BIODIVERSITY AND INFRASTRUCTURE SYNERGIES AND OPPORTUNITIES FOR EUROPEAN TRANSPORT NETWORKS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 101006661.

Deliverable D5.3

Development and use of the European Defragmentation Map

Due date of deliverable: 30/06/2023

Actual submission date: 23/06/2023

Project details

Project acronym	BISON
Project full title	**B**iodiversity and **I**nfrastructure **S**ynergies and **O**pportunities for European Transport **N**etwork
Grant Agreement no.	101006661
Call ID and Topic	H2020-MG-2020 / MG-2-10-2020
Project Timeframe	01/01/2021 – 30/06/2023
Duration	30 Months
Coordinator	ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS (CERTH/HIT)

Document details

Title	Development and use of the European Defragmentation Map
Work Package	WP5
Date of the document	23/06/2023
Version of the document	Final version after successful review
Responsible Partner	Cindy Baierl (Uni Kassel), Heinrich Reck (CAU) & Marita Böttcher (BfN) and for special chapters, in cooperation with Mathias Herrmann, Vaclav Hlavac, Holger Meinig, Henning Nissen, Franziska Peter, Martin Strein, Jürgen Trautner & Manuel Weidler
Reviewing Partner	CEREMA (Eric Guinard), ZARAND (Radu Mot)
Status of the document	Final
Dissemination level	Public

Document history

Revision	Date	Description
01	30.05.2022	Extensive workshop paper
02	25.5.2023	First Draft
03	31.5.2023	Second Draft
04	23.6.2023	Revised report

CONSORTIUM - LIST OF PARTNERS

Partner no.	Short name	Name	Country
1	FEHRL	FORUM OF EUROPEAN NATIONAL HIGHWAY RESEARCH LABORATORIES	Belgium
2	MTES	MINISTERE DE LA TRANSITION ECOLOGIQUE ET SOLIDAIRE	France
3	CERTH/HIT	CENTER FOR RESEARCH AND TECHNOLOGY HELLAS	Greece
4	CDV	CENTRUM DOPRAVNÍHO VÝZKUMU- TRANSPORT RESEARCH CENTER	Czech Republic
5	UGE	UNIVERSITÉ GUSTAVE EIFFEL	France
6	SPW	SERVICE PUBLIC DE WALLONIE – DIVISION MOBILITE – INFRASTRUCTURES	Belgium
7	UPGE	UNION PROFESSIONNELLE DU GENIE ECOLOGIQUE	France
8	UIC	INTERNATIONAL UNION OF RAILWAYS	France
9	CEREMA	CENTRE D'ETUDES ET D'EXPERTISE SUR LES RISQUES, L'ENVIRONNEMENT, LA MOBILITE ET L'AMENAGEMENT	France
10	Agristudio	AGRISTUDIO	Italy
11	WWF RO	WWF ROMANIA	Romania
12	UKF	FAKULTA PRÍRODNÝCH VIED - UNIVERZITA KONŠTANTÍNA FILOZOFA V NITRE	Slovak Republic
13	BMK	BUNDESMINISTERIUM FUER VERKEHR, INNOVATION UND TECHNOLOGIE	Austria
14	AMPHI	AMPHI CONSULT	Denmark
14a	FPP	FPP - WITH AMPHI CONSULT	Poland
15	FRB	FONDATION POUR LA RECHERCHE SUR LA BIODIVERSITE	France

16	UNILIM	CENTRE DE RECHERCHES INTERDISCIPLINAIRES EN DROIT DE L'ENVIRONNEMENT DE L'AMENAGEMENT ET DE L'URBANISME - EQUIPE THEMATIQUE DE L'OBSERVATOIRE DES MUTATIONS INSTITUTIONNELLES ET JURIDIQUES - UNIVERSITE DE LIMOGES	France
17	OFB	OFFICE FRANÇAIS DE LA BIODIVERSITE	France
18	BAST	BUNDESANSTALT FUER STRASSENWESEN	Germany
19	BMVI	BUNDESMINISTERIUM FUER VERKEHR UND DIGITALE INFRASTRUKTUR	Germany
20	ZARAND	ASSOCIATA ZARAND	Romania
21	UASVM-CN	UNIVERSITATEA DE STIINTE AGRICOLE SI MEDICINA VETERINARA CLUJ NAPOC	Romania
22	GDDKIA	GENERALNA DYREKCJA DROG KRJAOWYCH I AUTROSTRAD	Poland
23	STUBA	SLOVENSKA TECHNICKA UNIVERZITA V BRATISLAVE	Slovak Republic
324	MINUARTI A	MINUARTIA	Spain
25	SLU	SVERIGES LANTBRUKSUNIVERSITET	Sweden
26	AWV	BRUSSELS AREA, BELGIUM - AGENTSCHAP WEGEN EN VERKEER	Belgium
27	CAU	UNIVERSITY OF KIEL	Germany
28	UNI KASSEL	UNIVERSITY OF KASSEL	Germany
29	BfN	BUNDESAMT FÜR NATURSCHUTZ	Germany
30	ARMSA	ARMSA	Poland
31	IP	INFRAESTRUTURAS DE PORTUGAL SA	Portugal
32	MDPAT	MINISTERSTVO DOPRAVY A VÝSTAVBY SLOVENSKEJ REPUBLIKY	Slovak Republic

33	ASTRA	FEDERAL DEPARTMENT OF THE ENVIRONMENT, TRANSPORT, ENERGY AND COMMUNICATIONS - FEDERAL ROADS OFFICE	Switzerland
34	NTIC	NETIVEI ISRAEL - NATIONAL TRANSPORT INFRASTRUCTURE COMPANY LTD	Israel
35	NCA	NATURE CONSERVATION AGENCY OF THE CZECH REPUBLIC	Czech Republic
36	RWS	MINISTERIE VAN INFRASTRUCTUUR EN WATERSTAAT - MINISTRY OF INFRASTRUCTURE AND WATER MANAGEMENT	Netherlands
37	TII	TRANSPORT INFRASTRUCTURE IRELAND	Ireland
38	Egis SE	EGIS ENVIRONNEMENT	France
39	TRV	SWEDISH TRANSPORT ADMINISTRATION - TRAFIKVERKET	Sweden
40	DTES.GEN CAT	DEPARTAMENT DE TERRITORI I SOSTENIBILITAT. GENERALITAT DE CATALUNYA	Spain
41	ANAS	ANAS (Italian road management authority)	Italy

ABBREVIATIONS

Most important

EDM	European Defragmentation Map
r+d	research and development
TI	Transportation Infrastructure

All

BfN	Federal Agency for Nature Conservation (Bundesamt für Naturschutz) = German Federal Government's central authority for national and international nature conservation
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit) =now Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)
CBD	Convention on Biological Diversity
CDDA	Common Database on Designated Areas
CMS	Content Management System
Corr	Corridor; see terms; e. g. ecological corridor vs mobility corridor vs verges as corridors etc.
DG ENV	Directorate-General for Environment =Commission department responsible for EU policy on the environment
EDF-corridor	European defragmentation corridor
EDM	European Defragmentation Map
EIA	Environmental Impact Assessment
EUNIS	European Nature Information System
FA	Functional area unit (area units wherein populations are functionally connected)

FP / fp	Fauna passage(s)
GI	Green infrastructure
Habitat-Net	GIS Algorithm for identifying Habit networks by a distance mirrorfront model
IENE	Infra Eco Network Europe
IA	Impact Assessment
IR	Impact regulation (see e. g., chapter mitigation hierarchy)
IUCN	International Union for Conservation of Nature
IWW	Inland Waterway
LDD	Long Distance Dispersal
LDDV	Long Distance Migration by Vectors
LDM	Long Distance Migration
MTES	French Ministère de la Transition écologique et solidaire
NHP	National Highway Plan
n.p.	not published (yet)
pSCI	proposed Site of Community Importance
PVF	photovoltaic facility, pv facilities
PV-GMS	photovoltaic ground-mounted systems
q.v.	Quod vide (for which see « elsewhere »)
r+d (-needs)	research and development (needs, proposed by BISON D5.3)
RRT	Rail Road Terminal
SAC	Special Area of Conservations
SCI	Site of Community Importance

SEA	Strategic Environmental Assessment
SPA	Special Protection Area (under the Birds Directive protected sites as part of the Natura 2000 network)
TEN-G	Trans-European Network for Green Infrastructure
TEN-T	Trans-European Transport Network
TI	Transport Infrastructure
TIH	Transportation Infrastructure Habitats
TVB	Trame verte et bleue
WVC	Wildlife vehicle collisions
V_E	Design speed: Expected$_{(E)}$ or planned traffic Velocity$_{(V)}$, defining rail or road design

EXECUTIVE SUMMARY

Marita Böttcher, Cindy Baierl & Heinrich Reck

A) Core results

1. **Habitat fragmentation can be avoided.**
   Habitat fragmentation due to transport infrastructure is preventable by proportionate means. For this purpose, important ecological corridors, regionally and locally important spatial ecological functions and animal mobility as well as sensitive species of the affected area (indicator principle) must be properly recorded during planning. According to survey results, the mitigation measures (e. g. fauna passages) as well as the compensation measures (e. g. habitat restoration) have to be designed coherently with each other. Life networks must become the guiding principle of any green planning and parity reconnection plans should be an obligatory part of new TI development, upgrading or bundling. In this respect, there is a great need to improve the proposal for a Regulation OF THE European Parliament and the Council on Union guidelines for the development of the Trans-European Transport Network amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) No 1315/2013. Because a professional consideration of fragmentation effects in the EU Directive also strengthens the consideration, funding and implementation of measures to avoid fragmentation effects at country level and thus effectively contributes to the maintainance of the resilience of species and habitats under climate change conditions in Europe.

2. **Transportation infrastructure can support ecological networks and, in intensively used agricultural and forestry landscapes, promote plant, insect or small fauna diversity at all.**
   This requires a targeted design and maintenance of “verges”/ “TI side-areas” (green spaces, accompanying areas and boundary elements) to improve the conservation status of endangered small animal or plant species. Precondition is the implementation of sufficient fauna passages and their hinterland integration as well as avoidance of the loss of valuable habitat loss by new TI construction or expansion. The “verges” can be used as feeding corridors to fauna passages and supplementary stepstone habitats of local eco-networks.

3. **The European Defragmentation Map (EDM) and planning principles to achieve life-friendly TI are ready for use.** While the European defragmentation map provides a first preliminary indication where defragmentation measures in the existing TI should be considered from a European perspective, the planning principles are immediately applicable but have to be implemented into national regulations and into European demands for any TI planning if the respective projects are supported by the EU.
   R+d needs to significantly improve the EDM are outlined. The r+d needs regarding planning principles and mitigation measures aim to further enhance the efficiency of planning procedures and the efficiency of measures for impact mitigation. Here, research results can still enable numerous improvements, and there is still a considerable need for development and coordination with regard to the compilation of regionally representative target and indicator species for ecological reconnection.

4. Pre-conditions for avoiding barrier effects and for sufficient defragmentation

Pre-conditions for avoiding barrier effects and for sufficient defragmentation is the avoidance of any unnecessary barriers and impacts as e. g. unsurmountable curbs and walls, inappropriate bundling of TI or inappropriate high traffic velocities, the application of best planning standards and, at strong barriers, the construction of a minimum density of functional fauna passages (ecologically connected to the hinterland) at intervals of approx. 2 to 5 km.

B) Content and Use of the European Defragmentation Map (EDM)

The EDM, which is presented and published as a web application, provides an overview of relevant national concepts for biotope networks, defragmentation measures and proposed defragmentation areas throughout the Trans-European Transport Network (TEN-T).

The following contents are integrated:

A) the national and international concepts for a biotope network and important national defragmentation measures (as far as available resp. existing)

B) the Natura 2000 network (with focuss sites under the Habitats directive) as well as other strictly protected areas in the countries

C) the entire Trans-European Transport Network (TEN-T) and the selection of sections that are particularly relevant for fragmentation

D) the results of a spatial analysis of A), B) and C) and in this context a criteria-based selection and highlighting of important defragmentation sections in the area of the TEN-T from a European perspective.

The EDM provides a first summary and overview of important biotope network concepts and their fragmentation by the TEN-T on European level. The attention is focused on the overlapping areas between ecological networks, as they represent the nationally significant habitats (core areas) AND habitat connections (corridors), and the barrier-relevant TEN-T. In addition, intersections of the sites designated under the Habitats Directive and the strictly protected areas with the barrier-relevant TEN-T, have been identified. As a main result of the spatial analyses preliminary prioritized overlapping areas are presented. Thus makes it possible and upgrading projects already at the European level and to integrate them into the financing of the projects by the EU (polluter pays principle). But it will also be possible to identify and finance defragmentation measures of European importance for the existing and completed TEN-T with a view to a European Defragmentation concept. In addition, the EDM information can help to avoid fragmentation, namely where the routes are only planned but the exact routes have not yet been determined.

All information presented in the EDM can be evaluated within the web application according to various aspects and criteria stored in the attributes to the spatial data. In its current design and presentation, the EDM has to be considered as a prototype that should be further developed and continuously updated and improved. To this end, future data management, maintenance and updating beyond the BISON project must be regulated and organised.

C) Planning principles

As impact assessment and the use of indicators is insufficient at all planning levels and scales, as is also impact avoidance and sustainably functional mitigation and compensation corresponding "best state of the art" approaches have been developed, which in turn was a suitable approach to identify knowledge gaps that need to be overcome to achieve biodiversity-friendly TI in a more efficient way.

The “planning principles” comprise:

1. Advice for the use of the European Defragmentation Map (EDM),
2. Proposals for efficient, scale-specific assessment procedures and for best indicators regarding (1) fragmentation impacts by TI on populations, habitat connectivity and related ecological functions and (2) mitigation measures,
3. Proposals for effective mitigation and for avoidance of unnecessary TI-related obstacles and traps, and
4. Proposals for the use of TI related habitats as eco corridors.

Special topics are:

- Context specific definitions of terms regarding ecological connectivity and planning,
- Most evident planning deficits,
- Efficient use of indicators and European target species for defragmentation,
- Minimum densities for ecological corridors and fauna passages and the functional role of animal mobility e. g. for wilderness areas,
- Parity reconnection plans and liveable roads and rails as silver bullet to sustainable TI development, and
- the role of bundling TI with power plants or bundling TI with one another.

As a compilation of planning rules and methods between the state of the art and the state of knowledge the “planning principles” are a basis for an advanced **EUROPEAN MANUAL for biodiversity saving TI-planning** which could be implemented in short time.

At the same time the compilation identifies the most important research and development tasks, the fulfilment of which would result in further, significant improvements in the sustainable preservation of biodiversity and a considerable acceleration of TI-planning procedures.

Most pressing r+d-needs are or concern,

regarding corridors,

- further identification and monitoring of supra-regional eco-corridors by using remote sensing data on habitat topology (automatic classification by artificial intelligence) and automatized analysis of habitat distance and habitat mirror fronts,
- quantifying the effects of habitat mirror fronts on ecological connectivity,
- compilation of an up-to date European long-distance migration network,
- development of methods for scale-adequate delineating of existing or recoverable animal migration routes,

regarding scoping and assessment procedures,

- identification of typical, impact factor-specific effect areas for all different types/modes of transport infrastructure,
- coordinated studies for the better understanding of the barrier strength for different guilds/indicative species of the impact factors (1) TI-width, (2) protection walls, (3) curb stones, (4) density and height of verge vegetation, (5) traffic velocity and (6) traffic density,
- long-term effects of ports on the occurrence and survival of representative target species (indicator species),
- falsification or validation of the alleged, unproven (or imbalanced) economical or ecological or safety benefits of (a) high traffic velocity, (b) bundling and (c) safety fences or safety walls,
- possibilities to enhance travel speed by optimizing traffic flow instead of high vehicle speeds,
- implementation of a general rule that curbs & co. are forbidden in TI construction or TI renovation if not individual case-specific justified,
- standards or construction models for easily surmountable curbs or armourstones,

regarding indicators,

- rules for the implementation of mandatory, scale-related indicator sets (standard indicator systems) into EU-regulations,
- the compilation of an EU-region-specific list of European target species for defragmentation,
- the testing of the representativeness of EU Natura 2000 target and indicator species for functioning eco-corridor networks and testing the Natura 2000 species and biotopes for the representation of biodiversity at all (for each of the different EU eco-regions),

regarding efficient mitigation,

- the development of a guidance/manual for of cross-sectional parity green infra structure concepts and its obligatory implementation,
- European standard rules for the implementation of large fauna passages across transport infrastructure,
- the identification and implementation of standards for watercourse underpass design that securely saves any migration needs for limnic and bank species,
- a survey of the quantitative effects of green-strip fauna passages on species representative for the different relevant guilds,
- low-cost construction types for overpasses and underpasses with prefabricated elements,
- a survey of existing TI where curbs & co. should be deconstructed or de-fencing should be applied,

regarding TIH,

- a survey of the effects of herb and grass density in verges (a) on the migration of the small fauna, (b) on the habitat quality for the small fauna and (c) on the traffic mortality of birds of prey,
- the assessment of eco-regional specific effects of soil management in TIH,
- (near-natural) methods to change species-poor verges to species rich habitats,
- a survey of the possible supra-local corridor effect of verges for different guilds an on the impact of TI-features which support or hinder supra-local dismigration.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1 INTENTION, WORKING PRINCIPLES AND CONTEXT SPECIFIC DEFINITIONS OF TERMS

Marita Böttcher, Cindy Baierl & Heinrich Reck

1.1 The Overall goal of Work Package 5, Task 5.2, Deliverable 5.3

The key goal behind Deliverable 5.3 is:

1. **to improve the European Green Infrastructure, especially the function of ecological corridors by overcoming TI-related barriers and**

2. **to avoid any significant further barrier effects**

while developing and maintaining transportation infrastructure.

Subject 1 of D5.3 is the European Defragmentation Map (EDM), which indicates priority sections to reduce barrier effects from the TEN-T and European eco-corridors that need to be protected from negative impacts on their functions or even improved as transport infrastructure is developed. **Subject 2** is detailed minimum standards for TI planning and for defragmentation planning, including guidelines for the use of the EDM. Related research and development neds (r+d needs) are identified.

Both subjects of task 5.2 follow the hypothesis that development of ecosystem networks along and across TI and proper avoidance, mitigation and compensation of impacts by proportionate means can lead to landscapes where effective transportation has no significant adverse effect on biodiversity (see also chapter 3.6.2). But such hypothesis must be verified or falsified and currently there is dire need for amendments to overcome deficits of the past and for parity (equal) development of GI and TI[1] to reach the key goal.

1.2 Working principles

1.2.1 European Defragmentation Map (EDM)

(1) **Processing and presentation of the current state of Ecological habitat networks on European terrestrial territory (national and transnational/biographical regions) including Natura 2000 Network and Nationally designated areas (CDDA) CDDA-Data[2]:**

[1] Which means the compensatory development of green infrastructure plans and its realisation while maintaining or building TI

[2] Common Database on Designated Areas: nationally designated areas

Identification, evaluation and unification of the main components of Ecological habitat networks as national and international important core areas, important migration and distribution corridors and existing defragmentation measures[3]; compilation and summary of key information (see annex 7) about the compiled Ecological network data[4]; compilation and presentation of the current Habitats Directive Sites[5], selection of nationally designated areas (CDDA) as a supplement of core areas of special importance in countries without Ecological habitat networks,

(2) **Identification and compilation of suitable indicators for evaluation and identification of defragmentation priorities on international/European level**; hereby differentiation between short-time usable indicators (based on sufficiently accurate, comprehensive and existing databases) and necessary indicators from a nature conservation point of view; first recommendations for priorisation,

(3) **Indicator-based determination, evaluation and presentation of sections in the TEN-T suitable for defragmentation measures of European importance** from a strategic perspective to avoid/mitigate habitat fragmentation impacts and biodiversity loss,

(4) **Analyses of appropriate Europe-wide available suitable spatial data** regarding connectivity, gaps[6], intersections to get hints and evidence for the current quality and structure and the **further development of national habitat networks and in perspective a Pan-European Habitat network** and

(5) **Compilation of research and development (R&D) needs**.

1.2.2 Planning Principles for safeguarding ecological connectivity

D5.3/2 identifies research priorities that are related to approaches for best practice for avoidance of severe barrier or fragmentation effects of TI or – the preferred approach – for environmentally friendly development of TI, which is even promoting biodiversity by defragmentation.

D5.3.2

(1) starts from too many evident deficits in planning, construction and maintenance of TI as e. g.
- that ecol. corridors are often neglected and/or inadequately preserved in TI planning or
- that the needs of species for migration, especially the needs of the small fauna are too often ignored,
- that the ecological function of migrating large mammals is not sufficiently considered
- that the affected biodiversity is improperly, incompletely or poorly represented by the indicators used for planning assessment or

[3] E. g. wildlife crossings as green bridges or underpasses with all available data like traffic specification, type of measure, species or habitat specific design

[4] Including information inter alia on topicality, methodology, data source, legal basic and liability or relevance in spatial planning

[5] pSCI, SCI, SAC

[6] No data quality analysing, just overall data gaps (esp. Ecological Networks)

- that some impact factors as e. g. low barriers as curbs or bundling are too often unnoticed or misjudged etc.,

  and

(2) presents, based on the deficits, best possible practice recommendations, which is to give practicable recommendations for planning (procedures) from the viewpoint of safeguarding or restoring ecologically important and functioning habitat and migration corridors as well as safeguarding essential species mobility or ecosystem networks.

Thereby

(3) decision-relevant lack of knowledge or know-how and the respective research and development needs (r+d-needs) become obvious.

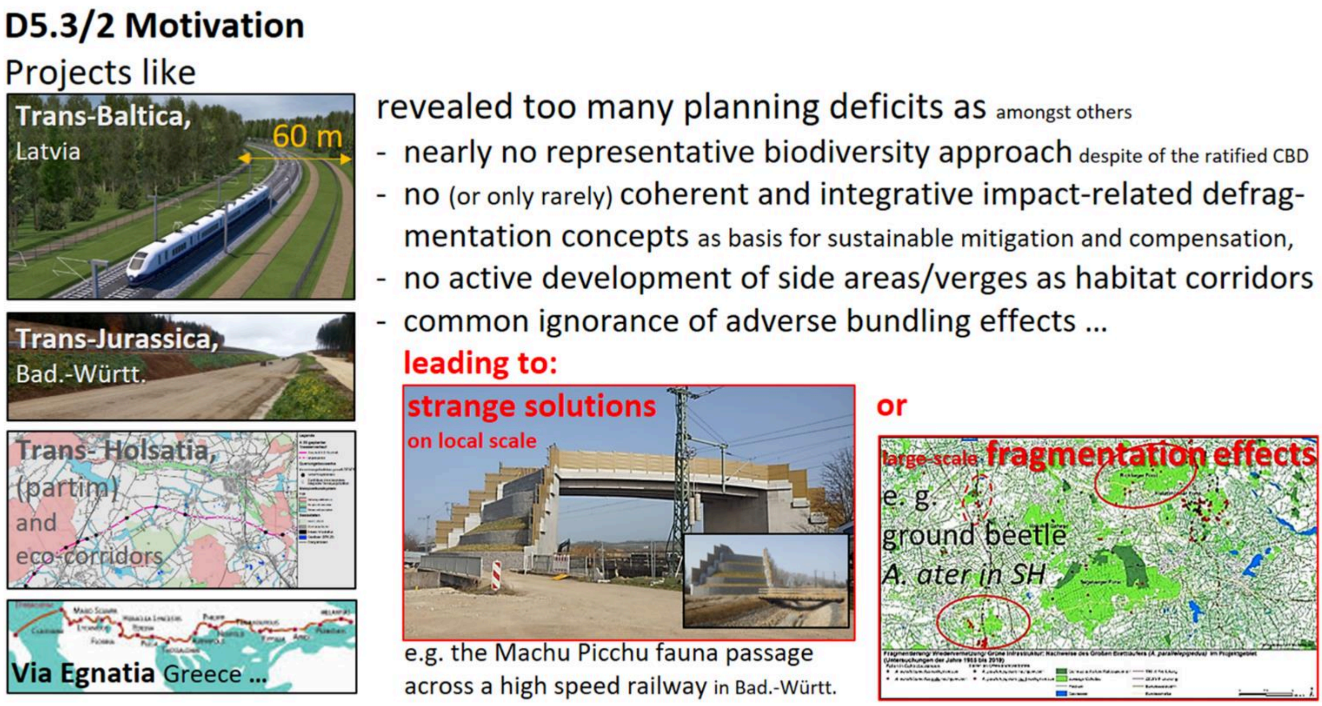


Figure 1: Starting point of D5.3 are planning (and implementation) deficits

Photo collage contributors: Vagolins, Reck, Strein, Nissen; for the fragmentation effects on ground beetles see Reck et al., IENE 2022 International conference; DOI 10.13140/RG.2.2.28643.53285

1.3 The terms are the ideas: Context-specific definitions (and synonyms)

Heinrich Reck, Cindy Baierl & Marita Böttcher

The terms are the ideas

Contextual definitions and interpretation of special terms with respect to TI-planning, ecosystem networks and defragmentation.

The most important terms or their relation to defragmentation priorities are:

- Functional connectivity
- Habitat corridor networks
- Wilderness areas

The least common but also crucial terms in this context which are also related with priority r+d needs are:

- Functional areas
- Mirror fronts
- Parity defragmentation concepts

1.3.1 Introduction: The terms are the ideas

Terms represent ideas. They affect the understanding of respective contributions to the BISON-reports and the attention to problems and solutions. Therefore, the sometimes different use or the "contextual meaning" of terms must be defined and the ideas behind explained. Such is the purpose of this chapter: It is the interpretation of relevant terms with respect to ecosystem networks. Additionally in some cases, tasks for TI-planning related to terms like migration corridors are highlighted.

Other terms than the specifically explained are used according to "Wildlife & Traffic - A European Handbook for Identifying Conflicts and Designing Solutions" (Rosell et al. 2022; https://handbookwildlifetraffic.info/annex-1-glossary/).

Table 1: Terms defined (in alphabetical order)

Term (page)	**Term** (page)
Acceptor (p 41) **Carpathian Corridors** (p 34) **Connectivity and defragmentation planning** (p 48) **Connectivity by defragmentation measures** (p 48) **Definitions for local – regional – nationwide – global and further related terms for area scales and stratification** (p 50) **Eco-corridors** (p 38) **Eco-nets** (p 37) **Emerald network** (p 36) **EU-eco-region** (p 50) **European Green Belt** (p 33) **Fragmentation and dissection** (p 49) **Fragmentation Index** (p 103) **Functional connectivity (of ecosystems or populations**) (p 45) **Functional Areas** (p 45) **Future Trans-European Nature Network (TEN-N)** (p 30) **Grass verge corridor** (p 38) **Grass verge overpasses and underpasses** (p 38) **Green and Blue Infrastructure** (p 35) **Green strip overpasses and underpasses** (p 179) **Guilds** (ecological and functional) (p 42)	**Habitat corridor networks** (p 29) **Habitat-Net** (p 45) **Impact regulation** (p 43) **Landscape corridor** (p 29) **Long distance dispersal** (p 39) **Long distance migration** (p 39) **Migration** (p 39) **Migration corridors** (p 39) **Migration path** (p 38) **Mitigation hierarchy** (p 43) **Mirror(ed) fronts** (p 45) **Natura 2000 network** (p 29) **Parity defragmentation plans** (p 43) **PEEN (Pan-European Ecological Network)** (p 32) **Project area – impact area – effect area – compensation area** (p 44) **Scale dependency of planning instruments** (p 50) **Stepping-stone corridor** (p 29) **Terms for roads and pathways** (p 51) **Target species** (p 41) **Terms for scales in the context of assessment procedures** (p 50) **Verge** (p 38) **Wilderness areas** (p 40)

1.3.2 Types of Ecological Networks

Human impact on natural ecosystems is the most important driver of the mass extinction of species in the last decades, accelerated and exacerbated by rapid climate change. Stopping this development is one of the greatest concerns for biodiversity conservation. Human civilizations across all continents have been transformed into vast agricultural expanses, where the original and natural ecosystems have often been reduced to small, isolated patches (Boitani et al. 2007). In densely populated and infra-structured Central Europe the fragmentation and isolation effects are more pronounced compared to the South-eastern parts of Europe, but here the development progresses too. National and transnational Ecological Networks are important components of the Green Infrastructure in Europe and a necessary complement to the establishment of protected areas for biodiversity conservation. It is thought that Ecological Networks can connect habitat patches and thus enable species to move across unsuitable areas. In some cases, they are species specific and operate on species-dependent scales. Although there are many variations in the definition of Ecological Networks, the most common goal of an Ecological Network is “to maintain the biological and landscape diversity of a region”. Ecological Networks are meant to ensure biodiversity conservation by protecting areas of assumed or known high species richness (core areas) and connecting them through corridors that should enable species to move across unsuitable areas (Boitani et al. 2007).

Habitat corridor networks

Synonym: eco-nets. Habitat corridor or ecological corridor systems consist of core areas, landscape corridors, stepping-stone corridors and features which, by virtue of their linear and continuous structure are essential for the migration, dispersal and genetic exchange of wild species. The idea of habitat corridor networks is behind many of the “corridor lines” of the EDM, other are e. g. migration corridors.

For more detailed information see chapter “Terms regarding eco-corridors”.

Natura 2000 network

Natura 2000 is an ecological network composed of sites designated under the Birds Directive (Directive 2009/147/EC) and the Habitats Directive (Council Directive 92/43/EEC). Stretching over 18 % of the EU’s land area and more than 8 % of its marine territory, Natura 2000 is the largest coordinated network of protected areas in the world. It offers a haven to Europe's most valuable and threatened species and habitats. Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. It stretches across all 27 EU countries, both on land and at sea. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive.

Future Trans-European Nature Network (TEN-N)

Despite a strong policy framework and significant efforts by Member States (MSs) to halt biodiversity loss and ecosystem degradation in Europe, the conservation status of protected species and habitats continues to decline along with the provision of ecosystem services. The new EU biodiversity strategy to 2030 addresses this decline with a plan to build a truly coherent Trans-European Nature Network. This will be built on the existing Natura 2000 network by analysing the potential connectivity between Natura 2000 sites using green infrastructure (GI) landscape elements important for delivering ecosystem services.

To do a step forward in the development of a TEN-N the EEA developed in cooperation with the European Topic Centre on Urban, Land and Soil Systems (ETC/ULS) an integrated assessment maps a GI network of protected Natura 2000 sites and unprotected natural and semi-natural terrestrial ecosystems (including agro-forestry) relevant for the movement of medium-large mammal species at the EU level (see Figure 2). Some of the main findings: around 80 % of forest and woodland dominated Natura 2000 sites are connected by natural and semi-natural terrestrial ecosystems outside the Natura 2000 network (including agro-forestry areas). Of these 50 % are fully connected by contiguous patches of unprotected forest and woodland. Around 15 % of disconnected Natura 2000 sites are less than 1 km apart but intersected by highways limiting species movement and do not form part of a potential green infrastructure (GI) network (EEA 2020).

Although Natura 2000 areas are wood-dominated, other area types have to be considered in a future TEN-N, thinking of the valuable open habitats (extensive grasslands, dry habitats, wetlands and flowing waters, which also needs connection.

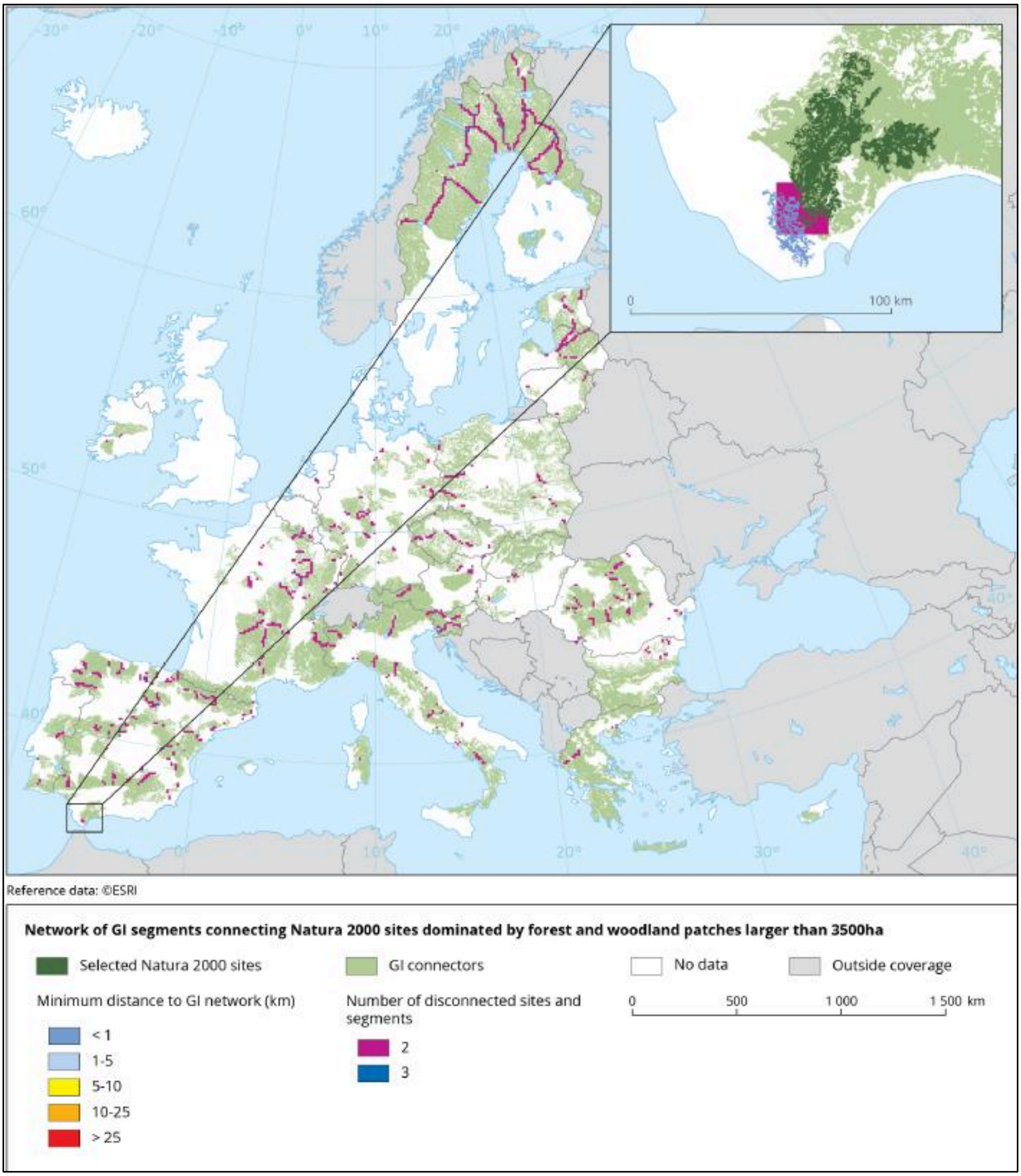


Figure 2: Network of GI segments connecting Natura 2000 sites dominated by forest and woodland patches larger than 3,500 ha

(Source: EEA 2020)

PEEN (Pan-European Ecological Network)

The Pan-European Ecological Network (PEEN) was developed to achieve the effective implementation of the convention of biological diversity (CBD) at the European level. Three subprojects: Central and Eastern Europe, completed in 2002; South-eastern Europe, completed in 2006; and Western Europe, also completed in 2006. PEEN identifies the core nature areas of European importance, existing corridors between these areas, and where new corridors could and should be established to meet the connectivity requirements of key species (see Figure 3).[7] ! No GIS-data; just schematic presentation of corridors.

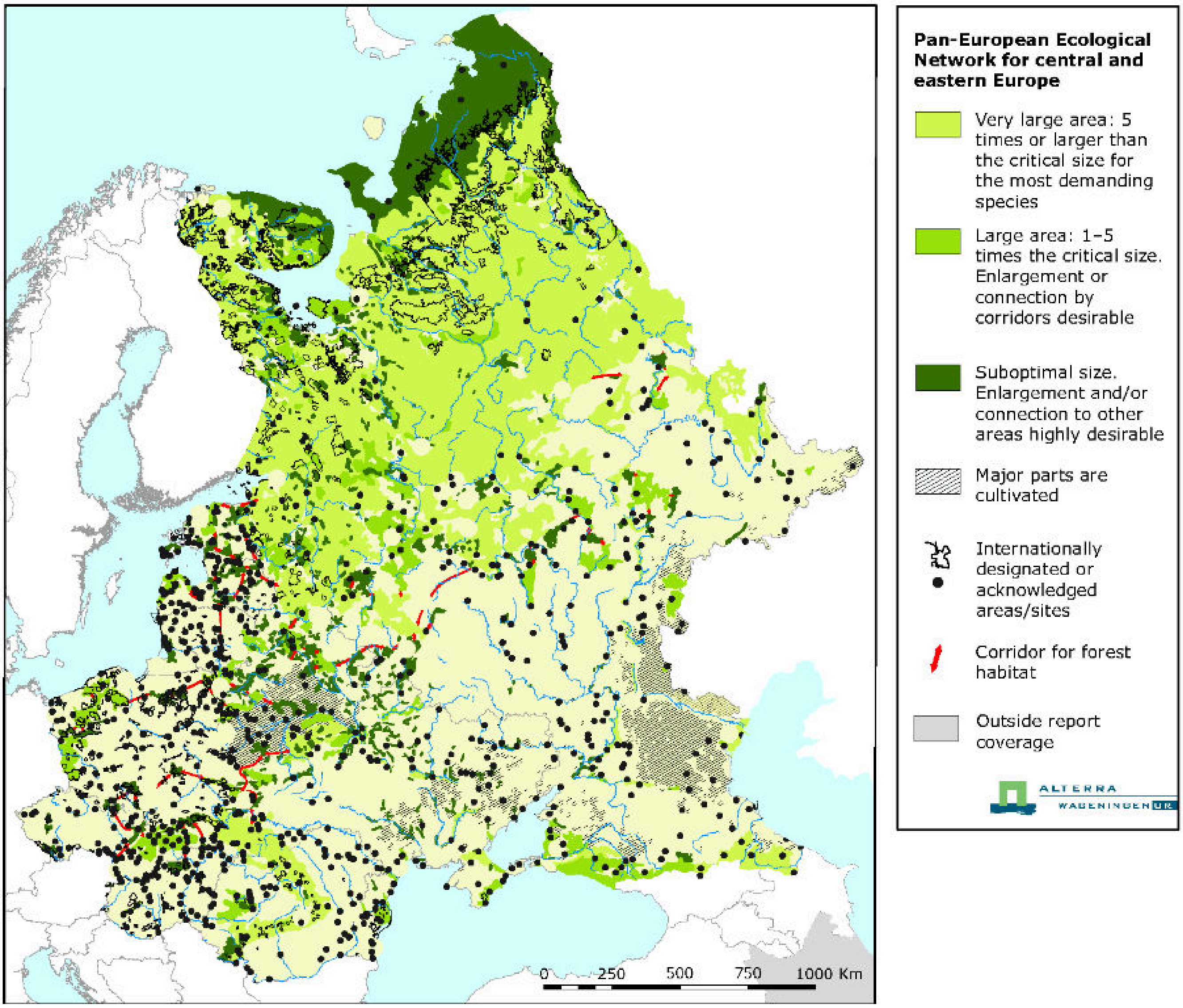


Figure 3: Pan-European Ecological Network for central and eastern Europe

(Source EEA 2009)

[7] https://www.eea.europa.eu/data-and-maps/figures/indicative-map-of-the-pan-european-ecological-network-for-central-and-eastern-europe

Transnational Networks

The **European Green Belt** serves as the backbone of a Pan-European ecological network crossing nearly all of the continent's biogeographic regions over an extend of 12.500 kilometres (Figure 4). The former border area – the Iron Curtain – separated Europe for more than four decades and lead to the establishment of a unique diversity fauna and flora. The protection and interconnection with adjoining valuable nature conservation areas is the main subject of the European Green Belt initiative.[8] With its practically undisturbed areas of nature and traditionally cultivated landscapes the European Green Belt can be seen as last stronghold of nature in the heavily fragmented landscape of Europe, playing an important role as an ecological network and as a central contribution to Green Infrastructure.[9] The European Green Belt Initiative was defined as an EU-level GI-project.

Figure 4: The European Green Belt

(Source: European Green Belt Association [10]

[8] See Joint Declaration of Intent on the European Green Belt. https://www.europeangreenbelt.org/activities/declaration-of-intent-on-the-european-green-belt/

[9] https://www.europeangreenbelt.org/european-green-belt/ecological-network/

[10] https://www.europeangreenbelt.org/european-green-belt/

The **Carpathian Corridors** were designed for one of the largest mountain regions of Europe constituting home to stunning ecosystems with exceptional richness of biodiversity, that are crucial for providing essential ecosystem services for millions of inhabitants of the region and maintenance of well-being of the human and natural environment. Arching across 7 countries, from the Czech Republic, across Poland, Slovakia, Ukraine and Hungary, and down to Romania and the tip of Serbia, the Carpathians are Europe's last great wilderness area - a bastion for large carnivores, with over half of the continent's population of brown bears, wolves and lynx, and home to the greatest remaining reserve of old-growth forests outside of Russia. For Safeguarding and increasing ecological connectivity between natural habitats, especially between Natura 2000 sites and other protected areas of transnational relevance in the Carpathian ecoregion the ConnectGREEN, SaveGREEN and TRANSGREEN projects were funded by the EU Interreg Danube Transnational Programme. As one main output of the ConnectGREEN Project "Restoring and managing ecological corridors in mountains as the green infrastructure in the Danube basin" an ecological network for large carnivores (as umbrella species) in the Carpathians was drafted, which consists of favourable and suitable habitats, movement/migration zones and critical zones (Vlkova et al. 2021, Okániková et al. 2021). The "twinning" project TRANSGREEN focused on integrating green infrastructure elements into TEN-T related transport infrastructure.

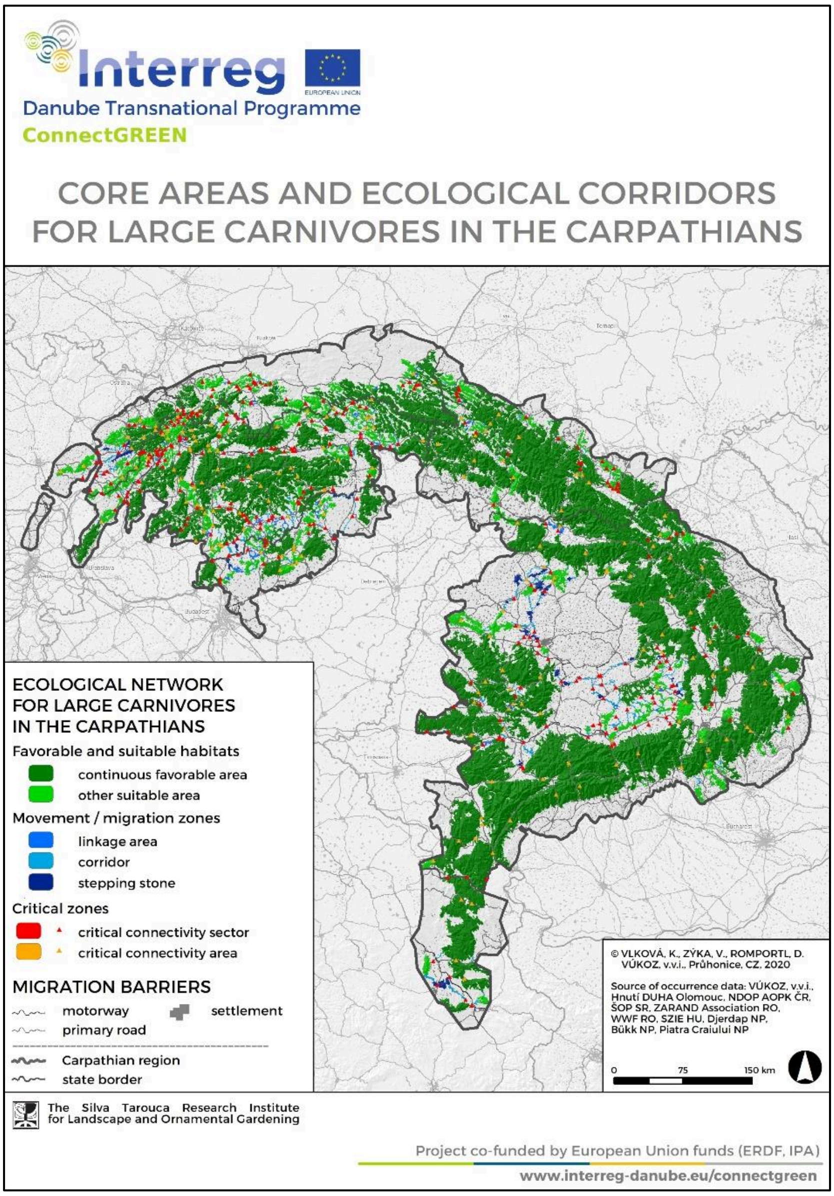


Figure 5: Map of ecological network in the Carpathians

Green and Blue Infrastructure (France)

The French "Trame verte et bleue" is a green and blue framework with the aim to restore on a national scale the ecological continuities of biodiversity reservoirs (core areas) and ecological corridors identified by the former regions. Originally 21 regions of continental France have drawn up their regional ecological coherence plans, which aim to identify the ecological continuities of the region. These plans were almost all adopted at the end of 2015 (except Picardy). Since 2016, the law on the new organisation of the territories has involved several important changes for the BTV, namely the merger of regions (13 new regions) and the appearance of a new integrating scheme. The raw regional data are at a scale of 1:100.000 and were only compiled for the purpose of producing regional maps, with each region using its own method. The national rendering therefore shows a strong heterogeneity from one region to another. For that reason, the rendering of the regional grids was standardised to improve the visibility and readability of the national map (Figure 6).

