holes are very dangerous for animals, as they often get inside the area of the road but are not able to find their way back.
- Gaps in fencing can be present on roads with lower traffic intensity – they allow the animals to pass the road in a clear and safe section.
- Fences should only be installed together with the fauna passages. It is very important to follow this general recommendation: if a fence more than 2 km long is built, the section should always contain a passage for relevant animal category as well.

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Fig. 10.56 Fences are often damaged, for example by fallen trees or by accidents. Animals usually find these gaps very quickly and get into a dangerous area between the fences. When they are then disturbed, they run across the road and become victims of traffic. © Václav Hlaváč

Fig. 10.57 During spring migrations, the installation of temporary barriers can prevent amphibians from entering roads and at the same time direct them to safe passages. The barriers must be removed after the migrations are over. © Jaromír Maštera

10.4.2 Barriers for amphibians and tiny mammals

General description and targets

Barriers are elements that are supposed to prevent animals from entering the road itself and at the same time direct them to fauna passages.

Construction types

Several types of barriers exist that differ from each other by function (guiding and trapping barriers) and by construction (temporary and permanent barriers).

A) Temporary barriers

- Are placed during construction in all selected critical spots (contact of the construction with watercourses, wetlands, etc.).
- Guiding barriers are built without "dropping traps" and their purpose is to direct animal movement to safe areas. Trapping barriers are supplemented by "dropping traps".
- Material of barriers – firm, smooth and full foil is ideal, unsuitable are textiles and perforated materials.
- Height of barriers above terrain level should be at least 50 cm. Bottom edge of the barrier should be embedded or earthed up against the direction of animal movement, similarly to the upper edge, which creates an arc that is difficult to overcome.
- Attachment of barriers – to woody, sufficiently deep embedded posts about 100 cm tall. The posts should be hammered to a depth of at least 15-20 cm on the other side of the barrier to where migration occurs. Maximum distance between the posts is 150 cm, in a structured terrain even less.
- Trapping containers – given the fact that in most countries, amphibians belong to protected species, manipulation with them is subject to different regulations, depending on the country. Capture and manipulation is always stressful for amphibians, therefore it can only be done by a specialist with corresponding authorization.
- Installing the barriers – should be done with the beginning of construction, early in spring at the latest. The barriers are then removed after the termination of the construction or in autumn (October/November).

B) Permanent barriers

- Are first installed after a full completion of the construction and serve as a basic measure to reduce amphibian mortality on roads and to guide towards suitable fauna passages.
- Are placed directly on regular migration routes of animals.

Fig. 10.58 Permanent barriers are built with the goal to guide migrating amphibians to a suitable passage. They are always constructed from both sides - in the direction of spring migration towards aquatic habitats and in the opposite direction from the aquatic to terrestrial habitats. © Jaromír Maštera

10.4.3 Artificial deterrents

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

- Sight – visual deterrents: lights, lasers, reflectors, mirrors (they reflect lights of vehicles into the surrounding landscape, which should discourage animals from entering the road in front of the passing vehicle).
- Hearing – acoustic deterrents: devices with recordings of disturbing noises activated before passing of a train, etc.
- Smell – olfactory deterrents: these take advantage of the fact that animals naturally avoid places with olfactory traces of predators or humans.

Fig. 10.59 Olfactory deterrents are used in many areas of the Czech Republic. Their purpose is to alert ungulates (especially the roe deer and the wild boar) that they are in a dangerous area. However, these deterrents only seem to have a short-term effect; real decrease in the number of accidents with fauna due to this method has not been proven yet. © Václav Hlaváč

10.4.4 Protection of birds: solution by noise barriers

General description and targets

Noise barriers are constructions on roads that limit noise levels coming from the traffic. Their primary function is to protect human health. With respect to animals they basically create a complete barrier and prevent animals from entering the infrastructure. Similar walls are sometimes used in certain parts of roads with frequent bird flyovers in order to force the birds to fly higher above passing vehicles and therefore reduce mortality.

In general, walls and noise barriers made of transparent material (glass, polycarbonate or acryl) are the most dangerous and cause high bird mortality in many places, as birds do not note them and want to fly to the space behind them. Injuries often occur in situations where the sky is reflected in the transparent wall as well. Mortality then impacts a wide species spectrum and numbers of killed individuals are often alarming.

Construction types

Several technologies are already available that effectively prevent bird mortality on transparent walls. Suitable solutions include:

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i) Using walls with vertical stripes 20-30 mm wide and in 100 mm distance from each other, glued on both sides of the noise barriers.

ii) Netted noise barriers: wire net with a 20 x 20 mm mesh.

iii) Dark polyamide fibres built directly into the material of the noise barrier – a modern method; the producer should have a certificate awarded by nature conservation authority for each type.

Silhouettes of raptors, used quite frequently in recent years, do not represent an efficient measure!

In some cases, the function of walls can be taken over by sufficiently high vegetation. For example, waterfowl and wetland birds (ducks, waders) usually perceive trees as an obstacle and fly over them in sufficient height.

Fig. 10.60 The process of installation of glued stripes to a noise protection wall on D47 motorway in the Czech Republic. In 2008, almost 200 dead birds were found along just 1 km long stretch of this motorway between Bohumín and Ostrava within 6 months. This mortality rate dropped practically to zero after equipping the wall with the stripes. © Jan Mayer

Fig. 10.61 Vertical stripes or wire mesh in glass are a reliable protection from bird injuries, they at the same time represent an acceptable solution with respect to architecture. © Václav Hlaváč

Fig. 10.62 Besides transparent protection walls, bus stops can become places of high bird mortality as well. The means of securing is similar in both cases. (The first bus stop on the top has been secured by school children, who did not want to find any more dead birds there). © Petra Hulvová

10.5 Measures on roads for drivers (traffic measures)

10.5.1 Warning signs

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

Location

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

Other general recommendations:

- The combination of a wildlife warning sign with a speed limit is slightly more effective.
- The effectiveness is further enhanced if signs are marked with flashing lights or a flashing speed limit sign, which are lit only during periods of high animal activity.

case study

Mitigation measures for the Eurasian otter *(Lutra lutra)* in Liptov region, Slovakia

High mortality rates of the Eurasian Otter (A) on the D1 motorway section between Ivachnová - Važec during the years 2016-2017 led to the cooperation between the National Motorway Company of Slovakia and the State Nature Conservancy

First, a special traffic sign 'Attention otter!' (B) was proposed and eight of these signs were installed on the Slovak roads. The sign has already been approved by the police, although it is not a standardized sign according to the Slovak Technical Norms.

Subsequently, new fences were installed near several bridges over the following years. Fences have been installed also in complicated terrain near the water reservoir of Liptovská Mara (C).

Fig. 10.63 Case study: Mitigation measures for the Eurasian otter (*Lutra lutra*) in Liptov region, Slovakia. © Stanislav Ondruš (A), NDS Archive (B,C))

10.5.2 Warning and detection systems

Wildlife warning systems combined with sensors have shown to be able to reduce the number of collisions. Heat sensors in the vicinity of 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. Normally, the speed limit sign appears dark and will start a light signalisation when activated by movement of animals. The use of detection and warning systems has begun to be used in many countries in recent years. However, their use is always tied to situations where animals cross the road only in a certain place. In a mosaic landscape, where there are no points (sections) with concentrated animal crossings, the use of these systems is limited.

In the case of railways, noise-warning systems that are activated by an incoming train are tested in areas with increased animal mortality. Shortly before the train passes, the device produces dog barking, human voices and other disturbing noises that make the animals leave the risk area of the railway.

10.5.3 Increasing visibility

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

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

Another measure is road light signalisation. It makes visibility better for drivers and animals can avoid these areas due to its presence. However, lighting has negative effects on other species such as insects and bats; therefore, this measure cannot be in general recommended.

11 Ecological Compensation

11.1 The concept of ecological compensation

Despite good planning and use of mitigation measures aiming to avoid or reduce adverse impacts on natural habitats, it is impossible to completely avoid the negative effects of infrastructure development. This realisation has led to the principle of ecological compensation in many European countries. Ecological compensation implies that specific natural habitats and their qualities, such as wetlands or forests, should be developed elsewhere when they are impacted by an approved project. Ecological compensation may be defined as creating, restoring or enhancing nature qualities in order to counterbalance the ecological damage caused by infrastructure developments. Ecological compensation can be applied to a whole range of impacts, including habitat degradation (a habitat is still present, but impacted) and loss of functions such as nutrient and energy flows.

Ecological compensation is a 'last resort' solution – it is only considered where planning and mitigation measures are not able to prevent the damage. Implementation of compensation measures is the responsibility of an investor of a given project. Ecological compensation should not be considered as an enabling activity to allow developers to get a planning permission by buying-off environmental objections.

Regarding the transport infrastructure, ecological compensation is generally undertaken outside a given road, which in many cases leads to complications with regard to the ownership of the surrounding land. Road agencies should put serious effort into acquiring land in the neighbourhood of the infrastructure for compensation objectives.

The basic types of compensation measures include (more details in Chapter 11.3):

- Creation and management of new habitats,
- Adaptation of farming activities to nature conservation considerations (e.g. meadow-birds or plants),
- Research enabling compensation to be targeted for the benefit of specific species.

In some cases (unique landscapes/habitats/populations) compensation measures are not acceptable; the activities must therefore be reconsidered for acceptable alternatives.

case study

Compensation measures for negative impact of D4 motorway construction in Slovakia

A significant negative impact of motorway D4 construction (section Bratislava, Jarovce - Ivanka pri Dunaji, north) on the Special Protection Area Dunajské luhy has been identified as a result of associated Environmental Impact Assessment; more specifically, it was associated with three subjects of protection: the black kite, the white-tailed eagle and the black stork. According to the government of the Slovak Republic, the planned construction of this D4 motorway section was of greater public interest than nature protection. Since the construction of a bypass around Bratislava has a negative impact on integrity of areas protected under the European Natura 2000 Network, it can only be allowed under the condition of implementing compensation measures. Therefore a compensation project has been prepared which includes the following measures: planting new forest stands, planting grassy cover, changes to allow water flow through Biskupické rameno and the protection of current forest stands. The National Motorway Company will be responsible for the implementation of the project as the investor.

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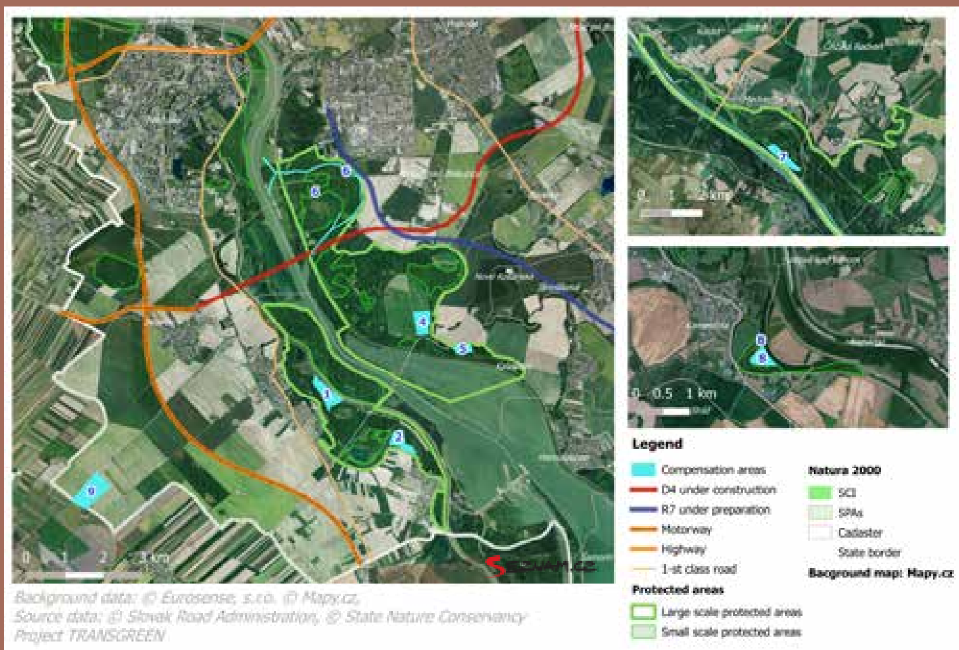

Special Protection Area Dunajské luhy © Barbara Immerová

Restoring and allowing water to flow through Biskupické rameno as a compensation for aquatic habitats that ceased to exist. A - filling up arm, B - filling up object. © Radovan Michalka

Fig. 11.1 Case study: Compensation measures for negative impact of D4 motorway construction in Slovakia. © Radovan Michalka

11.2 Legal obligations

11.2.1 Legislative order – international and national level

Compensation measures can be set legislatively at international or national level. Within the EU, compensation measures are adjusted in the Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (Habitats Directive), specifically in Article 6.4. This regulation is then adopted into the legislation of the individual member states. According to the Habitats Directive, compensation measures represent one of the possible tools to maintain overall cohesiveness and conservation of individual subjects of protection of particular Natura 2000 sites.

Compensation is also mentioned in the EIA Directive (Directive 2011/92 EU, amended later by Directive 2014/52/EU), which demands "measures envisaged to avoid, prevent or reduce and, if possible, offset significant adverse effects on the Environment". Similar provisions are included in other relevant international biodiversity related conventions as well.

11.2.2 Formal compensation policy: non-legislative regulation

Where compensation is linked to formal national policy, usually less stringent measures are required:

- Economic or social necessity may, in exceptional cases, justify the project development, under the condition that the ecological damage is compensated for.
- Compensation in terms of comparable ecological values as well as financial compensation are both permitted, though less preferable.
- Compensation measures do not necessarily have to be implemented before the project starts.

11.2.3 Voluntary agreements

Non-legislative policy requires less stringent conditions for the implementation of the compensation principle. In the assessment process, socio-economic and nature conservation interests are weighed against each other.

Partial conclusion: Compensation measures have to be taken (i) if a development is foreseen to have significant impacts on areas that are protected by the EU Birds and Habitats Directives, by international conventions (e.g. the Ramsar Convention), or by national regulations in some countries and (ii) if a development is foreseen to have impacts on areas of high conservation value in which a non-legislative compensation policy is operative.

11.3 Types of compensation measures

11.3.1 Habitat creation

Creation and management of new habitats is a key field that can significantly reduce negative impact of road/railway constructions on nature. Habitats are implemented off the surface of the road/railway construction. Habitats for conservation of species newly created as part of the compensation measures, also called spare/replacement habitats, belong to this group. Vegetation belts along roads/railways implemented for the protection of settlements can be classified here as well.

11

Creation of spare/replacement habitats currently belongs to the most required measures in the road construction process. Primarily the following basic topics are under solution: A) placement of a spare/replacement habitat, B) dimensional and technical parameters, C) ensuring suitable ecological conditions, D) means of implementation, including funding.

A) Placement of a spare/replacement habitat. A spare/replacement habitat must be placed in an area that ensures basic macro-ecological conditions (first of all climatic and geological conditions) for a long-term existence of the species of interest. For this reason, a suitable locality needs to be searched in the following order:

- Directly at the impacted locality or in its immediate neighbourhood,
- Near the impacted locality, in areas bordering with another locality inhabited by the given species,
- In a more distant territory, in areas of occurrence of the given species,
- In a more distant territory, in areas where the given species has not occurred earlier.

B) Dimensional and technical parameters. These are habitat-specific and have to be approached based on requirements of the given taxon.

C) Ensuring suitable ecological conditions. Meeting the macro-ecological requirements is given first of all by the selection of locality. Nevertheless, the technical solution of the habitat must deal with a wide spectrum of micro-ecological conditions. Requirements of all species of interest, their developmental stages, seasonal cycles (places for breeding, wintering, hibernation, etc.) and life needs (obtaining food, hiding spots, basking, etc.) must be respected.