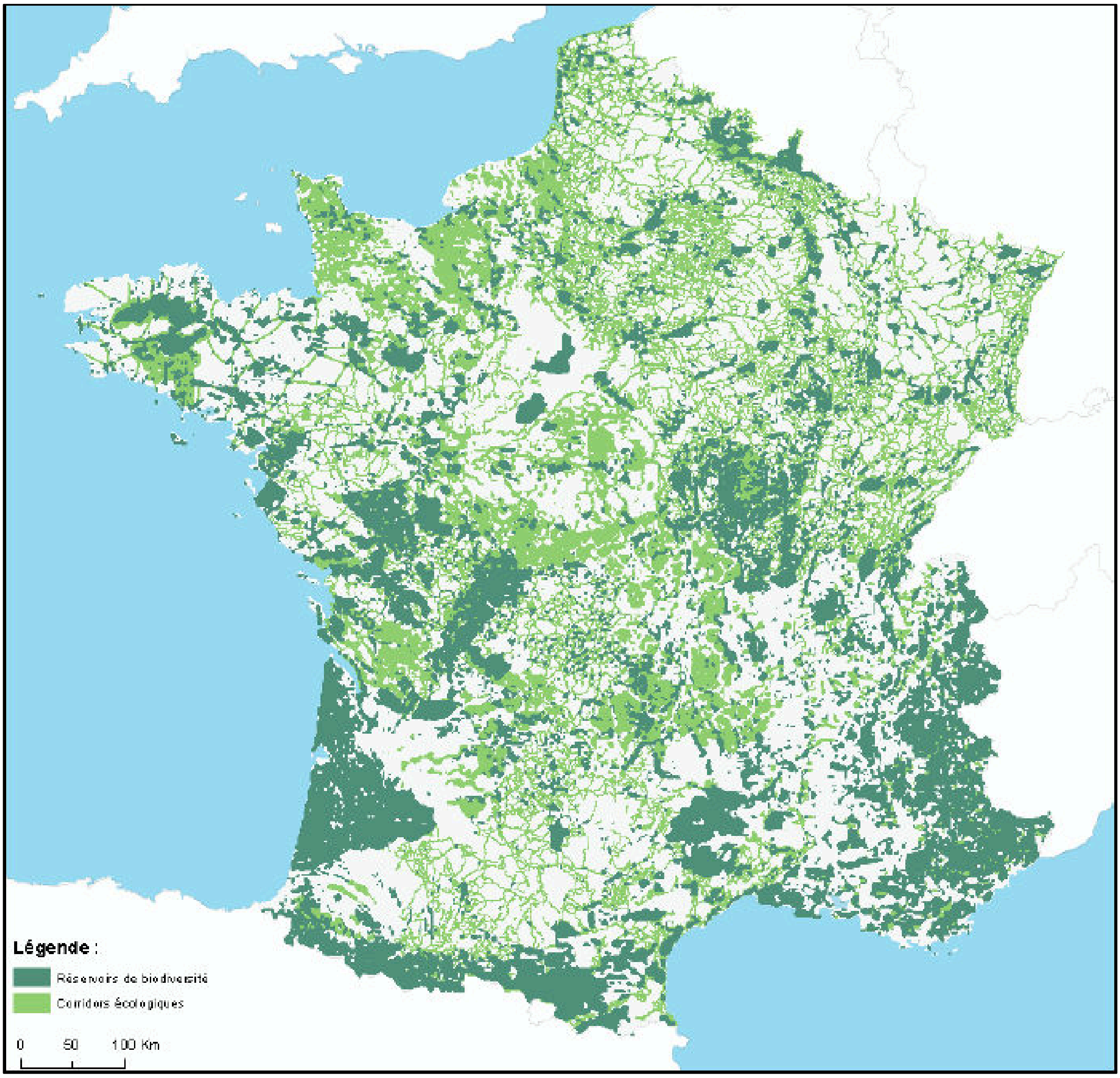


Figure 6: Final national map of the French ecological network Trame verte et bleue

Through cartographic generalisation techniques (selection, simplification and harmonisation) the cartographic representation of regional TVB data at the national scale was realised. For example, the areal biodiversity reservoirs and diffuse corridors mapped according to the modalities (grid + regional thresholds) are combined with the linear ecological corridors whose width has been harmonised. Watercourses are not considered part of the blue network to maintain the readability of the map (the density of the elements is very high in some cases). The final national map is used to restore the Green and Blue Belt policy and to communicate it at national and international levels but has no legal or regulatory value (Billon & Sordello 2017).

Emerald network

The Emerald network is an ecological network for the conservation of wild animal and plant species and natural habitats of European importance. It consists of the Areas of Special Conservation Interest (ASCI) designated under Recommendation No. 16 (1989) and Resolution No. 3 (1996) of the Standing Committee to the Bern Convention. Before being officially adopted as Emerald Network sites, all sites proposed to join the Network are thoroughly assessed at biogeographical level for their sufficiency to achieve the ultimate objective of the Network. This objective is the long-term survival of the species and habitats of the Bern Convention requiring specific protection measures. Once the areas proposed are officially adopted as Emerald Network sites, they must be designated and managed at national level. Before an emerald area is adopted as such, is has the proposed or candidate status. The national designation and management measures are decided and put in place to contribute to the main objective of the Network and their efficiency will be regularly monitored. The Emerald network involves all the European Union member States, some non-Community States and a number of African States. In Europe the Natura 2000 sites are considered as the contribution from the EU member States to the Emerald Network.

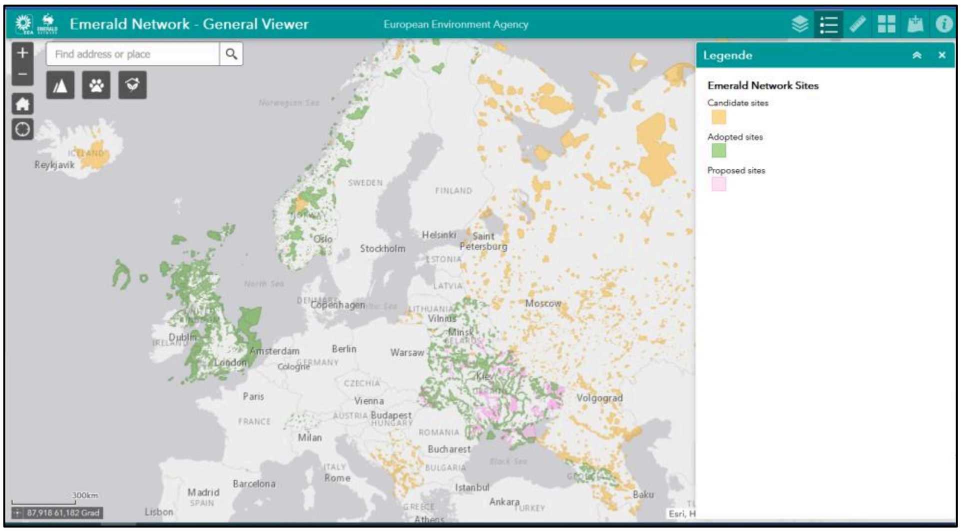


Figure 7: Emerald Network – General viewer of the European Environment Agency[11]

[11] Data viewer: https://emerald.eea.europa.eu/, data download: https://www.eea.europa.eu/data-and-maps/data/emerald-network-data-1 (The Emerald Network aggregated database is updated annually).

1.3.3 Terms regarding eco-corridors and verges, migration, wilderness and defragmentation measures

Eco-Corridors[12] and eco-nets[13] in relation to grass verge corridors, migration corridors and to wilderness areas

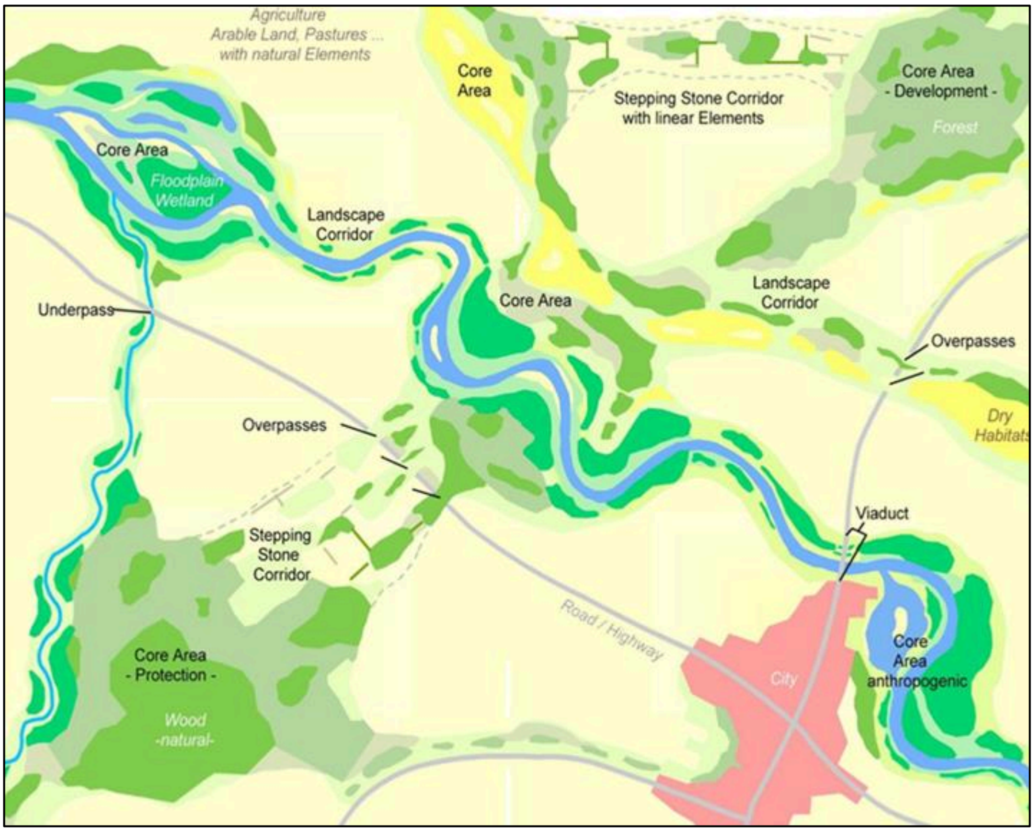


Figure 8: The idea of habitat corridor networks
(fig. from Hänel 2004 in Reck et al. 2011, drawn after Klijn et al. 2003. The fig. explains the main approaches behind many of the "corridor lines" of the EDM but also of the PEEN; other are e. g. migration corridors; see below).

Habitat corridors or ecological corridor systems consist of core areas, landscape corridors, stepping-stone corridors and features which, by virtue of their linear and continuous structure are essential for the dispersal, genetic exchange and migration of wild species. The idea of habitat corridor networks is behind many of the "corridor lines" of the EDM, other are e. g. migration corridors. The idea is also related to the Habitats Directive, Article 10: "Member States shall endeavour, where they consider it necessary, in their land-use planning and development policies and, in particular, with a view to improving 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. Such features are those, which, by virtue of their linear and continuous structure (such as rivers with their banks or the traditional systems for marking field

[12] Synonym for ecological corridors
[13] Synonym for ecological networks

boundaries) or their function as stepping-stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species".

In the context of safeguarding biodiversity, **habitat corridor networks** (= synonym to eco-corridors or landscape corridors or stepstone corridors or eco-nets) must be supplemented by mobility corridors or pure migration corridors respectively and TI-verges or TI side areas, which can be designed as corridors at least for the small fauna.

Grass verge corridors and especially **Green strip or Grass verge overpasses and underpasses** may be a further supplement. Verges can and should be used as feeding corridors for fauna passages (fp) but grass verge fp (that means near natural verge design along TI on traffic bridges or traffic underpasses – or even as standalone solution) could be part of defragmentation concepts. They will never replace large fp but could be a necessary supplement and even reduce the needed numbers of large fp.

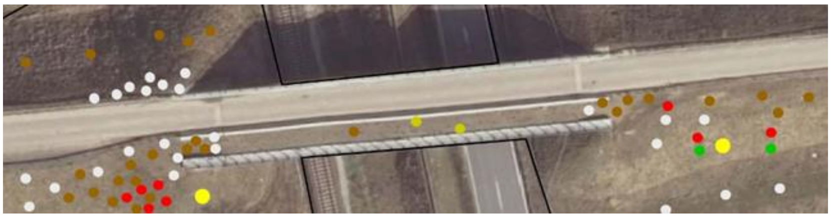
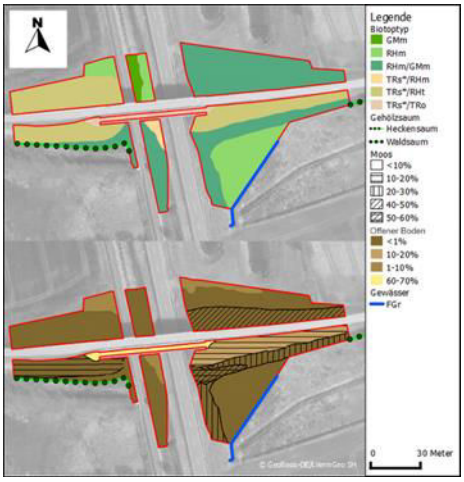


Figure 9: Grasshoppers on and around a green strip fauna passage

The colours (Hänel in Strein et al. n.p.) symbolize different species; the strip passage would have been used by even more species if the vegetation (Müller in Strein et al. n.p.) had no such high contrasting to the surroundings.



Verges as, in this context, longitudinal, TI related habitats

Verges in the context of the report is both very broad and narrow bands of vegetation along transport infrastructure. In most cases, these are differentiated into a **narrow intensive maintenance area** (directly at the edge of the carriageway) and a **broader extensive maintenance area**. When referring to verges as a habitat or corridor, the extensive maintenance area is usually used.

Migration paths

On local level sub-habitats can also be connected, e. g. within the eco-corridors, by (pure)migration paths for species with large activity areas or territories.
Fragmentation affects all types of mobility needs; it affects **trivial ranges**, **migration ranges** and **dispersal ranges**.

Long distance dispersal and migration

Regarding, **Long Distance Dispersal** (LDD), **LDD by Vectors** (LDDV) and **Long-Distance Migration** (LDM), the LDM-, LDD- or, LDDV-corridors must be detected in TI planning and their function must be especially preserved for flightless species. For species able to fly, it is of great importance to keep bottlenecks like narrow notched mountain passes, or directing straits or valleys etc. free of TI-related traps (lighting) or collision risks [r+d-needs comprise a European-wide compilation of such bottlenecks as information base for TI planning and defragmentation measures].

LDM etc. should be defined according to different dispersal guilds; e. g. for larger mammals LDM corresponds to distances of > 25 km and LDD corresponds to distances of > 100 km. For the smaller flightless fauna, for zoochorous plants and for zoochorous smaller fauna LDDV could already correspond to distances of < 5 km. For flying or anemochorous species LDM) could be a distance > 250 km. In order to develop common ideas, a definition is needed, but such is not yet available.

Migration corridors

Eco-corridors are the best corridors for random dispersal. The nearest distance or the least-cost distances define e. g. the survival of metapopulations, adaptability to habitat dynamics or re-colonization.

Migration corridors are different. They are either defined routes for seasonal or inter-generational change of habitats or living-areas or they are defined by orographic or landscape features as e. g. hill-ranges or water courses which direct dispersing specimens to specific routes (the latter can but must not be the same as eco-corridors).

Migration corridors must not (but can) be related to chains of nearby stepstone habitats. They can also be (for some species) just areas without too much spatial resistance or barriers. They can be individually learned by specimens or passed down from generation to generation (including transhumance corridors learned by shepherds and/or lead animals) or they are pre-defined as general direction by genetic disposition.

r+d-needs regarding migration corridors

Migration corridors of animals must be identified and kept free from barriers and traps or restored (e. g., for seasonal ungulate migration up and down mountain ranges or for amphibian migration between spawning and summer habitats or especially in bottleneck situations as are e. g., mountain passes for insect or bird migration which can be threatened or blockrd by TI-related mortality or light emissions etc.). As migration corridors are not sufficiently deducible by landscape features but often known by animal observers' information on important European or supra-regional corridors must be compiled for TI-planning and on regional and local level project-specific detected for assessment of TI-impacts and for defragmentation. Methods for detection must encompass more than habitat suitability and habitat topology (e. g. Strnad 2013) and should be refined and standardized for EIA and IR.

Safeguarding Long distance migration / dispersal corridors for animals in Europe is not only of interest for populations of species that depend on annual long-distance migration like reindeer or alpine red deer or migrating fish etc. but also with regard of:

- the function of migrating (large) herds or flocks as vectors and bioengineers (thereby the replacement for wild mammals by transhumance must be replaced again by the original wild species without losing the last remnants of transhumance either),
- the function of dispersal corridors for flightless species which are often determined by orographic features of the landscape (and land use features too),
- the critical role of bottle necks for the migration of flying species (bats, birds, insects) that must be kept free from light pollution and e. g. infrastructure that leads to high amounts of roadkill or rail kill or slaughter at wind turbines and
- the need, that small animals can follow climate change in sufficient numbers (on the long run) across large distances with respect to altitude and latitude.

Therefore, a minimum network of migration corridors (or migration possibilities) without artificial barriers must be re-developed or – if still in existence - protected in its function. The most urgent task is to draw up a European long-distance migration network so that it can be integrated in land use planning (from state development plans to local zoning plans or from TEN-T to local traffic) and landscape planning (from environmental development plans on state level to the local level).

Wilderness eco-corridors and defragmentation

Safeguarding or re-development of wilderness areas results in special demands on habitat networks and defragmentation

Wilderness needs either extremely large undissected areas or functioning integration into habitat networks and eco-corridor systems; that is because dynamics (physical dynamics as well as e. g. dynamics by large herbivores) are on the one hand the driving forces for biodiversity and, on the other hand, lead to (temporary) local extinction of species which must be compensated by enhanced dispersal possibilities.

Therefore, the integration of wilderness areas into eco-networks and overcoming of barriers near wilderness areas should have priority.

1.3.4 Terms related to planning

Target species

Target species are defined in general as a species or group of species that is the subject of a conservation or mitigation action or the focus of a study. Target and indicator species in the context of D5.3 serve:

a) to represent the demands of species on habitat quality and the connectivity or functional connectivity of respective habitats or populations, i.e., to illustrate the needs,

b) to monitor the effectiveness of measures and

c) to verify the effectiveness of measures.

In the context of defragmentation, we request that target species should be representative for all affected ecological guilds. The respective species systems have to be compiled project-specific on the one hand but on the other hand a European list of target species for defragmentation (and barrier impact assessment) should be compiled because the species listed in the annexes of the Habitat Directive fail to be representative for ecosystem connectivity and spatial functions of ecosystem.

Why bats and birds are not in the focus of the report

The D5.3 report focuses on TI-related barrier effects and the necessary defragmentation of ecosystems for flightless species but less, for example, on the traffic mortality although such is closely linked to the barrier effect of TI.

Therefore, species able to fly and especially birds and bats are only considered in exceptional cases in this report. Regarding ecological corridors and migration corridors, this means that the necessary density and quality of e. g. resting areas (which can be interpreted as stepping-stone biotopes for birds and other flying species) and bottle necks in flight migration corridors are merely not addressed.

Acceptor species or guild

Species group, species or specimen which is affected by an (TI-related) impact type – at best being featured by the most sensitive or most demanding representative.

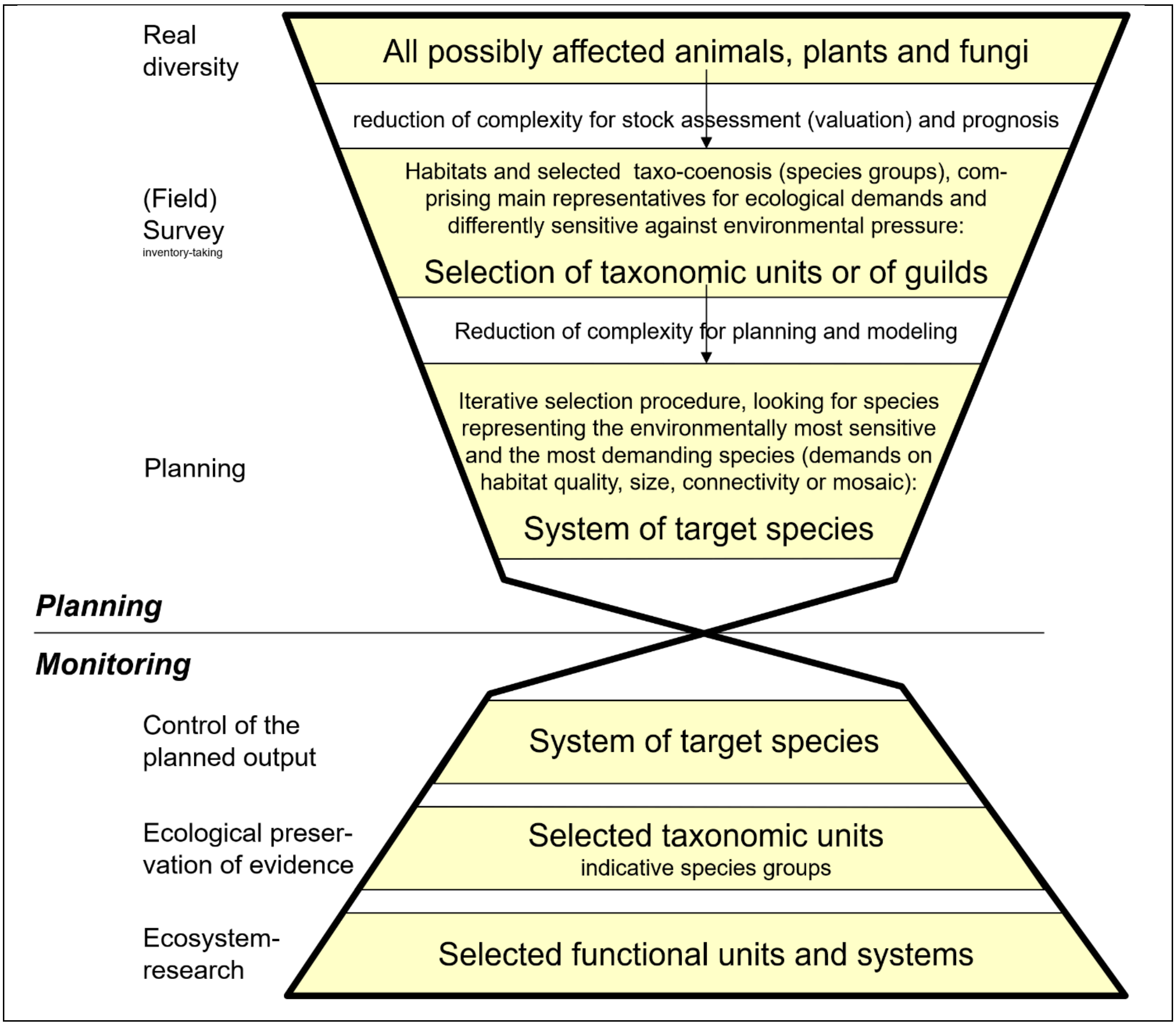


Figure 10: The target species approach (after Reck 2004)

Ecological and functional guilds

Guilds are groups of species:

a) that use specified resources (including space) in similar ways, or

b) that belong to the same mobility type (e. g. flightless species with random dispersal or migrating species with directed movements etc. or zoochorous or anemochorous etc. dispersers) or that show similar behavior or

c) that react to environmental impacts or climate etc. in a similar way or with similar sensitivity.

Species of a defined taxonomic group can also more or less represent a guild (e. g. bees are mostly pollinators and therefore part of the pollinator guild – but of course not every bee is a pollinator) but often taxonomic groups are divided in different guilds (as mammals can be divided in herbivores or carnivores or omnivores). All in all, guilds are defined according to the locations, attributes, or activities of their component species.

Parity defragmentation plans

(Synonyms: “parity reconnection plans” or “parity defragmentation concepts” or “parity green infrastructure concepts” or “parity reconnection concepts”)

Parity reconnection plans can be the silver bullet to biodiversity friendly TI development. They will lead to better planning, less conflicts and accelerated realization.

Existent biotope network planning at the **supraregional level** usually only needs to be adapted locally when new TI is developed. The given large-scale, e. g. statewide ecological relationships remain in place. At the **regional and local level**, things are different: On regional and local level upgrading or new installation of TI can alter both, habitat topology and connectivity in a way that reformation of planned or realized habitat networks is necessary on the one hand – and, on the other hand, the improvement of habitat networks and connectivity is the most efficient compensation measure.

If measures to safeguard biodiversity through the parallel development of habitat networks are integrated from the outset into the new planning of transport infrastructure and if appropriate avoidance and compensation measures are defined proactively, planning delays due to nature conservation concerns can be avoided.

Parity means an obligatory parallel and equal planning and development of TI and Green infrastructure on the polluter-pays principle.

Precautionary planning for reconnection, if necessary, across several TI sections or respectively the identification of priority sites for eco passages, biotope corridors and wildlife migration routes on regional scale also provide a suitable framework for best restitution while renovations.

Mitigation hierarchy and impact regulation (IR)

Mitigation planning is part of the EIA but more so of IR. Related plans shall contain information about requirements and measures relative to achievement of specified purposes of nature conservation and landscape management and, especially, relative to avoiding, mitigating (reducing) or eliminating adverse effects on nature and landscape. The obligations of the intervening party are:

(1) to refrain from causing any avoidable adverse effects on nature and landscape. Adverse effects shall be considered avoidable if reasonable alternatives are available for achieving the purpose of the intervention, at the same area, with lesser or no adverse effects on nature and landscape. Where adverse effects cannot be avoided, reasons for such unavoidability must be provided.

(2) to compensate (= impact regulation) for any unavoidable adverse effects by means of nature conservation and landscape management measures (compensation measures). An adverse effect shall be considered to have been compensated as soon as the impaired functions of the natural balance have been restored in an equivalent way and landscape appearance has been restored or re-designed (see also parity defragmentation plans) in a manner consistent with the landscape. An adverse effect shall be considered to have been substituted as soon as the impaired functions of the natural balance, in the relevant natural area, have been restored to an equivalent value and landscape appearance has been re-designed in a manner consistent with the landscape.

Impact regulation

Impact regulation as part of TI project approval comprises avoidance and, if not fully applicable, mitigation and complete compensation of all significant impacts (on the ecosystem and on landscape amenities). In some EU member states such is mandatory for any impacts in any area or landscape or habitat type if valuable compartments of ecosystems are affected.

Project area – impact area – effect area – compensation area

The terms are explained in the following figure and closely related to scoping procedures and tasks regarding the mitigation hierarchy.

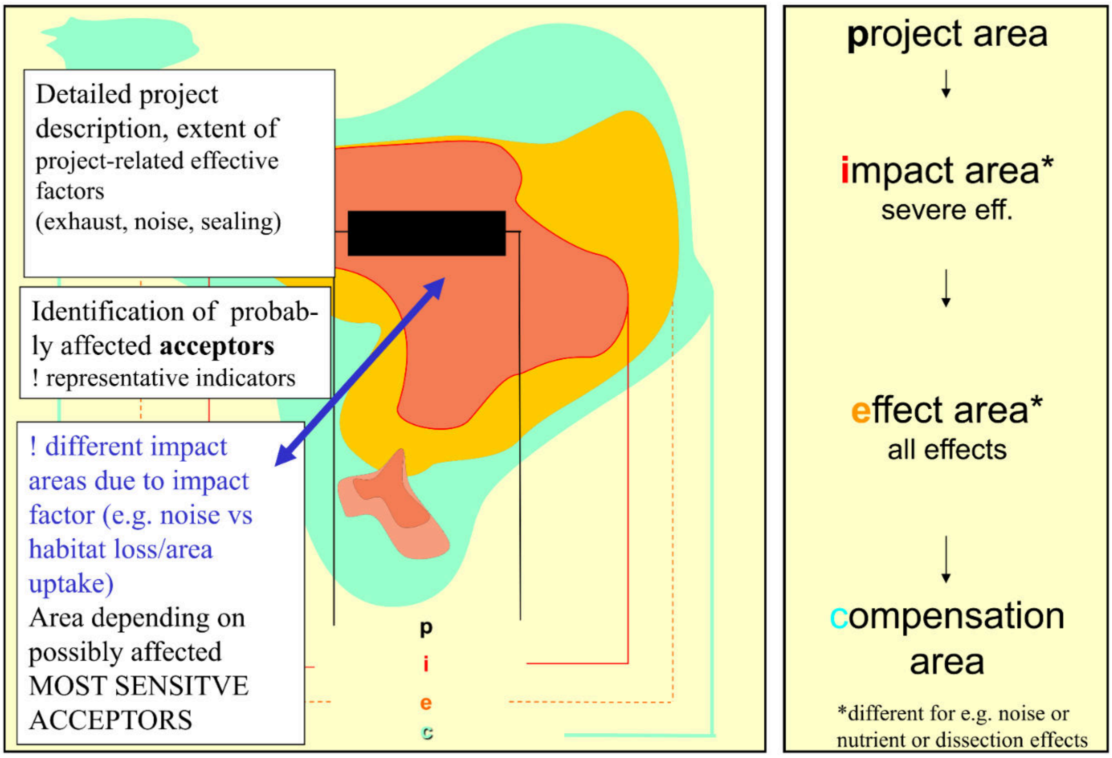


Figure 11: Project, Impact, Effect and Compensation Areas (after Herbert, M. / BfN, in lit.)

R+D needs are to identify typical, impact factor-specific effect areas for all different types of transport infrastructure (see fig. V_E in chapter “deficits”). Especially the impact areas of barrier effects are underestimated in assessment procedures and respective survey areas are wrongly chosen.

Functional connectivity (of ecosystems or populations)

A sufficient degree to which:

- living beings (fauna and flora) can secure survival via metapopulations dynamics and react to natural and anthropogenic patch dynamics by sufficient movements between habitats and
- migrating species or species that need different habitat types on a daily, seasonal or lifetime basis as well as key species are able to move between habitat patches or ecosystems in a sufficient number to survive and to fulfil their ecological role as vector or bioengineer.

Functional Connectivity does not necessarily depend on direct habitat connectedness.

Functional Areas (FA)

Systems of functionally connected habitats that are hierarchically interconnected according to distance classes and land use in between. Depending on the distance class (e. g. 100, 250, 500, 1000, or 1500 m), on the one hand they reflect metapopulation systems for species of different mobility, on the other hand dispersal axes for stenotopic species and buffer zones for sensible biotope types. Functional areas of the distance class 500 m (FA 500) show spatial connections of habitats which usually are up to 500 m apart (or, in case of adjacent very large habitats, up to 1000 m), with no settlement areas in between. The "mirror fronts" of the respective habitats play a crucial role for connectivity.

Mirror fronts and Habitat-Net

Mirror fronts are boundary lines of similar habitats that face ('mirror') each other.

The likelihood of animals finding their way to the next suitable habitat or a wildlife crossing is determined by:

1. the number of dismigrating animals (population size and/or number of individuals on boundary lines),
2. the lengths of habitats' boundary lines and their locations relative to one another ('mirrored fronts), and
3. the spatial resistance between the habitats.

The effects of mirrored fronts are highlighted in the following figures. The term **Habitat-Net** refers thereby to a GIS Algorithm for identifying Habit networks by a distance-mirrorfront model (Hänel 2007; see also Hänel & Reck 2011

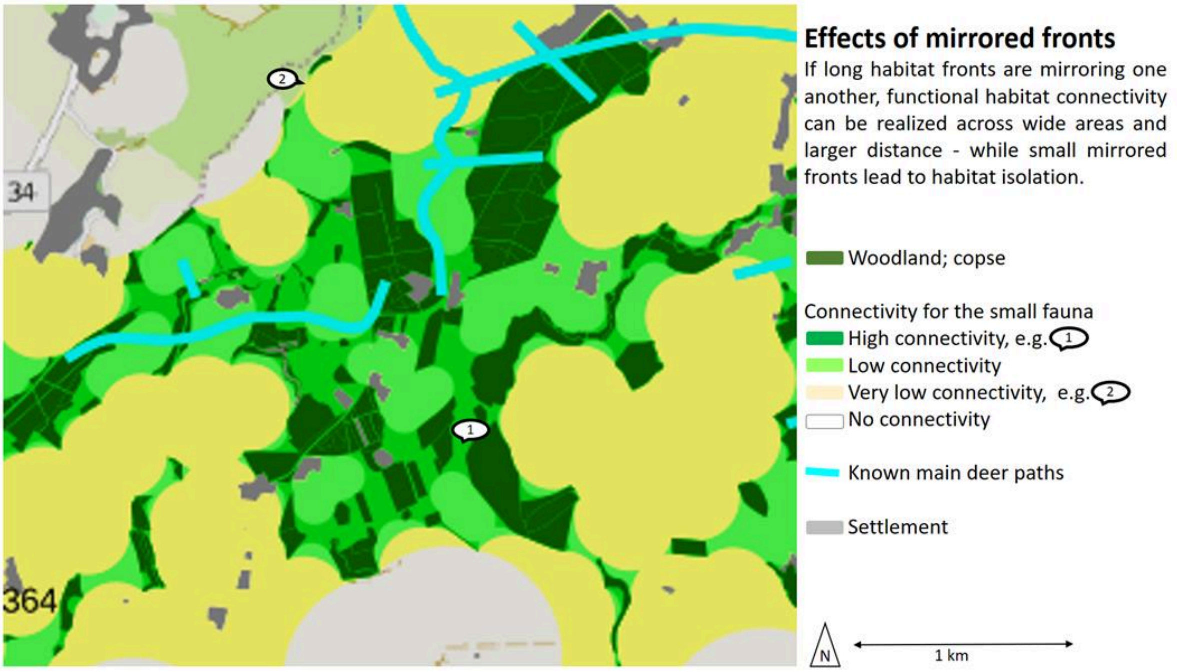


Figure 12: Effects of mirror fronts on woodland connectivity for randomly migrating species (a) Habitat-Net

Not only randomly migrating species react on mirror fronts. In the Plön municipality ungulate activity between woodlands and respective roadkills were significantly more concentrated in habitat networks created by the distance-mirrorfront model Habitat-Net, than at other places or in open land and waterway biotope corridors.

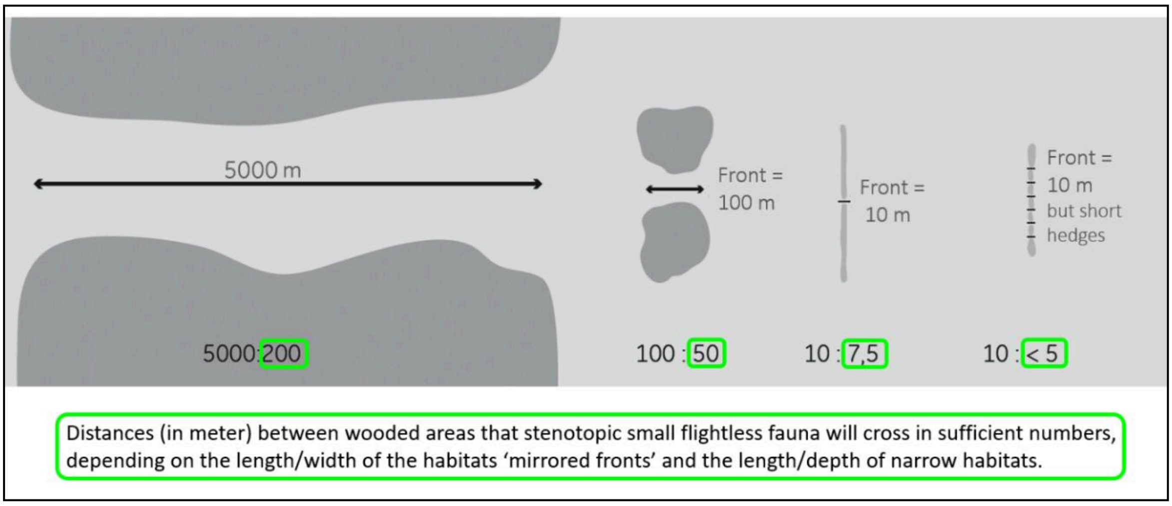


Figure 13: Effects of mirror fronts on woodland connectivity for randomly migrating species (b) Distance hypothesis

Hypotheses on the distances between wooded areas that stenotopic small flightless fauna will cross in sufficient numbers, depending on the length/width of the habitats 'mirrored fronts' and the length/depth of narrow habitats. If larger woodlands face each other along lengthy 'mirrored fronts' of approx. ≥ 5 km (5000:200), woodland species will probably usually cover distances ≥ 200 m across richly structured open land (without particular barriers). Where there are short 'mirrored fronts' of approx. 500 m, they often will still cover distances of approx. 50 m; and where there are very short 'mirrored fronts' of 10 m, only distances of 7.5 m (10:7.5) or even just 5 m (10:5) will be covered regularly, depending on the extent (depth/length) of the wooded areas. Assumptions, derived from (too few) studies on the occurrence of woodland species in open land, in copse or hedges and from the use of broad and narrow open-land corridors in woodland (from Reck et al 2019).

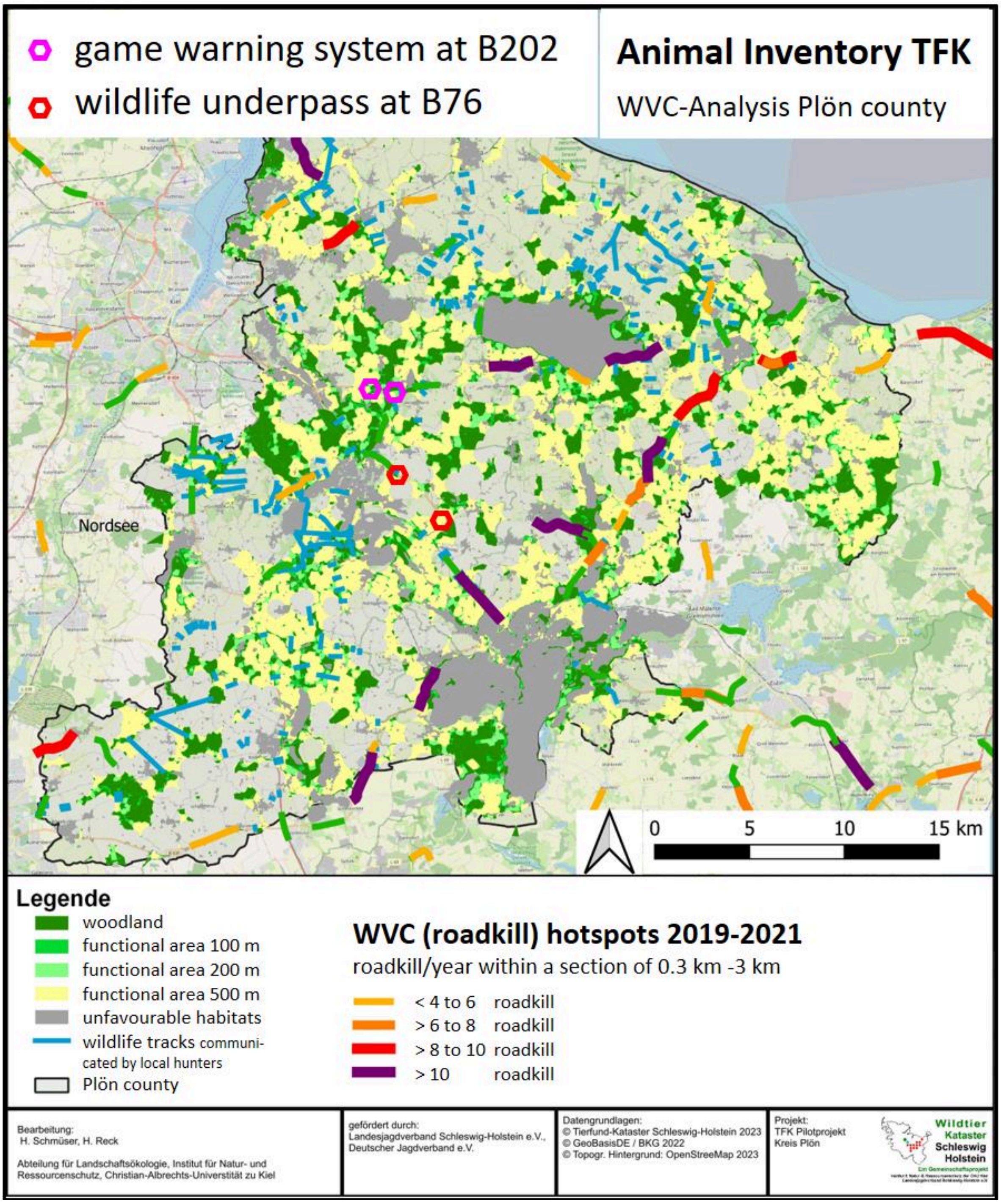


Figure 14: Traffic kill and Habitat Net in Plön county

The correlation between WVC hot spots and the modelled habitat net (modelling with regard to mirror fronts, method see https://www.researchgate.net/publication/285088499_National_Priorities_of_reconnecting_ecosystems) is evident. Thereby WVC-reports of hunters (Schmüser et al. 2014, www.tierfundkataster.de) and police differed in the Plön study while the comparative analyses of spatial distribution, totals by body size, and the composition of roadkill hotspots by Guinard et al. (n.p.), with data obtained using two survey methods: i) one conducted monthly by an ecologist, ii) one conducted daily by patrol agents indicate that these survey methods are efficient in locating mortality hotspots, and complementary in terms of identifying different groups of body size, with patrol agents detecting all large fauna and the ecologists recording more small species. Guinard et al. suggest therefore combining methods to obtain more representative data of the road mortality.

Connectivity and defragmentation planning

Connectivity and defragmentation planning means

- to secure sufficient ecosystem connectivity by delineating and safeguarding existent ecological networks against fragmentation or
- the delineation of most efficient defragmentation measures, needed against already existing and excessive fragmentation of ecosystems (re-development of habitat networks and migration corridors).

"Ecosystem connectivity makes a decisive contribution to the preservation of biodiversity. To protect indigenous species so effectively that people can experience them in their natural habitats, it is necessary:

1. to strengthen threatened populations and to stabilize them by re-establishing the exchange of individuals between isolated populations (population network, maintaining genetic diversity),
2. for migrating species and mobile key species (bioengineers) to be able to change habitats (among other things, a sufficient number of migration corridors must remain), and
3. to re-enable [recolonization of lost areas and/or] spatial adaptation pro-cesses to natural and anthropogenic landscape dynamics – also in order to mitigate or to avoid adverse effects of climate change (maintaining sufficient dispersal movement)."