Small water reservoirs, ponds or pools are among the important implemented measures for the compensation of lost habitats. It is advisable to diversify ecological parameters as much as possible, for example: jagged banks, different slope gradients, different depths of the reservoir, combination of sunny and shaded places, part of the reservoir overgrown with vegetation, installing supplementary elements (stones, tree stumps, and branches), a continuous belt of dry land, etc. It is always possible to modify the conditions based on the particularities of individual species.

The necessity to ensure a wide range of different ecological requirements implies a recommendation to diversify ecological parameters of spare/replacement habitats from all realistic viewpoints, in relation to ecology of the given species (dimensions, irregularity of shape, water source, sunlight, vegetation, etc.). Diversity of the spare/replacement habitat increases the probability of its optimal use.

11.3.2 Habitat enhancement

Enhancement of habitats implies that the compensated habitat is present, but not one of the right quality. Former impacts may have caused the habitat deterioration. Compensation may include measures needed to enhance the habitat quality (such as reducing grazing pressure, raising the water table). The advantage of enhancing the quality of the existing habitat is that often the soil and its hydrological properties are close to those required to meet the conservation objectives. This measure is widely used in some countries, especially in the case of forest habitats.

The enhancement needs to be focused on:

a) Wildlife corridors (improving their function by planting trees, e.g. as a guiding structure for a fauna passage).

b) Linkage areas in a wider range, especially related to the need for support of large target species connectivity in the wider area.

c) Replacement habitats for slowly-moving species (amphibians etc.).

11.3.3 In-kind/out-of-kind compensation

Compensation aims at a 'no net loss' situation for the protected species and habitats. Thus, compensation measures should preferably aim at creating similar ecological qualities to the area impacted ('in-kind' compensation). (Note: The EU 'No Net Loss' initiative is related to the aims of the Biodiversity Strategy, it is an initiative to ensure there is no net loss of ecosystems and their services e.g. through compensation or offsetting schemes).

However, it may be legitimate to compensate in terms of comparable qualities ('out-of-kind' compensation). This is the case when in-kind compensation is not feasible and out-of-kind compensation favours the persistence of important species that are impacted by the infrastructure developments.

In-kind compensation involves replacement with the same habitats, species or functions; out-of-kind compensation involves replacement with alternative habitats, species or functions. In-kind compensation is typically carried out for three types of impacts:

1. Habitat loss: creation of habitat patches of the same size and quality (on-site or off-site); upgrading existing habitat may also be effective as a secondary approach.

2. Habitat degradation: upgrading habitats.

3. Habitat isolation: a combination of enlarging and upgrading habitats or increasing the connectivity of isolated habitat patches.

11.3.4 Measures linked to fauna passages

Securing the continuity of fauna passages to the surrounding landscape is an absolutely essential step. The situation is problematic especially in intensively used agricultural landscape, where guiding vegetation elements are needed, but their implementation means changes in land use. In such cases, purchase of the land within necessary extent is usually the only solution. Wildlife corridors and the surroundings of fauna passages need to be protected by spatial planning and spatial (land use) plans. Gaining estates for the planting of a guiding corridor in a landscape without forest stands or other denser vegetation can be considered an important compensation measure.

Fig. 11.2 A green bridge on D1 motorway near Suchdol nad Odrou (the Czech Republic) was built on a significant migration corridor between two mountain ranges (Beskydy and Jeseníky). Unfortunately, the crossing point of the migration corridor with the motorway is located in agricultural landscape without a forest cover. Therefore, in order to improve the efficiency of a green bridge, associated land has been purchased to plant new vegetation that will connect the green bridge with further located existing forest cover. © Mapy.cz

11.3.5 Translocation

Rescue transfers belong to ex situ measures where the conservation of individuals takes place out of the original locality. Their basis lies in capturing individuals at an endangered locality and their transfer to a different place. It is, from the nature conservation viewpoint, a controversial measure, usually used in exceptional cases only, when protection of local populations cannot be secured by other means.

Rescue transfers are divided based on two main viewpoints: (i) target locality of the transfer (existing habitats, new habitats, original locality), (ii) regime of the transfer (single-stage, two-stage transfer).

Ex situ measures are both very complex and complicated and bring many risks. They need to follow particular legislation and should be carried out by a specialized company.

11.4 Following activities

In order to make sure that the compensation measures have been successful, the following activities should be considered:

- Monitoring during and after implementation.
- Incorporating compensation sites in local conservation and land use plans, implying that the sites are protected against future developments.
- Transferring the management of acquired compensation sites to well-established conservation organisations.
- Including management of measures in the overall compensation plan.
- Compensation is more likely to be sustainable at sites requiring minimal management input.
- Attaching contingency measures to compensation plans so that measures will be adjusted if the results are unsatisfactory.

Partial conclusion: Compensation conservation measures, especially creating new spare/replacement habitats should be enforced in all intentions that in some way negatively influence the subjects of protection. Given the fact that even small elements with areas in the order of tens of square kilometres are significant in the landscape, it is advisable to impose compensation measures even in the cases of small projects.

11

12

Monitoring the Impact of Transport on Nature

In order to reach sustainable development of transport infrastructure in the Carpathians, it is necessary to know the real effects of transportation on biota. Monitoring the effects of transportation on biota is an important part of the process of planning, construction, operation and maintenance of transport infrastructure. It provides information about the negative impacts of transportation on nature and feedback on the effectiveness of the applied solutions. By that it significantly contributes to optimisation of construction processes and to effective prevention, reduction or compensation of negative impacts on nature. Chapter 12.1 contains definition of monitoring, its general principles and integration into processes of road planning and implementation. Chapters 12.2 - 12.4 provide a brief overview of main types of monitoring associated with building new transport infrastructure, including used methods, and Chapter 12.5 is devoted to proposal of minimum standards and responsibilities for monitoring.

12.1 General principles

12.1.1 The need for monitoring and its objectives

Objective information about populations of individual species in the surroundings of a transport infrastructure and information about their changes caused by transportation is necessary in order to be able to successfully limit negative effects of transportation on wildlife. Such information can be gained solely by a correctly designed monitoring. The following can only be found out by means of monitoring:

- How many animals really die on roads and what is the effect of this mortality on the populations of respective species.
- How the barrier effect of a linear transport infrastructure becomes evident in populations.
- The disturbing effect of traffic manifested in populations of target species.

Monitoring is also a mechanism that allows planners to check the effectiveness of measures which have been applied in order to reduce the infrastructure's impact on the habitat fragmentation. Monitoring of effectiveness provides an important feedback and allows to:

- Avoid repeating mistakes.
- Provide new information for improving the design of mitigation measures.
- Identify the measures with an optimal relationship between cost and benefit.
- Save money for future projects.

It is therefore clear that monitoring is a basic tool that helps effectively protect wildlife from negative impacts of transportation. Properly designed monitoring is also a tool that ensures maximum effectiveness of funds spent on mitigation measures. For these reasons, it should be of general interest to include monitoring into the process of planning and authorization of transport infrastructure. From this viewpoint, it is important to prepare a recommendation suggesting what type of monitoring and in what extent should represent a general standard for authorization of transport infrastructure in the Carpathian countries.

Fig. 12.1 Annual direct observation using a fixed network of observation sites helps with detecting changes in the bear population in Malá Fatra, Slovakia. © Michal Kalaš

12.1.2 Definition of monitoring

In general, monitoring should consist of regularly repeated measurements of selected variables. An activity can only be called monitoring if the following requirements are met:

- Measurements are standardised.
- The selected variables indicate ecological processes of interest or properties that need to be detected.
- The scale (both in time and space) of measurement is appropriate for the detection of change.

Without clear objectives for monitoring, these requirements cannot be fulfilled. The establishment of these objectives and the selection of methods, standards, scale and criteria for the evaluation of the effectiveness of measures require basic ecological knowledge of the systems affected. Therefore, the involvement of ecologists or wildlife biologists in the design of monitoring schemes is fundamental (COST 341 Handbook).

12.1.3 Designing a monitoring programme

Basic monitoring framework must be part of preparation of each transport infrastructure construction or modernization process. Monitoring programme should be part of the EIA process and should always include:

a. Monitoring the state of biota in the defined territory, performed as three phase monitoring:
   - before construction,
   - during construction,
   - after putting the infrastructure into operation.

b. Monitoring negative effects.

c. Monitoring effectiveness of implemented measures.

The monitoring programme needs to include the entire process from analysis of input materials and setting the goal of monitoring through the description of monitoring processes and methods to setting the form of outputs and recipients of the outputs.

Fig. 12.2 Police data on accidents caused by wildlife provide valuable information about where the species often cross the infrastructure. However, these data usually concern only larger mammals; smaller species that do not cause significant damage to vehicles are usually missing in the police statistics. © Michal Kalaš

12.2 Monitoring the state of biota

It is generally necessary to consider all relevant groups of species while proposing a monitoring programme. Table 12.1. shows the characteristics of particular species groups in relation to monitoring. When preparing a monitoring program, it is necessary to select groups of animals relevant to the specific construction. While for smaller buildings the monitoring can only focus on one or two groups, a wider range of animals should become the target of monitoring for large constructions in a sensitive area.

Fig. 12.3 Monitoring mortality by checking the roads on foot brings findings about the species occurrence, migration routes and helps to identify critical points with frequent road kills. It is always necessary to abide by the safety rules when carrying out this type of monitoring. © Václav Hlaváč

Table 12.1

Monitoring different groups of animals and corresponding possible subjects of evaluations.

No.	Animal category	Subject of evaluation
1	Terrestrial invertebrates	Changes in species composition in selected species (groups) as a result of fragmentation Effect of road edges on species diversity
2	Fishes and other aquatic animals	Changes in species composition as a result of fragmentation (adjustments to watercourses in the surroundings of bridges) Changes in species composition as a result of contamination by road run-off
3	Amphibians	Effects of fragmentation and mortality on abundance Effect of water pollution on reproduction
4	Reptiles	Changes in abundance due to mortality
5	Birds	Mortality caused by traffic Mortality on transparent screens Effect of disturbance on nesting populations
6	Terrestrial mammals up to the size of fox and badger	Changes in abundance due to fragmentation and mortality (the ground squirrel, the badger, etc.)
7	Otter and other semiaquatic animals	Effect of mortality on population abundance
8	Mammals living on trees	Effects of fragmentation and mortality on abundance (edible dormouse)
9	Bats	Effect of noise and light on hunting activity Mortality caused by traffic
10	Medium-sized mammals	Effect of mortality on abundance Identification of critical sections regarding traffic accidents Effect of fragmentation
11	Large Mammals	Identification and use of migration corridors Mortality caused by traffic Effect of fragmentation on populations (monitoring genetic variability) Use of the environment in wider surroundings of construction (telemetry)

Note: When monitoring fauna traffic mortality, it is often necessary to enter the road surface. Especially on motorways, it can lead to the risk of an accident. Safety rules according to the laws of a given country must always be respected during the monitoring process.

Goal

The goal of monitoring is to gain basic expert data set about the development of biota before construction, during construction and in the first phases of operation. Monitoring continues the biological surveys carried out in the phase of road planning (EIA, documentation for planning and building proceedings) and becomes the resource material for further evaluation after a longer period of operation (5, 10 years). The description of changes in biota during the consequential phases: preparation – construction – operation is the first indicator of effects of roads/railways on wildlife.

Fig. 12.4 A lynx equipped by a collar with a transmitter. Data from telemetry tracking provide information about the use of the environment inside the animals´ home ranges, their daily movements and behaviour with respect to the transport infrastructure. Slovakia, Malá Fatra. © Michal Kalaš

Analysis of the issue

Monitoring is based on former surveys and deals with all relevant animal groups that have been determined in the EIA process and other procedures as priorities from the nature conservation point of view. The goal is a complex description of not only development of occurrence and abundance of individual species, but also of entire habitats. Concurrently, it is necessary to identify individual negative factors (see Chapter 12.3) and to monitor their physical or chemical characteristics.

Process of solution

- **Monitoring concept** – a detailed monitoring concept needs to be prepared approximately three years before the planned beginning of construction. It should be prepared based on former biological surveys, migration studies, EIA documentation, statements of state administrations and other expert resource materials. The concept determines target animal groups and priority species that will be dealt with in the monitoring. It also sets physical and chemical environmental factors to be observed (in relation to evaluated animal groups).
- **Selection of locality** – basic localities (for respective groups) to be monitored constantly during the entire period are determined based on the monitoring concept. According to partial results, additional localities can be selected to complement the basic localities.
- **Monitoring the pre-construction phase** – should be initiated minimally 2 years before construction begins (so that results from at least 2 complete vegetation seasons are available). The state of populations of target species or of natural habitats (especially under the Habitats Directive and habitats of nation-

Fig. 12.5 Snow tracking provides data about the occurrence and behaviour of mammals in the area of intended construction. When it is carried out before, during and after construction, results can prove impacts of construction on the occurrence (presence or density) of the given species in an area affected by the construction. © Radu Moț

12

al importance), of supportive and disturbing effects, their detailed map visualization as a base for evaluating changes during construction all need to be ensured and described as part of the pre-construction phase.

- **Monitoring the construction phase** – yearly monitoring according to a unified plan (usually 2-3 years).
- **Monitoring the operation phase** – yearly monitoring according to a unified plan (minimum 2 years of operation).
- **Assessment of the monitoring** – a complex evaluation of the entire series of monitoring. Proposals of measures.

Used methods

The methods used are given by evaluated groups of animals; they can also differ based on the factor, whose effect is being monitored. The most commonly used methods are described in Table 12.2:

Fig. 12.6 Electrofishing is a generally used method of monitoring fish species. It can be used to find out changes in species spectrum, but also changes in density or age structure of individual fish species. Romania. © Radu Moț

Table 12.2

Monitoring fauna before construction, during construction and during operation of a road/railway (so-called three-phase monitoring) – recommended methods for individual animal categories.

No.	Animal category	Common methods of monitoring
1	Terrestrial invertebrates	Special monitoring methods are used for individual groups of invertebrates; their description is beyond the scope of these guidelines. If this animal category is the subject of monitoring, monitoring methods must be proposed by an appropriate expert on the given species (group of species).
2	Fishes and other aquatic animals	Monitoring species composition and the age structure of populations by electrofishing. Other methods are used to monitor the use of fish crossings (fish telemetry, camera and detection systems).
3	Amphibians	Using special life-traps – inventorying of newts in aquatic environment Capture-recapture method – allows to estimate abundance Inventorying of amphibians migrating along barriers Monitoring mortality on critical road sections *
4	Reptiles	Visual control of suitable habitats in suitable weather conditions Checking potential hiding spots including artificial ones Monitoring mortality on roads and bicycle paths *
5	Birds	Common methods of qualitative and quantitative surveys Acoustic monitoring with the use of electronic records of bird voices Monitoring nesting density in a selected area (for example owls, waterfowl) Monitoring bird mortality caused by traffic (on-foot checking) * Monitoring bird mortality on transparent screens (on-foot checking) *