Ecological connectivity safeguards the unimpeded movement of species and the flow of natural processes that sustain life on Earth (CMS, 2020). It can be expressed for reconnection/defragmentation concepts as structural connectivity for species; as a measure of habitat permeability based on the physical features and arrangements of habitat patches, disturbances and other land, freshwater or seascape elements presumed to be important for organisms to move through their environment. Structural connectivity is used in efforts to restore or estimate functional connectivity where measures of it are lacking (Hilty et al., 2019).

Connectivity by defragmentation measures

Connectivity by defragmentation measures means
(1) in the context of TI, overcoming linear barriers by fauna passages and reducing barriers as e. g. fences in ecological corridors and core habitats and
(2) overcoming islandization or respectively habitat isolation by increasing habitat size or density (by creating landscape corridors or stepping-stone corridors including linear habitats in between) to compensate for connectivity loss by distance or former down-sizing of habitats.

Fragmentation and dissection

Fragmentation comprises two main components:

1. „dissection“ (e. g., linear, route and traffic-caused barriers and/or edge effects by linear habitat degradation) and
2. „islandization“ (e. g., thinning out and downsizing of habitats, causing, among other things, the loss of habitat or population connectivity by distance).

Affected by dissection are:

- bioengineer functions which are responsible for natural biogeneous heterogeneity,
- vector functions (↔ passive dispersal) and
- functions of habitat connectivity or of active dispersal
  - within metapopulations,
  - for adaption to habitat dynamics (e. g. due to land use change or climate change) and
  - for seasonal habitat change

and thereby primarily flightless species with active or zoochore dispersal (and due to high mortality sometimes bats and butterflies).

1.3.5 Terms for scales, measures and TI

Definitions for local – regional – nationwide –global and further related terms for area scales and stratification

Term	Ca. area size
local	1 to 100 km^2 (up to ± 500 km^2)
regional	2,500 km^2 (± 250 ± 5,000 km^2)
supra-regional	10,000 km^2 (± 2,500 - ± 25,000 km^2)
state-wide	25,000 km^2 (± 10,000 - ± 50,000 km^2)
supra state-wide	50,000 km^2 (± 25,000 - ± 100,000 km^2)
nation-wide	250,000 km^2 (± 75,000 - ± 750,000 km^2)
EU-eco-regional*	1,000,000 km^2 (± 100,000 - ± 1,500,000 km^2)
across ecoregions (or transnational)	5,000,000 km^2 (± 500,000 - ± 5,000,000 km^2)
European	10,000,000 km^2 (± 10,000,000 km^2)
intercontinental	25,000,000 km^2 (> 10,000,000 km^2)
global	500,000,000 km^2 (± 500,000,000 km^2)

EU-eco-region

The term “EU-eco-region” is used for the “Natura 2000 Biogeographical Regions” which are the Boreal, Alpine, Atlantic, Continental, Mediterranean, Pannonian, Steppic Black Sea and Macaronesian regions.

Scale dependency of planning instruments and of assessment results

While plans for impact regulation (IR) need resolutions of at least 1:5,000 (or e. g. for details 1:500 or even 1:50), project-related green infrastructure networks can be planned in 1:10,000 or, e. g. for SEA-related defragmentation concepts regarding country-wide transportation networks, in the scale of 1:100,000. The indicators concerning biodiversity aspects have to change with the scales.

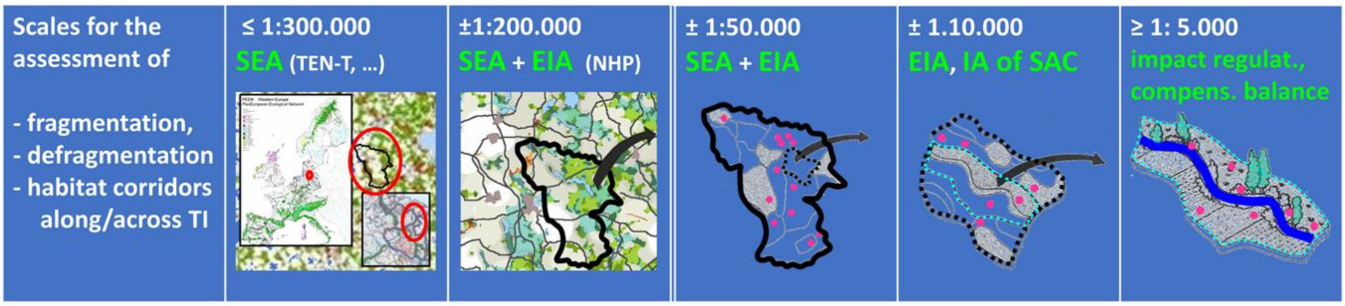


Figure 15: Scales and related instruments
[highly modified after Reck & Kaule 1994; background in the second table column: PEEN and partim German habitat corridors and Habitat-Net Germany; red circles indicating the area featured in the scales 1: 200,000 (Hab-Net Germany) and 1: 50,000]
As ecological balances depend on the given frame conditions and the chosen or appropriate scales, any assessment results should be checked for validity on the next higher and lower scale.

Terms for roads and pathways

Roads are often named or grouped by design "types", i. e., motorways, other divided roads, 2-lane roads. Whilst motorways will always cater for a flow function, the other road types are often not used consistently to reflect a particular function, and designs within the road type groups can vary considerably.[14] This is also the case for the road types defined in the TEN-T which distinguishes:

- Motorways,
- Rural two-lane roads,
- rural road with separate directions,
- urban roads (& types not defined).

Except for motorways, we found no literature-based definitions for the other road types mentioned in the TEN-T dataset. This is why own interpretations of the other types have been created.

Motorway

Motorways are roads with at least 4 lanes, with demarcation and security features and partly fenced. According to Eurostat, UNECE & ITF (2019) motorways are defined as “Road, specially designed and built for motor traffic, …, a) Is provided, except at special points or temporarily, with separate carriageways for traffic in two directions, separated from each other, either by a dividing strip not intended for traffic, or exceptionally by other means…”. In the handbook[15] motorways are defined as “major arterial road that features two or more traffic lanes of traffic moving in each direction, separated by a central reservation called ‘median’ and controlled entries and exits”.

Rural two-lane roads

Major roads with similar design standards as motorways. They have two or more traffic lanes of traffic moving in each direction (4 lanes).

Rural roads with separate directions

Minor arterial road that features one, not separated traffic lane of traffic moving in each direction. This low-to-moderate capacity road is located outside urban areas.

Urban roads

Road located within the boundaries of a built-up area and can be designed as different types and in different level/degrees of use.

[14] https://road-safety.transport.ec.europa.eu/statistics-and-analysis/statistics-and-analysis-archive/roads/road-classification_en
[15] https://handbookwildlifetraffic.info/

Further types and names for roads and pathways

- Highway (federal road), major roads but not motorways, usually with two or more lanes in each direction
- Country road (state road)
- County road (district road)
- Municipal road (local road)
- Residential street
- Farm road, forest road (paved cart track)
- Dirt road
- Foot Path
- Game path

2 EUROPEAN DEFRAGMENTATION MAP

Cindy Baierl, Marita Böttcher & Heinrich Reck

2.1 Preface

“It is essential to accurately assess the environmental impacts of transport activities already at the initial planning stage so as to avoid unnecessary environmental harm that could involve e. g. air quality, noise, greenhouse gas emissions, fragmentation of habitats, and loss of biodiversity and water resources. If identified early in the process, environmental control mechanisms can them be more easily developed relating to the construction and operation of the new transport infrastructure projects. In that context promoting alternative modes of transport to road is also an important policy option to be considered.”[16]

The objective of the Regulation (EU) No 1315/2013 according to Art. 5 No.1 e) (Resource-efficient network) is the planning, development and operation of the Trans-European Transport Network (TEN-T) in a resource-efficient manner through the assessment of strategic environmental impacts and with the establishment of appropriate plans and programmes, as well as the contribution to mitigating the effects of climate change. However, in contrast to air quality, noise, CO^2 emissions, the effects of fragmentation of habitats, the loss of biodiversity and water resources are only very generally addressed as environmental impacts.

It is true that/indeed, according to Art. 36, environmental impact assessments of plans and projects are to be carried out in accordance with Union law on the environment, including Directives 92/43/EEC, 200/60 EC, 2001/42/EC, 2009/147/EC and 2011/92/EU. However, these are not sufficient to avoid fragmentation effects, as none of these regulations sufficiently represents habitat connectivity. This also applies to the Habitats Directive. Article 10[17] of the Habitats Directive is intended to improve the ecological coherence of NATURA 2000 sites by means of linear structures and small-scale structures, because these are essential for the migration, dispersal and genetic exchange of wild species. In fact, sufficient connectivity between NATURA 2000 sites alone has not yet taken place in most EU countries. Due to this omission existing connectivity corridors between NATURA 2000 sites but also other areas important for biodiversity, have not been sufficiently considered in many plans, and their fragmentation by linear infrastructures is often not or not sufficiently compensated. This applies to many infrastructures already implemented, under construction or planned within the framework of the TEN-T. On the other hand, it is scientifically accepted that the fragmentation of habitats and even more so the fragmentation of

[16] https://europa.eu.int/comm/ten/transport/2005_03_31_tent_consultation/doc/working_paper_en.pdf

[17] “Member States shall endovour, whre they consider it necessary, in their land-use planning and development policies and, in particular, with a view to improving the ecological coherence ot the Natura 2000 network, to encourage the management of features of the landscape which are of major importance for wild fauna and flora. Such features are those which, by virtue of their linear and continous structure (such as rivers with their banks or the traditional systems for marking field bouderies) or their function as stepping stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species.” https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:01992L0043-20130701

(functional) corridors are impairments that must be avoided or compensated for, as biodiversity cannot be maintained without their functions. Because this is known to experts, nationwide biotope network planning has been developed throughout Europe for decades to find a remedy. At EU level, the results of the Pan European Ecological Network (PEEN)[18] generated for this purpose are not suitable for the management of impacts, because the overlapping of the TEN-T with the PEEN does not allow for a sufficiently precise assessment of the focal points of conflict between the two networks. And even at the state level, existing usable biotope network plans are often only included in impact assessment management if competent experts are involved in infrastructure planning. Another argument that is repeatedly raised is that the measures to maintain connectivity, such as green bridges, are too expensive. This argument should be reconsidered by the fact when one realizes that 1 km of a motorway in Austria, for example, costs 18.6 million €[19] and in Germany between 6 - 20 million €[20], a green bridge in the most expensive version in Germany currently costs 5 million €.

At EU level, the TEN-T funding programme therefore does not consider the measures to reduce fragmentation effects, although their costs can be estimated in the same way as costs for CO^2 reduction or noise prevention. However, what applies to the avoidance of CO^2 emissions or noise prevention, which are taken into account in all regulations issued so far on the TEN-T, also applies to measures to avoid and compensate fragmentation effects: the sooner the costs can be estimated in the planning process at the upstream level and, in the case of the TEN-T, are co-financed by the EU if necessary, the sooner the measures are implemented in practice.

Therefore, the aim of this project contribution is to provide an initial basis for the assessment and management to avoid fragmentation of functional corridors throughout Europe. This will allow to integrate the currently delineated corridors into the planning process right from the beginning and to estimate the costs and, if necessary, to finance the necessary defragmentation measures also from EU funds within the framework of the TEN-T. We are trying to reach this goal with 2 approaches:

a) with a compilation of all available biotope networks at the European level in a web-based map and first indications for the reconnection of habitats from a European perspective and

b) with a compilation of planning hints and new methods that support the integration of fragmentation and barrier effects from the highest planning level to local implementation.

2.2 Introduction

The administrative working base for the development of the EDM is the TEN-T in connection with Regulation (EU) No 1315/2013 and the EU Green Infrastructure Strategy.

[18] https://www.eea.europa.eu/data-and-maps/figures/indicative-map-of-the-pan-european-ecological-network-for-central-and-eastern-europe
[19] https://de.statista.com/statistik/daten/studie/1275481/umfrage/kosten-fuer-infrastruktur-nach-verkehrsweg-in-oesterreich/
[20] https://www.verkehrsrundschau.de/nachrichten/transport-logistik/hintergrund-was-kostet-ein-kilometer-autobahn-2999089

The basis for the development of a TEN-T was established by the Guidelines for the development of the trans-European transport network (Decision No 1692/96/EC of 23 July 1996, amended by Decision No 1346/2001/EC of 22 May 2001 and Decision No 884/2004/EC of 29 April 2004). With Official Journal L 348 of the European Union of 20 December 2013, Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on guidelines for the development of the trans-European transport network, as last amended in 2019[21] was adopted.

The Regulation provides the legal basis for the implementation of the TEN-T, describes the rules and is complemented by supplementary maps in Annexes I (Maps of the Comprehensive Network and Core Network and Annex) and III (Indicative Maps of the Trans-European Transport Network - extended to certain third countries). The high-resolution maps of the TEN-T measures are available on the network at European Comission website[22] and form an important basis of information for planners and the public. In comparison to TEN-T, the EU Green Infrastructure Strategy (GI-Strategy) was adopted almost 10 years ago in 2013. The GI integrates among other things developments that already include the publication of numerous guidance documents by the committee for the Activies of the Council of Europe in the field of Biological and Landscape Diversity in 2002 as part of the development of the PEEN. In this sense, the GI could be seen as the further development of the PEEN at the strategic level. Due to numerous identified planning deficiencies (see chapter 3.1), the GI-Strategy should ensure that the protection, restoration, creation and enhancement of green infrastructure become an integral part of spatial planning and territorial development. Aim of the strategy is to promote the deployment of green infrastructure across Europe, as well as the development of a Trans-European Network for Green Infrastructure in Europe, a so-called TEN-G, equivalent to the existing networks for transport, energy and ICT (Information and Communication Technolgy). Although this strategy has been available for 10 years and many countries have nationwide biotope network plans, there is a lack of a map of ecological corridors for Europe comparable to the core network of the TEN-T, which at least allows an overview of the existing corridor network and can also be used by planners and the public to avoid fragmentation effects.

2.3 Material & Methods

2.3.1 Preparatory work

Obtaining data for creation a map compilation is fraught with several difficulties: identification of the right data, clarification of administrative responsibilities, choosing the right contacts, getting permission to work with the data, finding explanations of the data (often just in national language), conversion of the data into a uniform format and projection. All this can significantly delay data acquisition and use, sometimes prevent it, and thus cause significant delays in the project.

Fortunately, this project was able to draw on existing preliminary work. In particular, the use of existing contacts proved to be very target-oriented and timesaving. A preliminary work of Czech Republic (Ministry of the Environment of the Czech Republic, Species Conservation Department (Martin Strnad)), who created the first map draft (Austria, Czech Republik, Poland and Germany), provided a valuable

[21] http://data.europa.eu/eli/reg/2013/1315/2019-03-06

[22] https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/mobile.html

basis for the creation of an EDM. Through the funding of two smaller research projects by the Federal Agency for Nature Conservation (Leipzig/Germany), this fundamental work on EDM was continued with a relatively limited time and financial budget, and first presentable results were achieved.

In particular, the identification and contacting of the right contact persons, smaller workshops as well as presentations of the results at the IENE conferences in 2012[23] and 2016 were among the important preliminary work. At the beginning of the BISON project in 2019, a basic data collection and visualization in a GIS-based map (Figure 16), a brief description of the so far integrated data and first simple exemplary spatial analyses (of the transnational connections, e. g. the overlap with the Natura 2000 network) had already been carried out. Without this preparatory work, the state of the map as it is now at the end of the BISON project would not have been possible.

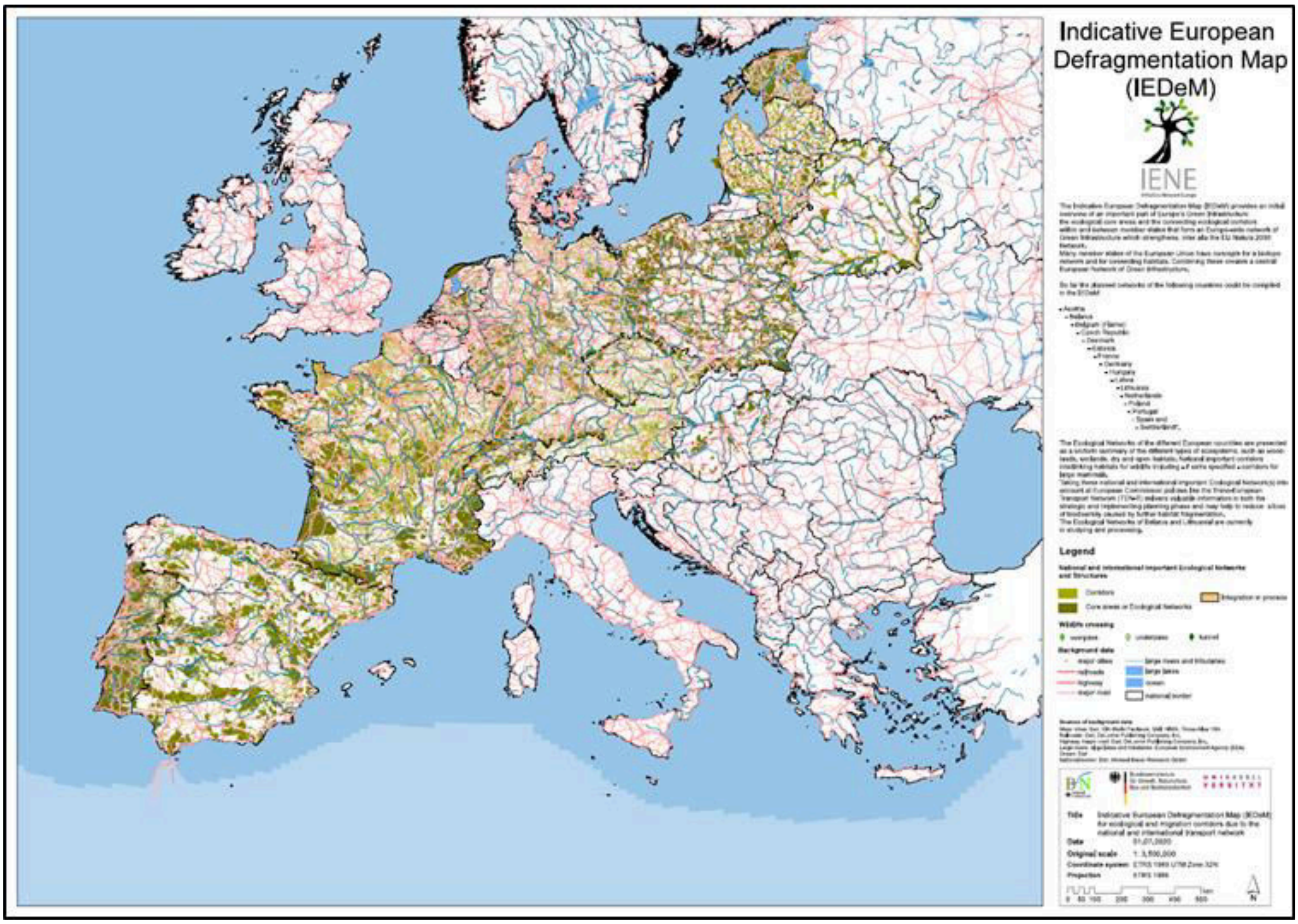


Figure 16: Updated Draft of the European Strategic Map for Defragmentation (2019)

[23] https://www.iene.info/content/uploads/2016/04/IENE-2012-Declaration.pdf, https://www.iene.info/content/uploads/2018/10/IENE2018-Final-Declaration-Def-14092018.pdf

2.3.2 Data procurement

Building on the data collection and contacts from the previous projects, the existing data base of ecological networks was checked for updates. For further completion and elimination of data gaps, especially of Ecological networks, the BISON questionnaire (https://bison-transport.eu/questionnaire/; dissemination April 2021) was used to receive recommendations and advice from the project consortium and the questionnaire distribution list. The knowledge gained from the questionnaire fell short of expectations. The further data research based on contacts, internet and source research and the follow-up contacting and data requests of relevant/competent institutions. As a result, the Ecological networks of 17 European countries[24] (Figure 17) and two transnational ones, the Carpathian Corridors (CZ, SK, HU, PL, RO, RS, UA) and the Alp-Carpathian-Corridor (AT, SK), could be obtained. In this context the data requests on defragmentation measures of six countries (AT, CZ, FR, DE, NL, CH) were successful.

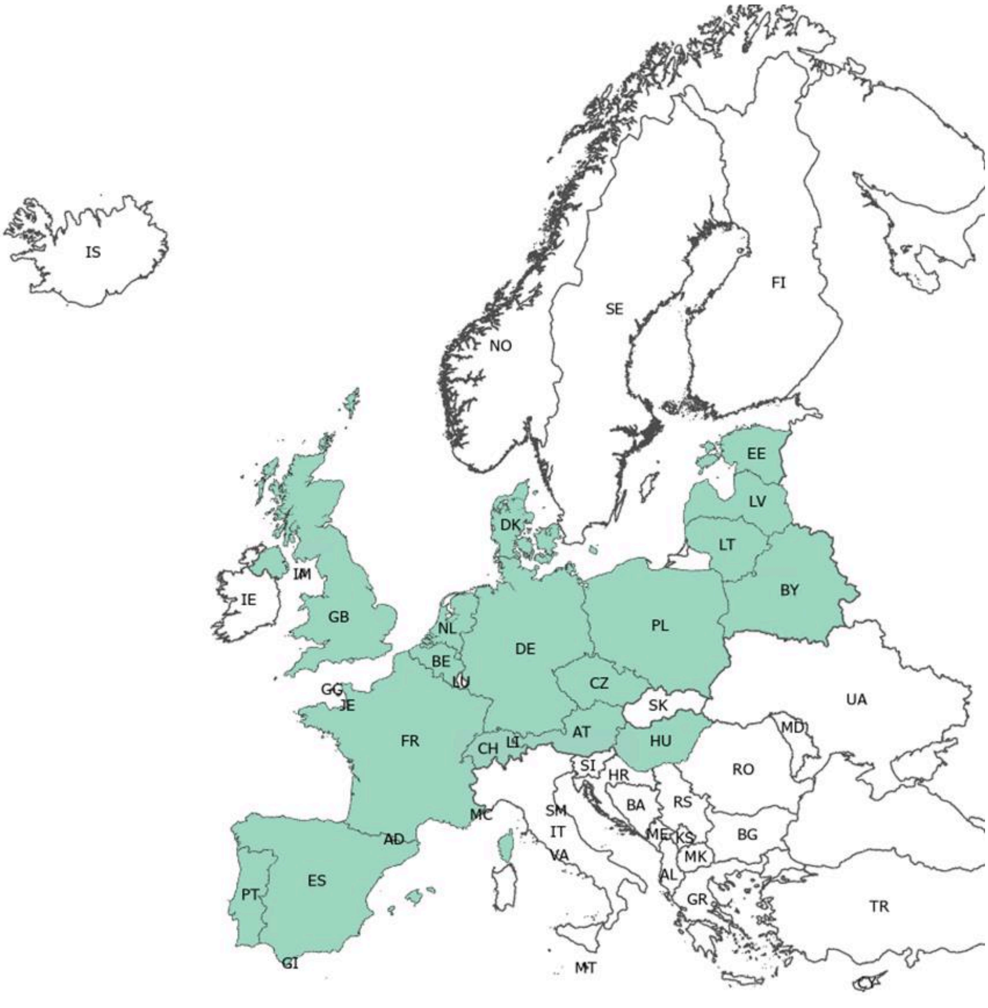


Figure 17: European countries with existing national Ecological networks integrated in the EDM (state 2022)

[24] For Belgium just the Flemish Ecological Network could be procured.

Information on European and national protected areas, in particular the Natura 2000 network and nationally designated protected areas was retrieved from official websites of the European Environmental Agency (EEA).[25] The digital GIS data of the European Transport Infrastructure (TENT-T) were provided by the European Union in April 2021 (Edit date 14/04/2021) via the BISON project management. Additional and background data come from various sources with free access.[26]

2.3.3 Integrated Data

2.3.3.1 Ecological Networks

As its main content, the European Defragmentation Map presents important elements of Green Infrastructure preferably of European or at least national importance. In the case that no differentiations/gradations existing on the different spatial scales, networks were also included that have been created at regional level for regions, provinces or municipalities and are available as a summarised data set for the respective national area. These networks (e. g. Lithuania, Denmark, France) were also integrated into the European map and included in the evaluations.

Ecological Networks represent (more or less) functional connected/related areas, often including or consisting of the NATURA 2000 areas as a backbone but depict more (than NATURA 2000) potential or real ecological connections between habitats/ecosystems. Sometimes they are created from or based on NATURA 2000 or parts of it (e. g. Spain's Ecological Network consists of Natura 2000 woodlands as core areas and connecting corridors, Lithuania). Beside their NATURA 2000 area backdrop a wider range of European Countries have Ecological Networks defined, which are more or less independent from NATURA 2000.

Although the Ecological Networks are developed and based on different methods, they all have their justification and represent an important and noteworthy part of the green infrastructure of the respective country or a transnational (biogeographical) region. This broad spectrum of applied methods requires a different spatial and content-related design of the networks. Therefore, they show a wide range of width, shape, structure and content.

Most Ecological Networks are designed to contain at least core areas and corridors. A few projects also add buffer and other types of areas (e. g. development or restoration areas, stepping-stones). Beside these, critical zones/sites with limited connectivity (e. g. due to crossing traffic routes) have already been identified in some networks (Czech Republic, Carpathians, Germany, Spain, Austria, Switzerland). The identified bottlenecks represent critical areas for connectivity along the corridors or in core areas; mitigation measures and solutions to acquire permeability should be considered here.

Existing protected areas (Natura 2000 sites, national and local reserves) are usually taken as the **core areas** of Ecological Networks. These areas are expected to represent the best areas available to ensure

[25] Natura 2000: https://www.eea.europa.eu/data-and-maps/data/natura-14; Nationally designated areas: https://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-17

[26] European Environmental Agency: https://www.eea.europa.eu/data-and-maps/data#c0=5&c11=&c5=all&b_start=0; ESRI Data and Maps: https://hub.arcgis.com/datasets/

biodiversity conservation but there is little evidence that existing protected areas represent ideal core areas for biodiversity (Boitani et al. 2007).

Ecological corridors should ensure the connectivity of core areas. Whereas in the past the connectivity of core areas through ecological corridors was mainly based on the structural features of the landscape (mainly vegetation), today they are predominantly based on the ecological requirements of one or more species (groups) and/or on biotope mapping in combination with selected types of species. Ecological corridors show different characteristics in the European countries or regions. There are **focal corridors** to connect differentiated core areas (e. g. Germany, Austria, Switzerland), for (potential, best) functional connections between them. Several countries have defined ecosystem-specific focal-corridors. Germany as an example pointed out such focal corridors for woodlands (with integration of habitats for large mammals), for dry habitats watercourses and wetlands. Furthermore, some countries defined **areal corridors** for selected ecosystems and/or as suitable territories for migration and dispersal of species/species groups. For example, Poland's Ecological Network shows areal corridors for forests and wetlands, as suitable for migration and dispersal of species/species groups; the Czech Republic defined them for large mammals.

The French green and blue network "Trame verte et bleue" (TVB) both types of corridors, where the focal corridors are sometimes shown as schematic with arrows to illustrate the ecological connection function (see Figure 28 in chapter 2.3.5.1).

The following table (Table 2) gives an overview of the integrated Ecological Networks and the country specific network elements. For detailed information about these ecological data see annex 7.

Table 2: Overview of Ecological Networks integrated in the EDM

Country	Data format V=Vector //	Generalized (G) // Differentiated[27] (D)	Designation of Cores	Designation of Corridors	Short characteristic and type of Cores // Corridors
National/regional Ecological Networks					
Austria (AT)	V	G	no	yes	Corridors: linear axes/focal lines focus on large mammals/forest connectivity, also consideration of amphibian corridors; Designation of International important bottlenecks in the corridors
Belarus (BY)	R	G	yes	yes	Network comprises nucleus zones, areal ecological corridors and protected areas. Cores: nucleus zones (specially protected natural areas and natural areas) Corridors: ensure communication between nucleus zones and allow wild plants and animals to spread and migrate; areal water corridors (along the major rivers) and areal corridors of forest
Belgium (BE) only Flanders	V	G	yes	no	Network comprises just cores Cores: The main ecological structures shown include areas of current (“large units of nature”) and potential (“large units of nature in development”) ecological interest; agricultural landscapes are also integrated

[27] E. g. for ecosystems or species groups

Country	Data format V=Vector //	Generalized (G) // Differentiated[27] (D)	Designation of Cores	Designation of Corridors	Short characteristic and type of Cores // Corridors
Czech Republic (CZ)	V	D	yes	yes	Network comprises national core areas and linear connecting national axes (corridors) and biotopes/cores for large mammals, areal ecological corridors for connecting these cores and critical barrier sites within the corridor areas. Cores: distinction of national core areas and biotopes/cores for large mammals Corridors: linear national axes (corridors) and additional areal corridors for large mammals; designation of critical zones
Denmark (DK)	V	G	no	no	Network (Green Map of Denmark) comprises Økologiske forbindelser (ecological connections) and potentielle Økologiske forbindelser (not considered). Cores & Corridors are not differentiated! As a backbone for the network Natura 2000 sites and other existing valuable natural areas were used.
Germany (DE)	V	D	yes	yes	Network comprises differentiated cores and linear national axes (corridors) Cores: functional spaces were determined for dry, wet and forest habitat complexes; forest habitat complexes integrate habitats for large mammals Corridors: nationally and internationally significant linear biotope network axes were ultimately derived form the functional spaces for dry, wet and forest habitat complexes. In the EDM the internationally significant linear biotope network axes were integrated.

Country	Data format V=Vector //	Generalized (G) // Differentiated[27] (D)	Designation of Cores	Designation of Corridors	Short characteristic and type of Cores // Corridors
Great Britain (GB) England Central Scotland Wales	V V V	D D D	yes yes yes	no yes yes	Networks comprises: England: Habitat Components (Cores) and different network zones (suitable for habitat recreation) Central Scotland: different habitats (woodland, grassland, wetland and bog and heath) as cores and key sites for connecting these habitats (areal Corridors) Wales: different habitats (woodland, unimproved grassland, calcareous grassland, marshy grassland, heathland, fens and bogs) as cores and three levels of habitat networks (core, focal and local networks) as areal corridors
Hungary (HU)	V	G	yes	no	The Hungarian Ecological Network (Országos Ökológiai Hálózat) comprises core areas, ecological corridors and buffer areas. It includes the national important natural and semi-natural areas (nature protected areas, Natura 2000 areas, high nature value areas)
Estonia (EE)	R	G	yes	yes	Networks comprises not differentiable cores and areal corridors Cores: compact natural areas with a territory of at least 100 km²; 12 major core areas (predominantly forests and swamps) Corridors: traverse the core areas
France (FR)	V	G	yes	yes	Network (Trame vert et bleu) comprises green (terrestrial natural and semi-natural environments) and blue (aquatic and wet networks) framework; cores, linear and aerial landscape corridors are distinguished Cores: Integrative representation of the significant terrestrial and aquatic ecosystems Corridors: areal landscape corridors and linear corridors (axes)

Country	Data format V=Vector //	Generalized (G) // Differentiated[27] (D)	Designation of Cores	Designation of Corridors	Short characteristic and type of Cores // Corridors
Lithuania (LT)	R	G	yes	yes	Networks comprises core areas, buffer zones, restoration areas, ecological corridors and stepping-stones. In the EDM just core areas and aerial ecological corridors on national and European level are integrated Cores: habitats of the greatest bioecological importance on national and European level Corridors areal migration corridors of animals and plants on national and European level
Latvia (LV)	R	G	yes	yes	Network comprises core areas, buffer zones and aerial ecological corridors of national and international importance, stepping-stones and nature development areas. In the EDM the core areas with its buffer zones and the aerial ecological corridors are integrated. Cores: habitats of national and international importance Corridors aerial ecological corridors connecting cores/buffer zones
Netherlands (NL)	V	D	yes	yes	Network (Ecologische Hoofdstructuur (EHS))[28] comprises differentiated core areas and linear corridors Cores: defined for large water bodies and for dry, wet and forest habitat complexes; forest habitat complexes integrate habitats for large mammals Corridors: linear core connecting corridors
Poland (PL)	V	G	no	no	Network was developed for Natura 2000 areas (esp. key species of large mammals), no differentiation of cores and corridors; Network focusses on large forest mammals and the coherence of forest and wetland habitats on a national and continental level

[28] The Nature Network of the Netherlands (NNN) is currently being developed. While the government is responsible for the NNN in the large waters, the provinces are responsible for the delimitation and development of the remaining NNN until 2027. So far just some provinces have data so far e. g. Utrecht.

Country	Data format V=Vector //	Generalized (G) // Differentiated[27] (D)	Designation of Cores	Designation of Corridors	Short characteristic and type of Cores // Corridors
Portugal (PT)	R	G	yes	no	Network consists just of core areas of nature conservation and biodiversity (including Natura 2000 areas, other areas designated at international level, areas of water in the public domain etc.)
Spain (ES)	V	D	yes	yes	Network (Red Estratégica de Corredores Ecológicos) comprises only woodland cores and linking linear corridors Cores: just consisting of Natura 2000 woodland habitats (forests and shrubs) Corridors: ecological corridors linking woodland; focusses on large scale movements of a representative group of forest mammals; 17 critical areas that are within these twelve corridors (called "bottlenecks") and that must urgently be restored have been identified.
Switzerland (CH	V	D	yes	Yes	Network (Réseau écologique national (REN)) comprises differentiated core areas and linear corridors Cores: differentiated for dry, wet and forest habitats Corridors: linear corridors as national axes (not differentiated for the habitat types
International // biogeographical Ecological Networks					
Carpathian Corridors	V	D	yes	yes	Cores: favourable and suitable habitats Corridors: movement/migration zones Critical zones: representing critical connectivity sectors within both, cores and corridors
Alp-Carpathian-Corridor	V	D	yes	yes	Cores: large forest areas, only rough demarcation, core wildlife zones Corridors: 4 modelled courses (bottlenecks) of connections between core wildlife zones; distinction between priority and secondary corridors

Country	Data format V=Vector //	Generalized (G) // Differentiated[27] (D)	Designation of Cores	Designation of Corridors	Short characteristic and type of Cores // Corridors
Alp-Atlas (SACA: Strategic Alpine Connectivity Areas)					Ongoing Data request (via wwf Romania, Hildegard Meyer) Cores: Ecological conservation areas where ecological connectivity already works quite well (SACA1) Other area categories: SACA 2: largescale areas with (a good) connectivity function between SACA 1 areas SACA 3: areas with barrier effects between SACA 1 areas ? are these Corridors/corridor areas?
DINALPCONNECT - Transboundary ecological connectivity of Alps and Dinaric Mountains					Project runs until August 2022 not sure about results, if there are/were suitable data produced

2.3.3.2 Defragmentation measures

During enquiries with the countries about their ecological networks, data sets for defragmentation measures were requested. Information/datasets were provided by 8 countries. A private list of greenbridges[29] was used to update the Czech data and to be able to integrate a current number of those structures in Romania and Slowakia (state 2021). Only larger structures (width from 50 m) were requested and/or selected from the data sets (if dimension was specified in the data attributes). They are differentiated into the three types: overpasses (O), underpasses (U) and tunnels (T). It is assumed, that these structures allow a general wildlife migration over the TI and have to be considered in the process of identification of defragmentation needs and priorities.

The EDM shows a selection of the location and type of the defragmentation measures. In most countries there is a lack of national data basis of defragmentation measures, therefore the shown measures do not reflect the currently built crossing aids.

Table 3: Overview defragmentation measures data

(state 2022,) types: (O=Greenbridges), (U=Underpasses), (T=Tunnels)

Country	Dataset Description
Austria	Point feature dataset with 53 items; types: (O), (U), (T); further attributes: street; state 2019
Czech Republic	Point feature dataset with 21 items, just green bridges (O); further attributes: width, length, purpose (wildlife, multifunctional), type (O); state 2016[30]
France	Point feature dataset with 105 selected items, types: (O), (U), (T); further attributes: street, width, length, class; state 2017
Germany	Point feature dataset with 138 selected items, types: (O), (U), (T); further attributes: street, year, purpose, width, length; state 2016
Netherlands	Point feature dataset with 52 selected items; types: (O), (U); further attributes: street; TI type, status (in preparation, completed, under construction); state 2019
Romania	Excel table with 3 features
Slowakia	Excel table with 4 features
Switzerland	Point feature dataset with 35 items; types: (O), (U), (T); further attributes: street, purpose, origin; state 2016

[29] Excel table provided by the Ivo Dostal (CZ), state 25/05/2021

[30] Dataset has been updated with the list of Green bridges from Ivo Dostal (n=31) from 2021

2.3.3.3 Natura 2000 Network

Data of the Natura 2000 network were requested from the European database of hosted and compiled by the European Environmental Agency (EEA). The Data are periodic submitted by the Member States of the European Union and annually updated. For the EDM the Sites of the Habitats Directive on terrestrial territory (state 2021) are considered. These are the Sites of Community Importance (SCIs) and Special Areas of Conservation (SACs) (see Figure 18).[31]

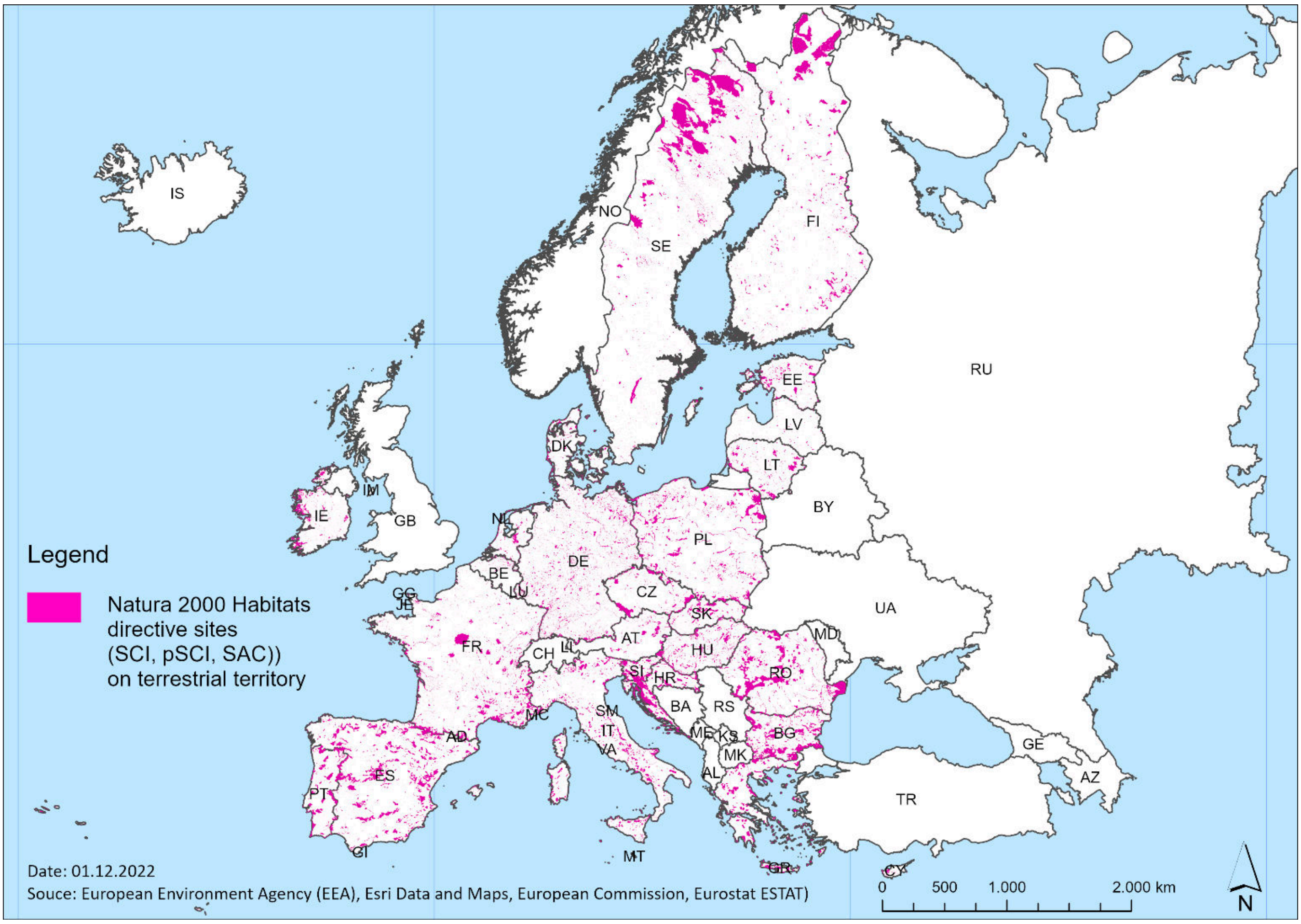


Figure 18: Habitats Directive Sites on EU terrestrial territory

(state 2021)

Extent, number and size of the areas vary greatly in the member states territories. The table below gives an overview about the area scope of the Sites of Community Importance (SCIs) and the percentage terrestrial land coverage. The percentage of area varies from a minimum of 7 % in Denmark to a maximum of 33 % in Slovenia.

[31] Data download: https://www.eea.europa.eu/data-and-maps/data/natura-14 [15/10/2022]

Table 4: SCI on the Member states terrestrial territories

Country	Surface area (km^2)[32]	Terrestrial SCI (km^2)[33]	% land area covered
Austria	83.879	9.378	11
Belgium	30.528	3.284	11
Bulgaria	110.370	33.629	30
Croatia	56.594	16.036	28
Cyprus	9.251	959	10
Czech Republic	78.868	7.952	10
Germany	357.376	33.550	9
Denmark	42.924	3.178	7
Estonia	45.227	7.806	17
Finland	338.440	42.200	12
France	633.187	48.893	8
Greece	132.049	21.912	17
Hungary	93.011	14.442	16
Ireland	69.797	7.162	10
Italy	302.073	43.007	14
Lithuania	65.286	6.461	10
Luxembourg	2.586	416	16
Latvia	64.573	7.421	11
Malta	315,4	41	13
Netherlands	41.540	3.118	8
Poland	312.679	34.266	11
Portugal	92.226	15.661	17
Romania	238.391	40.310	17
Slovakia	49.025	6.151	13
Slovenia	20.273	6.634	33
Spain	505.944	118.282	23
Sweden	438.574	55.023	13

[32] Source: Eurostat (https://european-union.europa.eu/principles-countries-history/key-facts-and-figures/life-eu_en) [14/03/2022]
[33] Source: Natura 2000 Newsletter Number 51, Febuary 2022; https://op.europa.eu/en/publication-detail/-/publication/2f41bbd8-9916-11ec-8d29-01aa75ed71a1/language-en/format-PDF/source-252120630 [14/03/2022]

2.3.3.4 Nationally Designated Areas (CDDA)

The CDDA is the official source of protected area information from the 37 European countries to the World Database of Protected Areas (WDPA). The European inventory of nationally Designated Areas contains information about protected areas and the national legislative instruments, which directly or indirectly create protected areas. The CDDA data can be queried online in the European Nature Information System (EUNIS)[34] and downloaded from the EEA website.[35] Geographical coverage of GIS vector boundary data: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kosovo under UNSC Resolution 1244/99, Latvia, Liechtenstein, Lithuania, Luxembourg, North Macedonia, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden and Switzerland.[36] Table 5 lists the countries and their strictly Nationally designated areas (used categories, see Table 6) on terrestrial territory in absolute and percentage land area shares.