No.	Animal category	Common methods of monitoring
6	Terrestrial mammals up to the size of fox and badger	Using special traps for capture of small mammals (mice, voles, insectivores) Analysis of owl pellets from the selected area Hair traps (wildcat) Cameras and phototraps Snow tracking (mustelids, fox, hare, rabbit, etc.) Direct observation (ground squirrel, hare, etc.) Monitoring mortality on roads *
7	Otter and other semiaquatic animals	Checking for signs of residence (spraints - excrements) under bridges over watercourses Monitoring tracks on snow – allows not only to prove the presence, but also to determine the abundance of the given species in the selected area (for determination of abundance only fresh "one-day-old" snow needs to be used) Cameras and phototraps Monitoring mortality on roads *
8	Mammals living on trees	Tracks on snow (squirrels, martens) Direct observation (squirrels) Analysis of owl pellets (the hazel dormouse, dormice) Hair traps (the hazel dormouse, dormice) Cameras and phototraps Special life-traps (dormice, the hazel dormouse) Acoustic monitoring in the summer (the edible dormouse) Monitoring forage residues (spruce cones, hazelnuts) – it is possible to determine the originator (dormice, the hazel dormouse, squirrels) Installation and checking of bird nesting boxes or special tubes (dormice, the hazel dormouse)
9	Bats	Using bat detectors (devices able to record ultrasound displays of bats and to determine species based on that) Trapping to nets Checking wintering sites and known summer colonies of bats Direct observation (often impossible to reliably determine the species) Monitoring road mortality *
10	Medium-sized mammals	Direct observation Tracking on snow and mud Cameras and phototraps Monitoring mortality on roads *
11	Large mammals	Tracking on snow and mud Phototraps and cameras Direct observation (bear – long-term network of observation places in the autumn) Telemetry Genetic analyses – it is possible to determine individuals and their relations or population abundance from found excrements/hairs Monitoring mortality on roads *

* Monitoring mortality is a standard method for road upgrading and for monitoring the effects of measures to reduce mortality rates. It can however be added as a supplement to 'three-phase monitoring' of the effects of new constructions on biota.

(see the note to table 12.1. – respecting the safety rules when monitoring mortality)

case study

Genetic monitoring of the wolf in Slovakia proved the existence of live subpopulations

Within western Carpathians, apparent differentiation of particular wolf subpopulations has been observed, as a consequence of topographic heterogeneity and 'sky island' biogeographic model, combined with admixture with the lowland population (orange and red symbols). However, anthropogenic effects including fragmentation could facilitate these patterns, especially higher dispersal resistance of valleys, characterized by high abundance of human settlements, linear barriers to gene flow and deforestation (Huck et al. 2010, 2011). For example, distribution of several genetic clusters is limited by the main motorway that crosses the Western Carpathians. Although wolves are not necessarily forest dwellers, recent forest transition in higher altitudes may strengthen genetic isolation of particular subpopulations. Regions: 1—Beskydy, 2—Orava, 3—Malá Fatra, 4—High Tatras, 5—Low Tatras, 6—Slovakian Central Mountains, 7—Levočské Mountains & Čergov Massif, 8—Slovak Paradise, 9—Slánské Mountains and 10—Poloniny.

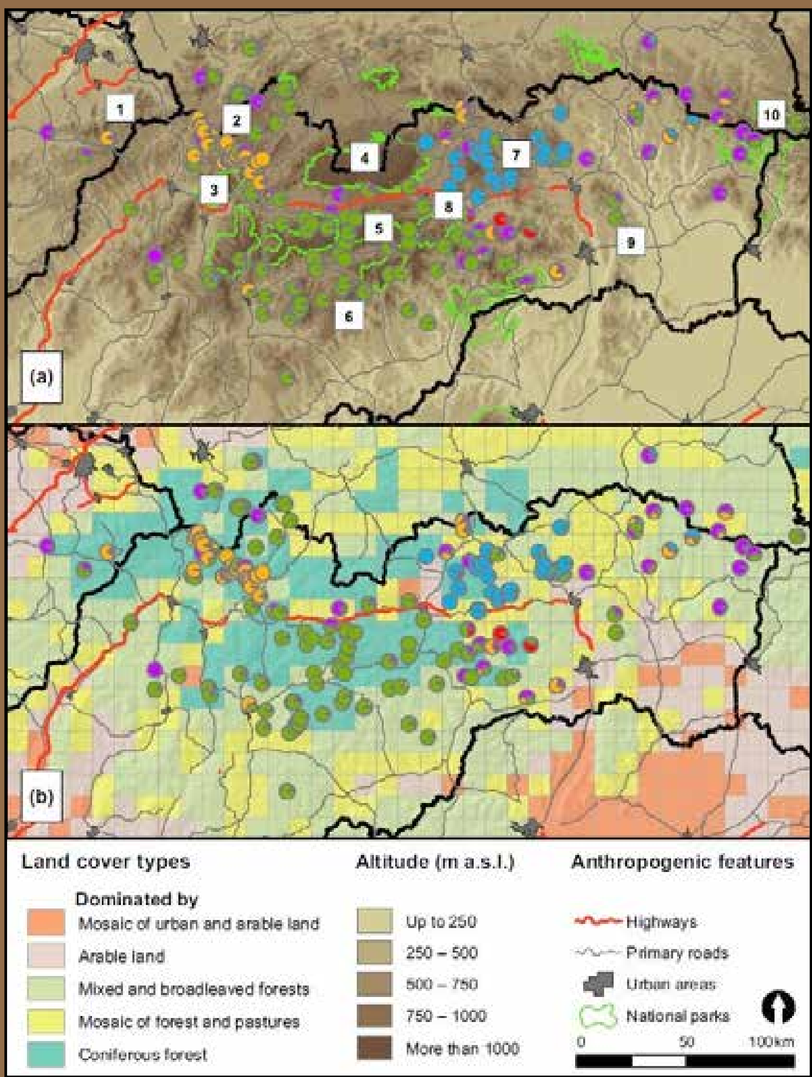

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Fig. 12.7 Genetic monitoring of the wolf in Slovakia proved the existence of five subpopulations. © Hulva et al. (2018)

Recommended organization:

- Financing of monitoring is the responsibility of the investor.
- Monitoring programme is prepared by the investor (during EIA process) and is approved by the nature conservation authority.
- Contractor (implementor) of monitoring is chosen by the investor and the nature conservation authority participates in this process of selection.
- Both the investor and nature conservation authority obtain the monitoring results, they together agree on the form of their release.

Fig. 12.8 Monitoring otter excrements under bridges is a standardly used method. It brings information about the presence of the species and about the frequency of use of a given underpass. DNA analysis of the excrements allows to identify individuals and set their number in the observed area. © Václav Hlaváč

12.3 Monitoring individual negative effects of transportation

Transportation affects biota in many ways (see Chapter 4). While monitoring, it is necessary to quantify physical or chemical influence of each factor, so that a base for comparison to changes in the abundance and species composition of biota is created. Evaluation of negative factors must be integrated as part of monitoring the state of biota in the preparation phase, construction phase and implementation phase (three-phase monitoring). Also, in specific cases, it can be further incorporated into individual separate studies only partially focused on the current issue. Basic methods that can be used to monitor different potential negative effects of transportation on wildlife are described in Table 12.3.

Fig. 12.9 Monitoring the barrier effect of roads can be done by snow tracking. Checking tracks on both sides of a road or motorway can clarify how many animals are discouraged, how many killed and how many successfully pass the infrastructure. © Václav Hlaváč

Table 12.3

Potential negative effects of transportation and possibilities to monitor them.

Influencing factor:	Characteristics of monitoring:
Elimination and transformation of habitats	Development of landscape cover in wider surroundings of the infrastructure is monitored – intensity and way of use, housing development, occurrence of barriers such as fences (map resources, aerial imaginary).
Fragmentation of populations and habitats	Genetic variability of populations on both sides of an infrastructure.
Mortality	Deaths of animals on roads due to collisions with vehicles should be monitored in most groups such as amphibians, otters, medium-sized and large mammals. Methods of evaluation: direct monitoring of mortality on roads, police statistics of accidents, questionnaires for drivers, online databases, etc. Monitoring the effectiveness of fences and barriers for amphibians is linked to mortality. Parameters of traffic (intensity, daily distribution, composition of traffic flow) and parameters of infrastructure (category, width, crash barriers, fencing, etc.) are monitored as input factors (see the note to Table 12.1. – respecting safety rules).
Noise disturbance	Initial input is noise measurement. Connection with hunting activity of bats, nesting occurrence of owls, waterfowl, etc.
Soil pollution	Initial input consists of dispersion studies; basic monitored component is the soil contamination (Na, Cl, heavy metals, polycyclic aromatic hydrocarbons, etc.). Development of soil contamination provides the best overview of cumulative effects of transportation and should be part of three-phase monitoring. Sensitive groups: soil invertebrates, potential effect on insects and others.
Water pollution	The effect lies in the contamination of water by petroleum substances, road salts and other contaminants from traffic (heavy metals, polycyclic aromatic hydrocarbons, etc.). Water quality in a watercourse above and below the point of mixing with road runoff, or in wetlands near the infrastructure are monitored as the initial figure. In the case of the aquatic animal species composition, quantitative representation or reproductive cycle (amphibians) is evaluated.