Table 5 Nationally designated areas (CDDA) on the state's terrestrial territories

State	Surface area (km^2)[37]	Terrestrial Nationally designated areas (km^2)[38]	% land area covered
Albania	28.748	4.008	14
Austria	83.879	8	0
Belgium	30.528	1.589	5
Bosnia and Herzegovina	51.209	1.705	3
Bulgaria	110.370	14.575	13
Croatia	56.594	7.642	14
Cyprus	9.251	1.376	15
Czech Republic	78.868	2.466	3
Denmark	42.924	4.996	12
Germany	357.376	22.349	6
Estonia	45.227	11.427	25
Finland	338.440	35.005	10
France	633.186,6	13.744	2
Greece	132.049	16.475	12

[34] https://eunis.eea.europa.eu/
[35] https://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-17
[36] EEA does not have permission to distribute some or all sites reported by Estonia, Ireland and Turkey. Following the United Kingdom's withdrawal from the EU on 31 January 2020, it ceased to be part of the EEA's institutional networks and governance.
[37] Source: Eurostat (https://european-union.europa.eu/principles-countries-history/key-facts-and-figures/life-eu_en) & https://www.statista.com/statistics/1277259/countries-europe-area/ [14/03/2022]
[38] Own calculation of CDDA areas (IUCN categories I to IV and so far undefined categories) on the states terrestrial territories (Based on layer Countries Europe)

State	Surface area (km^2)[37]	Terrestrial Nationally designated areas (km^2)[38]	% land area covered
Hungary	93.011	2.456	3
Iceland	103.000	18.288	18
Ireland	69.797	585	1
Italy	302.073	26.999	9
Kosovo	10.887	1.314	12
Latvia	64.573	6.050	9
Liechtenstein	160	18	11
Lithuania	65.286	3.227	5
Luxembourg	2.586	1.968	76
North Macedonia	25.713	2.052	8
Malta	315,4	141	45
Montenegro	13.812	1.034	7
Netherlands	41.540	11.836	28
Norway	323.802	44.117	14
Poland	312.679	77.906	25
Portugal	92.226	1.875	2
Romania	238.390,7	6.278	3
Serbia	88.871	3.344	4
Slovakia	49.025	4.727	10
Slovenia	20.273	12.908	64
Spain	505.944	49.892	10
Sweden	438.574	49.178	11
Switzerland	41.284	5.029	12

For the EDM a selection of strictly protected areas within the area backdrop of nationally Designated Areas is used. These are the protected area management categories I to IV classified by the International Union for Conservation of Nature (IUCN) (Dudley 2008) and so far, categories that cannot be defined (Table 5), so as not to lose perhaps important areas of this backdrop (Figure 4).

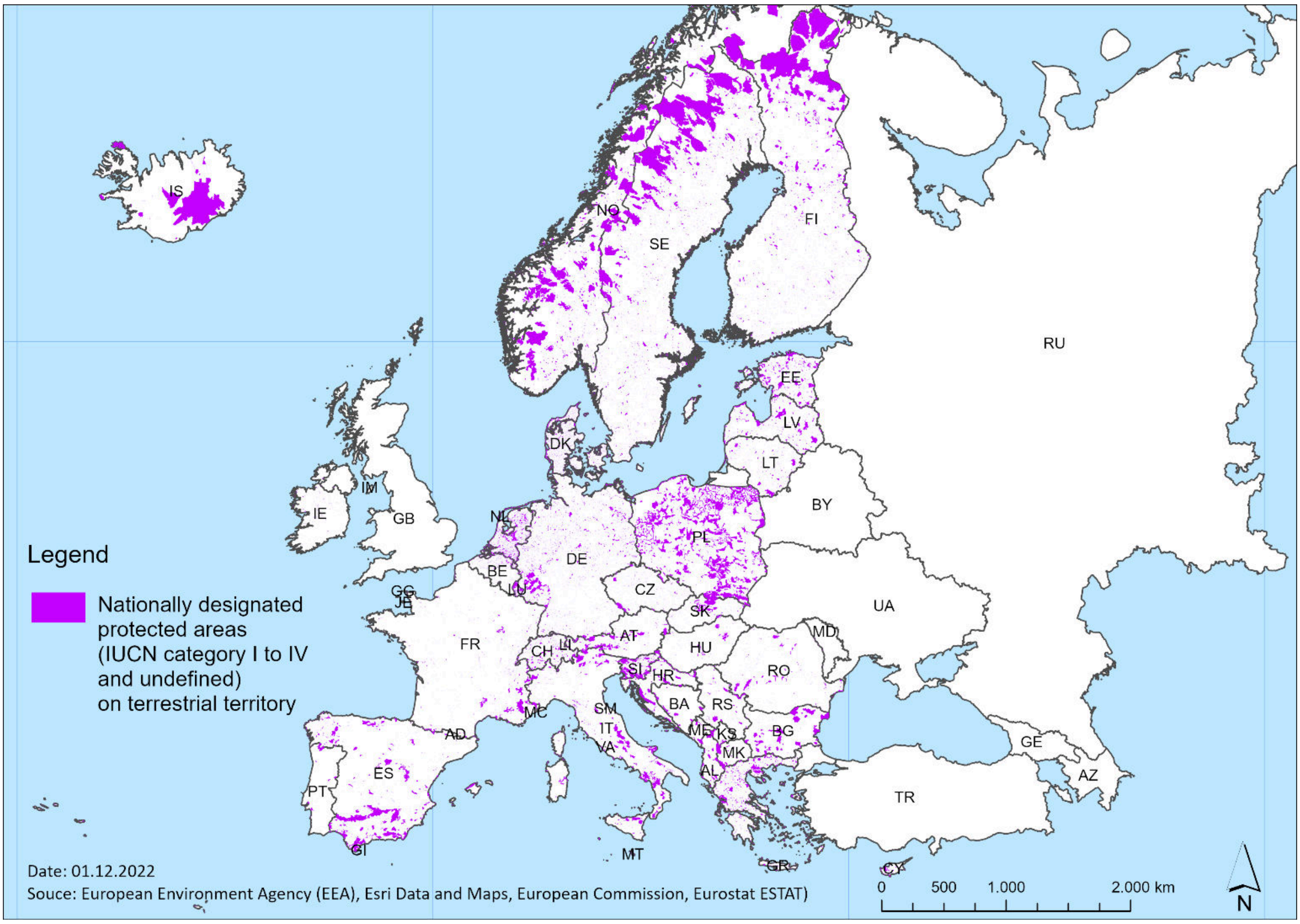


Figure 19: Nationally designated protected areas (IUCN category I to IV and undefined) on terrestrial territory (state 2021)

Table 6: IUCN protected area management categories

Protected area management category	Description	Total number of Areas (n) on terrestrial territory of all 37 countries
Ia	Strict nature reserve: Strictly protected for biodiversity and also possibly geological/ geomorphological features, where human visitation, use and impacts are controlled and limited to ensure protection of the conservation values	8.822
Ib	Wilderness area: Usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, protected and managed to preserve their natural condition	2.69939
II	National Park: Large natural or near-natural areas protecting large-scale ecological processes with characteristic species and ecosystems, which also have environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities	2.090
III	Natural monument or feature: Areas set aside to protect a specific natural monument, which can be a landform, sea mount, marine cavern, geological feature such as a cave, or a living feature such as an ancient grove	4.856
IV	Habitat/species management area: Areas to protect particular species or habitats, where management reflects this priority. Many will need regular, active interventions to meet the needs of particular species or habitats, but this is not a requirement of the category	56.405
V	Protected landscape or seascape: Where the interaction of people and nature over time has produced a 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	
VI	Protected areas with sustainable use of natural resources: Areas which conserve ecosystems, together with associated cultural values and traditional natural resource management systems. Generally large, mainly in a natural condition, with a proportion under sustainable natural resource management and where low-level non-industrial natural resource use compatible with nature conservation is seen as one of the main aims	
not applicable	concerns protected areas in the countries: Sweden, Denmark, Estonia, Belgium, Slovakia, Slovenia, Bulgaria, Greece	33.851
not assigned	concerns protected areas in the countries: Sweden, Portugal, Spain, Netherlands, Switzerland, Poland, Finland	15.973
not reported	concerns protected areas in the countries: Norway, France, Croatia, Serbia	844

[39]Wilderness areas are mainly reported in Estonia, Sweden, Finland, Luxembourg and Slovenia. Obviourly no designated protection status in other countries (e. g. Germany has an area backdrop of wilderness areas).

2.3.3.5 Traffic data

Traffic data of the Trans-European Transport Network (TEN-T) are significant for the European Defragmentation Map. Other (national) transport data, e. g. more specifying data like traffic volume data (vehicle/day) or number of tracks in case of rails have not been researched. The Trans-European Transport Network (TEN-T) policy addresses the implementation and development of a Europe-wide network of railway lines, roads, inland waterways, maritime shipping routes, ports, airports and railroad terminals. The ultimate objective is to close gaps, remove bottlenecks and technical barriers, as well as to strengthen social, economic and territorial cohesion in the EU. The current TEN-T policy is based on Regulation (EU) No 1315/2013)[40].

TEN-T comprises two network 'layers':

- The Core Network includes the most important connections, linking the most important nodes, and is to be completed by 2030.
- The Comprehensive Network covers all European regions and is to be completed by 2050.

A TEN-T dataset for using in this task of the BISON Project was provided by the European Union in April 2021 (Edit date 14/04/2021). The data map of the entire ("Comprehensive") network consists of **roads**, **railways** and **inland waterways** as linear transport infrastructure elements. They are available as vector-based polylines (Figure 20). **Ports**, **airports**, **rail-road terminals** (RRT) as areal transport infrastructures (TI) are presented as point layers without information on the areal extent (Figure 21). The data have different and differently extensive attributes for further selections and evaluations (Figure 22).

[40] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013R1315

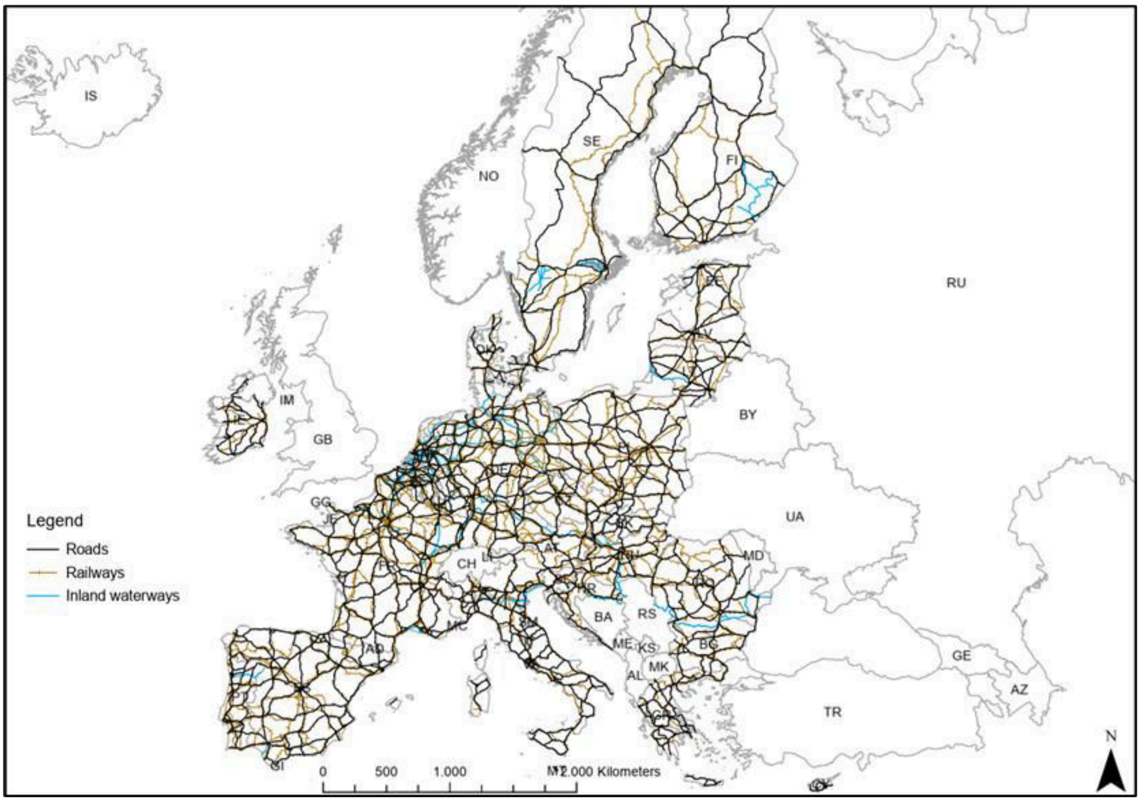


Figure 20: Linear TEN-T infrastructure

(polylines; Edit date 14/04/2021)

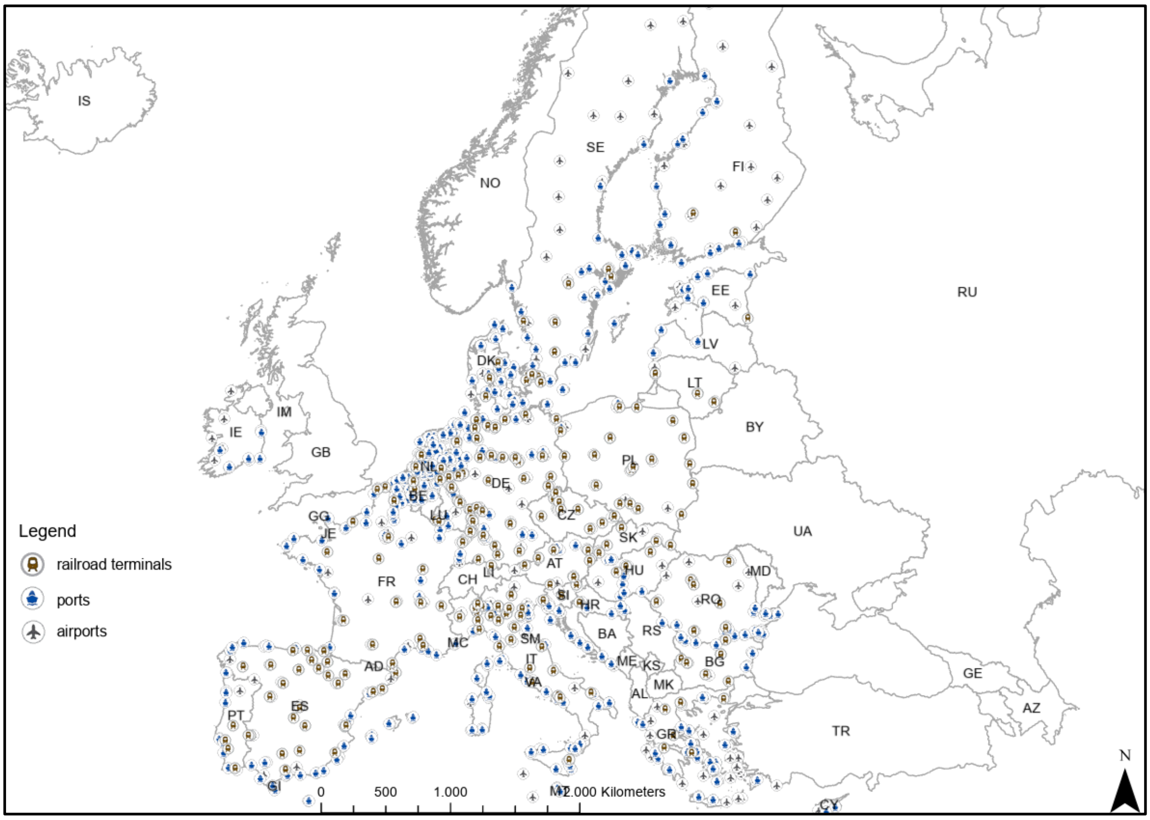


Figure 21: Areal TEN-T-infrastructure

(point features; Edit date 14/04/2021)

Depending on the transport respectively the object mode, the attribution varies in scope and precision.

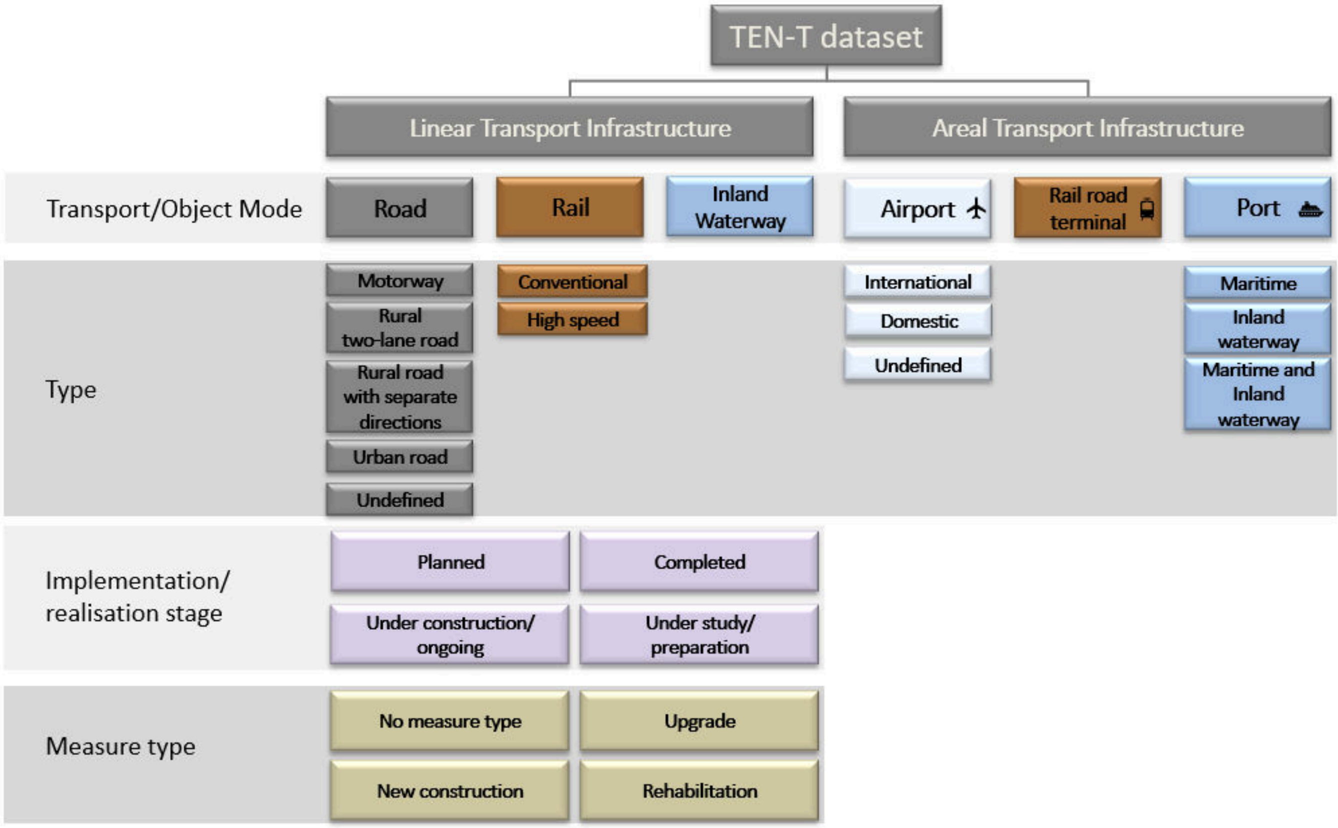


Figure 22: Content and attribution of the TEN-T dataset

(Edit date 14/04/2021)

With the exception of the Inland Waterways (IWW) and the Rail road terminals (RRT) for all other transport and object mode types are defined. Unfortunately, there are gaps in the road type designation; 28 % of them are 'undefined' (no record in the data attribute table). For the linear transport infrastructure elements of the TEN-T the implementation/realisation stage as well as the measure type is defined. Beside already finished ('completed') roads and rails routes, there are 'planned' routes, routes 'under construction/ Perez' and routes 'under study/preparation'. For the 'planned routes', the specific routes have not yet been determined. The category routes 'under study/preparation' includes both, already fixed routes (often upgrades of existing roads) and new routes with non-precised routings. The 'completed' routes are already finished whereas routes under construction are being built at present. The different stages of development require and enable different possibilities for influencing planning processes with regard to avoidance, mitigation and defragmentation measures. Therefore, in the EDM the above-mentioned different implementation types are presented as different layers.

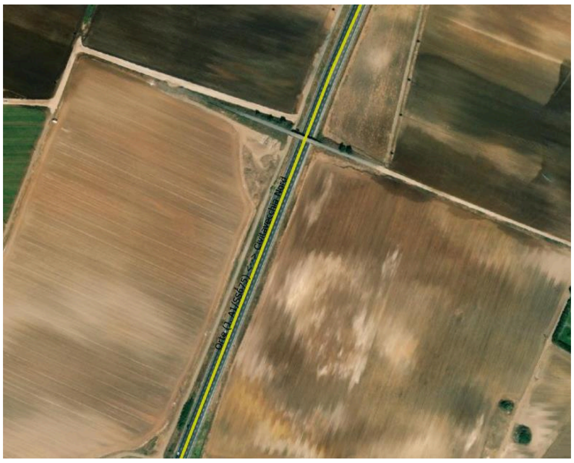
For the EDM, a rough selection of the TEN-T transport infrastructure in terms of a barrier effect is used to get a first overview of the impairment severity due to fragmentation (for further explanation see chapter 2.3.4.4). For further investigation the road types[41] (Figure 10) 'motorways', 'rural two-lane roads' and 'undefined roads' are selected. 'Motorways' use to be roads with at least 4 lanes, with demarcation and security features and partly fenced. According to Eurostat, UNECE & ITF (2019) motorways are defined

[41] 'motorways', 'rural two-lane roads', 'rural roads with separate directions', 'urban roads' and 'undefined roads'

as “Road, specially designed and built for motor traffic, …, a) Is provided, except at special points or temporarily, with separate carriageways for traffic in two directions, separated from each other, either by a dividing strip not intended for traffic, or exceptionally by other means…”. There are no official definitions for the other road types mentioned in the TEN-T dataset. Based on aerial photographs was found out, that rural two-lane roads show similar design standards as motorways and have as well 4 lanes. Rural roads with separate directions have only two lanes, are so smaller in width, lower in traffic and lower barrier-relevant characteristics. Urban roads are located in clearly by settlement characterized areas and are therefore not further considered.

Type of road: Motorway
Country: PL

National road Number: A4
Location: Krayzie - Krzywa



Type of road: Rural road with separate directions
Country: IT

National road Number: SS675/SS1bis
Location: Orte - Civitavecchia Nord

Type of road: Rural two-lane road
Country: CZ

National road Number: R6
Location: Cheb - Schirnding / Pomezi n/O

Type of road: Urban road
Country: AT

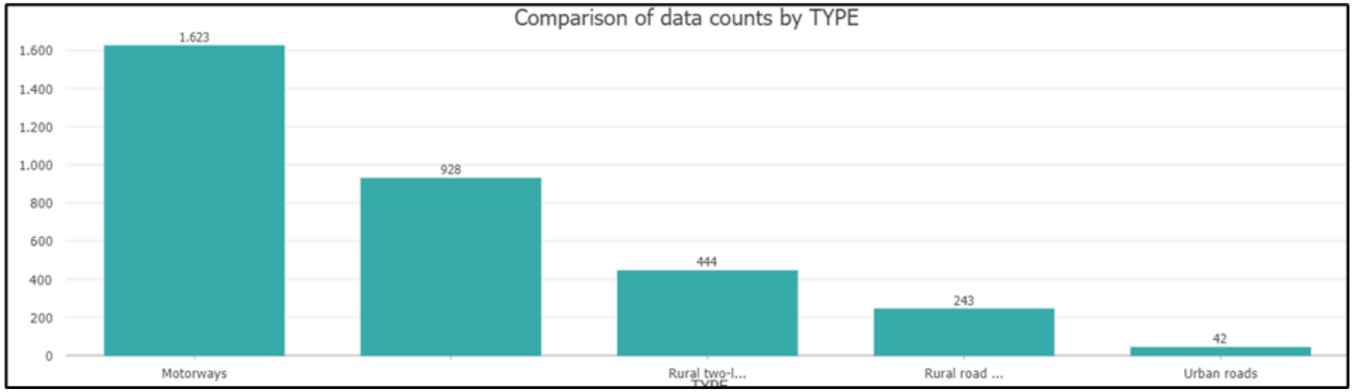
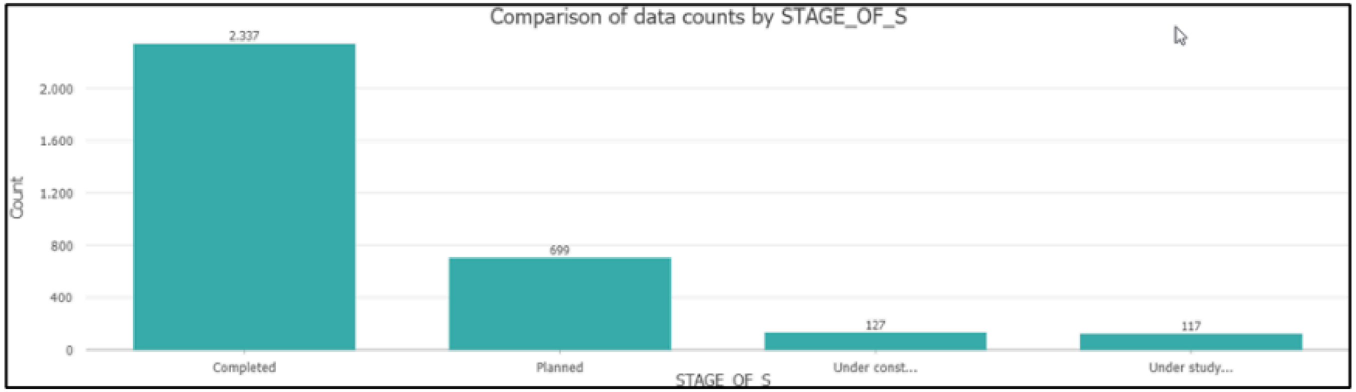
National road Number: S18
Location: Wolfurt-Lauterach - Hoechst

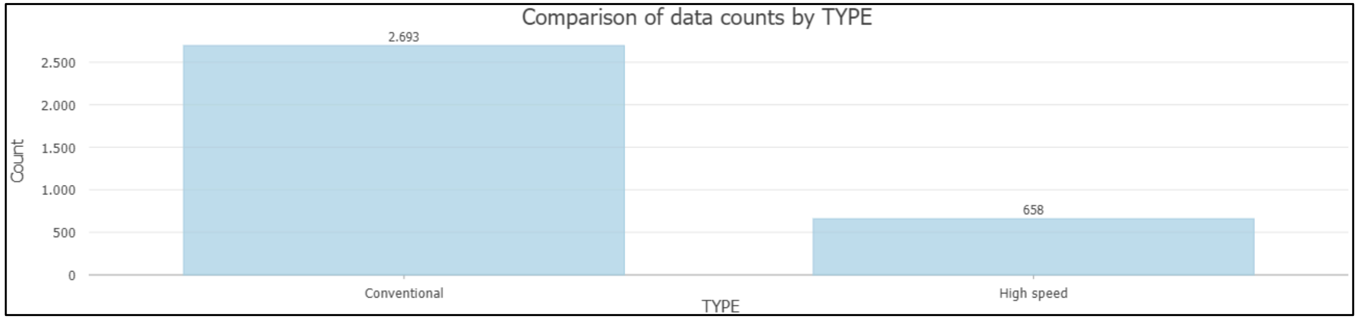
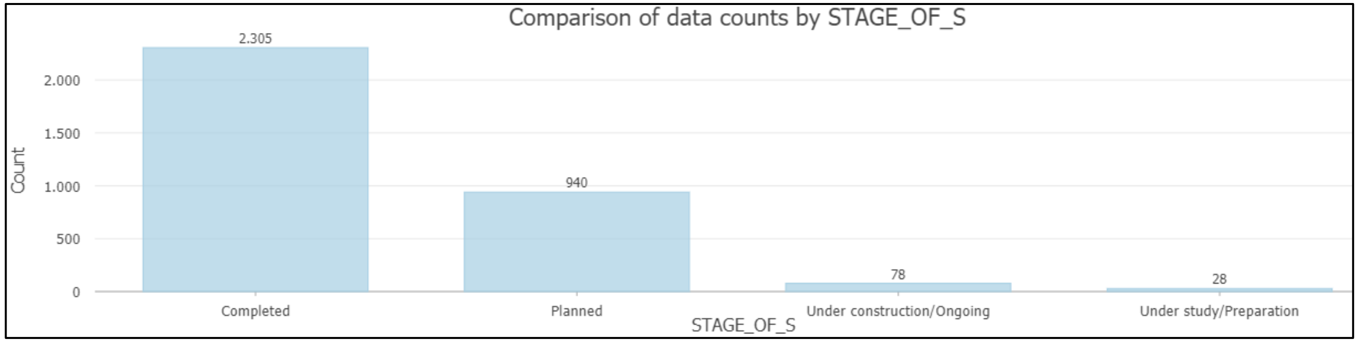
Figure 23: Different road types in the TENT-dataset

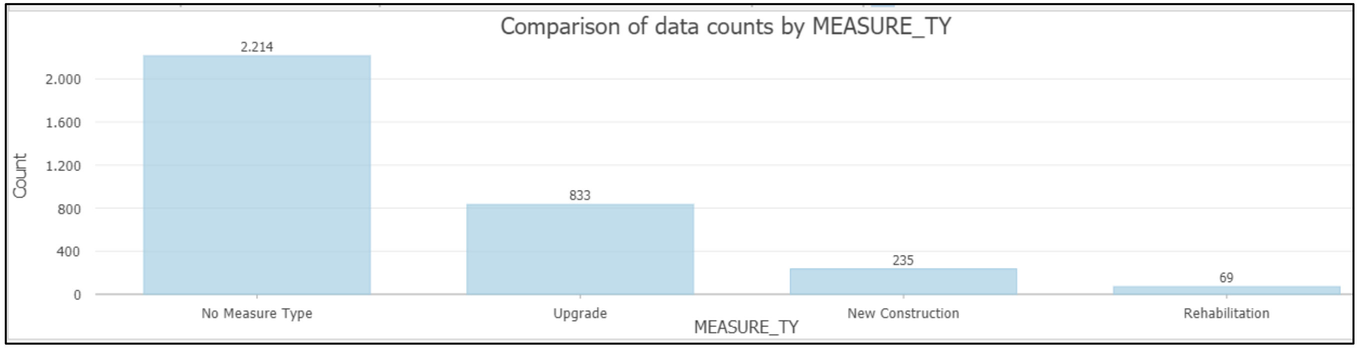
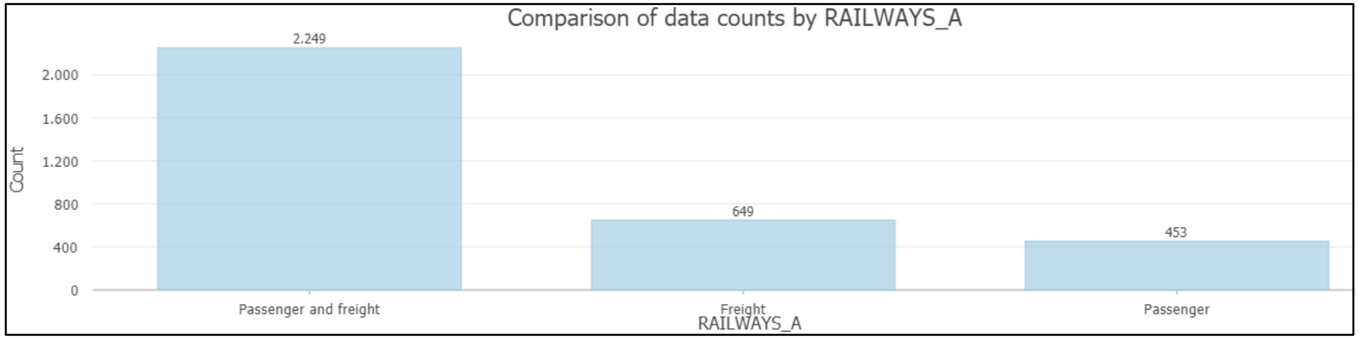
(Source of the aerial photo: https://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer, Google street view)

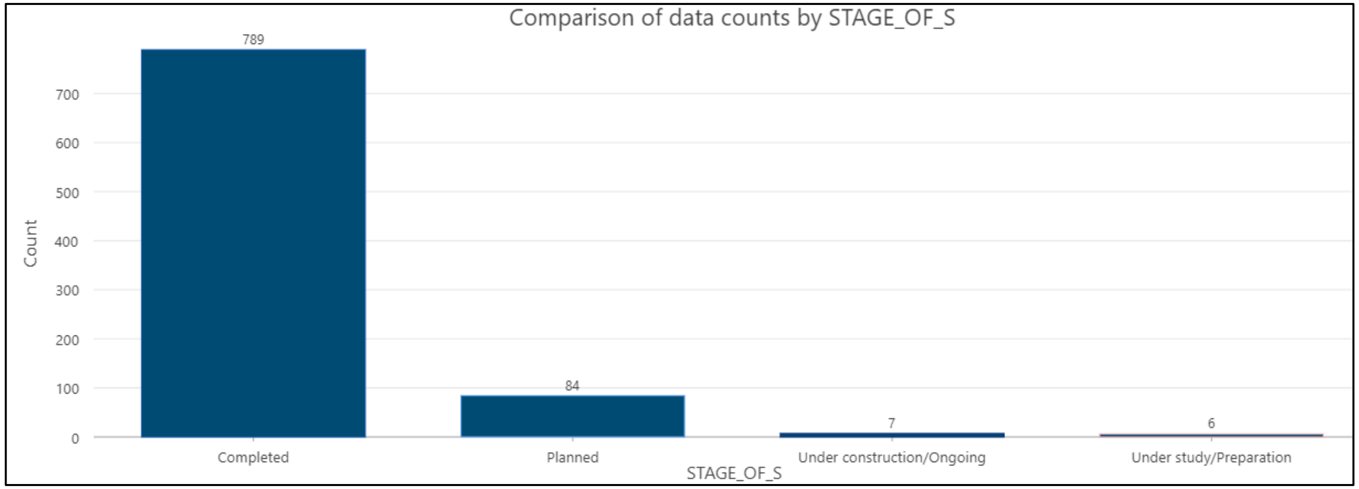
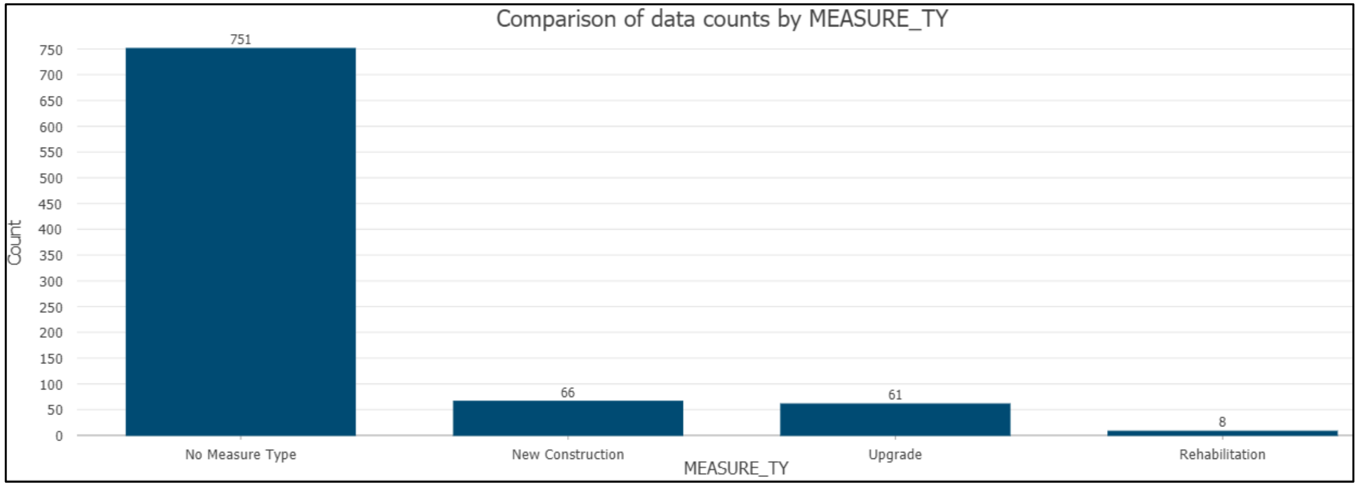
Of the railways the high-speed rails are considered in the further analyses. Only when determining bundled traffic routes conventional railways are also included. As there is no differentiation of the inland-waterways, e. g. between natural and canalised ones, all inland waterways of the TEN-T dataset are further considered. The consideration of ports, airports, rail-road terminals (RRT) as areal transport infrastructure is limited based on the available TEN-T data. The point features of the ports, airports and rail-road terminals don't allow specific spatial analyses, these data will only be used and displayed in the EDM as additional information.

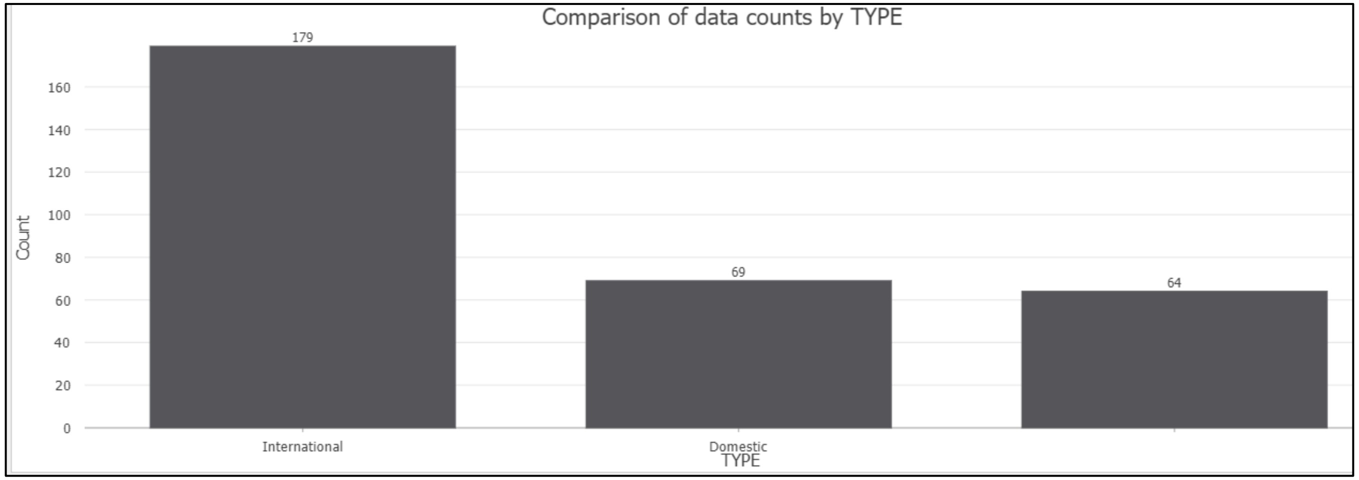
Table 7: Available TEN-T Traffic data

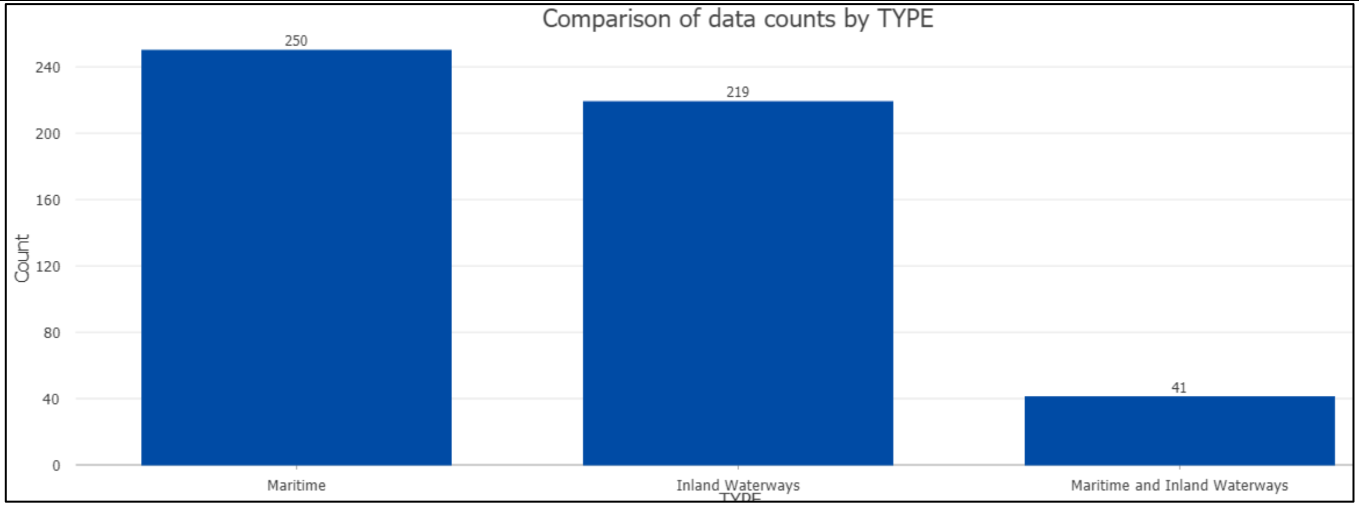
TEN-T data	Differentiating options
Type of TI: Roads **Dataform:** polyline **Original Dataset name:** roads_GL2017_EU27 **Attributes:** Affectness of the TENT-T core network; name; type; stage of realization; measure type	**Type of road:** motorway (n=1.623), rural two-lane road (n=444), rural road with separate directions (n=243), urban roads (n=42), not defined (n=928)  **Stage of implementation:** completed (n=2.337); planned (n=699); under construction/ongoing (n=127); under study/preparation (n=117  e. g. Completed → Sections for defragmentation measures, proofing of realized defragmentation measures; planned, under construction → mitigation and if still applicable avoidance of defragmentation; under study → avoidance of defragmentation; examine options for routing **Measure type**: no measure; upgrade; new construction; rehabilitation

TEN-T data	Differentiating options
	Intended use in the EDM: visual presentation of all road types; for spatial analyses (defragmentation needs) just selected types; different layers for stages of implementation
Type of TI: Railways **Dataform:** polyline **Original Dataset name:** railways_GL2017_EU27 **Attributes:** Affectness of the TENT-T core network; name; type; stage of realization; measure type; railroad mode	**Type of rail:** conventional (n=2.693); highspeed (n=658)  **Stage of realisation:** completed (n=2.305); planned (n=940); under construction/ongoing (n=78); under study/preparation (n=28)  e. g. Completed → Sections for defragmentation measures, proofing of realized defragmentation measures; planned, under construction → mitigation and if still applicable avoidance of defragmentation; under study → avoidance of defragmentation; examine options for routing **Measure type**: no measure (n=2.214); upgrade (n=833); new construction (n=235); rehabilitation (n=69)

TEN-T data	Differentiating options
	 **Railroad mode**: freight and passenger (n=2.249) freight (n=649); passenger (n=453) 
	Intended use in the EDM: visual presentation of all railway types; for spatial analyses (defragmentation needs) just high speed (but conventional railways are considered in the determination of bundled sections); different layers for stages of implementation

TEN-T data	Differentiating options
Type of TI: Inland waterways **Dataform:** polyline **Original Dataset name:** iww_GL2017_EU27 **Attributes:** Affectness of the TENT-T core network; name; stage of realisation; measure type	**Stage of realisation**: completed (n=789); planned (n=84); under construction/ongoing (n=7) under study/preparation (n=6)  **Measure type**: no measure (n=751); new construction (n=66); upgrade (n=61); rehabilitation (n=8) 

TEN-T data	Differentiating options
	Intended use in the EDM: visual presentation of all inland waterways; for spatial analyses use of all inland waterways; different layers for stages of implementation
Type of TI: Airports **Dataform:** point (n=312) **Original Dataset name:** airports_GL2017_EU27 **Attributes:** Affectness of the TENT-T core network; name; type	**Type of airport:** international (n=179), domestic (n=69), not defined/empty field (n=64) 
	Intended use in the EDM: visual presentation of all airpots with symbol; for spatial analyses consideration of the airports in a specific bufferzone around identified defragmentation sections
Type of TI: Rail-road terminals (RRT) **Dataform:** point (n=212) **Original Dataset name:** rrt_GL2017_EU27 **Attributes:** Affectness of the TENT-T core /corridor network; name	
	Intended use in the EDM: visual presentation of all rail-road terminals with symbol; for spatial analyses consideration of the rail-road terminals in a specific bufferzone around identified defragmentation sections
Type of TI: Ports	**Type of port:** maritime (n=250); inland waterway (n=219), maritime and inland waterway n=41)

TEN-T data	Differentiating options
Dataform: point (n=510) **Original Dataset name:** ports_GL2017_EU27 **Attributes:** Affectness of the TENT-T core /corridor network; name; type of port	
	Intended use in the EDM: visual presentation of all ports with symbol; for spatial analyses consideration of the ports (e. g. just inland waterway ports) in a specific bufferzone around identified defragmentation sections

2.3.4 Data processing

2.3.4.1 Processing of digital vector data

After the data review (including the corresponding explanations and publications), the relevant vector data of Ecological networks were requested from the responsible institutions or, if possible, downloaded from the Internet. Subsequently the **selection of relevant network elements** followed. In the process of Ecological network data integration into the EDM relevant elements were selected. Potential, to be developed or restored elements, as well as buffer zones were not considered (exception: Latvia, see chapter 2.3.5.4). The focus was on **core areas** as valuable habitats and areas, **connecting corridors**, **critical barrier sites** (if designated) and already realised **crossing aids (defragmentation measures)**. Partially network elements cannot be differentiated (e. g. Poland) or they are defined as cores (e. g. BE (Flanders)) or corridors (e. g. UK (England)). Datasets of Ecological Networks consisting of several layers were usually combined into one layer. During this process of **merging**, attributes of the individual layers were unified in terms of terminologies to ensure a uniform and comprehensible presentation of the data later in the final web application. As far as possible, ecosystem-specific and further differentiations remain stored in the data attributes. Rarely ecological networks with several layers are integrated into the EDM, for example in the case of overlaying core areas and corridors (Spain). If necessary, the data were reprojected or transformed to fit the map's coordinate system (WGS 1984 Web Mercator (auxiliary sphere)). Processing of the TEN-T data included the identification and interpretation of relevant attributes mainly for distinction of the different barrier effects of the different transport infrastructures.