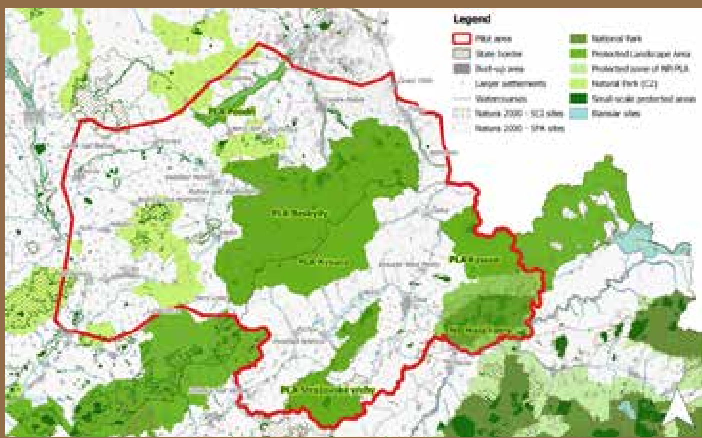
Fig. 12.10 Monitoring mortality in the Czech Republic has shown that it is very high in road sections with a noise protection wall installed only on one side of the infrastructure. Animals try to cross the road, but have to go back because of the barrier, which increases the risk of an accident. © Václav Hlaváč

case study

Monitoring of fauna traffic mortality in trans-boundary area of the Western Carpathians (CZ-SK)

The Western Carpathians area on the border between the Czech and Slovak Republic is characterised by high density of the road network. The roads of European importance (AGR agreement) with high traffic intensity cause the barrier effect, which is most evident in the form of animal mortality. The TRANSGREEN study focused on recording the vertebrate mortality on selected roads in order to identify critical points of frequent animal collisions with passing vehicles. A total of 1,364 killed animals of 49 species were recorded between April 2018 and March 2019 over the whole model area. There were 608 findings in the Czech Republic and 756 in Slovakia. The most common species surveyed were: the hedgehog (155 ex.), the hare (110 ex.) and the squirrel (106 ex.). Based on clustering data analysis (KDE +) (Bíl M. et al. 2016), 10 critical sites for middle-sized mammals (such as the fox, the marten and the badger) were identified; 12 sites for birds; 5 for hare; 4 for amphibians and 3 critical sites for reptiles. For some identified critical sites, measures to reduce the impact of transport on animals have been developed as part of the Catalogue of Measures to introduce the problem for the responsible authorities.

Identification of the model area



The share of individual categories in the recorded road-kills

Animal category	No. of records	Share
Amphibians	118	8.7 %
Reptiles	66	4.8 %
Birds	198	14.5 %
Small mammals	737	54.0 %
Semiaquatic mammals	22	1.6 %
Squirrel	119	8.7 %
Bats	12	0.9 %
Middle-sized mammals	79	5.8 %
Large Mammals	10	0.7 %
Not identified	3	0.2 %
Total	1,364	100 %

Example with mortality monitoring results – NP Malá Fatra (Slovakia)

Fig 12.11 Monitoring of fauna traffic mortality in transboundary area of the Western Carpathians (CZ-SK). © Ivo Dostál

12.4 Monitoring effectiveness of implemented measures

Measures to ensure the permeability of transport infrastructure and to reduce the mortality of fauna are currently already a standard part of most transportation constructions. However, a fundamental issue constitutes the fact that there is often no verification as to whether the measure really fulfils the purpose for which it was implemented. These gaps in information are caused mostly by no clearly set goals for the implementation of such measures; their fulfilment is therefore not checked either. Authorities responsible for infrastructure construction usually perceive measure implementation as a formal obligation and do not have any interest in checking their effectiveness. As a consequence of these situation flaws, malfunctions of the implemented measures are not often detected. Therefore, measures not fulfilling their purpose can be repeated. The goal of monitoring effectiveness is to bring an important feedback that allows for elimination of errors and flaws. Thanks to this feedback, it is then possible to increase effectiveness of funds spent on fauna protection in the construction of transport infrastructure. Monitoring the effectiveness of implemented measures should therefore be in the interest of not only nature protection authorities, but also investors. Monitoring the effectiveness of fauna passages or monitoring the effectiveness of measures reducing mortality is typically carried out as part of the effectiveness monitoring.

12.4.1 Monitoring effectiveness of fauna passages

Goal

The goal of monitoring effectiveness of fauna passages is to gain feedback on if and to what extent implemented measures serve their purpose. These findings are essential in order to detect errors/flaws and non-functional measures, to correct the deficiencies identified and as a consequence help reach better results with the same amount of funds.

Analysis of the issue

Fauna passages – both single-purpose and multi-purpose – represent a basic measure to avoid fragmentation of populations. The first step to verify their functionality is to find out if the passage is used by target species or not. Nevertheless, this piece of information is usually insufficient to assess the impacts of the measure on the entire populations. It is therefore neces-

Fig. 12.12 The most common method in assessing the efficiency of fauna passages is the use of phototraps. They must be installed not only in the passage itself, but also in its surroundings. This enables to verify which animals have not used the passage. © Michal Kalaš

Fig. 12.13 The use of small underpasses by fauna can be easily monitored by means of phototraps. It provides information about what species and at what frequency actually pass through. © Václav Hlaváč

12

sary to also monitor the frequency of use (that is how many animals use the passage in a single unit of time). Even this figure need not be sufficient – there are for example known cases of only a limited number of local individuals using the passage with a high frequency. The overall frequency of use then seems to be high but benefit for the particular population can be very low. It is for this reason advisable to deal with the question of how many different individuals actually use the passage. Such data are essential for evaluating the quality of the given fauna passage. If a passage is widely used by a high number of individuals of the target species, it can be concluded that it was technically well designed and correctly placed. On the other hand, low frequency of use or a small number of individuals suggest that the passage was not rightly placed or technically designed (insufficient dimensions, disturbance, unsuitable material, unsuitable guiding structures, other barriers limiting the access, etc.). In such a case it is necessary to monitor the behaviour of animals near the passage in more detail and by that clarify the reasons why they do not use the passage.

ATTENTION!!! It is important to keep in mind that the frequency of using a fauna passage in the case of rare species inhabiting large areas in low densities (large carnivores, moose) can be very low (for example just a few individuals during several years). This is true especially for migration corridors of large carnivores outside of their permanent distribution areas, since maintaining the permeability of these corridors is essential for long term survival of the populations. In such cases the absence of the target species during the monitoring period cannot be viewed as a reason to report a negative evaluation of the given passage.

The abovementioned monitoring of effectiveness of implemented measures is always related to the functionality of a specific fauna passage. However, the general goal while ensuring the permeability of the newly built infrastructure is not just a well-functioning fauna passage, but firstly it is about avoiding fragmentation of populations. The question then arises whether such a well-functioning fauna passage is a sufficient solution for the long-term survival of a population. (A contrary question can be whether ten suggested fauna passages are not needless, when perhaps half of this number of passages is sufficient for the connectivity of populations). It is very complicated to find an answer to this question. The consequences of fragmentation can become evident first in a long-term horizon (high tens or hundreds of years), but meanwhile, other significant influences – currently difficult to anticipate – will likely be asserted. Moreover, the fragmentation of populations cannot be evaluated only based on the level of genetic variability (so called 'sink' part of a population can, when isolated, disappear even in case its genetic capability is still good).