2.3.4.2 Preparation of raster data and image data

The integration of pixel-based raster data in the EDM was done depending on the original data. On the one hand, these are **positionally accurate raster data** (e. g. Portugal), on the other hand, image data without spatial extension information (e. g. Lithuania). In preparation for the spatial analyses the positionally accurate raster data have been **converted into vector data**.

Pixel-based image data, which were downloaded in different resolutions, first required an **editing with image processing software** to select relevant network elements based on the color values. Depending on the image quality and resolution this was achieved with varying quality and accuracy (see chapter 2.3.5.1). **Georeferencing** was used to fit the selected image data into the GIS/the map with as much positional accuracy as possible. In addition to the display characteristics, the attributes have also been adapted and standardised, as with the vector data, and sub-differentiations (e. g. type of core area) have been retained. These data have been **converted into vector data** too for the further spatial analyses.

2.3.4.3 Compilation of explanatory description for the integrated Ecological networks

During the process of data research and collection relevant information on the Ecological networks have been compiled to “Description for contents and use of national and international ecological networks” (see annex 7). The following aspects are covered in this background information: Original title; Network description (content and main criteria); important websites; data form, state and source; relevance for spatial planning; planning level; planning instruments and implementation level and contacts. In cases of integrated defragmentation measures are additionally included: description of the defragmentation measures; important websites, data form and source; relevant habitats/species; legal instruments (HABITATS Directive II and IV, national conservation acts) and contacts. Furthermore, literature was researched and references listed.

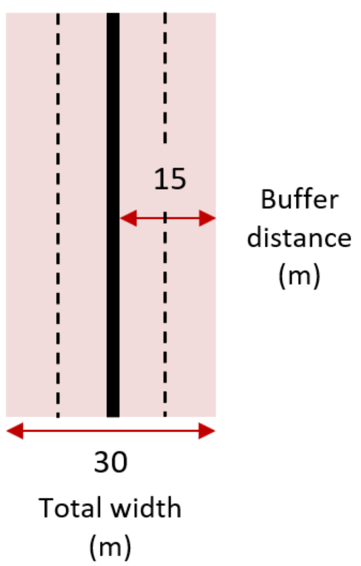
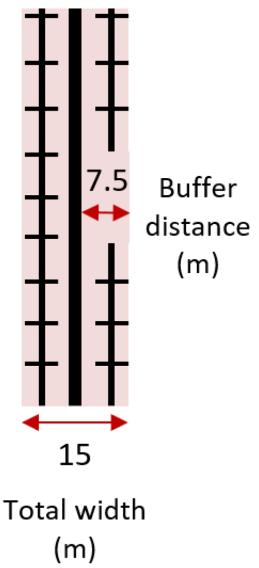
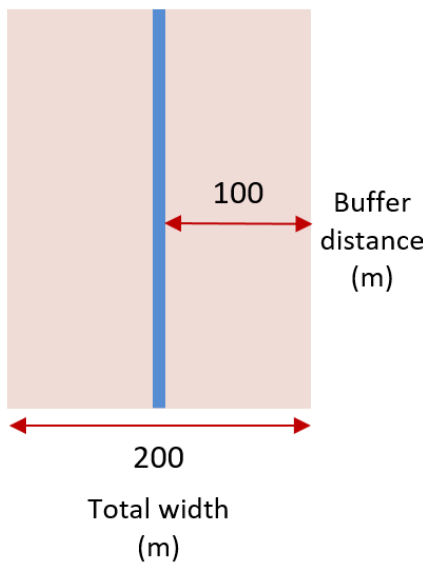
2.3.4.4 Spatial analyses of ecological and transport infrastructure data

With the integration of the ecological and transport data as vector data into the GIS, a basic requirement for the spatial analysis and intersection of the data were met. These data preparations for integration into the GIS (and later into the Web-GIS) and as a prerequisite for further spatial analyses was time-consuming and computationally expensive and required powerful hardware and software equipment.

By distinguishing the barrier effect of different TEN-T infrastructures (see chapter 2.4.2), only the severe overlapping areas of TEN-T routes (at a maximum distance of 150 m) were identified. To point out and evaluate defragmentation areas on European scale (incl. weighting and prioritisation) for a later consideration in discussions and planning decisions, suitable indicators were identified discussed in several expert workshops and finally applied (see chapter 2.4.1 and 2.4.3). The decision on which indicators to use was preceded by numerous overlay tests of relevant ecological data and the TEN-T dataset.

To apply the indicator **bundling transport routes**, the following methodology was used to identify the relevant sections of the TEN-T. Selected TEN-T transport Infrastructures with strong barrier effects was supplemented with conventional railways before the parallel or tangential routing of different transport was examined. For consideration the different widths of different traffic routes and modes literature were researched and the determined widths randomly remeasured in aerial photographs. As a result, the polylines representing the linear TI in the TEN-T have been buffered as follows: all barrier relevant road types with 15 m (assumed total width 30 m for four-lane roads), the high speed and the conventional railways with 7.5 m (assumed total width 15 m for double-track railroad lines) and the inland waterways with 100 m (assumed total width 200 m). The first buffering process (see Table 8) brought the polylines to the assumed width of the routes and converted them to a polygon format.

Table 8: Buffer distances/assumed average width of barrier relevant traffic routes

<table>
<tr><th>Roads (four-lanes)</th><th>Railways (double-track)</th><th>Inland waterways</th></tr>
<tr>
<td>
</td>
<td>
</td>
<td>
</td>
</tr>
</table>

By a second buffer step all polygons were buffered with distance of 75 m to determine the spatial relationships of parallel/tangential traffic routes at a maximum distance of 150 m. Bundled routes are only those that consist of different transport modes, e. g. road and rail or road and inland waterway, within a 150 m wide 'transport corridor'. The attribute "bundled" was then transferred to the corresponding route sections of the TEN-T.

The **spatial overlay analyses of the TEN-T with the ecological data** were realized in three single steps. The preselected barrier effective sections of the TEN-T have been intersected with: 1. the Habitats directive sites of the Natura 2000 area backdrop, 2. the strictly protected, nationally designated areas (CDDA) and 3. the Ecological network elements of national /international importance. Within the framework of these analyses was examined if the identified overlapping sections/areas also affect other ecological area backdrops: Natura 2000 habitats and/or CDDA and/or/ Ecological networks. Another step was if defragmentation measures are affected due to existent or planned barrier effects of TI within 500 m buffer zone and if areal TEN-T transport infrastructure is located within a 5 km radius.

The results of these spatial queries are used for the further qualification (incl. weightening and priorisation) of the identified overlapping sections.

In the EDM existing and planned linear TEN-T infrastructure is distinguished. Different layers show the status of implementation of the specified linear transport infrastructure. A differentiation of already finished ('completed') routes, 'planned' routes, routes 'under construction/ongoing' and routes 'under study/preparation' is necessary, because the various stages require different demands in terms of the planning status and of further needs (e.g to focus on avoidance of fragmentation for planned routes and to focus on defragmentation for completed routes). However, the overlay in the GIS is done in one step with a subsequent selection of the routes in the implementation phases mentioned above.

2.3.4.5 Creation of a web map and GIS data integration

Building on the ecological and traffic data processed and stored in a local GIS project a suitable web application for the publication of the map contents was identified with the cloud-based ArcGIS Online web GIS platform (ESRI). ArcGIS Online allows to use, create and share geographic information with partners/customers or the public. The access to the map and data can be regulated individually as required. The data and map are stored in a secure and private infrastructure tailorable to the demands of mapmaking and IT needs. For incorporation the GIS data into ArcGIS Online a further data preparation and processing have been carried out. This included a standardization, simplification and reduction of attributes, the harmonisation of terms (in accompanying attribute tables), adaptions and specifications of the layer and map layout and a creation and storage of data descriptions (summary, data specification, meta data, source references, tags etc.) (see chapter 2.4.4).

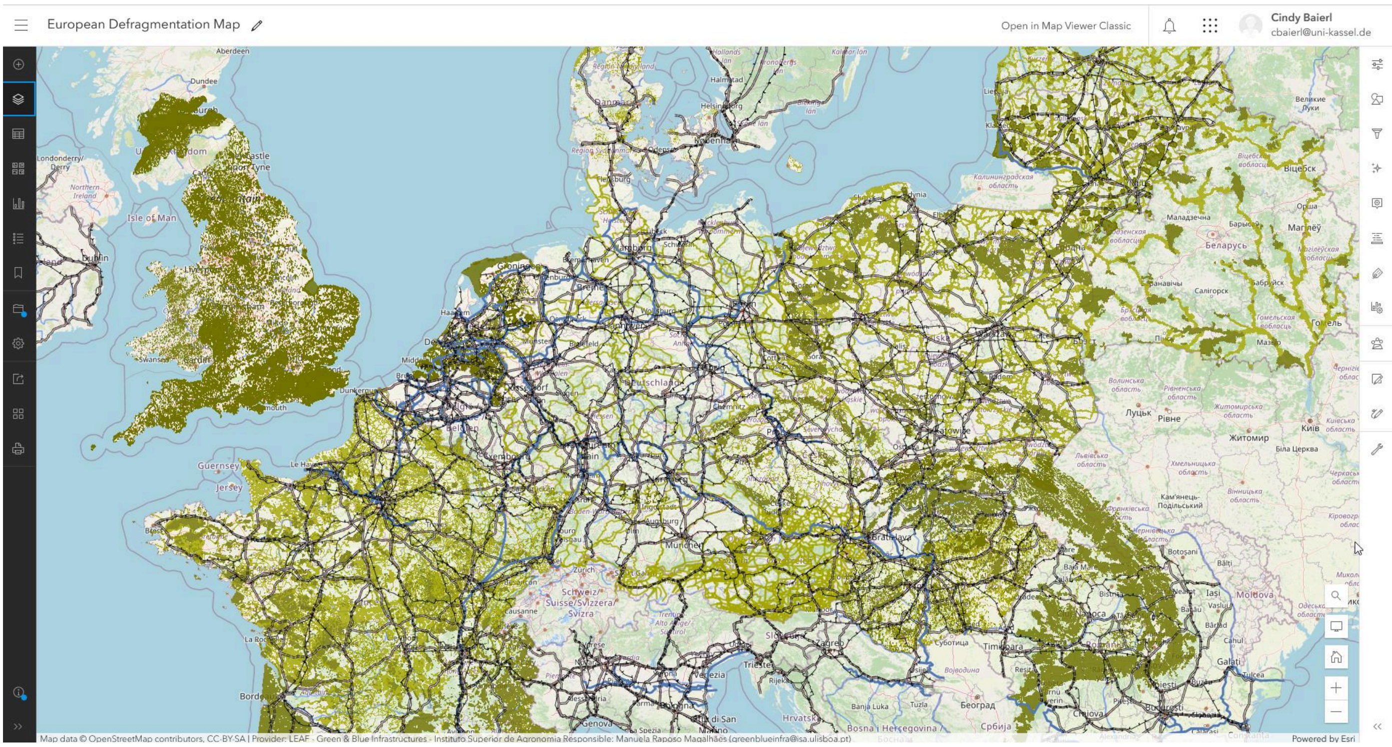


Table 9: Available TEN-T Traffic data

2.3.5 Data critic (inconsistencies, lacks, sources of error)

In this chapter the most important known (data) errors and their possible effects in the EDM and its contents are named and illustrated with pictures.

2.3.5.1 Ecological Networks

The ecological networks integrated in the EDM are available in different data formats. It can be assumed that vector data could be integrated into the map with positional accuracy by standardizing the coordinate systems and projections. In the case of raster data, which occur in very different qualities and resolutions, a precise data integration in area and position proved to be hardly possible. The lower the resolution and the smaller the format of the raster image, the greater the inaccuracies (Figure 24).

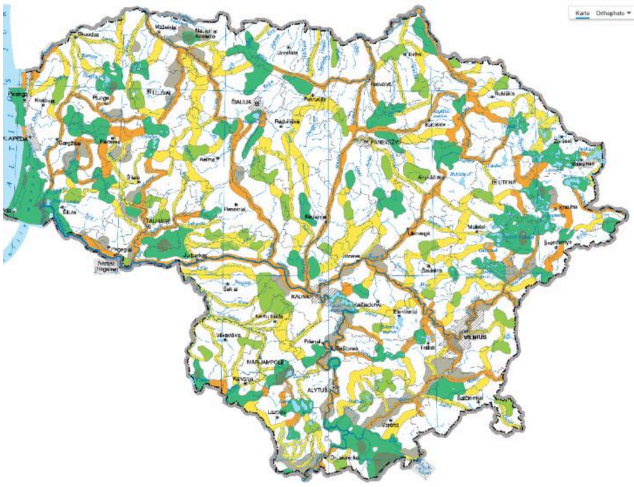
Original pixel-based raster data	Presentation in the EDM
	
In the Ecological network of Lithuania can be accessed via Web Map Service (WMS) in the geoportal https://www.geoportal.lt/map/. The data was saved as a screenshot for later use in the EDM	The size-limited screenshot and low resolution made a precise fitting into the EDM difficult. As a result, there are positional deviations and distortions of the content.

Figure 24: Ecological network of Lithuania

To identify and evaluate the areas of overlap with the TEN-T, all ecological raster data were converted into vector format in the GIS. Through the transformation of the pixel-based raster data artificial modifications of the areas, especially of the edge areas, occurred. Furthermore, the original pixel structure is also present at the edges of areas and does not correspond to the original or real area boundaries. In addition, artificial holes are formed within the areas (Figure 25).

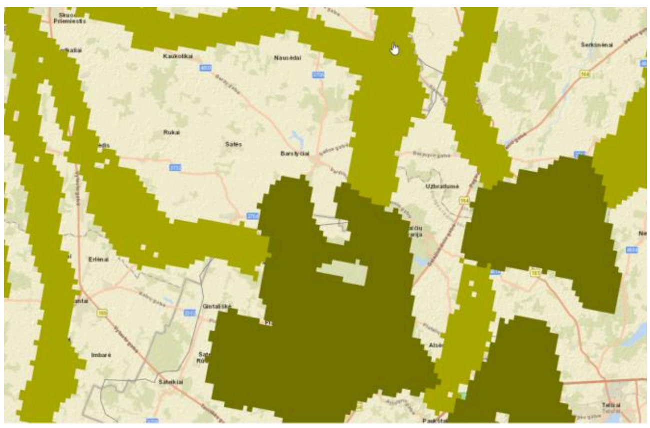
Extracted pixel-based raster data	Result of the transformation into vector format
	

Figure 25: Transformation of raster into vector format

Using image processing software, ecological network elements were selected from images to be displayed and used in the EDM. It was not always possible to select and distinguish the relevant area categories correctly based on the color values (Figure 26). Despite manual post-processing, not all inaccurate area delineations could be eliminated.

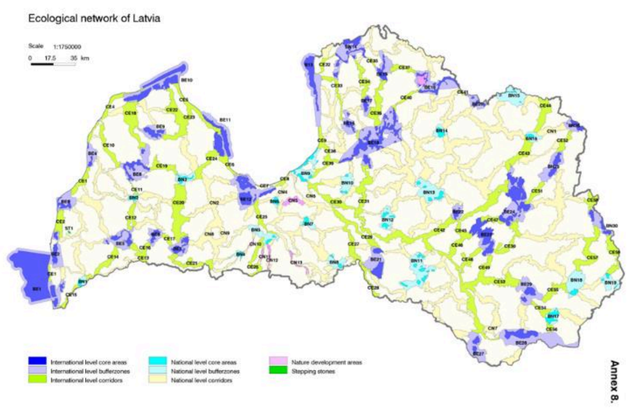
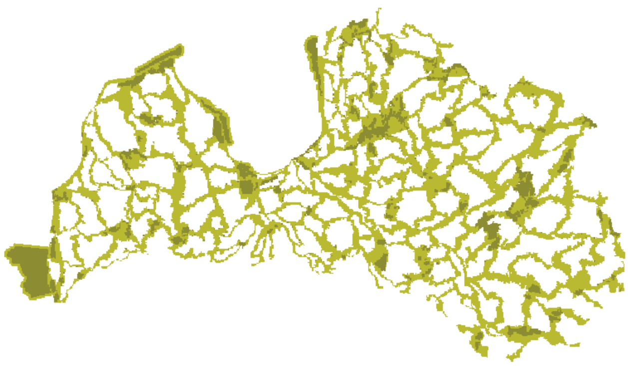
Original pixel-based raster data	**Presentation in the EDM**
	
The Ecological network of Latvia includes buffer zones, which link core areas and corridors. Actual the EDM doesn’t integrate buffer zones. In the absence of suitable data and to maintain the plausibility of the data, here they are exceptional integrated.	Result of the color-based selection, conversion into vector data and unification of the area categories into core areas and corridors. Original buffer zones are represented as corridors.

Figure 26: Ecological network of Latvia

Ecological Networks without differentiation of network elements (e. g. Estonia, Denmark) are integrated in the EDM similar colored as corridors but are named and handled as origin (Figure 27).

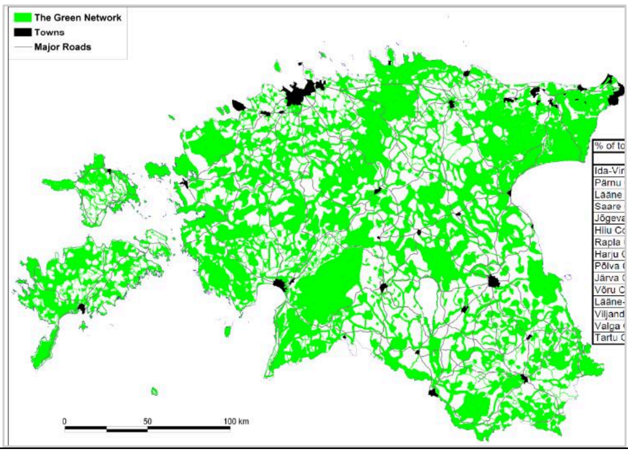
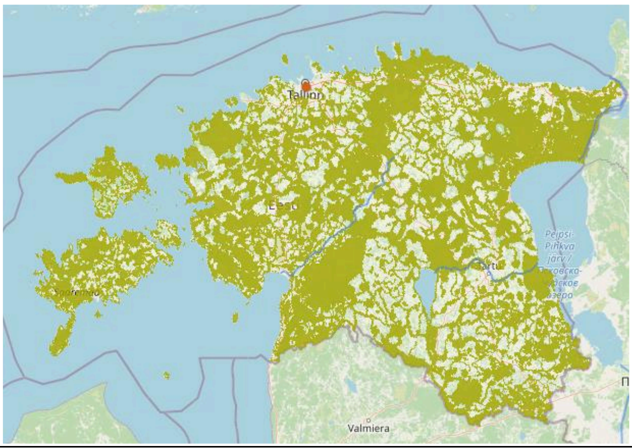
Original pixel-based raster data	**Presentation in the EDM**
	

Figure 27: Ecological network of Estonia- original pixel-based raster data

Another remarkable fact are the different scales of the national ecological networks. These are not always nationally or internationally designated ecological structures or areas. Some countries have developed their ecological network bottom up. Regional ecological networks (at the level of districts, municipalities, federal states etc.) have been compiled into a national data set (e. g. France, Denmark, see Figure 28).

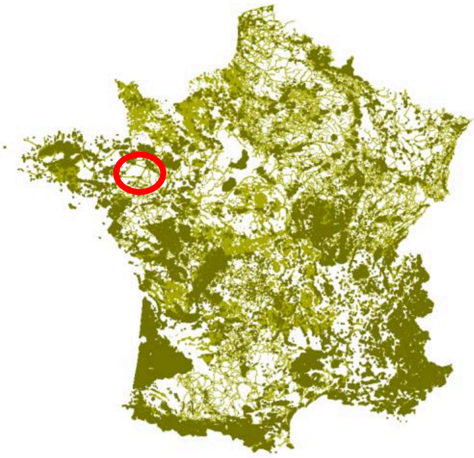
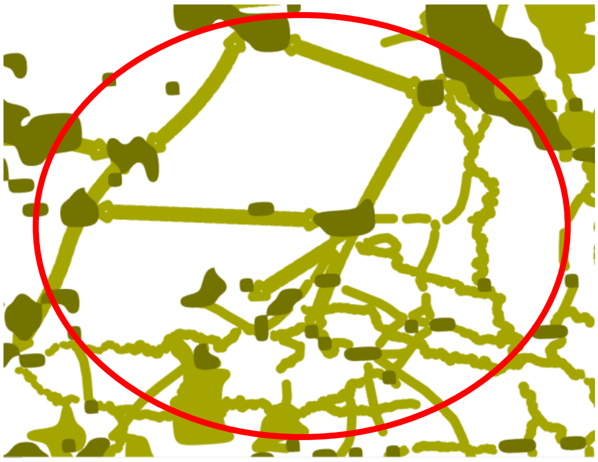
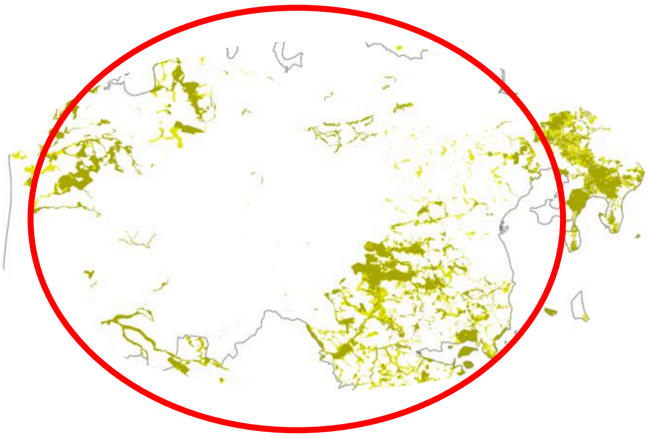
Ecological network of France (Trame verte et bleue)	
 Regional schemes of ecological coherence co-developed by the regions and the State; edited and compiled at the national level	 Different ecological corridor types and presentation styles in the border region between Brittany and Pays de la Loire in the northwestern part of France
Ecological network of Denmark (Green Map of Denmark "Grønt Danmarkskort")	
 In the Green Map of Denmark "Grønt Danmarkskort" municipalities' nature themes are compiled in one coherent nature network.	 The "density of valuable existing and potential nature areas varies in municipalities. Here in the area around Herning (central Jutland, Midtjylland region) is very low compared with adjoining East Jutland region (e. g. municipality Skanderborg or Horsens).

Figure 28: At regional level developed and nationwide compiled Ecological networks (examples)

Due to their different origins, these networks are very heterogeneous in their extent, content and presentation. Even if there was no distinction and selection of the relevant scale levels (national/international) was possible, these at (and for) lower spatial levels developed ecological networks were also integrated and evaluated in the EDM.

Data gaps are one major problem/deficit. Ecological network data are not available for all regions and countries in Europe. For example, there is little data on national ecological networks, especially for South-Eastern Europe (on the Balkan Peninsula) and Scandinavia. However, the Natura 2000 network is representative for all countries of the European Union but not for e. g. Great Britain, Norway, Switzerland and some countries of the Balkan region. Because Natura 2000-sites are considered as the contribution from the EU member States to the Emerald Network, the Emerald network with its Areas of Special Conservation covers just non-EU countries (and some non-Community States, several African States). It should also be mentioned at this point that the TEN-T expansion considered in the EDM is limited to the region of the EU member states.

2.3.5.2 Nationally designated areas (CDDA)

In the EDM the valuable (strictly protected) area categories should be included in the evaluations and analyses of the critical defragmentation sections. For a selection of the relevant areas the IUCN protected area management categories are usable for decision-making (see chapter 0, Table 6). Among the considered categories are “not applicable”, “not assigned” and “not reported” areas in the significant number of 50.668 (from 125.540). That means for over 40 % of the protected areas the actual protection status is not specified. The consideration of all these undefined categories bears the risk that among them there are also protected areas with little strict protection status (and thus nature conservation value). However, this risk is accepted to consider all valuable strictly nationally protected areas in any case.

2.3.5.3 TEN-T dataset

A closer look at the TEN-T dataset reveals several inconsistencies regarding the road type assignments, undefined road types and the digitization of the routes. These coincidentally noticed inconsistencies haven’t been eliminated, because a complete check and correction of the TEN-T data set was impossible within the scope of the project. This must be observed and checked when using the data, including the results of the analyses.

While working with the TEN-T dataset wrong road type assignments were detected randomly.

Defined type: Rural road with separate directions
Actual type: Rural two-lane road
Status: Completed
National road Number: DN22
Country: RO
Location: Constanţa - Tulcea

Defined type: Rural two-lane road
Actual type: Rural road with separate directions
Status: Completed
National road Number: R6
Country: CZ
Location: Karlovy Vary - Sokolov

Defined type: Rural road with separate directions
Actual type: Rural two-lane road
Status: Completed
National road Number:
Country: EE
Location: Haademeeste - Ainazi/Ikla

Defined type: Rural two-lane road
Actual type: Rural road with separate directions
Status: Completed
National road Number: A2
Country: PL
Location: Minsk Mazowiecki - Janow

Figure 29: Incorrect road type assignments in the TEN-T dataset

(Source of the aerial photo: https://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer)

One problem in the TEN-T road dataset are the undefined types (n=928). This road type was checked by using aerial photograph samples. The fact that the degree of expansion and the classification on national level is often comparable with motorways/ rural roads with separate directions (Figure 30) led to the decision that the undefined road type remain in the data set of the roads to be used in the further barrier analyses.

Type of road: undefined
National road Number: A060
Country: DE
Location: Prüm - Bitburg

Type of road: undefined
National road Number: A64
Country: FR
Location: Tarbes - Martres-Tolosane

Type of road: undefined
National road Number: E20/E45
Country: DK
Location: Last mile (E45 - E20)

Type of road: undefined
National road Number: -
Country: BE
Location: Aalbeke - Aalbeke/Mouscron

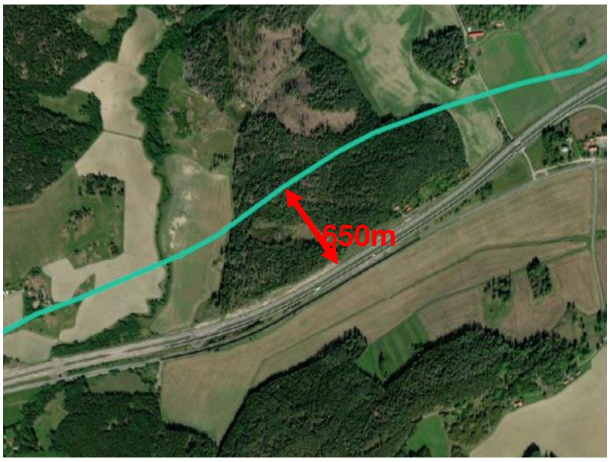
Figure 30: Road examples undefined types

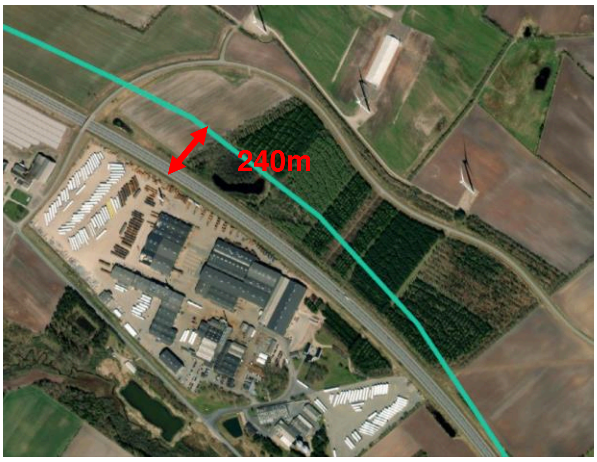
(Source of the aerial photo: https://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer)

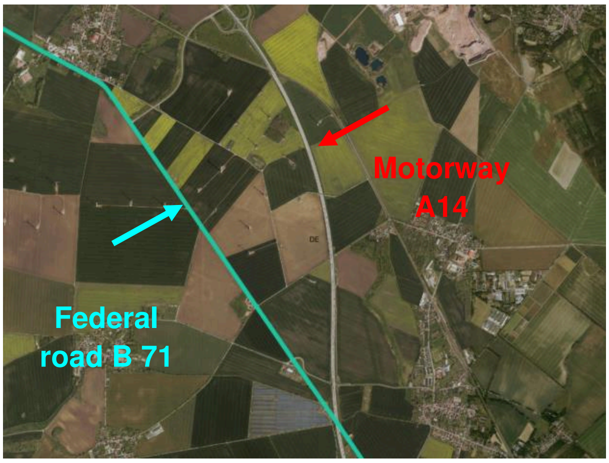
As the following examples illustrate inaccuracies in the digitization of the routes in the TEN-T dataset are obvious (including the digitisation of wrong routes). This mainly concerns railway lines and roads. Simplified digitisations are particularly noticeable on curved routes; major deviations from actual routes occur also at tunneled route sections (

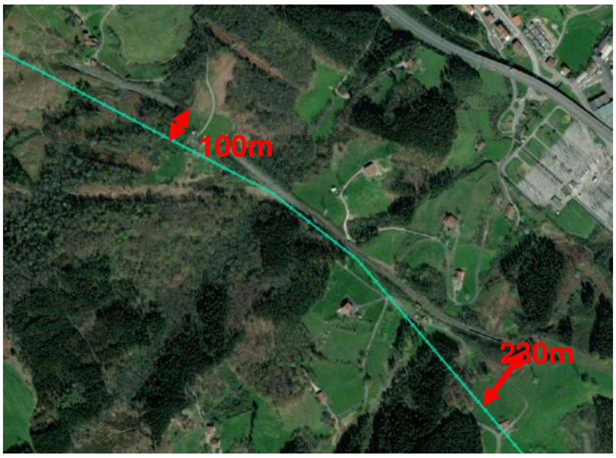
Figure 31).

The mentioned deviations have been double-checked in the current TENtec Interactive Map Viewer[42] and are there obvious as well.

<table>
<tr>
<td>


Type of road: motorway
Status: Completed
National road Number: E4
Country: SE
Location: Nyköping - Soedertaelje (J. E20/E4)
</td>
<td>


Type of road: Undefined road
Status: Completed
National road Number: 18
Country: DK
Location: Vejle (exit 60) - Herning
</td>
</tr>
<tr>
<td>


Type of road: motorway
Status: Completed
National road Number: A14
Country: DE
Location: Kreuz Magdeburg - Dreieck Halle-Nord
</td>
<td>


Type of rail: conventional
Status: Completed
Country: ES
Location: Altsasu - San Sebastian
</td>
</tr>
</table>

Figure 31: Positional inaccuracies of the digitalized routes
(Source of the aerial photo: https://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer)

[42] https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html [last access 01/02/2023]

2.3.5.4 Consequences of data inaccuracies and errors

The quality of the analyses and result working with data can only be as good as the source data. As shown in this chapter data gaps and inaccuracies became obvious but couldn't be filled or eliminated within the scope of the project. We have found very **heterogeneous data** (in content, quality, form) **of ecological networks** throughout Europe. The **lack of data** results in insufficient representation of critical defragmentation sections in countries without ecological networks. Depending on the original scale and/or the original spatial reference level of the ecological network there no clear distinction can be made between regionally and nationally/internationally significant ecological structures. Nevertheless, all ecological networks available for country areas or summarized at country level are presented and evaluated in the EDM. The integration of data of different formats, qualities and resolutions as well as the conversion of raster data into vector format caused area deviations and inaccuracies (shape and position).

Discrepancies were also found in the **TEN-T** data. The **incorrect or missing road type assignment** in the TEN-T dataset attributes causes to an inaccurate selection of TEN-T routes for further analyses, including the consideration of neglectable routes on the one and a lack of consideration of routes with strong barrier effects on the other hand. Through obviously **inaccurate route digitisation** in the TEN-T dataset it come to an incorrect determination of bundled sections. Moreover, critical defragmentation sections are identified, that are not critical defragmentation sections at all and really critical defragmentation sections are not recognized. But state 2023 this is a first preliminary usable approach for the identification defragmentation needs. The next step must be the general improvement of data basis.

2.4 Results

2.4.1 Indicators for assessing defragmentation needs across transport infrastructure on European scale

There is a requirement for indicator-based determination, evaluation and presentation of sections in the ecofriendly and sustainable TEN-T suitable for defragmentation measures of European importance from a strategic perspective to avoid/mitigate habitat fragmentation impacts and biodiversity loss.

Indicators for recording and evaluating fragmentation effects and principles for avoiding and compensating fragmentation on European level must be derived in such a way that they both meet EU-wide requirements and take due account of regional differences in Europe. Fragmentation effects and the planning of defragmentation measures must be optimized for all planning levels (from Strategic Environmental Assessment (SEA) to Impact Regulation (IR)) so that the entire biodiversity concerned is represented. (see chapter 3.2.2, Table 18).

Here, a distinction is made between indicators that can be used and applied with the currently available data and indicators that are recommended from a professional point of view, but which cannot be applied at the present time due to the data situation (see chapter 2.6).

First indicators for assessing defragmentation needs have been defined. The following four data categories/contexts were used:

- Protected Areas
- Ecological Corridors // Networks
- Distribution of species
- Migration

The categories 'Protected Areas' and 'Ecological Corridors // Networks' are area-related with reference to core areas and corridors for (large-scale) connectivity within the national territories and beyond, transnationally. 'Distribution of species' and 'Migration' are species-related indicator categories and reference, for example, of long-distance migratory species.

More professionally reasonable and justified indicators are considered useful and are listed as well. However, they often lack the necessary data basis. This are e. g. 'Distribution of species' and 'Migration' as species-related indicator categories and reference, for example, of long-distance migratory species.

The following table (Table 10) lists only indicators for defragmentation needs of European importance. Chapter 2.4.2 refers to indicators for assessing the barrier effect of the linear transport infrastructure of the TEN-T.

*Table 10: Basic/general indicators for assessing defragmentation needs**

* *currently applicable* / *limited applicable* / *currently not applicable*

Indicator	Description	Applicability	Feasibility with existing data	Application in The EDM
Category // Context of Protected Areas				
Affecting Natura 2000 network	Only habitats directive (SCI, SAC)	Databases (Natura 2000) available	yes	yes
Conservation Status of habitats (only Annex I Habitats Directive) at member state level[43]	Percentage of habitats conservation status (good, unknown, poor, bad); based on the definition of favourable conservation status from Art. 1 of the Habitats Directive; Periods: 2013-2018, 2008-2012	At state, biogeographical or habitat group level in a 10 x 10 km grid	yes	no (not applicable on European scale)
Affecting strictly protected nature reserves	Nationally designated areas (CDDA-Data), only IUCN categories I-IV)	Databases (CDDA) available	yes	yes
Connectivity of endangered habitats	Habitat selection (only/not only habitats after Annex I /Habitats Directive)? Possible criteria: - distances between habitats - habitat density - barriers	Databases (besides Natura 2000 and CDDA)	no, resp. only for Annex I Habitats (Habitats Directive)	no (not applicable on European scale)
Fragmentation-Index[44]	Assesses the severity of the specific fragmentation effect based on the size of the separated habitats. Use in the EDM to measure the fragmentation effect of protected areas	Databases (Natura 2000 and CDDA) available	yes, (related to the protected areas)	yes
Category // Context Ecological Corridors (Networks)				
Affecting Ecological Networks (Habitat Networks)	developed and based on different methods for national/transnational level; networks have a wide range of width, shape, structure and content; predominantly consisting of core areas (habitat sites) and corridors (for migration)	If existing/available GIS or raster data; missing networks in several states	partly	yes
Sum of habitat areas in a corridor section (core areas and corridor sections)	Number of high-quality biotopes/ habitats in a defined spatial unit of the Ecological network		no (lack of data)	no

[43] https://www.eea.europa.eu/signals/signals-2021/infographics/state-of-nature-in-europe-habitats/view; https://www.eea.europa.eu/publications/state-of-nature-in-the-eu-2020

[44] COST Office 2006

Indicator	Description	Applicability	Feasibility with existing data	Application in The EDM
Impairment of possible future ecological corridors	Requirement of the EU Biodiversity Strategy 2030: creation and integration of ecological corridors as part of a Trans-European Nature Network; focussed on the connectivity of Natura 2000 areas[45]	Not yet, corridors are still not defined.	no	no
Category // Context Distribution of species sensitive to fragmentation				
Occurrence of selected protected species under Habitats Directive	selected species of Annex IV and V (e. g. *Lynx* pardinus in Spain); for the assessment of connectivity needs; mostly expert knowledge	Selection of representative species for biographical regions; indicator/ target species for biotope network (occurrence, distribution)	no (Natura 2000 database not sufficient)	no
Occurrence of endangered or endemic species	Protection of species, which are especially threatened by extinction (through habitat loss, loss of genetic variation); e. g. Common European adder (*Vipera berus*); for the assessment of connectivity needs; mostly expert knowledge, but not generally available, especially, especially for species threatened with extinction	Limited data; limited spatial significance	no (selection of relevant species is missing, no comprehensive information on distribution areas)	no
Category // Context Migration				
Long distance migration routes (including transhumance)	Species moving through different media, using various modes of locomotion and transport. Basic driving forces are ecological and biogeographic factors like seasonality, spatiotemporal distributions of resources, habitats, predation and competition. Distinction between flightless and flying species: routes of the flightless species and only bottlenecks for the flight species; important for the functional connection of habitats through livestock; for the validation of connectivity measures at the subordinate spatial levels	Transnational migration routes are mostly not identificated/ designated	no (lack of data)	no

[45] EC 2021

Indicator	Description	Applicability	Feasibility with existing data	Application in The EDM
Important migration corridors of endangered species, covers special situations like e. g. mountain passes or the Strait of Gibraltar	Endangered species are particularly threatened with extinction, because they currently survive in mostly small and fragile populations. Disturbances or interruptions of their intra-and inter-migration through corridors significantly increase the risk of extinction; usable for the validation of connectivity measures at the regional and local scale.	Migration corridors are often not identificated/ designated	no (lack of data)	no
Migration routes of large animal herds	Migration of large animal herds (ungulates/hooved mammals, e. g. *Cervus elaphus* in Hungary, *Rangifer tarandus* in Norway) is a fundamental ecological process, whose effects cascade up and down terrestrial food webs (provide the prey base for large carnivores and scavenger populations) and underpins terrestrial biodiversity. Yet ungulate migrations are disappearing at an alarming rate.	Migration routes of large animal herds are mostly not identificated/ designated; efforts for a first-ever global atlas of ungulate (hooved mammal) migrations existing[46]	no (lack of data)	no
Guild or species-specific modelled corridors	After various methods modelled corridors, e. g. habitat connectivity for smaller fauna or least cost-distance corridors for the establishment of wildlife corridors	Refers to the claims and needs of single species/guilds; limited transferability to other species/species groups; used in the planning process on regional scale	no	no
Focal points of wildlife accidents	Focal points of wildlife accidents are in areas with a high population density of widespread species corresponding to the suitability of the landscape (habitat quality); can also be significant for rare species or big herds (e. g. for reindeer in Sweden or bears e. g. in Greece). With increasing size and traffic volume the number of wildlife accidents increases (exception: fenced highways).	Missing/incomplete statistics of focal points of wildlife accidents; used in the planning process on regional scale	no (lack of data)	no

[46] Kauffman et al. 2021

During the research more indicators for assessing defragmentation needs have been evaluated but found not suitable for the EDM and its European reference scale. For example, the indicator for assessing landscape fragmentation (not habitat fragmentation!) due to urban and transport expansion, the "**Landscape fragmentation Effective Mesh Size**" (meff) / "**Effective Mesh Density**" (seff). A raster file is here the basis for assessing landscape fragmentation due to urban and transport expansion and the indicator value. The computation is based on the method of Effective Mesh Size (Jaeger 2000) and can be interpreted as the area that is accessible to animals when starting a movement at a randomly chosen point inside a landscape without encountering a physical barrier.[47] Physical barriers are fragmentation geometries and are defined as the presence of impervious surfaces and traffic infrastructure, including medium sized roads. On European scale they are identified using the Copernicus Imperviousness and the TomTom TeleAtlas datasets. Evaluations of this are available for all of Europe.[48] The Effective Mesh Size /Density is considered as not suitable as indicator for assessing defragmentation needs, because it is not related to landscape habitat quality and thus has no reference to defragmentation.

The "**Potential threats to soil biodiversity in Europe**" (European Commission 2016) [49] assesses the spatial distribution of threats on a European scale with reference to soil microorganisms, fauna and biological functions. The developed maps were based on 13 potential threats to soil biodiversity which were proposed to experts with different backgrounds in order to assess biodiversity threat und the level of risk. The focus on soil biota doesn't fit the requirements and purpose as an indicator for assessing defragmentation needs and remains therefore unconsidered.

2.4.2 Indicators for assessing the barrier effect of transport infrastructures on European scale

To access the barrier effect of transport Infrastructures (TI) on European scale traffic-related indicators were determined. Depending on the traffic volume, traffic mode and degree of expansion, TI causes different barrier effects. With respect to data access, availability and quality/specification the barrier effect of selected European transport infrastructure was basically estimated on expert opinion due to the current state of knowledge for the Trans-European Transport Network (TEN-T) and lead to a selection of TI assumed to have a strong **barrier effect**. Due to lack of the availability of traffic volumes data could not be included in the assessment.

The limited data significance of real transport infrastructures (ports, airports, rail-road terminals) on the one hand and the focus on defragmentation demands on the other hand led to the concentration on barrier effects of **linear transport infrastructures**. For these the TEN-T datasets contains beside concrete spatial information about route courses usable attributes (e. g road/rail type, stage of implementation) for the specification of the barrier effect.

In addition to the barrier effects of the individual transport routes, traffic route **bundling** can lead to an intensification of the barrier effect. Traffic route bundling is the principle of running the paths of several (different) traffic routes next to each other in a confined space. It is usually implemented by adding another traffic route in the immediate vicinity of an existing one and running the routes almost parallel and tangential.

---

47 https://sdi.eea.europa.eu/catalogue/srv/api/records/53bb9d36-0e28-4486-aa06-dc488671c84e
48 https://www.eea.europa.eu/data-and-maps/data/landscape-fragmentation-effective-mesh-density
49 https://esdac.jrc.ec.europa.eu/content/potential-threats-soil-biodiversity-europe

From a nature conservation point of view, the bundling of routes is associated with advantages and disadvantages. While on the one hand bundling (new or apparently new) can avoid landscape fragmentation, on the other hand it can increase habitat or population fragmentation effects. Habitats are more separated by the parallel location of routes than by single alignments. Depending on the habitat quality between the routes, it contributes to strengthening or weakening the barrier effect of the bundling route. In the case of wider distances, the area enclosed by the routes can - for example when the vegetation here is adapted to the surroundings - develop habitat quality for various species groups. The large overall width of closely bundled routes can no longer be crossed by less mobile species; e. g. for species of forest habitats, the wide corridor of routes with little vegetation represents a barrier. Protective barriers between routes are absolute barriers for flightless species, depending on their design (Baierl et al. 2023 in prep). In consultation with experts and based on expert knowledge bundling within the close distance of max. 150 m was examined as an indicator for a high barrier effect of linear transport infrastructure (for further information see chapter 3.4.1 The critical role of bundling).