Fig. 12.14 Phototraps allow to record numbers of individuals using the fauna passage, direction of their movement, and in some cases even individuals repeatedly using the passage can be recognized. Overpass on D1 near Dolní Újezd, the Czech Republic. © Friends of the Earth, Czech Republic

Fig. 12.15 Checking tracks in snow at the edge of an underpass gives a good overview about the use of fauna passages. However, using this method is limited only to days with an optimal snow cover. © Václav Hlaváč

Fig. 12.16 Given the fact that the goal of building fauna passages is to prevent the fragmentation of populations, it is necessary to gain data about the state of the target species in wider surroundings. Telemetry tracking of bears provides information on how they use their environment, including behaviour of individuals in relation to transport infrastructure. NP Malá Fatra, Slovakia. © Michal Kalaš

Assessing the effectiveness of fauna passages with respect to impacting populations is methodically a complicated task, which cannot be completely solved by a standard monitoring of effectiveness of fauna passages. In order to clarify these impacts, it is necessary to extend the monitoring by also following the development, social and the genetic structure of the given population. These forms of monitoring often require specialized processes, including expensive equipment (telemetry tracking of individuals, genetic analyses, etc.). Furthermore, development of a population is always given by many different factors; therefore, a multidisciplinary approach to clarifying the dependence between transport infrastructure and state of population is necessary. This already clearly exceeds the financial and capacity possibilities of standard processes of monitoring effects of transportation on wildlife. For this reason, this type of evaluation has been so far in practice applied rather in the form of expert or scientific studies that are assigned only in selected 'model cases'.

Process of solution

- Programme for monitoring effectiveness should be worked out and assessed within the EIA process. It is necessary to select measures for monitoring. It should basically contain all measures aimed above all at ensuring the permeability of transport infrastructure for fauna. However, more extensive multi-purpose measures, in which ensuring permeability is only one of the purposes, can be included as well. If a greater number of small measures exist in a given section, for example adapted culverts, it is possible to choose only some of them for monitoring as a sample.
- All measures to ensure permeability should have a clearly defined goal, especially for what animal groups they are built and what use is expected. The extent and goal of monitoring is then set based on this information.
- The area range of monitoring is determined based on types of measures and target species. It can be just a fauna passage itself, but

more often it is suitable to monitor even the surroundings of the fauna passage, so that it is clear whether and in what abundance target species occur here. Given the fact that the goal of building a fauna passage can be a reduction in mortality in its surroundings as well, it is advisable to widen the range of monitoring to the adjacent part of the road.

Fig. 12.17 The use of narrow underpasses can be monitored with the help of specially prepared mud boards. It is possible not only to determine species from the tracks, but a computer analysis can in some species even distinguish among individuals. Tracks of a European Polecat. ©Václav Hlaváč

- Time frame of monitoring is set. Monitoring the use for first three years is recommended as optimal. After that it is desirable to repeat the monitoring at least once every five years.
- It is not possible to make only the animals themselves the subjects of monitoring, it is also necessary to follow changes in land-use in wider surroundings of a fauna passage.
- The means of processing the gained results and of their distribution must also be part of the monitoring programme of each measure.

Used methods

In monitoring the effectiveness of the implemented measures, methods given by the evaluated groups of animals are used as well. The most frequently used methods are summarized in Table 12.4.

12.4.2 Monitoring effectiveness of fences

Goal

The goal of monitoring the effectiveness of fences is to gain feedback on if and to what extent fences serve their purpose. These findings are essential in order to detect errors/flaws and non-functional measures and as a consequence help reach better results with the same amount of funds.

Analysis of the issue

Fences are usually installed along four-lane roads and high-speed railways, but sometimes even first-class roads are fenced. The main goal of fencing is ensuring the traffic safety and eliminating collisions with animals, especially with those that can cause serious accidents or in other ways threaten the traffic safety. The second accompanying goal is animal protection. Experience shows that many fences are built in a way that is not functional. There are many causes for this state – unsuitable position of fences, low quality of material, bad anchorage to surface, poor connection to bridge objects or failure due to insufficient maintenance. Animals in such cases easily get inside the fenced area and a number of collisions can then be similar to those in unfenced sections. It also needs to be counted with the fact that if only a selected section is fenced, animals try to go around the barrier. As a consequence, high mortality may just move from a specific section to its bordering sections. It is also important to emphasize that even rightly installed fences need not fulfil its function for 100% - for example the lynx will be able to overcome most fences. Fences are built either as part of the transport infrastructure construction or additionally in order to increase the traffic safety. In the former case it is usually counted with the fact that a sufficient number of fauna passages has to be placed. If, however, additional fencing is being implemented in sections where no passages exist yet, a serious issue arises, as the road becomes a total barrier. It is therefore clear that monitoring the effects of fences needs to get permanent attention.

Table 12.4

Monitoring the effectiveness of fauna passages – recommended methods for individual categories of species.

No.	Animal category	Common methods of monitoring
1	Terrestrial invertebrates	Special monitoring methods are used for individual groups of invertebrates; their description is beyond the scope of this handbook. If this animal category is the subject of monitoring, relevant methods must be proposed by an appropriate expert on the given species (group of species).
2	Fishes and other aquatic animals	Monitoring the use of fish crossings: fish telemetry, camera and detection systems Monitoring species composition and age structure of populations by electrofishing
3	Amphibians	Monitoring mortality on critical road sections Visual inventory of amphibians migrating along barriers Visual inventory of amphibians migrating through an amphibian tunnel Capture-recapture method (marking individuals on one side, control capture on the other side)
4	Reptiles	Visual control of suitable habitats in suitable weather conditions Checking potential hiding spots including artificial ones Monitoring mortality
5	Birds	-
6	Terrestrial mammals up to the size of fox and badger	Cameras and phototraps Recording animal tracks on beds of sand, mud or powdered marble (only underpasses) Recording footprints with ink beds (only underpasses) Snow tracking Monitoring mortality on roads
7	Otter and other semiaquatic animals	Cameras and phototraps Checking for signs of residence (excrements, markings) under bridges over watercourses Monitoring tracks on snow and mud Monitoring mortality on roads
8	Mammals living on trees	Cameras and phototraps
9	Bats	Using bat detectors (devices able to record ultrasound displays of bats and to determine species based on that) Comparison of number of flights over a motorway and using an overpass or underpass
10	Medium-sized mammals	Cameras and phototraps Tracking on snow and mud
11	Large mammals	Cameras and phototraps Tracking on snow and mud Telemetry Genetic analyses (recommended) Monitoring mortality on roads

(see the note to Table 12.1. - respecting safety rules when monitoring mortality)

Process of solution

- If fencing is part of the transport infrastructure construction, its effect is monitored within basic three-phase monitoring. Increased attention should be paid to monitoring mortality (always also in connecting sections).
- When construction of fencing continues a fauna passage, the function of fencing is evaluated within monitoring the effectiveness of the fauna passage.
- If fencing is planned additionally on the existing infrastructure, it is necessary to prepare a separate monitoring programme for this intention, including optimally two years of monitoring the given section before building the fence and two years of monitoring after its installation.
- Monitoring needs to be properly designed so that it provides information about the effects of fencing on mortality, but also whether the barrier effect has increased or not.

Fig. 12.18 Monitoring the efficiency of fences is a difficult question with respect to methodology. When assessing fences, it is necessary to keep in mind that they can just transfer mortality to other unfenced sections. Moreover, the function of fences is always linked with the function of fauna passages, which eliminate the barrier effect of fences. © Václav Hlaváč

Fig. 12.19 Artificial animal light deterrent equipped on a roadside post. The reflective element reflects light from an approaching car to the road side and by that warns the animals. Decrease of animal traffic mortality due to such light deterrents has so far not been satisfactorily confirmed. Beskydy, the Czech Republic. © Martin Strnad

Methods used

- Monitoring mortality – is carried out before and after the installation of fences.
- Registering the proportion of animals that succeed in crossing the transport infrastructure – is carried out by checking for tracks in snow by two workers – on both sides of the infrastructure (alternatively by using a drone), this is fundamental before the fence installation.
- Monitoring the behaviour of animals along the fence (snow tracking, phototraps).