Indicators for assessing the barrier effect of TI on European level have been elaborated primarily amid the TEN-T dataset and with respect to further professional requirements. Thresholds focuses in this case on different TI types and bundling effects of different transport modes and should be considered as a first evaluation that has to be validated. The as a narrow bundling of TI considered distance of 150 m can create the most extreme barriers. Table 11 lists the indicators and contains brief justifications of the indicator selection.

Table 11: Basic/general indicators for assessing the barrier effect of TI on European scale

currently applicable / *limited applicable* / *currently not applicable*

Indicator	Description	Applicability	Feasibility with existing data	Application in the EDM
Roads	Type classifications allow a selection of relevant barrier effective roads. These are **motorways, rural two-lane roads and** the category of **undefined** types (a lot of national highways in this category!). The road types **urban roads** (within settlements) and **rural roads with separate directions** (two lanes, narrow width, lower traffic, …) are not considered.	Database with specifications (TEN-T) available	yes	yes
Rails	Type classifications allow a selection of relevant barrier effective rails. **High speed rails** (at least 250 km/h) are assessed as such. HSR require wider routes, more structural protection measures (e. g. against noise or load shedding) and are partly fenced. Thus, HRS create or reinforce insurmountable obstacles. **Conventional rails** with their low barrier effect are not considered.	Database with specifications (TEN-T) available	yes	yes
Inland waterways (IWW)	**Waterways of international importance** (rivers and canals) with specific minimum technical	Database (TEN-T) available, but without information on degree of	yes (with restrictions; no differentiation of waterways possible→	yes

Indicator	Description	Applicability	Feasibility with existing data	Application in the EDM
	characteristics[50]; connecting industrial regions, urban/ metropolitan areas and ports.	expansion/ naturalness.	consideration of all IWW)	
Bundling	Determination of **bundling different transport modes** (e. g. road and railway); consideration of a narrow **bundling distance** (**150m**), which is strengthening the barrier effect of the bundling route. When determining the bundling sections, all roads with a strong barrier effect (see above), all railway lines (HRS and conventional) and all IWW are taken into account.	Database with specifications (TEN-T) available	yes (requires identification of bundling sections in the TEN-T transport network on the basis of TEN-T data)	yes
Ports	Point layer without information on the areal extent of the ports	Limited due to the data format (point information)	partly	yes (within the limited scope of possibilities)
Rail-road terminals (RRT)	Point layer without information on the areal extent of the RRT	Limited due to the data format (point information)	partly	yes (within the limited scope of possibilities)
airports	Point layer without information on the areal extent of the airports	Limited due to the data format (point information)	partly	yes (within the limited scope of possibilities)
Surmountainbility the traffic roads	Consideration of: • traffic volume/count* • width, • accompanying structures (e. g. fences) *measured in vehicles per day; critical thresholds vary in the regions ("habituation effect")	TEN-T database defines just road types; traffic volume/count information are missing. Just for some countries (e. g. SK, DE, CZ) can provide relevant data	no (lack of data)	no

[50] As waterways of international importance apply waterways from class IV. They allow the passage of a vessel or a pushed train 80-to-85-metre-long (260 to 280 ft) and 9.50-metre-wide (31 ft). Where a waterway forming part of the network is modernized or constructed, the technical specifications should correspond at least to class IV, should enable class Va/Vb to be achieved at a later date, and should make satisfactory provision for the passage of vessels used for combined transport. Class Va allows the passage of a vessel or a pushed train of craft 110 m long and 11.40 m wide, and class Vb allows the passage of a pushed train of craft 172 to 185 m long and 11.40 m wide. (ECMT 1992)

2.4.3 Indicators for setting priorities

For prioritisation of defragmentation needs and safeguarding connectivity functions the differently rated importance of the various Green Infrastructures (nationally designated areas, Natura 2000 (only habitats directive), Ecological Networks (cores and corridors)) must be combined with the barrier effect of different TI types. At this stage, only indicators for which data is currently available can be used.

Indicators suitable to derive defragmentation priorities on a Europe-wide level must reflect the following contents:

- the most significant areas (size and/or quality) for biodiversity conservation as core areas for EU-wide nature conservation,
- the eco-corridors of national and international importance,
- species that can migrate over long distances on an (inter)national level (e. g. red deer (*Cervus elaphus)*, wolf (*Canis lupus)*, lynx *(Lynx lynx*), brown bear (*Ursus arctos*), moose (*Alces alces*), reindeer (*Rangifer taradus*), European bison (*Bison bonasus*), migratory fish species (e. g. salmon (*Salmo salar*), European eel (*Anguilla anguilla*))
- the strong barriers in the TEN-T on the above-mentioned nature conservation-related contents must be significant for ecological structures of European relevance, their functioning and connectivity.

The determination of priorities is realised through a combination of both indicator categories A) the indicators for assessing defragmentation needs across transport infrastructure of European importance (see chapter 2.4.1) and B) the indicators for assessing the barrier effect of TI on European level (see chapter 2.4.2) in a matrix. The prioritization presented here is an initial proposal that needs further development.

The following tables (Table 12 to Table 15) shows the linked and preliminary prioritised criteria for the three Ecological area backdrops (Ecological Networks, Natura 2000 habitats directive sites, strictly protected nature reserves) presented, which were examined and are shown in the EDM.

In the area backdrops of the ‘Natura 2000 habitats directive sites’ and the ‘strictly protected nature reserves’ the **Fragmentation Index (FI)** is used as a criteria to better assess the degree of fragmentation. Originally the FI has been developed to quantify the degree of fragmentation of habitat areas (COST OFFICE 2006). If a habitat (A), which is considered homogeneous in itself is dissected into two parts (A1+A2), it can be postulated that the fragmentation impact is largest in case of a median cut (A1=A2). In contrast, the impact of fragmentation is considered relatively low if the cut is located close to the edge so that only a small part is cut off. This relation can be expressed by the formula $4 \times A1 \times A2/(A1+A2)$. To distinguish less crucial fragmentations of Natura 2000 habitats directive sites’ and other ‘strictly protected nature reserves’ (e. g. at edges, along the area boundaries) and significant fragmentations from ecological point of view (on bottlenecks, median cuts) the FI was calculated. Through the classification type “natural breaks” FI-values were allocated into 10 classes with the most severe fragmentations being grouped in the highest FI class 10 and the lowest in class 1. Natural breaks are based on natural groupings inherent in the data. Class breaks that group similar values and maximize the differences between classes are identified. The locations are divided into classes with boundaries that are set where there are relatively big differences in the data values. It is recommended to neglect the lowest FI-Class 1. FI-classes 2 to 10 indicate significant fragmentation in these areas and indicate that defragmentation measures should be examined here as a priority. The impairment of a further ecological area backdrop (‘Habitats directive sites’, ‘Strictly protected nature reserves’ or the ‘Ecological Networks’) is used as a further criteria for the assessment of fragmentation. In this case, the possible defragmentation requirements were evaluated according to a higher priority.

The narrow bundling of linear TEN-T transport infrastructure (150 m) of different transport modes has the highest priority in defragmentation in all three ecolological area backdrops because of the strong barrier effect.

The results presented for the prioritisation of the fragmentation sections are not to be understood as precise, but always concern section areas. These must be reviewed in the further planning process, e. g. by country experts, and compared with the country concepts, significant corridors of the countries that could not be included in the EDM, such as the transhumance corridors in Spain, nationally significant migration corridors and nationally protected or high quality areas, etc.. Therefore, under no circumstances the areas presented should be directly incorporated into the planning process without review. However, this does not diminish the strategic value of the results, as they provide for the first time an overview of the severity of habitat fragmentation in Europe, on the basis of which reconnection needs and associated costs can be determined.

Affecting Ecolog. Networks (Habitat Networks)

Total number of overlapping sections between barriereffective TEN-T and Ecological Networks (= Search areas for defragmentation needs): **14.029**

Table 12: Matrix for determination of prioritised search areas for defragmentation needs in the area backdrop of Ecological Networks

<table>
<tr><th colspan="2" rowspan="2">Indicator</th><th colspan="3">for assessing defragmentation priorities across transport infrastructure of European importance</th></tr>
<tr><th>Affecting Ecolog. Network</th><th>Affecting Ecolog. Network AND Habitats directive sites OR strictly protected nature reserves</th><th>Affecting Ecolog. Network AND Habitats directive sites AND strictly protected nature reserves</th></tr>
<tr><td rowspan="4">for assessing the barrier effect of TI on European level</td><td>Road (motorways, rural two-lane roads and undefined)</td><td>II [5.965]</td><td>II [1.674]</td><td>I [439]</td></tr>
<tr><td>High-speed rail</td><td>II [2.232]</td><td>II [569]</td><td>I [180]</td></tr>
<tr><td>Inland waterway (IWW)</td><td>III [821]</td><td>III [1.053]</td><td>II [161]</td></tr>
<tr><td>Narrow bundling of different transport modes</td><td>I [708]</td><td>I [171]</td><td>I [56]</td></tr>
</table>

***Rank**: I = high; II = medium; III = low*   *[total Number of sections]*

Table 13: Statistic of preliminary prioritised search areas for defragmentation needs in the area backdrop of Ecological Networks

Level of defragmentation priority	Total number of sections	Relative frequency
I	1.554	11 %
II	10.601	76 %
III	1.874	13 %
Sum	14.029	100 %

***Rank**: I = high; II = medium; III = low*

Affecting Habitats directive sites AND/OR strictly protected areas

Total number of overlapping sections between barriereffective TEN-T, Habitats directive sites and strictly protected areas (= Search areas for defragmentation needs): **5.813**

Table 14: Matrix for determination of prioritised search areas for defragmentation needs in the area backdrops of Habitats directive sites and strictly protected areas

Indicator		for assessing defragmentation priorities across transport infrastructure of European importance		
		Minor fragmentation/affection of Habitats directive sites AND/OR strictly protected areas	**Significant fragmentation of Habitats directive sites OR strictly protected areas**	**Significant fragmentation of Habitats directive sites AND significant fragmentation of strictly protected areas**
for assessing the barrier effect of TI on European level	**Road (motorways, rural two-lane roads and undefined)**	**III** [2.921]	**II** [376]	**I** [92]
	High-speed rail	**III** [983]	**II** [68]	**I** [17]
	Inland waterway (IWW)	**III** [886]	**II** [161]	**I** [25]
	Narrow bundling of different transport modes	**II** [231]	**I** [45]	**I** [8]

Rank: *I = high; II = medium; III = low* *[total Number of sections]*

Minor fragmentation is indicated by low FI-values (FI-class 1) due to marginal fragmentation or area boundary touches. Significant fragmentation is indicated by high(er) FI-values (FI-class from 2) caused by extensive/critical fragmentation. Significant fragmentation effects cause approximately 14 % of the fragmentation sections.

Table 15: Statistic of defragmentation priorities in the area backdrop of Habitats directive sites and strictly protected areas

Level of defragmentation priority	Total number of sections	Relative frequency
I	**187**	**3,5 %**
II	**836**	**14,5 %**
III	**4.790**	**82 %**
Sum	**5.831**	**100 %**

Rank: *I = high; II = medium; III = low*

2.4.4 The European Defragmentation Map as Web map application

As a main result the EDM will be presented and published as a web application. This was realized by building an interactive web map with ArcGIS Online, a web-based mapping software by ESRI.[51] The EDM allows their users to interact with the data, zoom in, and search on the map. With intuitive analysis tools, selected information can be accessed, displayed and partially downloaded (depending on individually data rights). Neither special GIS knowledge or skills nor GIS software are required to use the map. The EDM is simply displayed and operated via a standard web browser.

Several contents, which are grouped can be displayed by selecting the corresponding layers. Each layer has describing attributes, which can be displayed as a legend on the right side of the map (see Figure 32). A wide variety of basemaps are available for the creation of an individual background, e. g. Open Street map, Imagery, Topographic.

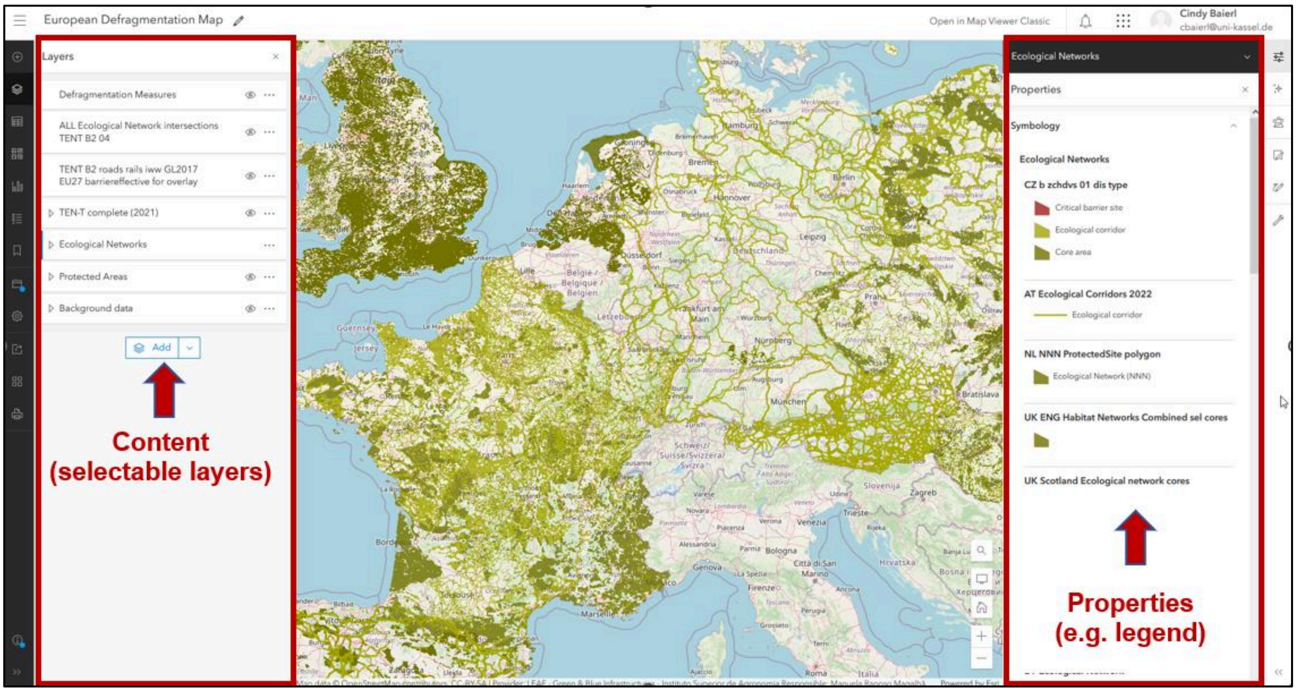


Figure 32: Basic structure of the EDM web application

As its main contents the EDM presents a compilation of the current state of Ecological habitat networks (see chapter 2.3.3.1) on European terrestrial territory, the Natura 2000 habitats directive sites designated by EU member states (see chapter 2.3.3.3), the selection of strictly protected areas within the area backdrop of nationally designated areas reas (see chapter 2.3.3.4) and the overlap sections of the three mentioned ecological area backdrops with the barrier-relevant TEN-T (see chapter 2.4.2). These identified sections may be of European importance for defragmentation measures and should be recognized in the further planning and realization of the TEN-T. Special attention should be paid to the overlapping areas between ecological networks and the barrier-relevant TEN-T (see Figure 33) as they represent the nationally significant habitats (core areas) <u>AND</u> habitat connections (corridors). In addition,

[51] https://www.esri.com/en-us/home

the overlap areas of the Natura 2000 sites designated under the Habitats Directive and the strictly protected areas with the barrier-relevant TEN-T have been identified.

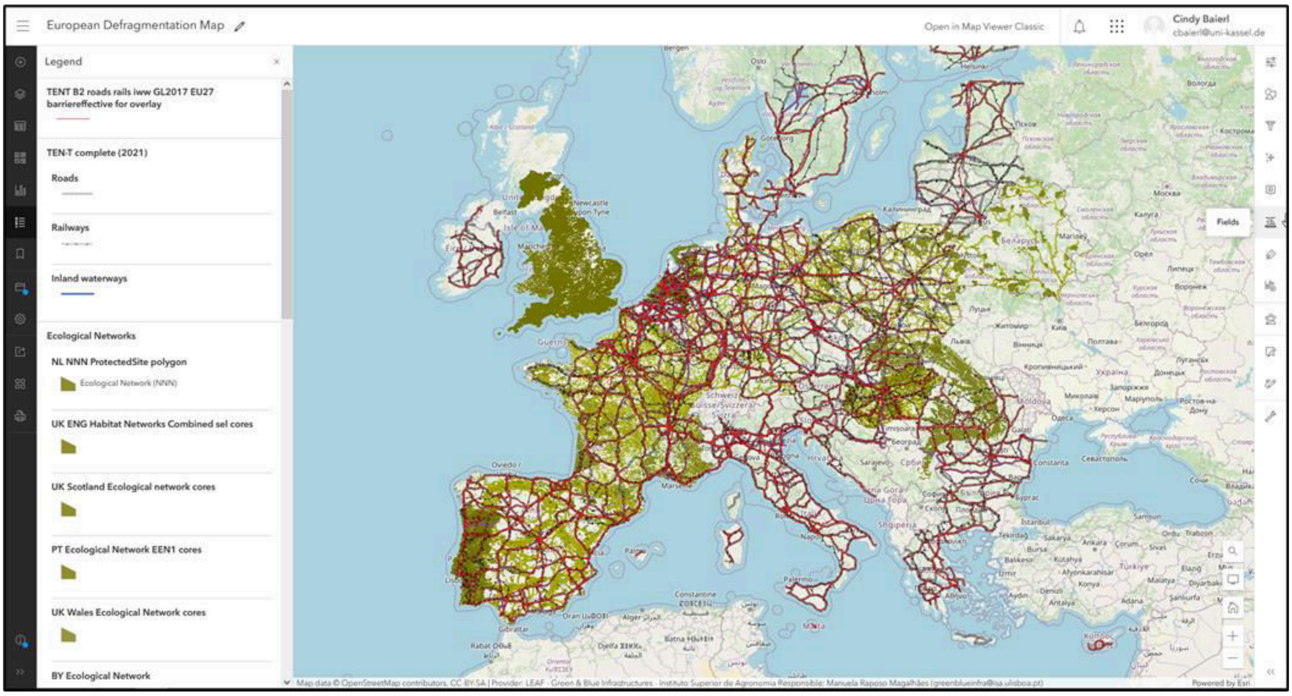


Figure 33: EDM –Ecological networks and the barrier relevant TEN-T

In a next step, all identified overlapping areas have been preliminary prioritized. They will be presented as a main result of the spatial analyses in the EDM (see Figure 34).

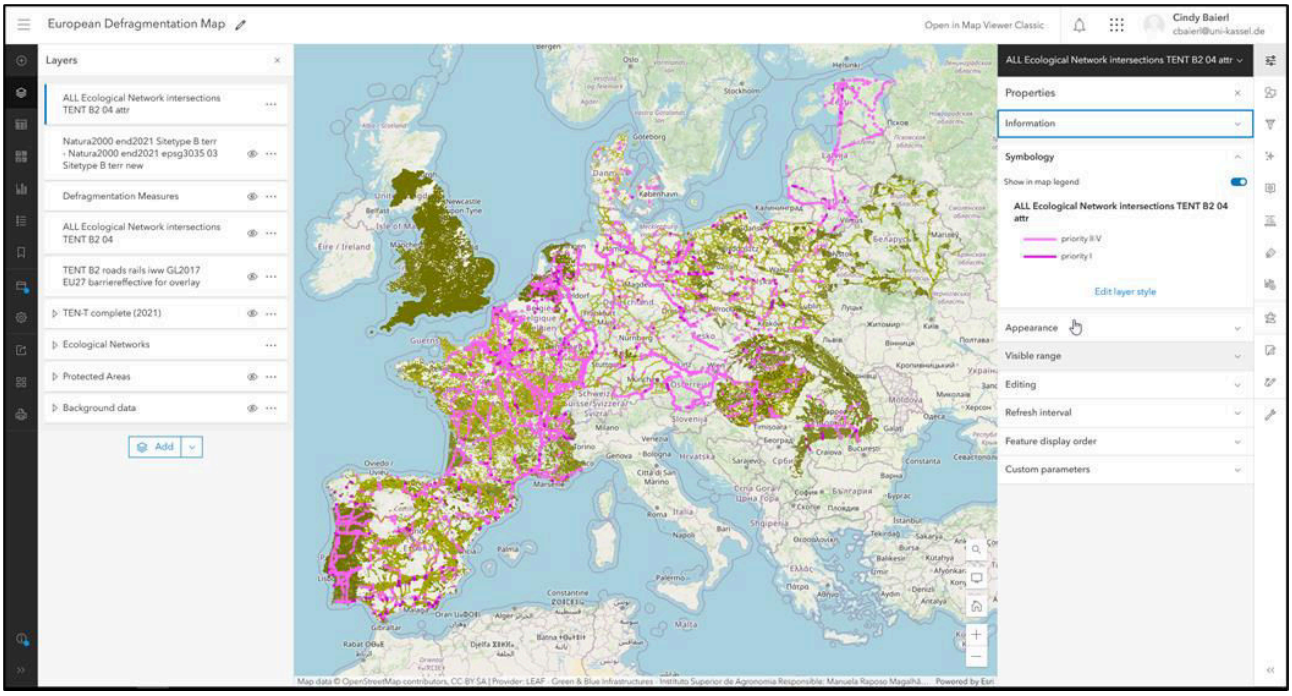


Figure 34: EDM – Small scale overview of the preliminary prioritised overlapping areas of ecological networks and the barrier relevant TEN-T

Looking at the map in Figure 34, it is noticeable that some major rivers (e. g. Rhine, Elbe, Maas, Lek) appear as overlapping sections. These rivers are focal corridors in the ecological network AND TEN-T inland waterways at the same time. Depending on the ecological condition and the level of use is relevant for the actual assessment of the barrier effect and the defragmentation needs. This should be noted for these overlapping sections and checked separately.

In addition, the small scale chosen for the map (approximately 1: 18,500,000) in Figure 34 shows the overall overlay, makes the overlay sections appear very massive and contiguous, but this is only due to the scale of presentation.

Map views at a larger scale (see Figure 35), on the other hand, clearly show the actual dimensions of the overlays.

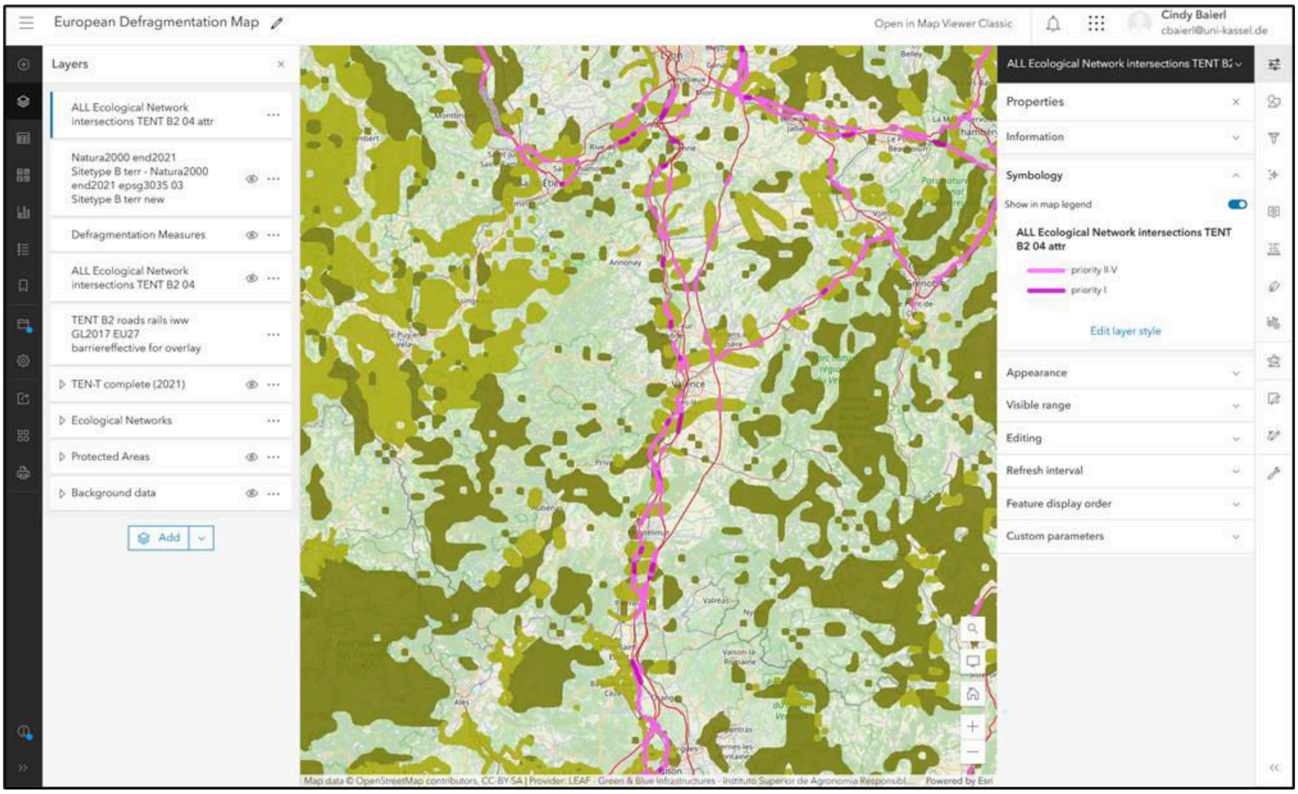


Figure 35: EDM – Large scale representaton (scale approx. 1: 1,150,000) of the preliminary overlapping areas of ecological networks and the barrier relevant TEN-T between Lyon and Avignon (FR)

For all overlapping areas between ecological networks and the barrier-relevant TEN-T was checked and assessed, if strictly protected areas are as well affected (see chapter 2.4.3). Narrow bundling of transport infrastructure was rated as prior in all three ecological area backdrops. The result of a first priorisation attempt is shown in Figure 34 and will be finalized in consultation with experts and project partners.

For all identified overlapping areas several information are stored in the explanatory attributes (tables). This includes, for example, information on the ecological network element/protected area concerned, on the TEN-T infrastructure relevant to the dissection and the results of spatial analyses on the presence of an existing defragmentation measure in the section (checked within 500 m radius) or of an airport, port or railroad terminal (checked within 5,000 m radius). The presence or absence of defragmentation measures or areal transport infrastructures are additional information for upgrading or downgrading the priority of the defragmentation section.

All information presented in the EDM can be evaluated according to various aspects and criteria stored in the attributes to the spatial data. Users of the EDM can create charts (Figure 36), filter contents, run analyses[52], they can change map styles and contents, configute pop-ups and labels.

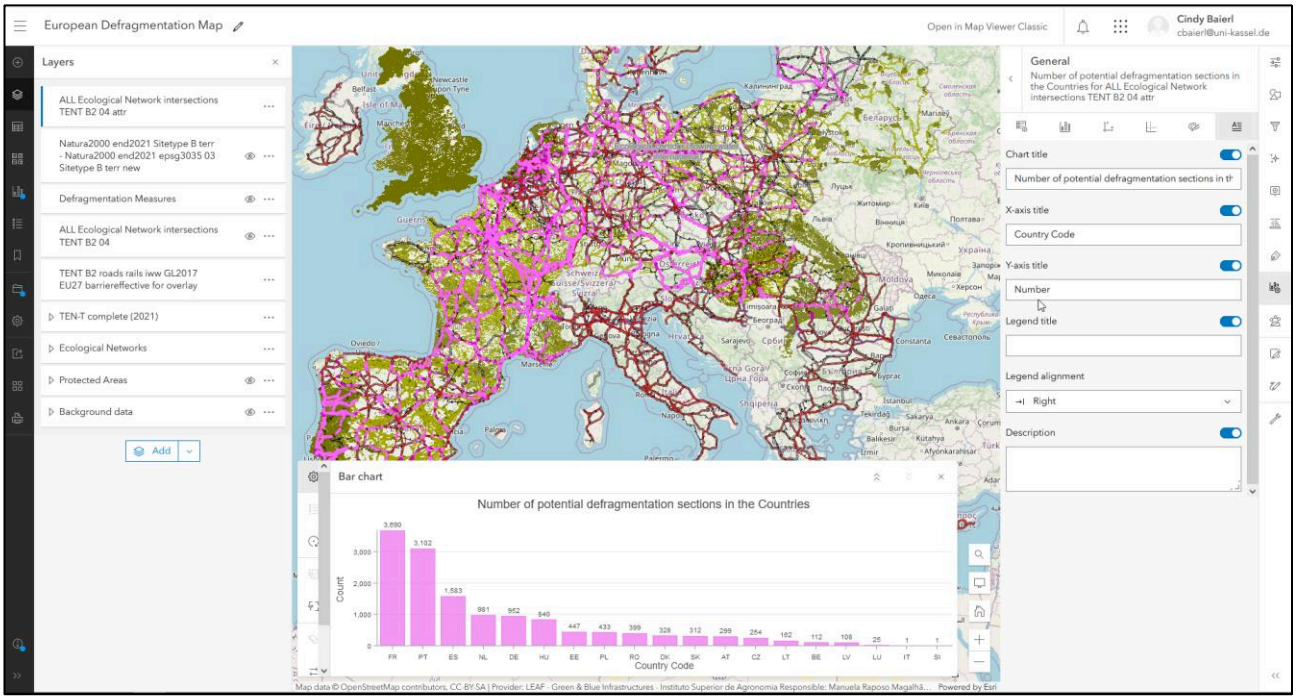


Figure 36: Example of simple chart creation within the EDM ArcGIS Online user interface

The European Defragmentaion Map in its current design and presentation fulfils basic requirements for their use but could only be developed as a prototype in the BISON project framework. It is strongly recommended to make use of the many possibilities for further development offered by the ARCGIS online platform with its Apps (dashboard, experience builder, story maps) to optimise the performance and quality of the presentation (see also chapter 2.6.1). In addition, the future data management, maintenance and updating beyond the BISON project must be regulated and organised.

[52] Analyse rubrics: Summarize data, Find locations, Enrich data, Analyse patterns, Use proximity, Manage data with divers analyses functions in each rubric

2.5 Conclusions / Application on EU Level

2.5.1 Improvement of Ecological Corridors of international importance (see chapter 2.5.2)

The compilation of the ecological networks of the EU states and regions in the EDM (see also chapter 2.3.3.1 and annex 7) clearly shows the differences in technical orientation, composition and methodology. The currently by EU states delineated corridors differ in underlying data and concepts from nation to nation and from ecoregion to ecoregion. They have been developed using a wide range of methods, e. g. HABITAT-Net (Germany), least-cost focal species approach from the BEETLE7 (Central Scotland), Nature Network of the Netherlands, Biotope of selected specially protected species of large mammals of national importance (Czech Republic), have different orientations (e. g. woodlands in Spain) and focuses (large mammals in Czech Republic). Accordingly, the area backdrops are quite different, but every country-specific Ecological Network represents valuable Green Infrastructure (GI) from at least the national point of view, that mostly go beyond the national and international protected areas and their connectivity. As a base of worth protecting and preserving (in terms of conservation, defragmentation and connectivity) area backdrop for a truly coherent Trans European Nature Network the Ecological Networks must be immediately improved and data lacks (especially in the northern and southestern part of Europe) has to be filled. Thereby a unification regarding all relevant ecosystem types is necessary.

The EU's biodiversity strategy for 2030[53], published on 20 May 2020, defines as a goal the creation and integration of ecological corridors as part of a Trans-European Nature Network to prevent genetic isolation, allow for species migration and to maintain and enhance healthy ecosystems. As a **main r+d need** to be prepared and in prerequisite to achieve this goal is the **identification of a truly functioning ecological corridor network for all ecosystem types in Europe and the migrating species** that are affected by their habitat fragmentation through transport infrastructure. In this context the establishment of a European database for defragmentation measures/crossing aids with descriptions is recommended.

Two approaches are conceivable:

1) Identification and mapping ecological networks (including corridors) networks according to a uniform method based on habitat topology and migration routes, while preserving regional differences.

2) Derivation of international important ecological corridors based on the national ecological networks/concepts.

Advantage of approach 1) would be the fill of data gaps (esp. in the North and Southeast Europe) through a completely new determination of an European Ecological Network (incl. corridors). In addition, comparability of data (and results) would be given by applying a uniform methodology. Remote sensing data (see chapter 2.6.2) and geospatial artificial intelligence (GeoAI, see chapter 2.6.3) could be used for modelling the Pan European Habitat network (with the determination and modelling the functionality of habitat corridors and the needs for reintegration). Prerequisite for the determination of an European Ecological Network are basic data on the habitats and ecosystems in Europe. These data could be automatically classificated and anaylsed using modern data and technologies as mentioned above.

[53] https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

Approach 2) would be preferable if the corridors were designated Europe-wide. As the EDM shows there are some data gaps regarding national ecological networks. These data gaps would remain for now. For countries with Ecological networks the assessment/ranking of (inter-)national important ecological corridors would have to be supported by the countries.

2.5.2 Improvement of the TEN-T (see chapter 2.4.2)

The Trans-European Transport Network (TEN-T) is a planned network of roads, railways, airports and water infrastructure in the European Union. The TEN-T network is part of a wider system of Trans-European Networks (TENs), including a telecommunications network (eTEN) and a proposed energy network (TEN-E or Ten-Energy). The TEN-T envisages coordinated improvements to primary roads, railways, inland waterways, airports, seaports, inland ports and traffic management systems, providing integrated and intermodal long-distance, high-speed routes The EU works to promote the networks by a combination of leadership, coordination, issuance of guidelines and funding aspects of development[54]. This should also cover an improved data base for projects which belong to the TEN-T, because this ensures comprehensive work between different administrations, in this case between the administrations of Nature Conservation, Transport Infrastructure and for the near future renewable energies. For the first improvement of the TEN-T the following aspects are important:

- For the roads the definitions of the different types of roads must be specified and for undefined types of road types definitions should be supplemented.
- The route digitization is incorrect and must be improved.
- There is a lack of data about the traffic volume, the width of the roads and accompanying structures (e. g. fences or protection walls) which have a big impact ot the severity of the barriere effect.
- For the future photovoltaic facilities must be integrated, because this construction can raise the barriere effect severly (see chapter 3.4 Better Impact assessment 3: Principles for avoidance and critical role of bundling (with special regard to fotovoltaic facilities).
- Depending on the further development of the TEN-T strategy, in particular to avoid barrier effects and secure hinterland connections for crossing aids in newly planned projects and upgraded projects TEN-T-Planning must cover a kind of Parity Reconnection Plan on European scale (cf. also with improvement with the (EU) No 1315/2013 Regulation, see chapter 2.6.5 and chapter 3.5.1).

2.5.3 Best indicators for a future European corridor system

The most successful way to realise defragmentation is the considerationof the most important European ecological networks (inventory and remaining potentials). Alternatively, it is possible to use standards for the necessary density of ecological corridors (see chapter 3.4) and for the necessary density of crossing aids (see chapter 3.5.3) as a guideline. Currently a compliation of all existing and available national and

[54] https://en.wikipedia.org/wiki/Trans-European_Transport_Network

transnational ecological networks is used. In the future a uniform European corridor system should be established under incorporation of Natura 2000 and other strictly protected, nationally designated areas; therefore, a suitable methodology (e. g. “Habitat-Net” (Hänel 2007), “Undissected functional areas” (UFR), occurrence of species, combination of habitat topology approaches with least-cost- path approaches and expert opinions) must be applied or elaborated. The current compilation of ecological networks in the EDM so far is based on very differently generated methods of the respective countries and in many cases only consider certain ecosystem types or species/guilds. Therefore, the national corridor systems should be further developed and assigned to a Pan-European Habitat network.

The most important indicators for (restorable) ecological corridors are:

- the density or location of strictly protected areas and habitats in need of protection in relation to each other (size, mirror fronts, distances), whereby a distinction must be made between water bodies, wetlands, dry biotopes (heaths, rough grassland, etc.) and forest biotopes. The best functioning habitat networks emerge from the position of the areas in relation to each other (see below),
- the location of inter-regional migration corridors of large mammals (wild species as well as transhumance routes) and
- the planning of ecological networks by individual countries or regions (as to be presented in the EDM).

Linking the above results is necessary to demonstrate a robust ecological network. This requires:

- the Modelling a Pan European Habitat network based on an automatic classification and analysis of habitats/ecosystem types (with remote sensing data and artificial intelligence) on European level. Here modelling the functionality of habitat corridors and the needs for reintegration, consideration of mirror fronts of the habitats and of protected areas (best functioning stepping-stone corridors),
- the compilation and/or modelling of large mammal migration corridors about minimum target densities for European ecological corridors,
- the assessment of the special demands of wilderness areas on habitat networks and defragmentation. Wilderness areas play a central role because, to safeguard their biological diversity, they must be particularly integrated into habitat networks and into migration corridors of large mammals (as bioengineers and vectors). In this respect, the location of real and planned or potential wilderness areas as the core and pivot points of an ecological network is another central indicator for the future European corridor system and
- an encouragement of the countries to complete and update their Ecological Habiat Networks (if necessary) and to align them with the European Habitat Networks where appropriate.

Based on these indicators, the most important European corridors could be derived, and prior defragmentation sections could be updated and presented.

2.5.4 Use of the EDM/applicability on European scale

The ongoing implementation and development of the TEN-T as a Europe-wide network of railways, roads, inland waterways, maritime shipping routes, ports, airports and rail-road terminals requires a strict consideration of the valuable European Green Infrastructure to reduce biotope fragmentation effects and negative impacts on biodiversity at the expense of social, economic and territorial cohesion in the EU.

The EDM can be used for different purposes respectively has various recipients:

DG Environment

For the further development of the strategy of a European-wide Green Infrastructure in conjunction with the biodiversity strategy of the EU. The biodiversity Strategy executes in this regard: …Biodiversity fares better in protected areas. However, the current network of legally protected areas, including those under strict protection, is not sufficiently large to safeguard areas, including those under strict protection, os not sufficiently large to safeguard biodiversity. Evidence shows that the targetzs defined under the Convention on Biological diversity are insuffienct to adequately protect and restore nature. Global efforts are needed and the EU itself needs to do more and better for nature and build a truly coherent Trans-European Nature Network. … and it is also said … In addition, in order to habe a truly coherent and resilient Trans-European Nature Network, it will be important to set up ecological corridors to prevent genetic isolation, allow for species migration, and maintain and ehance healthy ecosystems. In this context, investments in green and blue infrastructure and cooperation across borders among Member States should be promoted and supported, including through the Europwan Territorial Cooperation.

Many of the ecological networks of the countries either contain the Natura 2000 sites (e. g. the German habitat network) or define corridors between them (e. g. the Spanish network). Therefore, the ecologigical networks presented in the map should used as a part for the strategic development of the truly coherent and resilient Trans-European Nature Network. In particular, the map is suitable for a strategic discussion and development of a “truly coherent and resilient Trans-European Nature Network”, since it also shows crossborder connections. For the strategic discussion of the transnational network, it is irrelevant that different data bases and methods are used for the presentation of the cross-border corridor areas, especially since the implementation of the “truly coherent and resilient Trans-European Nature Network” must finally be done by the individual member states. Accordingly, the area backdrops are quite different, but every country-specific Ecological Network represents valuable ecological networks from at least the national point of view. For this cross-border cooperation, the country-specific networks are described in terms of the data basis and the methodology as well as the expert contacts (see annex 7).

For the first time all available ecological networks developed by European countries are presented in one view in the EDM. But the map must be improved in the future with all now lacking ecological networks mostly in eastern Europe, in parts of southern and northern Europe and with all existing defragmentation measures in all European countries.

In summary, the map can be used for information, discussion, analysis and development:

- to illustrate the status of the national networking plans available in Europe (state 2022),

- for strategic transnational cooperation and development for the cross-border development and implementation of ecological networks and
- for the development of cross border european wide wildlife corridors in connection with the Bern Convention and the Convention on Migratory Species (CMS).

DG Move

Use of the map– In Generel

Different map layers can be used for the determination of fragmentation sections. Before using the maps, every user should inform himself about what contents are depicted in the map and where the limits and, if applicable, possible errors of the illustrations lie. Building on this information, the questions that can be answered with the use of the maps should then be formulated. However, it is equally important to be aware of which questions cannot be answered with the use of the maps and which information may need to be consulted from other sources. (see e. g.Table 21 and Table 22). If this is not carefully taken into account, there is a serious risk that false conclusions will be drawn, which, however, cannot be attributed to the instrument - in this case EDM - but to the incorrect use of the data basis.

Use of the map and the identified priorities in the context of the different planning stages of the TEN-T

Four planning stages of TEN-T projects are distinguished: 'completed', 'under construction/ongoing', 'under study/preparation' and 'planned'. In general, if defragmentation areas have been identified in the EDM in the TEN-T (motorways, railways, inland waterways or bundling of motorways, railways, inland waterways) for the different planning states, it should be examined (at national level) whether defragmentation measures are planned and/or implemented.

As no definitions for the different planning stages of the TEN-T could be found in the literature, they were defined as follows:

a) **'Completed' projects**: these are projects that have been built and handed over to traffic.

b) **Projects 'under construction/ongoin'**: these are projects that are under construction.

c) **Projects 'under study/preparatio'**: the project is currently undergoing all the planning and assessment processes required in the respective country and by the EU, e. g. the EIA.

d) **Newly 'planne' projects**. These are projects for which a decision has been made to implement the projects, but which are not yet in a planning and assessment process. In any case, however, the start and end points of the project are known.

The further procedure for deriving defragmentation measures depends on the planning status of the respective project (see also Chapter: Better impact assessment)

a) **'Completed' projects**

(1) If core areas are dissected by road- or railroute in a way, that they lose their function, it must be examined, in addition, if defragmentation measures can restore the

functionality as a habitat. If so, relevant defragmentation measures at least should be checked at the national level.

(2) If terrestrial migration corridors and ecocorridors of of European and national importance are fragmented without any defragmentation measure, defragmentation measures should be constructed.

b) **Projects 'under construction/ongoing'**

(1) If protected areas or core areas of ecological networks are further dissected by the mode of transport to be upgraded, it must be examined, in addition to other compensation measures, whether defragmentation measures are required.

(2) If the upgraded route crosses e. g. ditches or rivers, the structures must be adapted to the current state of technology and ecological knowledge.

(3) If migration corridors and ecocorridors of international and national improtance are fragmented by the upgraded route defragmentation measures should be constructed.

b) **Projects 'under study/preparation**

(1) For the newly planned projects the EDM can give an indication to avoid fragmentation of core areas in the planning process and to mitigate the fragmentation of corridors of international and national importance. Much more on national level the scoping process is the most important step to avoid fragmentation in the overall planning process (see chapter 3.2.4).

(2) For newly planned projects, the primary rule is that the fragmentation of core areas must be avoided in any case. The task of route planning is therefore to avoid the fragmentation of core areas. In all EU member states, the Habitats Directive must be applied if NATURA 2000 sites or species and habitats of Annexes I, II and IV are affected.

(3) In a second step, the fragmentation of eco-corridors and the coherence of protected area must be reduced (see chapter 3.5.1). For this purpose, appropriate avoidance measures such as green bridges etc. must also be planned in the required number and density (see chapter 3.5.3) at the beginning phase of planning procedure as part of a defragmentation concept to be carried out in parallel. This is necessary because structures to be planned for the defragmentation measures can significantly influence the design of the structure of the respective mode of transport.

c) **Newly 'planned' projects**

For the newly planned projects the EDM can give an indication to avoid fragmentation of core areas in the planning process and to mitigate the fragmentation of corridors of international and national importance. Much more on national level the scoping process is the most important step to avoid fragmentation in the overall planning process (see chapter 3.2.1).

2.6 Research and Development needs

2.6.1 Improvement of the EDM

The recommendations and ideas for improving the map relate on the one hand to its presentation, display and use, and on the other hand to the content of the map. Within the BISON project we had limited capacities to exploit and optimise the display, analysis and evaluation possibilities of the map contents with the very powerful GIS software ArcGIS Online. Therefore, we propose:

- e. g. the elaboration of an **ArcGIS dashboard**[55] to present the map data in an easy-to-read format (see example in Figure 37). Dashboards are visual displays showing all relevant information on a single screen, facilitating understanding quickly and easily. Map users will be enabled to retrieve information by presenting spatially based analytics using intuitive and interactive data visualizations on a single screen. This would help to make decisions, visualize the status quo (in real time), derive trends and inform relevant audiences like the public or decision makers.

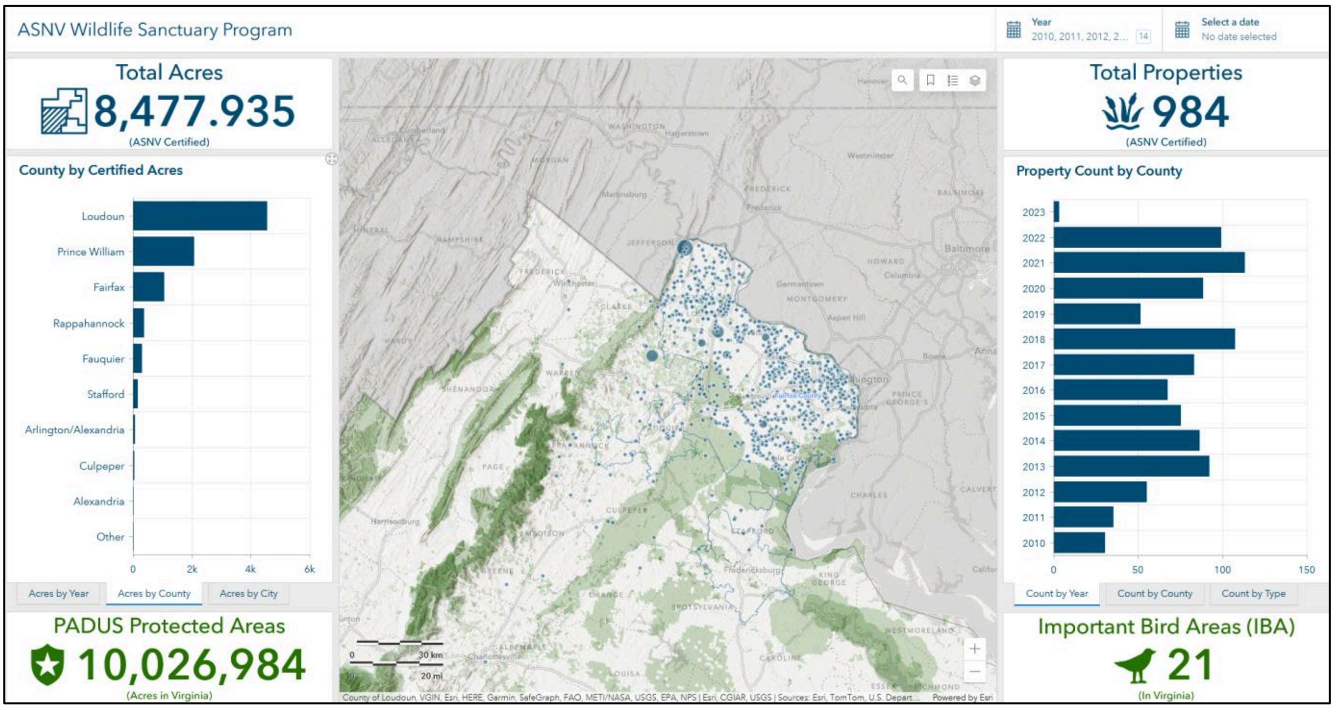


Figure 37: Exemplary dashbord of the ASNV Wildlife Sanctuary Program

(Source: https://www.arcgis.com/apps/dashboards/96896859c42c4301a8032609493a9e00)

- e. g. to build an immersive web app with the ArcGIS Experience Builder56, a highly configurable solution for building compelling web apps without writing codes. This web application (see example in) will be configured for the audience by unifying web maps, apps, pages, interconnected widgets, and both 2D and 3D data through a flexible drag-and-drop interface.

[55] https://www.esri.com/en-us/arcgis/products/arcgis-dashboards/overview
[56] https://www.esri.com/en-us/arcgis/products/arcgis-experience-builder/overview

Building multiple purpose-driven, customized views of the information using multipage web experiences, flexible designs, built-in screen groups, and viewing options is possible. With the given information and through configurable widgets the audience can be engaged to interact with data, content, and even each other.

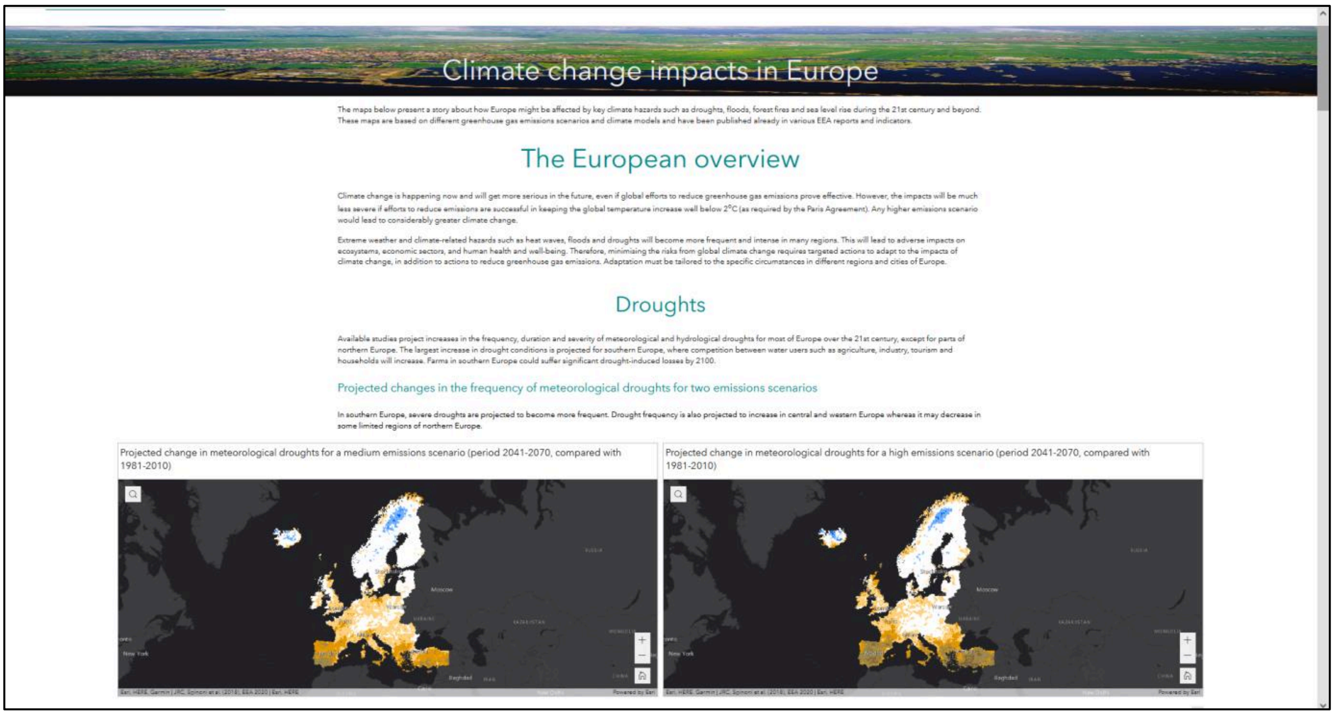


Figure 38: Exemplary ArcGIS Experience Builder web application of the EEA about the climate change impacts in Europe

(Source: https://experience.arcgis.com/experience/5f6596de6c4445a58aec956532b9813d/page/The-European-overview/)

To supplement the content of the EDM we recommend:

- the complementation of the missing ecological networks in eastern and northern Europe for states, which have no nation-wide corridor maps by funding state-wide planning and/or modelling a consistent corridor framework across Europe,
- the improvement of the existing networks (e. g. implementation of missing habitat types/ networks/Ecosystems, Migration corridors …),
- the establishment of a meta-information system of all major defragmentation measures (green bridges, fauna bridges, fauna tunnels) in Europe (with a short description),
- the identification and compilation of data on transport infrastructure at the EU and national levels needed for a more accurate and complete assessment of the specific barrier effects of each mode and type of transport.
- An overlay with European map of artificial lightening (example see Figure 39) and idenitfication of the “dark areas”. Artificial lightening is a big threat for biodiversity. 60 % of mammals and much more invertebrates are norcturnal or active at twilight. It is important to protect the darker areas against artificial light with lightening plans when planning motorways. Often service

stations and rest areas are planned in semi-natural areas, which are illuminated at night and contribute to light pollution of protected areas (see also chapter 3.1).

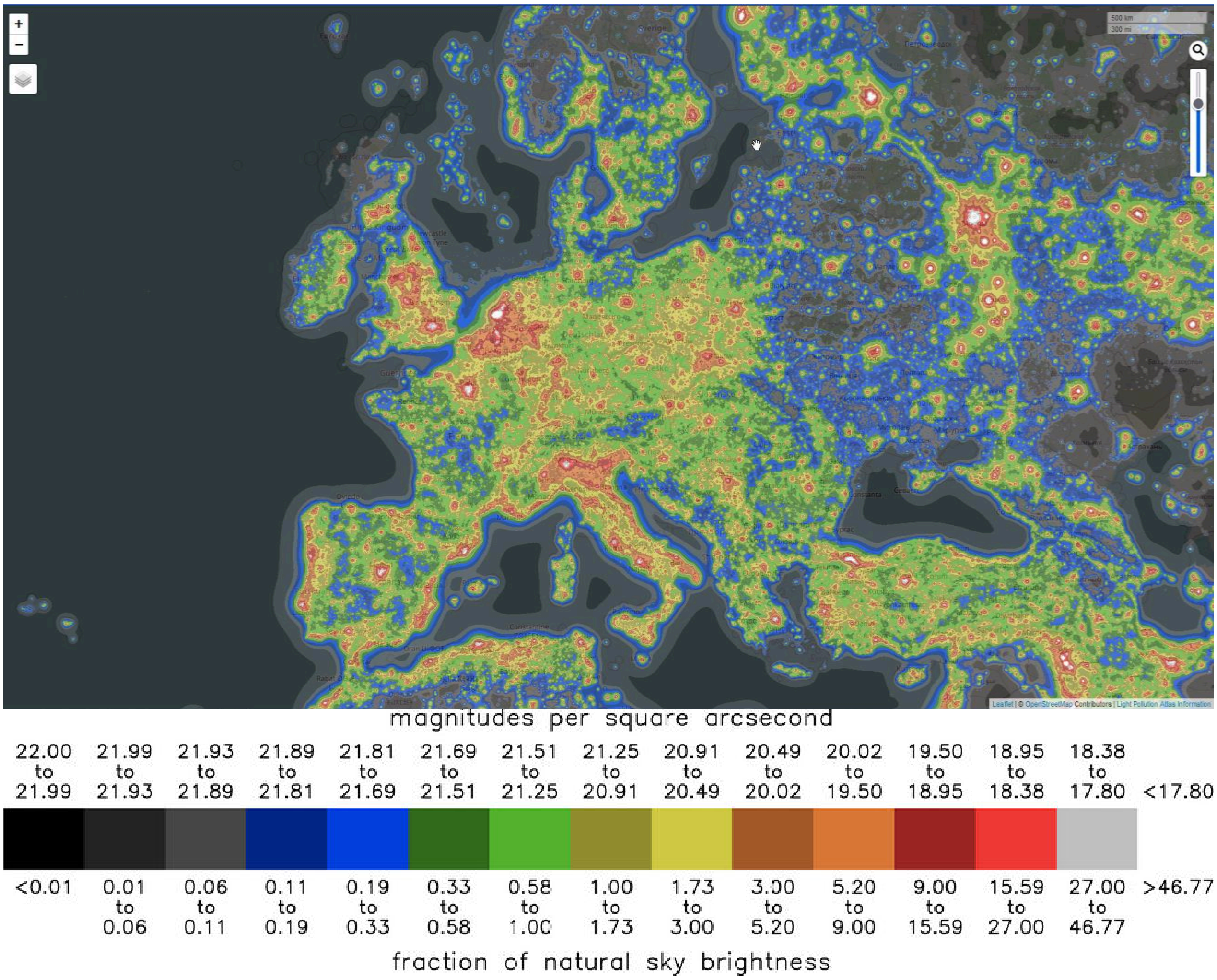


Figure 39: Light Polulution Atlas 2020

(Source: https://djlorenz.github.io/astronomy/lp2006/overlay/dark.html)

2.6.2 Use of Remote sensing data

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers "sense" things about the Earth. Remote sensing is an efficient tool for monitoring the Earth at low cost and in a short time.

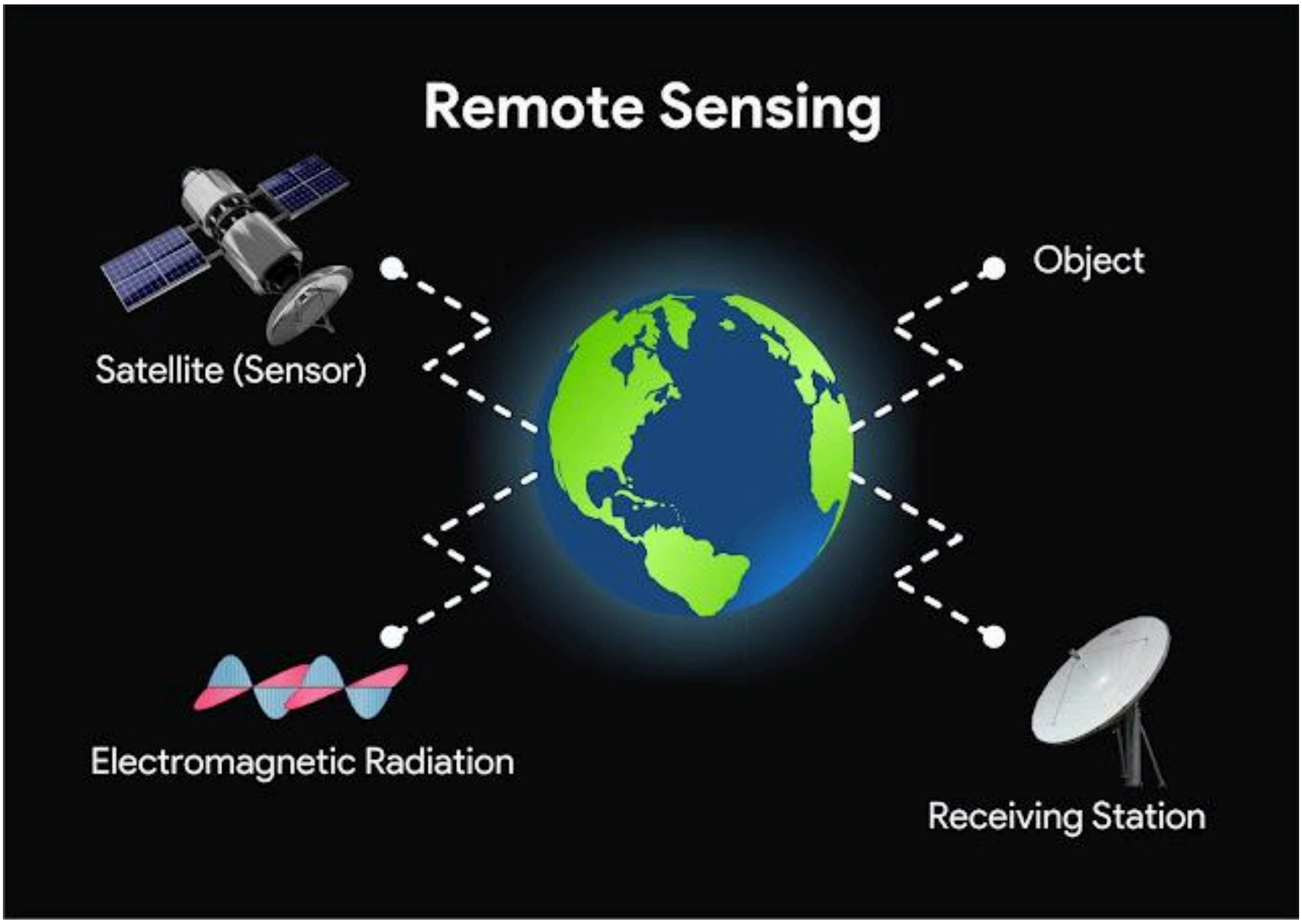


Figure 40: The process of remote sensing

(Source: https://www.studyprobe.in/2020/06/remote-sensing.html)

Copernicus[57] is the European Union's Earth observation programme, served by a set of dedicated satellites (the Sentinel families) and contributing missions (existing commercial and public satellites). Copernicus also collects information from in situ systems such as ground stations, which deliver data acquired by a multitude of sensors on the ground, at sea or in the air. The Copernicus services transform this wealth of satellite and in situ data into value-added information by processing and analysing the data. The vast majority of data/information delivered by Copernicus is made available and accessible to any citizen, and any organisation around the world on a free, full, and open basis.

[57] https://www.copernicus.eu/en

Maps are created from imagery, features and anomalies are identified and statistical information is extracted. The **Copernicus Land Monitoring Service (CLMS)**[58] provides geospatial information on land cover and its changes, land use, vegetation state, water cycle and Earth's surface energy variables to a broad range of users in Europe and across the World in the field of environmental terrestrial applications. As one famous output are the wide spreaded, vector-based CORINE Land Cover datasets[59] to mention, that includes 44 land cover and land use classes. One aspect, in the context of habitat continuity and connectivity, would be worth to be analysed and determined within the CLMS to be a meaningful working bases for promoting and preserving biodiversity is an **automatic identification of habitat topology.** A basic, sufficient knowledge about habitat topology would provide suitable conditions for the construction of ecosystem-specific habitat networks and subsequently for the reduction of disturbances (e.g through transport infrastructure) in their numbers and spatial correlation. In addition, gaps in the habitat networks would be obviours and the need for action could be derived from them. These would help protect metapopulations (and prevent further loss of biodiversity) where populations are linked by dispersal (Edge & Fortin 2020).

Beside this we need in general more information about distribution, extend and state of habitats and ecosystems as a fundamental prerequisite for political decisions and programs, measures and initiatives based on them. Several aims of the EU Biodiversity Strategy 2030, e. g. the restoration of 15 % of degraded ecosystems, the expandtion of protected areas to 30 % of the EU's land and sea, the creation and integration of ecological corridors as part of a Trans European Nature Network to prevent genetic isolation or the effectively management of all protected areas and monitoring them, require a good and precise data basis, data evaluation and data management.

A combination of remote sensing data evaluation, **airborne laser scanning** (as a measurement method for determining the height structure of the earth's surface) under exploiting the possibilities of artificial intelligence would qualify and improve the results of the mentioned proposal of an automatised identification of habitat topology.

58 https://www.copernicus.eu/en/copernicus-services/land

59 https://land.copernicus.eu/pan-european/corine-land-cover

2.6.3 Use of (Geospatial) Artificial intelligence (GeoAI)

Artificial intelligence is probably the most influential and ground-breaking technology, able to speed up and improve big data analyses. Integrating Artificial Intelligence (AI) into GIS Technologies opening up previously unimaginable possibilities in prediction, image and data classification and image and data clustering contextes. AI GIS is a phrase that refers to a group of technologies that combine artificial intelligence (AI) with GIS operations such as spatial data processing and analysis algorithms (GeoAI). AI GIS has progressively been the major focus of geoscience research and application in recent years.

GeoAI is a spatial data processing and analysis algorithm that integrates AI. GeoAI is divided into two parts: geospatial machine learning and geospatial deep learning. Using Geospatial Machine Learning in GIS, users may tackle a number of GIS application challenges such as geographical clustering, spatial classification, and spatial regression. The Geospatial Deep Learning algorithms can include 3D data analysis and image analysis. Geospatial Artificial intelligence (GeoAI) applies spatial machine learning and deep learning teqniques to help solve complex problems and derive deeper insights in powerful and innovative ways. The continuously self-learning and constantly improving system of data evaluation could be used e. g. for an automatic identification of habitat topology. First approaches of habitat classification using AI and Deep Learning have been developed and published recently (Perez Carabaza & Boydell 2021, Kramer et al. 2022)

By training the system with various important parameters and criteria the performance and result of automatised habitat detection will enhance. Some GIS-softwares offers integrated machine learning processes within their GIS-systems (e. g. QGIS, SuperMap GIS, ArcGIS (see Figure 41)).

Figure 41: ArcGIS as an End -to End-Geospatial AI System

(Source: http://www.esri.com)

2.6.4 Indicators for assessing the need for defragmentation and the barrier effect of transport infrastructures

Various indicators for the assessment of defragmentation needs and the barrier effect of transport infrastructures are currently not useable (see chapter 2.4.1 & chapter 2.4.2 , Table 10 & Table 11), because the data are insufficient or non-existent.

The following table (Table 16) lists these indicators and assigns them corresponding R&D requirements. Data gaps regarding information on traffic infrastructure (planned and already realised) concerning all transport modes and has to be filled.

Table 16: Research & development needs related to the criteria for determining defragmentation needs and barrier effects

Indicator…	Description	R&D needs
…for determining defragmentation needs		
Affecting strrictly protected nature reserves	Nationally designated areas (CDDA-Data), only IUCN categories I-IV)	Comprehensive integration/consideration of wilderness areas
Connectivity of endangered habitats	Habitat selection (only/not only habitats after Annex I /Habitats Directive)? Possible criteria: - distances between habitats - habitat density - barriers	Usage of remote sensing data (and GeoAI) for identification of endangered habitats
Sum of habitat areas within a corridor section (core areas and corridor sections)	Number of high-quality biotopes/habitats in a defined spatial unit of the Ecological network	Creation of a suitable data background of high-quality habitats e. g. with remote sensing data; Definition of threshold minimum habitat size on European level; Definition of applicable ecosystem-/habitat types
Occurrence of selected protected species under Habitats Directive'	selected species of Annex IV and V (e .g. Lynx pardinus in Spain); for the assessment of connectivity needs; mostly expert knowledge	Building a database with a selection of representative species for biographical regions (Natura 2000 database is insufficient); Designation of indicator/target species for the biotope network (with occurrence and distribution)
Occurrence of engangered or endemic species'	Protection of species, which are especially threatened by extinction (through habitat loss, loss of genetic variation); e. g. Common European adder (Vipera berus); for the assessment of connectivity needs; mostly expert knowledge, but not generally available, especially, especially for species threatened with extinction	Selection of relevant species
Long distance migration routes (including transhumance)	Species moving through different media, using various modes of locomotion and transport. Basic driving forces are ecological and biogeographic factors like seasonality, spatiotemporal distributions of resources, habitats, predation and competition. Important for the functional connection of habitats through livestock; for	Identification and designation of transnational migration routes

Indicator…	Description	R&D needs
	the validation of connectivity measures at the subordinate spatial levels	
Migration routes of large animal herds	Migration of large animal herds (ungulates/ hooved mammals, e. g. *Cervus elaphus* in Hungary, *Rangifer tarandus* in Norway) is a fundamental ecological process, whose effects cascade up and down terrestrial food webs (provide the prey base for large carnivores and scavenger populations) and underpins terrestrial biodiversity. Yet ungulate migrations are disappearing at an alarming rate.	Identification and designation of migration routes
…for assessing the barrier effect of transport infrastructure		
Roads	Type classifications allow a selection of relevant barrier effective roads. These are motorways, rural two-lane roads and the category of undefined types (a lot of national highways in this category!). The road types urban roads (within settlements) and rural roads with separate directions (two lanes, narrow width, lower traffic, …) are not considered.	Specificised data e.g on width, traffic volume[60], protection devices (e. g. fences, kind of guard rails) for a correct assessment of the barrier effect are needed. Without such detailed information just a rough estimation of the barrier effects of different road types are possible.
Railways	Type classifications allow a selection of relevant barrier effective rails. High speed rails (at least 250 km/h) are assessed as such. HSR require wider routes, more structural protection measures (e. g. against noise or load shedding) and are partly fenced. Thus, HRS create or reinforce insurmountable obstacles. Conventional rails with their low barrier effect are not considered.	Specificised data e.g on number of tracks/the width, train frequency and the level of expansion (conventional or highspeed (and here also the type: graveled or ballastless/slab track)) are needed to a precise estimation of the barrier effects.
Inland waterways	Waterways of international importance (rivers and canals) with specific minimum technical characteristics; connecting industrial regions, urban/ metropolitan areas and ports.	Information on level of expansion and the width are essential. There is a big difference if the IWW is an artificial canal or a natural/seminatural river. Different techniques of riverbank shoring causes more extensive or lesser barrier effects, which requires individual consideration and treatment.
Bundling of transport infrastructures	Determination of bundling different transport modes (e. g. road and railway); consideration of a narrow bundling distance (150m), which is strengthening the barrier effect of the bundling route. When determining the bundling sections, all roads with a strong barrier effect (see above), all railway lines (HRS and conventional) and all IWW are considered.	Bundling increases barrier effects. Responsible factors for this are large(r) widths of the bundled traffic routes, higher total volumes and more protection devices/ accompanying structures. The effects of bundling on biodiversity have not yet been sufficiently researched, including the **critical distances between the different transport routes**. This must be clearified. Bundling effects with other transport and energy infrastructures like powerlines or photovoltaic installations still can't considered because of data lacks.

[60] *Measured in vehicles per day; critical thresholds vary in the regions ("habituation effect")

2.6.5 Improvement of the proposal for a Regulation of the European Parliament and the Council on Union guidelines for the development of the Trans-European Transport Network amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) No 1315/2013[61]

In December 2013, with the Regulations (EU) 1315/2013 (TEN-T Guidelines), and (EU) 1316/2013 (Connecting Europe Facility 1), the TEN-T network has been defined on three levels, the Comprehensive network and the Core network, and therein the 9 Core network corridors. In (2) it is written, that "…the planning, development and operation of trans-European transport networks contribute to the attainment of major Union objectives, as set out in, inter alia, the Europe 2020 Strategy and the Commission White Paper entitled "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system" ("the White Paper"), such as the smooth functioning of the internal market and the strengthening of economic, social and territorial cohesion. Their specific objectives also include allowing the seamless, safe and sustainable mobility of persons and goods, ensuring accessibility and connectivity for all regions of the Union, and contributing to further economic growth and competitiveness in a global perspective. Those specific objectives should be achieved by establishing interconnections and interoperability between national transport networks in a resource-efficient and sustainable way…".

This regulation is currently being revised in connection with the other regulations mentioned. In the draft of the proposal, landscape fragmentation is also mentioned as a significant impact for the first time in the recital (15). Also, parts of the regulations in Art. 4 (iii), (iv) (Objectives of the trans-European transport network) and Art. 5 1. (g) (Ressource-efficient network and environmental protection) state that the protection of the environment should be strengthened and that the impacts on the environment conservation should be reduced. According to the current state of knowledge, the costs resulting from impacts are to be determined based on the existing regulations under European law for environmental protection and nature conservation. However, the problem here is that fragmentation effects, which can also be estimated at the European scale, are only inadequately covered by these regulations. This fact and a hitherto missing working tool are are possibly the cause that until now it has been very difficult to estimate the costs of avoiding habitat fragmentation. With the development of EDM, however, a rough estimation is now possible. This means that the costs for possible crossing aids could be integrated into the cost-benefit analysis already at the EU level.

According to the 'polluter pays' principle, establishing an european defragmentation program for the existing single or bundled transportinfrastructur of the TEN-T is suggested. The programme should cover the pro rata costs for the planning and construction of crossing aids (e. g. greenbridges) in accordance with the costs required in the respective countries. Every 5 years, an accountability report together with a map on the progress of the built defragmentation measures should be submitted by the authority responsible for the TEN-T on European level. In connection with the development of a European Defragmentation program there is a need for the development of standards about defragmentation in the EU (e. g. the length of undissected ecological corridors or undissected functional areas).

[61] Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU Text with EEA relevance. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R1315

3 PLANNING PRINCIPLES AND RESPECTIVE R+D NEEDS

Heinrich Reck, Marita Böttcher & Cindy Baierl

3.1 Planning Deficits - leading to wrong decisions

Heinrich Reck, Marita Böttcher, Cindy Baierl, Niki Voumvoulaki &, Lazaros Georgiadis

Regarding sustainable ecosystem networks, the too many planning deficits require immediate improvement

especially

1. Defragmentation concepts have to be part of any TI-decisions, with TI-administration responsible for:

   1.1 safeguarding eco-networks and ecosystem functions across roads, rails, waterways, ports & co. and

   1.2 overcoming significant barriers from the past.

plus

2. EU-wide guidelines for scoping, for the selection of ecological planning indicators and for reducing unnecessary impacts as well as for using TI side areas to create habitats and corridors (or respectively TI for well-being / TI for life) have to be implemented.

3.1.1 Unnecessary deficits as motivation to improve planning procedures

Instead of a preliminary remark: A repetition of the contextual definition of the term "fragmentation of ecosystems"[62].

Fragmentation comprises two main components:

1. „dissection" (e. g., linear, route and traffic-caused barriers and/or edge effects by linear habitat degradation) and
2. „islandization", e. g., thinning out and downsizing of habitats - causing, among other things, the loss of habitat or population connectivity by distance.

Rationale and methodical approach

Besides the general (urgent) needs for better safeguarding biodiversity due to extreme loss of habitats and ecosystem networks by islandization effects, unnecessary impacts due to inappropriate development of TI (causing additional barriers in the ecological networks) and obvious planning deficits plus corresponding knowledge deficits are one of the motivations to improve planning procedures and to outline minimum standards and priorities for application-oriented research and development (r+d).

The following deficit list is the result of screening numerous current planning documents, mostly from Central Europe (dealing with roads or rails, some waterways and one single airport whose enlargement nearly dissected a Natura 2000 area). In addition, larger TI projects as the Trans-Baltica railroad in Latvia (analysis by Vagolins 2019) or the Via Egnatia in Greece (on the basis of interviews and field trips) as well as official "brief descriptions of European traffic projects" were taken into account, supplemented by discussions about significant deficits within two BISON-workshops participated by experts from Czechia, France, Greece, Romania, Spain and Sweden.

3.1.2 Main planning deficits and related r+d needs in a nutshell

The following deficits were the most obvious in current TI-planning. The related r+d-needs are roughly outlined but explained in detail in the other chapters of the report.

List of main planning deficits with regard to ecological corridors or fragmentation

I. **Neglecting existent indicative maps and plans for ecological networks as well as missing standards for the quality and density of ecological corridors and for defragmentation[63].** Reasons are (1) ignorance[64], (2) contradictions between different eco-corridor approaches and/or planning levels, (3) difficult acquisition procedures to get information on existing corridor

[62] As the chapters of the report are intended to be separately readable and comprehensible, a certain redundancy of information is unavoidable.

[63] E. g. about appropriate densities and dimensions of habitat corridors as well as of fauna passages

[64] ignorance of e. g. the idea of Article 10 of the Habitats Directive or the European Green infrastructure strategy or the European biodiversity strategy which requires functioning ecological corridors (and thereby especially missing the needs for safeguarding unique left-over potentials for the restauration of eco-networks)

plans or (4) incompleteness of the respective concepts (leaving out important ecosystems or guilds and/or parts of the respective areas)

Resulting r+d need is the development of nested and integrative corridor concepts from European to local level[65] and, for scales > 1:50,000, the special development and realization of parity green infrastructure concepts[66] according to planned or existing TI (as prominent indicator for sustainable TI)[67] .

II. Inappropriate selection of indicators sufficiently representing all significantly affected species or ecological guilds and ecological functions as e. g.

- **neglecting the demands of the small fauna, especially of flightless insects, that is neglecting the main share of species affected by barriers due to TI**
- **single-species specific planning (concentration on strongly protected species which don't represent biodiversity at all[68])**
- **neglecting the vector functions and the function as bioengineer of large ungulates (which mostly are not listed as endangered species)**
  while concentrating on strongly protected species (unbalanced prioritization of Annex IV and Annex A species; cf. Trautner et al. 2021[69])

Resulting r+d needs concern the compilation of a representative and eco-regional stratified list of indicators and indicator taxa (regarding the ecological guild principle) for which surveys (adapted to different scales) should be obligatory and comprise the critical assessment of the representation of biodiversity (affected by TI) by Natura 2000 species and biotopes for the different eco-regions in the EU.

---

[65] "Ecological connectivity should be an important consideration in environmental assessment, but it is often considered too late in the Environmental Assessment process, at a scale of analysis often unsuitable for capturing landscape-scale effects and relying on overly simplistic metrics or qualitative approaches. Connectivity consideration will need to be required explicitly and supported by best-practice guidance to address the conditions that should trigger a connectivity analysis, the required types of approaches, and the kind of information required to inform decision-making" (Patterson et al. 2022)

[66] = parity reconnection or respectively defragmentation plans

[67] Thereby guidelines for plausibility checks of existent GI-concepts and guidelines for TI-specific parity GI-concepts would be helpful and special research is needed e. g. for the assessment of the impact of stepping-stone biotope topology / mirrored fronts and for barrier impacts of different land use.

[68] Without conflating or integrative optimization for all affected species or guilds and so often creating unnecessary conflict of goals or contradicting solutions.

[69] "The current focus in the classification of "particularly planning-relevant species" on their protection status under European law in e. g. Germany (and numerous other nations) means that the protection of many other endangered species, including even those for which respective states have a special responsibility to protect, is neglected. In this respect, the safeguarding of biological diversity in the context of impact management is jeopardised. This also applies insofar as the functional (species- and population-related) habitat connectivity is not sufficiently taken into account."

III. Inappropriate definition of impact areas and disregarding the needs for cross-sectional mitigation[70] of barrier effects

Resulting r+d needs concern guidelines for appropriate survey areas (scale[71]-specific as well as guild-specific); guidelines for the delineation of impact areas of barrier effects and (again) the implementation of cross-sectional parity green infra structure concepts[72]".

IV. Inappropriate selection of impact factors for plan assessment, thereby

- **neglecting the role of alternatives like lower traffic-velocity standards,**
- **neglecting the negative effects of bundling transportation infrastructure and of bundling transportation infrastructure with solar power plants and other industrial development of side areas[73] or**
- **neglecting the negative effects of (mostly unnecessary) curb stones or of protection walls or of maintenance roads or other secondary TI**

Resulting r+d needs concern the compilation of a complete list of relevant impact factors with respect to the respective TI-types, regulations about ways for their treatment in EIA and IR and pars pro toto research about their exact impact on sensitive taxa/guilds and other environmental assets as well as questioning the alleged, unproven (or imbalanced) economical or ecological or safety benefits of high traffic velocity[74], bundling[75] and safety fences or walls.

V. Neglecting the role and opportunities of verges and side areas as ecological corridors, and the role of soil management for optimizing habitats and minimizing maintenance (and construction) costs.

Resulting r+d needs concern a guidance for eco-region-specific design of verges[76] and other TI- side areas as habitat and corridor while the principles for substrate management could be the

[70] Section-wise assessment of larger TI can be (partially) misleading for the task of fragmentation assessment. fragmentation and defragmentation concerns have to be (additionally) assessed and complementary avoided or mitigated at least for the next bordering TI sections.

[71] or specifically for the respective planning instruments and tasks i. e. SEA, EIA or IR (IR = impact regulation)

[72] = parity reconnection or respectively defragmentation plans

[73] or respectively effects of too narrow interstitial space or improper interstitial land use or habitats [bundling can have 2 effects with respect to (de-)fragmentation 1. Creating unsurmountable barriers (plus increased area consumption, more efforts and costs for protection walls, traffic bridges) and (2) Creating space for nature because of spacing areas. The latter is currently corroded by further use as e. g. bundled photovoltaic plants with additional fencing etc.]

[74] The effects of lower velocity TI has always to be compared as an obligatory alternative in SEA and EIA.

[75] Of great relevance is the comparison of habitat consumption and the efforts for emerging needs for larger TI-buildings as subways, the comparison of barrier effects for different spatial bundling arrangements or the comparison of remaining possibilities and of the costs for the mitigation of barrier and other impacts.

[76] Verges can be valuable habitats and are no ecological trap with the exception of shrubbery that is developed too closely to the traffic lanes (the dependency of traffic kill from shrub-distance to traffic is not understood well enough, possibly a distance of 3 to 5 m will be sufficient to avoid extra animal losses).

same all over the EU[77]. A survey of the corridor effect of verges for different guilds is necessary because supralocal or cross-sectional effects are not calculable yet (while local corridor function is evident and proofed). Besides the habitat and corridor function (verges as source habitat), possible and disputed trap effects and verges as sink habitat have to be balanced.

VI. Neglecting of the opportunity for Parity Green Infrastructure planning and implementation while TI development and maintenance

Resulting r+d needs concern a guidance for planning and the development of legal obligations for implementation. Parity Reconnection plans could be a silver bullet to biodiversity friendly TI development and accelerated planning and project realization.

VII. Inappropriate consideration of (a) foreseeable environmental changes, (b) range expansion of target species, (c) of limited left-over opportunities for defragmentation and (d) of upgrading

While the needs for adaption of drainage systems and underpasses for water courses due to climate change and higher flooding risks are meanwhile part of TI-planning, the needs of higher dispersal possibilities of flightless species to adapt their living-area to climate change is often ignored, as is the (aspired) range expansions or the recolonization of lost areas by large herbivores (as red deer) or large carnivores (as bears) due to the fulfilment of international conventions or national law. Regarding e. g. fencing, that means that fencing has not only to be planned for the largest deer (e. g. roe deer) living at a place but also for red deer or even brown bear if there is a possibility for recolonization in the lifespan of the fence or TI. Regarding eco-corridors, not only existent corridors have to be protected in their functions but also possibilities to rebuild corridors if such are in need[78] and if opportunities for reintegration into functioning networks are restricted.

With respect to later upgrading of TI expansion reserves are sometimes part of planning and design. However, the necessities regarding the effects of e. g. wider TI on barrier effects or fauna passages are mostly forgotten. Fauna passages should either be adaptable or planned for wider TI from the beginning. If e. g. underpasses have to be prolonged, the requirements for width and height (openness) can be disproportionally greater and for the enhanced barrier effects further mitigation or compensation may be necessary.

[77] Using nutrient-poor soils or raw ground will probably be best for creating valuable herb vegetation and minimizing maintenance (and construction) costs. Just if shrubs and trees are the targeted vegetation soil treatment must be adapted to local climate.

[78] See chapter minimum densities

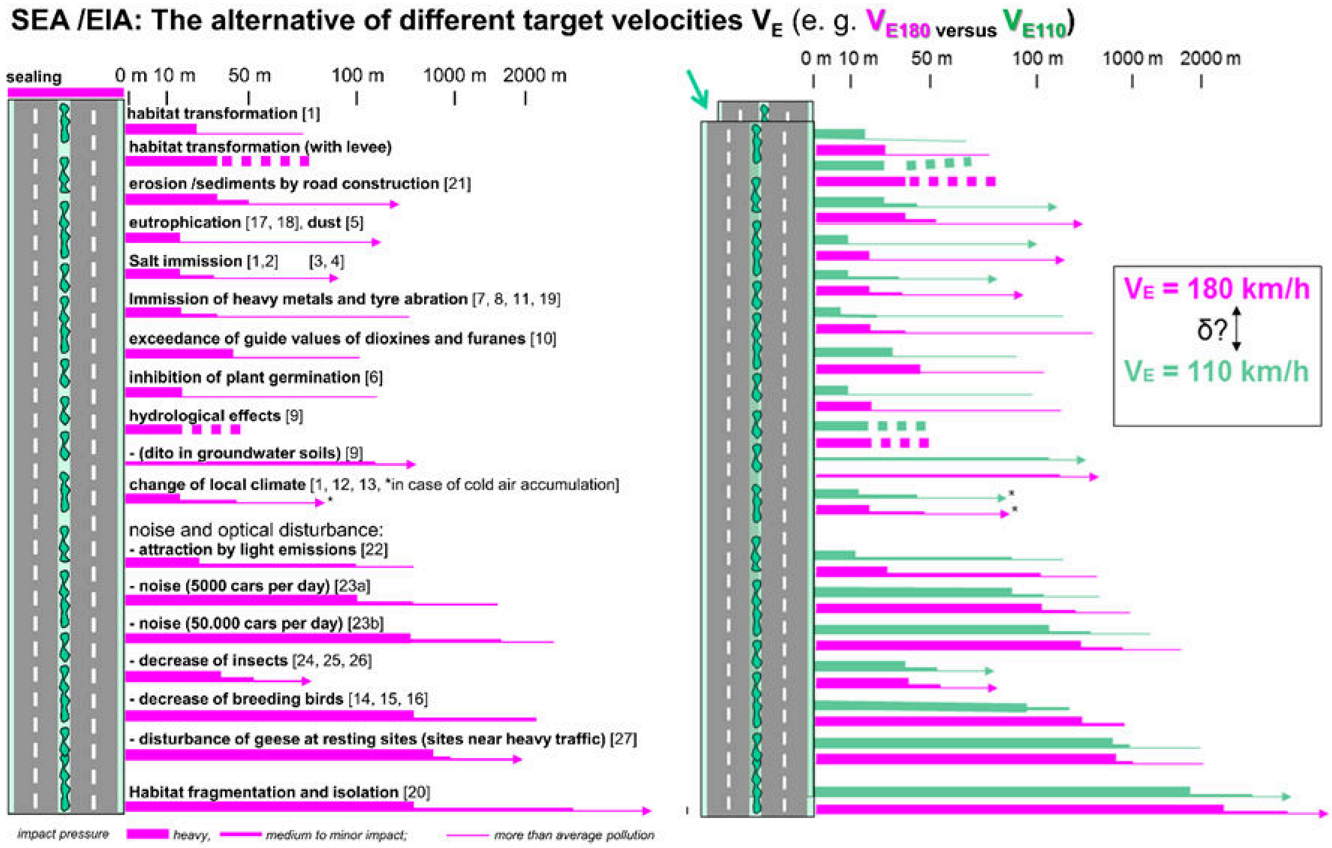


Figure 42: Different (target) velocities V_E (e. g. V_{E180} vs V_{E110}) lead to different impact areas and impact weight
The result of high velocities, target velocities V_E as well as driven velocities, is higher or (mostly) disproportionally higher habitat loss, eutrophication, emissions of carbon dioxide (due to exhausts as well as due to the higher consumption of construction material as concrete), higher noise and its masking effects, higher traffic or TI kills, reversing effects on animals or respectively barrier effects at all (from Reck 2013);respective r+d needs concern e. g. cost-benefit balances regaring lowering motorway VE to max. 110 km/h and highway VE to max. 90 km/h or lowering the velocity of high-speed railways but speeding up entry and exit times by e. g. wider doors.

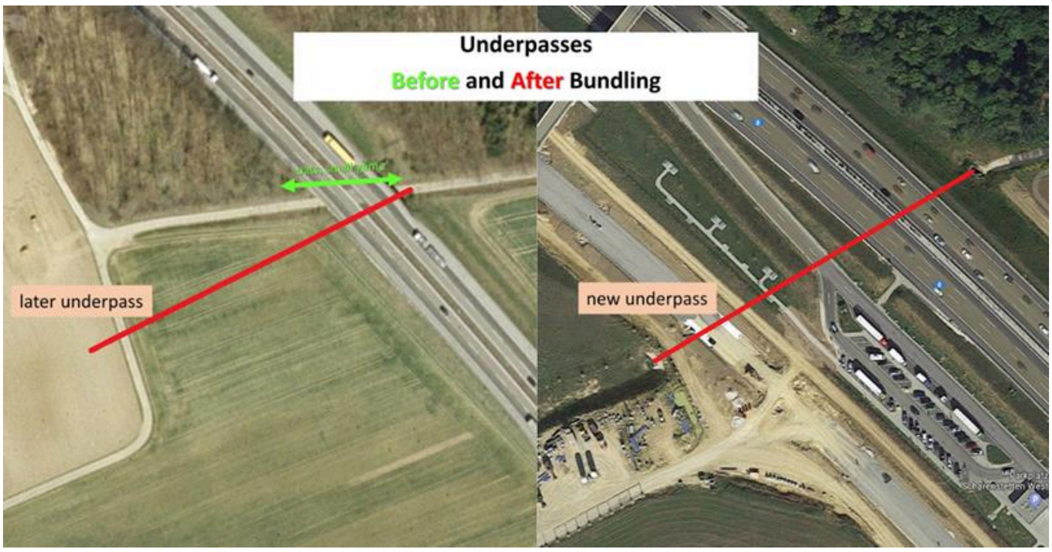


Figure 43: Underpass length before (photo 2007) and after bundling (photo 2018)

The former underpass is replaced by a traffic overpass (without green strip improvement) and a fauna underpass (mainly intended for bats. Very long and small underpasses are dysfunctional for nearly any species (photo collage by U. Holst, n.p.).