12.4.3 Monitoring of artificial deterrents

Goal

The goal of monitoring the effectiveness of artificial deterrents is to gain feedback on if and to what extent such deterrents serve their purpose.

Analysis of the issue

Noise, light or scent deterrents seem to be a very suitable and economically modest solution, especially for two-lane roads and for railways. Light and noise deterrents are based on activation by the coming vehicle (train) and animals have time to leave the dangerous area. Scent deterrents function permanently, they do not react to the passing vehicles, but should inform the animals that they are moving through a "dangerous area" and should leave it as fast as possible. Therefore, the general principle of this solution is to allow animals to cross the road/railway while maximally lowering the risk of collision. Practice has so far shown that the effectiveness of these tools is more often presented as an advertisement by their producers rather than as results of expert studies or long-term monitoring.

Therefore, monitoring the effectiveness of these warning tools is very much needed. If a certain type is proven to have sufficient effectiveness, it could become a very useful and inexpensive solution.

Process of solution

In order to demonstrate the effectiveness, it is suitable to carry out monitoring of mortality:

- At the same locality at least one year before and one year after installing the deterrents,
- At several comparable localities from which half will be equipped with the deterrents and half not.

> **ATTENTION!!!** Given the fact that road mortality – especially in species such as the roe deer or the wild boar – changes with current composition of agricultural crops, it is necessary to select a method that eliminates the influence of these disturbing factors on gained results.

Used methods

Monitoring methods in this case rest in recording animal mortality on roads equipped with artificial deterrents and on control roads without these tools. Mortality can be monitored:

- By a pedestrian control along the road (railway) – provides the most accurate results, but is the most time-consuming.
- By a bicycle-ride control – can only be done on lower class roads.
- By a car-ride control – the least accurate, many details are missed, but is time-saving, enables to monitor large extent of sections.
- Frequency of controls: in case of sufficient capacity everyday control is optimal, it can however be lowered down to one control per week.
- Focus of monitoring: only mammals are a relevant group for monitoring the effectiveness of warning systems/artificial deterrents.

Besides the types of monitoring described above, other types of monitoring often need to be carried out in practice, for example:

- Effects of transparent screens on bird mortality.
- Effects of noise-protection walls on the use of fauna passages.
- Level of road mortality in a specific species (what percentage of population is killed on roads).
- Effects of technical elements and parameters on animal mortality (notches, embankments, crash barriers, etc.).
- Effects of trees and bushes on road edges on mortality of individual species.
- Effects of road edges on spreading of non-native species.
- Effectiveness of barriers and passages for amphibians.
- Effects of a watercourse (due to a bridge object) on fishes and other aquatic animals.

It is advisable to plan these activities based on monitoring schemes mentioned above, always with regard to specific goals and conditions in a given situation.

12.5 Standards and responsibility for monitoring

As mentioned above, monitoring is an essential tool in improving the functionality of measures designed to protect fauna and in increasing the effectiveness of funds spent on these measures. It is therefore necessary that monitoring becomes a mandatory part of the decision-making processes and authorizing constructions and reconstructions (modernizations) of transport infrastructure. At the same time, standards for minimum extent of monitoring to always be ensured need to be set.

There are many decision-making processes relating to transport infrastructure. They are not always about authorizing new constructions, even modernizations (upgrading) of the existing infrastructure have significant impacts on nature. However, often only individual measures, such as fencing of the existing road, noise-protection walls, equipping with crash barriers, vegetation adjustments, etc., are the subject of authorization. Also, additionally built measures on current infrastructure (fauna passages, etc.) are implemented more and more frequently. Moreover, even measures relating to the traffic itself can impact fauna – for example changes in speed limits, etc.

The recommended minimum standards of monitoring for basic types of construction are provided in the next part. In case only partial adjustments are being decided or there is a combination of more decision-making processes, it is necessary to prepare the monitoring programme individually. The following standards can then serve as methodical guidance.

It should be emphasized that standards only relate to monitoring that has been assigned as a condition for construction authorization or as a measure – it is so called **'mandatory monitoring'.** Based on the specific needs and financial possibilities, the environmental and transportation authorities can assign other studies and monitoring activities as well, which do not directly continue the decision-making about new constructions – this is so called **'above-standard monitoring'**. It is represented for example by:

- Scientifically demanding monitoring that exceeds the standard monitoring frame (for example monitoring long-term effects of a motorway on genetic structure of populations on both sides of the motorway, using methods of satellite telemetry, etc.).
- Effects of disturbance by traffic on wildlife during operation on existing roads.
- Identification of places with increased fauna traffic mortality on existing roads.

The extent of this monitoring is determined by its contracting authority.

12.5.1 Standards of minimum extent of monitoring

Minimal extent (standard) of monitoring set for new constructions and reconstructions (upgrading) of transport infrastructure and for implementation of measures that are subject to an authorization process is shown in Table 12.5.

Table 12.5

Overview of recommended minimum extent of monitoring for different types of constructions.

Type of construction	Minimum extent of monitoring	Minimum monitoring period
New constructions	Monitoring fauna before, during and after starting operation of the construction – "three-phase monitoring" (recommended methods are described in Table 12.2). Monitoring impacts of construction (noise, soil pollution, water pollution).	2 years before construction, during construction, 2 years after construction is finished 2 years after construction is finished
Upgrading	▪ Three-phase monitoring reduced according to real needs. ▪ Registering the proportion of animals that succeed in crossing the transport infrastructure. ▪ Fauna traffic mortality.	2 – x – 2
Fauna passages	Effectiveness of fauna passages – (recommended methods are described in Table 12.4).	3 years after operation starts and then every fifth year
Fences and other barriers	▪ Registering the proportion of animals that succeed in crossing the transport infrastructure. ▪ Fauna traffic mortality.	2 – x – 2

12.5.2 Responsibility for monitoring

A fundamental requirement in organizing monitoring is the need for cooperation of both transportation and nature conservation authorities (and other involved organizations in these sectors) on its preparation, implementation and using its results. If the monitoring was ensured by only one side, it is very likely that the results would not be reliable for the other side. Unfortunately, even cases when each of these sides organizes and finances its own monitoring are known from practice. Such a system is not effective, needless duplicities in work arise and as a final consequence this way does not lead to needed cooperation.

The following principles apply to new constructions and reconstructions where minimal extent of monitoring (mandatory monitoring) is set:

- **Monitoring is financially ensured by investor of the construction.**
- **Preparation of monitoring programme must be based on knowledge about ecological conditions in a given area, therefore the preparation is to a large extent a task for nature conservation authority – it discusses and approves the proposed plan with investor.**
- **Contractor (implementor) of monitoring is usually selected based on competitive tendering that belongs to the responsibility of investor. Investor invites nature conservation authority to participate in the competitive tendering.**
- **Partial monitoring results are presented to both investor and nature conservation authority.**
- **Final report is handed over to both investor and nature conservation authority, and they together decide about its release.**

The extent and means of above-standard monitoring will always depend on its contracting authority. However, even in these cases, the exchange of information between the transportation and environmental sectors is very much needed.

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13

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Project Partners

Austria – WWF Central and Eastern Europe (former WWF DCP, project lead)
Czech Republic – Friends of the Earth Czech Republic – branch Olomouc, Nature Conservation Agency, Transport Research Centre
Hungary – CEEweb for Biodiversity
Romania – Association “Milvus Group”, WWF Romania
Slovakia – National Motorway Company, State Nature Conservancy of the Slovak Republic, SPECTRA – Centre of Excellence of EU – Slovak University of Technology in Bratislava

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Austria – Ministry for Transport, Innovation and Technology
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Poland – Ministry of Infrastructure and Construction
Romania – Ministry of the Environment, Ministry of Transport
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