3.2 Better impact assessment 1: Scale-specific compilation of decision-relevant information and best indicators regarding barrier effects and defragmentation

Σ

Fragmentation effects are insufficiently addressed in impact assessment and all too often, the respective mitigation or compensation measures do not even meet minimum requirements for safeguarding biodiversity.

Especially

- vector and bioengineer functions of animals
- superregional migration corridors of larger mammals and
- dispersal needs or metapopulation systems of the small fauna are neglected.

In addition, the largely inappropriate representation of biodiversity at all but in particular of (de-)fragmentation effects and corridor needs by the habitats and species listed in the Annexes of the Habitat Directive results in inappropriate measures even in the case if Special Areas of Conservation i.e., Natura 2000 is affected.

Therefore **preliminary ad hoc* minimum standards for appropriate indicators are provided**
and
r+d needs for improvement are listed in this chapter.

*Ad hoc means compiling and adapting existing approaches as a European proposal. The indicator discussions regarding planning, TI and biodiversity started before the 1990ies (cf. Riecken 1990) and the given proposal is close to an expert's state of art at least from the viewpoint of ecoregions with moderate climate but it has to be adapted especially for the warmer regions of Europe.

3.2.1 Introduction: The state of scoping in planning procedures with respect to project description and standard indicators

Scoping, that is almost a commonplace, is most relevant for impact assessment and respective impact avoidance.

Scoping (in the broader sense) has four main objectives:

- Getting an appropriate idea for the extent of relevant (positive and negative) impact factors of a project,
- early avoiding of unnecessary negative impacts and

- early assessment of possible mitigation or compensation or even possible benefits of a TI project for the environment, which is possible if the relevant project attributes and project opportunities are regarded from the beginning[79], and
- clarification of the information that is already available for and the information that is needed in the further assessment, planning and approval procedures.

Scoping and planning can be an iterative process where, due to early decisions and growing database, new solutions, new alternatives or new information can be developed or needed. Good scoping and planning sometimes has to be spiralling.

Mutually supportive planning requires early ecological support, especially for the technical planning (early introduction of solution ideas), in the best case, through equal (parity) planning of transport routes and wildlife routes.

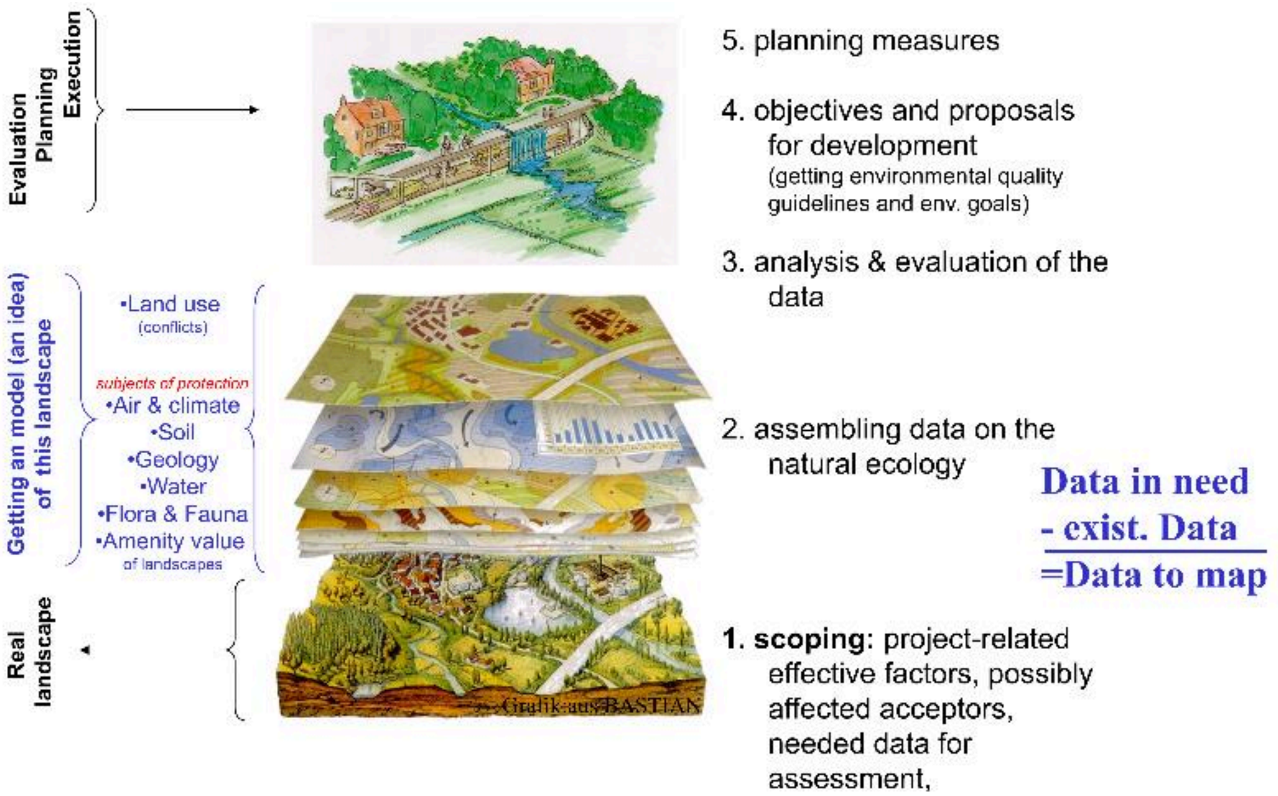


Figure 44: Order of scoping and planning
Sketches from MJPO (Multi-Year Programme for Defragmentation in the Netherlands and from BfN/Bastian (brochure on landscape planning in the FRG).

[79] See also chapter 3.5.1

r+d

As an adequate representation of the impact areas regarding fragmentation effects is deficient in many cases:

Standard ranges for environmental surveys regarding barrier effects should be compiled (as roughly outlined for larger scales on the left side of the following figure).

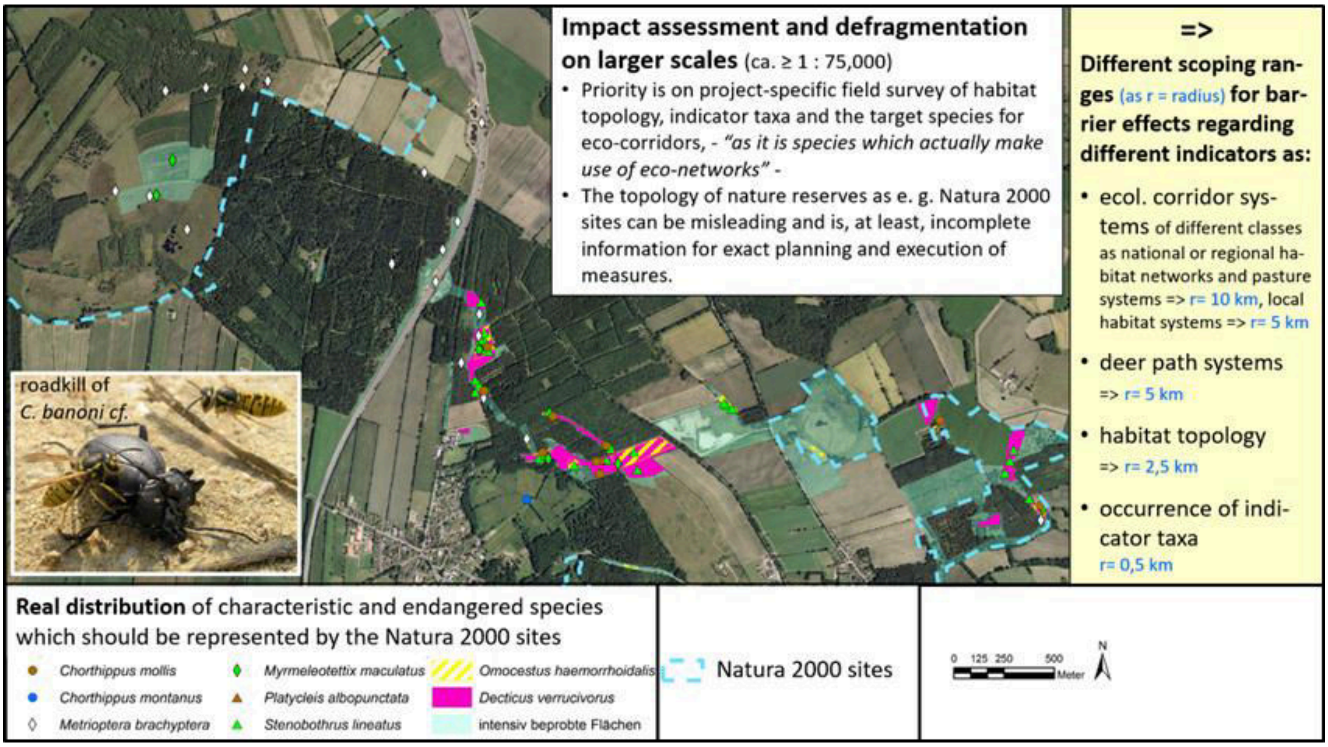


Figure 45: Indicative outline of needed standards for survey areas
Standards regarding fragmentation effects on scales > 1: 75,000. Related r+d needs comprise e. g. conventions on minimum scoping ranges with respect to traffic modes and planning type (e. g. new construction or upgrading or bundling).

Table 17: Scoping ranges for barrier effects regarding different indicators (i)

i = supra-local habitat corridors	*i = local habitat corridors, main deer paths, existing species inventories*	*i = up to date habitat topology*	*i = up to date occurrence of indicator taxa*
r = ca. 10 km	*r = ca. 5 km*	*r = ca. 2.5 km*	*r = ca. 0.5 km*

3.2.1.1 Contents of the following subchapters

The following chapters highlight further scoping and information deficits and possible improvements and give (with respect to the EDM) an idea about appropriate indicators for TI planning to achieve conflict free (or conflict poor) TI solutions with regard to (de-)fragmentation effects. r+d needs are described. **Most important in this respect would be the development of regulations for a mandatory implementation of the standard indicator tables (chapter 3.2.4 ff) into scoping procedures and the provision of corresponding analyses as condition for project approval**.

r+d

Development of regulations for:

- a mandatory implementation of the standard indicator tables (chapter 3.2.4) into scoping procedures and
- a mandatory provision of corresponding analyses as condition for project approval.

3.2.2 Project description: The most relevant impact factors

∑

Description of decisive features of TI projects, relevant for the assessment of impacts by (de-)fragmentation

A complete description of (possibly) relevant project features is essential for any scoping and planning procedure.

Regarding barrier effects, the following features are too often misregarded or disregarded:

- bundling of TI or bundling of TI with other technical infrastructure,
- protection curbs or protection walls or protection fences and
- soil and vegetation management of TI-side areas.

Many of TI-related barrier effects could be avoided without negative effects on the respective TI function (e. g. by reducing traffic velocity or by avoiding obstacles like curbs) and many positive effects on biodiversity could be achieved if the relevant parameters are regarded from the beginning of a TI project (see also PARITY chapter).

Special r+d needs concern:

- effects of bundling,
- effects of traffic velocity,
- effects of soil management in side areas and
- effects of verge design or greening.

Rationale and list of relevant TI-project features

For scoping and, therein, the selection of indicators a clear idea of the relevant impact factors is the basis of any assessment and it is affecting impact avoidance as well as compensation.

According to different planning scales in the range from 1: 3.000.000 to 1: 300 different information is needed. The following exemplary and incomplete list shows the need for a clear project description and highlights factors, which are too often neglected with respect to fragmentation or safeguarding and redevelopment of ecological corridors. It is related to different planning scales.

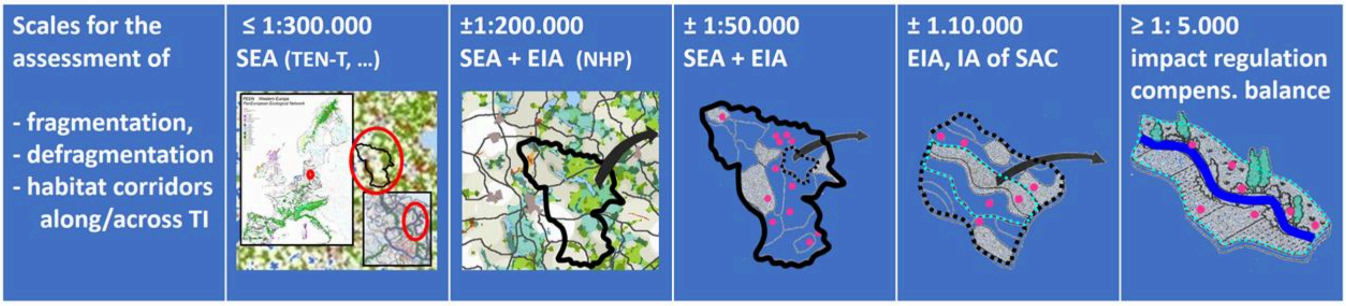


Figure 46: Scale categories and related planning instruments*

SEA = Strategic Environmental Assessment, TEN-T = Trans-European Transport Network, EIA = Environmental Impact Assessment, NHP = National Highway Plan, IA = Impact Assessment, SAC = Special Area of Conservation, compens. = compensation.
**highly modified after Reck & Kaule 1994; background in the second table column: PEEN and partim German habitat corridors and Habitat-Net Germany; red circles indicating the area featured in the scales 1: 200,000 (Hab-Net Germany) and 1: 50,000]*

Table 18: Impacts and appropriate scales for assessment

Impact factors / features to be considered (* = too often neglected features are highlighted with an asterisk)	**Appropriate scales for assessment**
Area consumption, TI-length, TI-width (number of lines or tracks)	all scales, (EDM ca. ≤ 1:200,000)
Temporarily area consumption for construction (which can be critically larger for bundling projects) leading to fragmentation by destroying stepping-stone habitats	ca. ≥ 1:10,000
Eutrophication (leading to reduced habitat quality and larger distances between habitats)	ca. ≥ 1:50,000
Lighting (light emissions scaring away or distracting migrating animals)	ca. ≥ 1:10,000
Scaring animals away	ca. ≥ 1:10,000
Bundling effects* negative effects of bundling TI and/or of bundling TI with other technical infrastructure as e. g. power plants, which are e. g.: - highly enhanced barrier strength and no possibility or disproportionally greater effort for fauna passages (at least underpasses can become dysfunctional due to increasing length)	all scales, for impact avoidance esp. 1:30,000 – 1:10,000, thereby regarding the EDM and systems of superregional eco-corridors and the network of protected

Impact factors / features to be considered (* = too often neglected features are highlighted with an asterisk)	**Appropriate scales for assessment**
- enhanced area consumption due to higher requirements on traffic bridges and tunnels as well as for access roads or maintenance facilities as drainage systems and due to larger construction sites - enhanced loss of valuable habitats (at least in populated areas) because (older) TI is often connected with highly diverse landscapes along rivers or along mountain bases Negative bundling effects are critically underestimated[80].	areas is of high relevance. Of great importance could be a parity eco-corridor network according to the TEN-T
Parallel maintenance roads or farming roads* leading to increased barrier effects if wrongly designed (parallel minor roads should, as a rule, be avoided as far as possible)	ca. ≥ 1:10,000
Water management by parallel ditches (leading either to stepping-stone habitats if carefully constructed but too often leading to extreme barriers)	ca. ≥ 1:50,000
Planned or expected traffic frequency	all scales
Traffic velocity*, affecting e. g. (1) barrier relevant area consumption due to the related road width etc., (2) mortality, (3) needs for barrier-effective fences or (4) needs for protective walls or solid railway tracks instead of ballast beds which are permeable for the small fauna, (5) eutrophication of stepping-stone habitats (the higher the velocity, the higher e. g. the NOx emissions)	all scales, but regarding alternatives (comparison of the effects of different speed designs and the related TI features): especially SEA and EIA (and approval procedures)
Special construction features as (1) a high or no interstice between rail beds and rails or (2) the construction of permeable noise walls versus gap-free noise walls or (3) the steepness of dams*	ca. ≥ 1:10,000
Construction of curb stones or e. g. above-ground cable boxes etc.* – in combination with e. g. gullies (all can be avoided or replaced by devices without barrier and trap effects)	ca. ≥ 1:10,000
Needs and effects of fencing (against the access of larger mammals or amphibians) – the fencing needs are often dependent to targeted speeds for traffic (design speeds) or to the design of verges (closeness of shrubs and trees and degree of coverage by low and tall herbs and by shrubs and trees) *	ca. ≥ 1:10,000
Soil management* regarding banks, verges or other side areas (leading, if wrongly executed, to barriers due to too dense vegetation or to loss of	ca. ≥ 1:10,000

[80] Underestimated, because (1) landscape fragmentation and habitat fragmentation or the fragmentation of ecological corridors are confused with each other. The terms landscape fragmentation and habitat fragmentation or fragmentation of habitat corridors refer to different facts and conservation assets. The term landscape fragmentation is closely related to the visual appearance of the landscape, whereas the term habitat fragmentation is related to spatial ecological functions and underestimated, because (2) the areas close to traffic are considered to be particularly polluted. The impact of agricultural inputs (fertilisers, pesticides) or soil cultivation on areas away from traffic is obviously weighted less heavily than the impact of noise or tyre wear, for example.
Only protected areas are generally less polluted as are very large low-traffic areas, and only in the latter or to bypass the latter bundling of TI can generally be more environmentally friendly.

Impact factors / features to be considered (* = too often neglected features are highlighted with an asterisk)	**Appropriate scales for assessment**
stepping-stone habitats due to eutrophication etc. and inhibiting the use of side areas as habitat corridors)	
Density and diversity of vegetated grass shoulders or verges / verge design* (too dense and nutrient-rich vegetation acts as severe barrier for the small fauna and can be responsible for high rodent activity causing accidents with owls and raptors). Topology and diversity of shrubs and trees (determining habitat quality and wildlife accidents). The structure of the verge vegetation depends on soil management or seed density and seed quality (if seeds are applied e. g. against erosion) or planting schemes and maintenance.	ca. ≥ 1:5,000 but the outlay for a verge design as habitat corridor could be assessed already in scales of ca. 1:10,000
Strong habitat contrasts between TI area as well as the verge area and the hinterland*	ca. ≥ 1:5,000
Verges as habitat corridors, side areas of junctions as stepping-stone habitats*	ca. ≥ 1:10,000

Further impact factors of TI, but rarely relevant in relation to lasting barrier effects are e. g.: (1) erosion due to construction, (2) pollutants, (3) impact on ground water levels or (4) noise.

Figure 47: Fauna underpasses below bundled TI are dysfunctional for most species (see chapter bundling)

r+d:

Integration and optimization of the given impact factor table as checklist into scoping procedures
or
as part of a scoping manual regarding barrier impacts

Different from the impact factors of TI, features for the assessment of the functioning of eco-corridor- and habitat networks are not described in detail in D5.3. Of great importance (besides the strength and location of barriers) are (1) a) the area and quality, b) the distances and mirrored fronts and c) the neighboring of habitats (see definition of habitat corridor) and (2) the occurrence, density and behavior of migrating large herbivores as such are mobile corridors.

3.2.3 Too often disregarded: Functions of animal mobility

Biogenic heterogeneity especially by herbivores as bioengineers and vector functions of mobile animals are a main natural precondition for recent biodiversity. Although essential for safeguarding biodiversity (especially after the large-scale disappearance of transhumance) and strongly affected by TI, the decisive ecosystem functions of migrating megaherbivores and impacts on their ecosystem functions are largely neglected in impact assessment and mitigation.

Methods to delineate large herbivore corridors or migration routes at all scales are urgently needed. The future “next” EDM should regard supra regional important migration routes (of wild and of domestic ungulates) in addition to habitat corridors. Especially wilderness areas must be fully accessible by the larger ungulates either by constructing attractive fauna passages or by decommissioning of isolating TI. Migration paths and associated accident hotspots are important decision-making indicators (see next chapter 3.2.4).

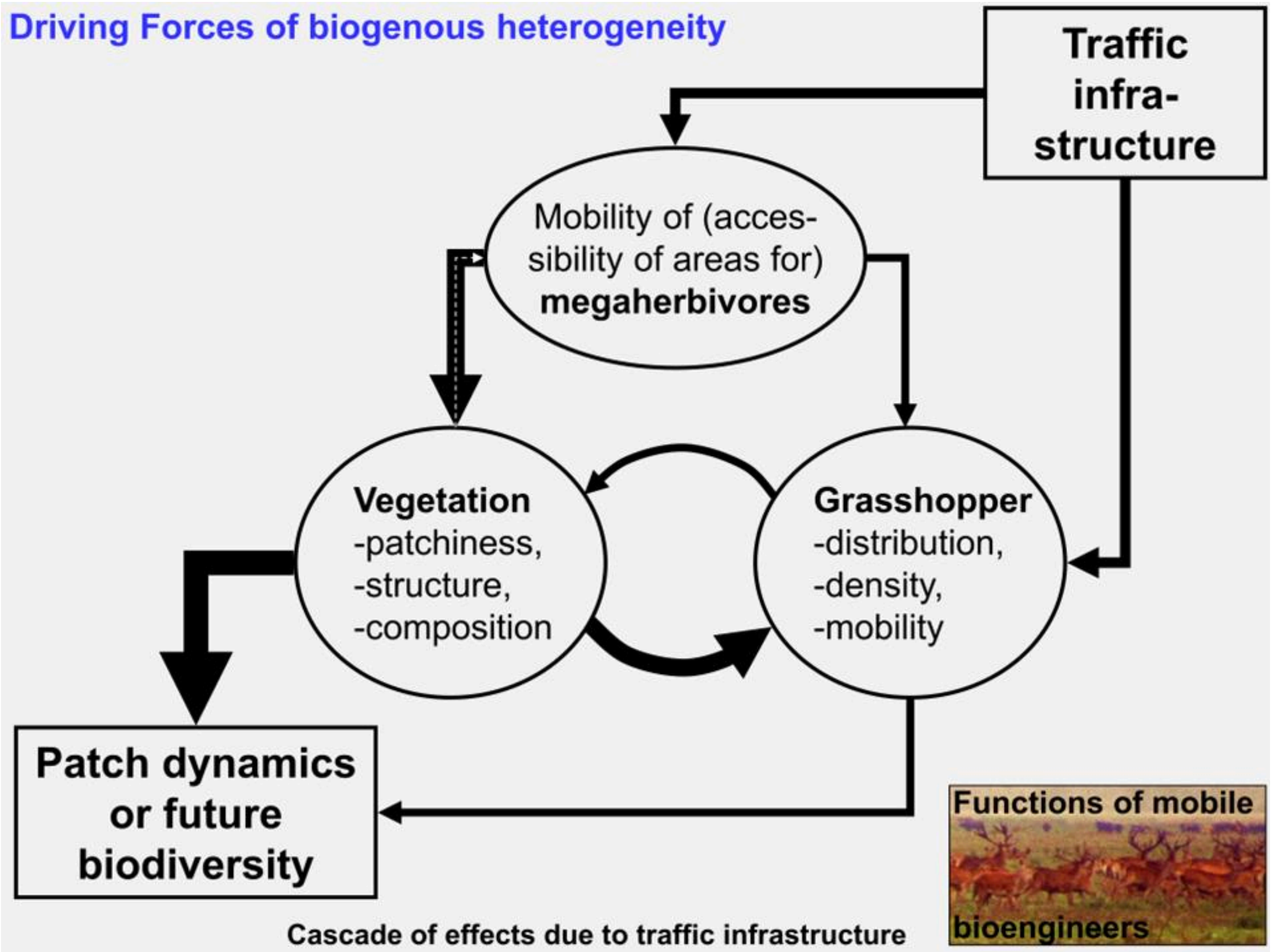


Figure 48: Functional cascade of the emergence of biogenic heterogeneity through the action of TI-influenced herbivores

Both the direct influence of large herbivores and their (at medium density) considerably promoting influence on e. g. grasshopper density is relevant. Grasshoppers can consume up to 10 % of the primary production of grassland biotopes in Central Europe (Ingrisch & Köhler, 1998, 182), even in the absence of the gradations of migratory grasshoppers that occurred repeatedly until the 19th century. The great importance of herbivory (by grasshoppers) for biological diversity was already described in the 18th century: "The grass caterpillar [= grasshoppers] seems to be created for the purpose of establishing a proper relationship between the grass and other plants, although it often does great damage to the meadow growth. For if this grass caterpillar did not sometimes make empty spaces, the grass, undisturbed in its growth, would spread so much that it would choke out other plants and consequently exterminate them. Therefore, one always finds far more plant genera in such meadows where these caterpillars have eaten the grass the year before than elsewhere" (Linné 1777). Although the "intermediate disturbance hypothesis", anticipated by Linné but only scientifically investigated in and from the 1970s onwards, is widely accepted in ecological science as an important control variable of biodiversity, there are still hardly any ideas outside of pasture landscape concepts on how this fundamental variable can be taken into account in the conservation of biodiversity in Central Europe.

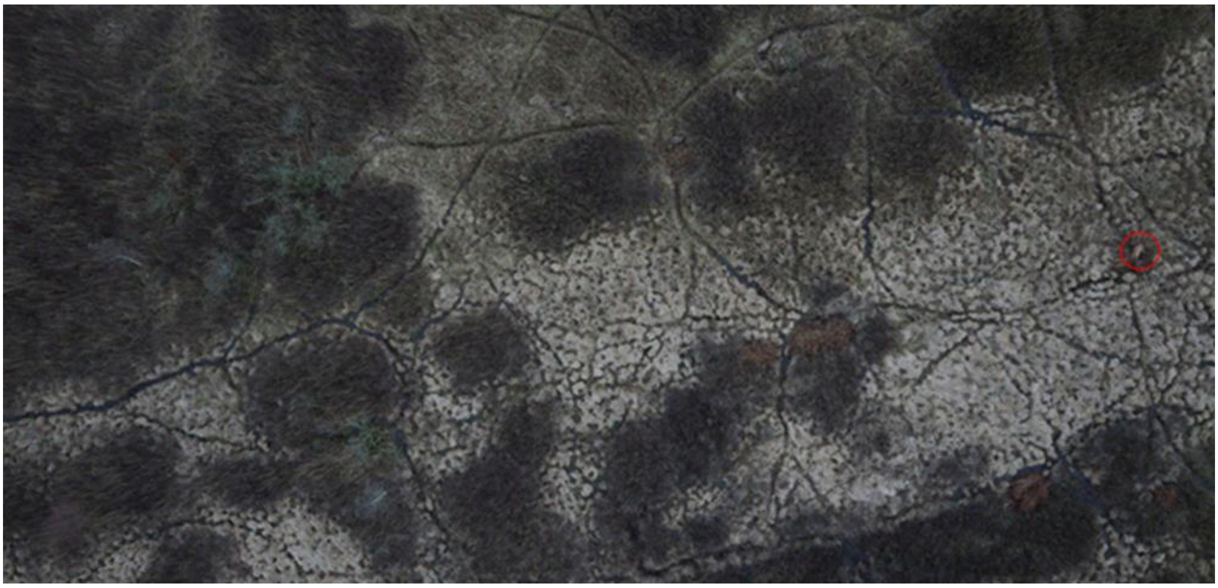


Figure 49: Red deer (red circle) and deer paths as decisive factors for biodiversity in a wilderness area in Northern Germany
(photo 2023: M. Schurawa, BioConsult SH / M. Meißner, Nature Foundation SH)

Figure 50: Mobile corridors
Red deer or sheep als mobile ecological corridors: Burdocks (centre) or adhesive cottongrass seeds (right) or grasshoppers (left) can be transported by larger mammals not only over long distances but to suitable destinations (photos: B.Schulz, B. Stöcker).

r+d needs concern:

the compilation of remaining supralocal drift paths of domestic ungulates and known existing or lost long distance migration corridors of wild ungulates on European and national scales

and

the development/improvement of methods for scale-adequate delineating of existing or recoverable migration routes and/or main deer paths (improvement of models for small-scale/large area application and methods for efficient mapping from local to regional scale as are standardized interviews with local experts and methods for remote sensing data analysis.

3.2.4 Best indicators* for assessment procedures and the role of the EDM

*Indicators regarding (de-)fragmentation effects at different scales

3.2.4.1 Introduction: Acceptors of fragmentation by TI and indicator systems for assessment

Fragmentation of habitats or remaining habitat networks threatens biological diversity.
Above all, this affects:

- flightless species whose life strategies are built on mobility (as well as small, isolated populations of flying species that are subject to high levels of traffic mortality) and
- species' ecological functions such as zoochory or habitat engineering by herbivory, movements along wildlife paths, rooting or the construction of burrows, setts, etc..

Indicators must meet all significant impact factors and represent all affected species or the respective ecological guilds. "From the viewpoint of building the transport infrastructure, … [the] requirements of the widest spectrum of species needs to be addressed – from insects, amphibians, small and medium-size mammals, through tree-crown species and bats to large mammals, which can also use forests as a migration corridor ... The barrier effect of individual road sections will vary depending on the given habitat value, but also according to the significance of their function as migration corridors - from local to regional." (Hlavac et al 2019, p61). The "demands of various groups (categories) of animals on permeability of transport infrastructure" must be considered with respect to the relevant planning scale.

Why insects?

While the effect of TI-related barriers on large mammals like lynx seems to be obvious to everyone the even larger impacts on flightless small animals or insects like ground beetles need a closer look on biodiversity and ecosystem functioning. The small fauna thereby builds the majority of the species and provides essential ecosystem services (Reck & van der Ree 2015). Moreover, especially the many flightless small species are suffering impacts on gene flow or on habitat and metapopulation dynamics sometime more than larger species because most of the species are stenotopic and only functioning habitat networks can guarantee their survival. For the survival of the stenotopic species habitat topology and accessibility is of great importance, meaning that surpassable distances (which depend on the length of mirror fronts) between special habitats determine survival or metapopulation structure as well as, of course, the barriers between the special habitats. Although (other than large animals) many of the small fauna don't migrate purposefully in habitat networks, habitat networks consisting of densely situated core and stepping-stone habitats are the precondition to reach each single habitat. The exchange between subpopulations and successful following natural and other habitat dynamics is essential for survival.

In the following

- scale-related indicators and the role of the EDM,
- indicator taxa and species for TI-barrier assessment and for defragmentation plans as well as the necessity for eco-regional adaption of the indicator taxa, regarding both: a) representativeness and sufficient redundancy and b) avoidance of undue expense and
- recommendations concerning European target species for defragmentation

are presented with regard to r+d needs.

3.2.4.2 Scale-related indicators and the role of the EDM

The **following tables** present a (preliminary) indicator system, which represents the minimum of needed information for decision-making. **It should be implemented as standard and continuously improved by testing its representativeness and its relevance for decision-making.** The role of the EDM is highlighted thereby.

Background is the largely inappropriate representation of biodiversity and especially (de-)fragmentation effects and corridor needs in impact assessment and impact regulation but also the even more inappropriate representation of biodiversity[81] and (de-)fragmentation effects by the habitats and species listed in the Annexes of the Habitat Directive.

Scale-related or scale-specific information means that, as a rule, the smaller the planning area or the larger the planning scale, the more details have decisive influence on planning. In 1: 200,000, one should know where to avoid areas and corridors with high importance for biodiversity when planning TI (and where e. g. large, well-integrated fauna passages will be needed dependent on the chosen alternatives). In the scale of 1: 10,000, one should exactly know where e. g. the Apollo butterfly or the European adder lives or where turtles are hatching, or where main deer paths are affected etc., to avoid or mitigate impacts. In the scale 1: 5,000 the exact location or dimension or necessary soil types for an ecological creek underpass must be located or a decision be made if and how pastures or - dependent on the local target species - meadows should be restored and how.

The EDM and/or further developed state-wide corridor systems and priorities for defragmentation measures at TI are relevant on all levels. But especially in ca. 1: 200,000 for avoidance and indication of needs for larger fauna passages that are part of well-structured eco-corridors and in 1: 5,000 to define sectors along TI, where further exact knowledge on biodiversity must be gathered to give the information at what exact place of an identified conflict sector measures would be most efficient for which ecological guilds, and how exactly they should be integrated into the hinterland. For the latter, following e. g. Hänel 2015 methods are already available.

[81] At least in Central Europe main ecological guilds and many threatened species like e. g. the European adder and habitats like pastures are under-represented by the Natura 2000 indicators.

Table 19: Symbols, abbreviations and survey requests with respect to scales and indicator mapping
The tab. Indicates the scales and respective planning instruments but also the methods for biodiversity surveys and the intensity to use those methods due to the different scales and/or traffic route lengths to be considered.

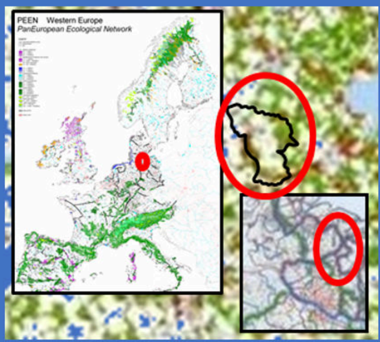
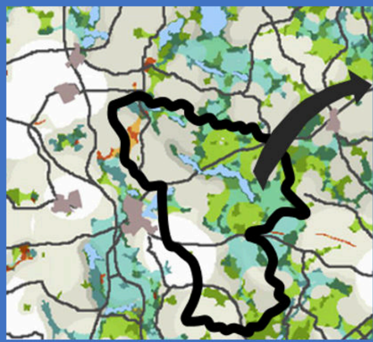
Scale-related indicators for the assessment **- of dissection effects due to transport infrastructure and** **- of defragmentation measures (including habitat corridors along and across TI)**	**S = ca. ≤ 1: 300,000** **SEA** (TEN-T …) + Localisation of supra-reg. important conflict pts. 	**S = ± 1: 200,000** **SEA + EIA1** (NHP) + regional important conflict points 
Range of respective scales and length of TI considered	ca. 1: 250,000 - 1: 5,000,000 l = 100 km – 2,500 km	ca. 1: 50,000 - 1: 500,000 l = 5 km - 250 km
Symbol-Legends used across scales	 Supra-regional important ecological corridors (eco-corridors, wildlife routes), based on interpretations of protected area and habitat configuration and land use, with strictly protected areas or habitats as core areas; also: migration routes of migratory species.	 Habitat networks: Core areas and connecting areas as results of e.g. Habitat-Net and, derived from this: Unfragmented functional areas (UFA); the ecological corridors listed in the column on the left are integrated in those more detailed networks.
Abbreviations used across scales	TI = Transport. infrastructure S = Scale SEA = (Basics for) Strategic Environmental Assessment TEN-T =Trans-European Transportation Network Ca./ca. = Circa L/l = Length i. s. = in the sense of rsp. = respectively s. = quod vide	a.s./u. Ä. = and similar e. g. = for example EIA1 = Environmental impact assessment or environmental impact study (EIS) in the sense of a spatial sensitivity study or corridor comparison NHP = National Highway plan or similar IA = Impact assessment

Table continuation: Symbols, abbreviations and survey requests with respect to scales and indicator mapping The tab. Indicates the scales and respective planning instruments but also the methods for biodiversity surveys and the intensity to use those methods due to the different scales and/or traffic route lengths to be considered.

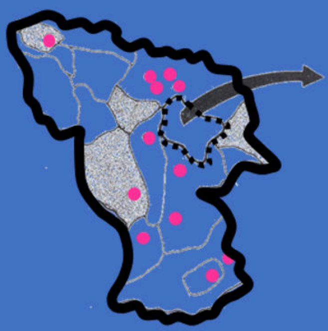
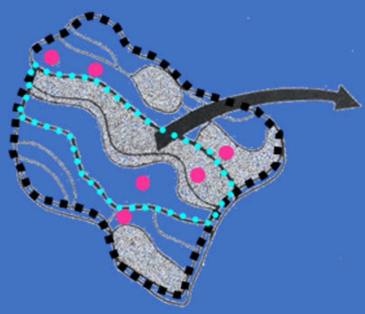
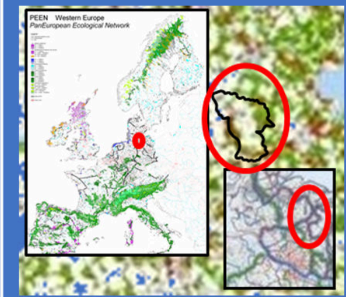
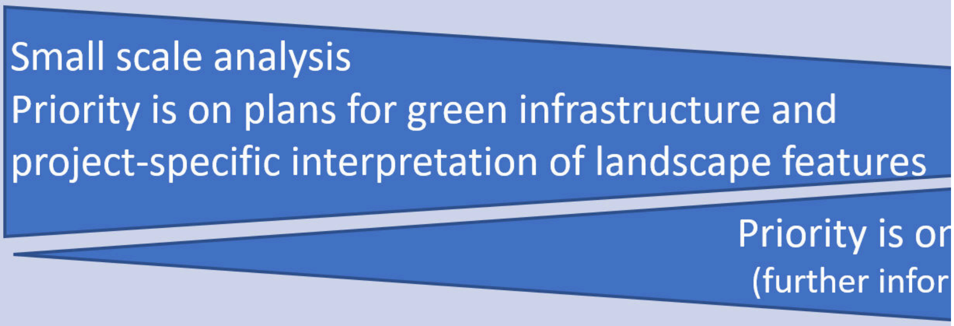
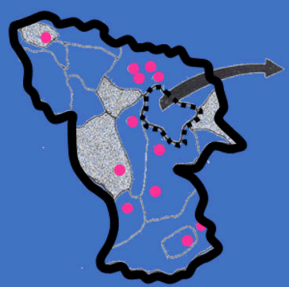
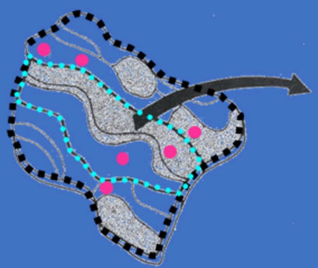
S = ± 1: 50,000 **SEA + EIA1** + important fauna passages 	**S = ± 1: 10,000** **EIA2, FFH-CA** + necessary defragmentation 	**S = ca. ≥ 1: 5,000** **Impact regulation** + avoidance/mitigation/compensat. 
ca. 1: 5,000 - 1: 50,000 l = 5 km - 100 km	ca. 1: 1,000 - 1: 10,000 l = 1 km - 75 km	a. 1: 500 - 1: 5,000 l = 0,1 - 25 km
 (Updated) Maps of valuable habitats (at a scale of ca. 1: 25,000) or area-wide mapping of the habitat types (S = ca. 1: 10,000), + determination of , scale-dependent either supra-local or at least strong game trails or amphibian migrat. paths	 Project-specific selected mapping areas for breeding birds and, if applicable, other indicators	● Project-specific selected sampling site for e. g. plant, bird reptiles, insect, ..., inventories details see below
Habitat-Net = One (of several possible) algorithms to identify areas for effective habitat connectivity (based on habitat topology)	UFA = Undissected functional areas (areas in which ecosystems or populations of species in need of protection are located in relation to each other in such a way that metapopulations can be safeguarded or re-established and in such a way that animal migrations are possible)	EIA2 = Final comparison of alternatives or variants, taking into account the feasibility of effective avoidance, mitigation and compensation measures. FFH-CA = FFH compatibility assessment FFH = Fauna-Flora-Habitat Directive

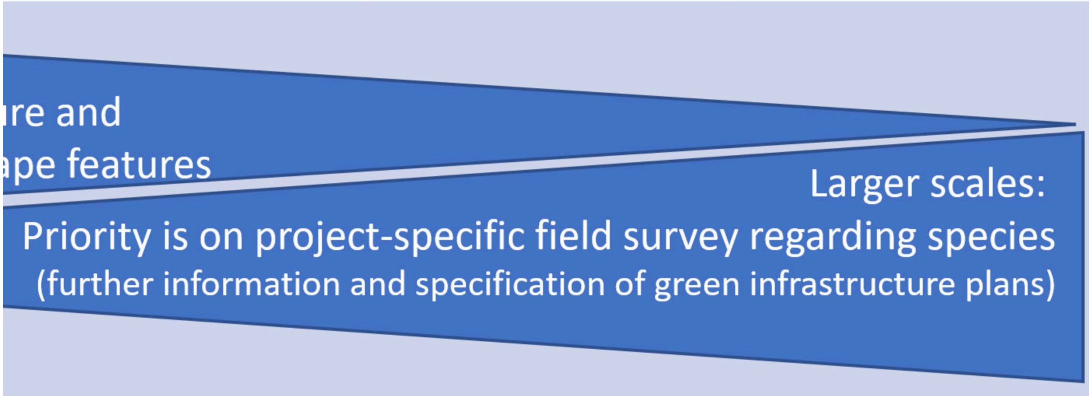
Table 20: Consecutive indicator sets for different scales and the impact of the EDM

Scales for the assessment of - fragmentation - defragmentation - habitat corridors along/across TI	≤ 1: 300,000 SEA (TEN-T, …)  + localisation of supra-reg. important conflict pts.	± 1: 200,000 SEA + EIA (NHP)  + regional important conflict points	± 1: 50,000 SEA + EIA  + important fauna passa
Existing plans or data *versus* Original field surveys			
Impact of the EDM* on TI planning *= currently based on national concepts that represent incoherent ecological approaches	Very high and to be used in context with Sites of Community Importance/ SCIs and other strictly protected areas	High but in need to be supplemented by existing or special developed regional eco-corridors	In need to be supp ted by existing or developed local e ridors
Further supplements in need (regarding ecological corridors and its function) **Additionally req. info:**	International + national migration corridors of migrating species … See tables i1 and i2	+ regional migration corridors of species See tables i1 and i2	+ road- & railkill h See tables i1 and
r+d needs concerning corridor maps and defragmentation priorities	e.g. European-wide methods to identify best corridors , based on habitat topology; criteria for prioritization.	e. g. methods (remote sensing, artificial intelligence) to identify best habitat corridors; methods to detect regional migration corridors, …	e. g. methods for mon rail- and roadkill hots

Tab. i1 see page 155, Tab. i2 see page 158

Table continuation: Consecutive indicator sets for different scales and the impact of the EDM

± 1: 50,000 SEA + EIA	± 1: 10,000 EIA, IA of SAC	≥ 1: 5,000 impact regulation compens. balance
 + important fauna passages	 + necessary defragmentation	 + avoidance/mitigation/compens.



In need to be supplemented by existing or special developed local eco-corridors	… to be supplemented by TI project-specific, parity reconnection concepts */**	… to be supplemented by TI project-specific, parity reconnection concepts*/ **
+ road- & railkill hotspots See tables i1 and i2	+ main game trails and amphibian or reptile migration paths See tables i1 and i2	See tables i1 and i2
e. g. methods for monitoring rail- and roadkill hotspots	* at the level of project approval an equal reconnection concept can in most cases lead to efficient safeguarding of biological diversity despite the intervention	** standard methods (minimum requirements) for the development of project specific but cross-sectional reconnection concepts must be developed

Tab. i1 see page 155, Tab. i2 see page 158

The table above shows the increasing need for project specific field surveys with increasing scale. The EDM* (see table above) or respective state corridor systems and (if given) national defragmentation priorities along TI have to be obligatorily integrated into TI planning and the ecological function of identified ecological corridors has to be secured or restored. For the time being many de facto corridors are not yet identified as are long-distance migration (all scales) or hot spots of vehicle animal collisions (scales ≥ 1: 50,000 that should be identified area-wide independent of a specific TI-project but in any case for TI-planning if not yet available. Regarding regional or local main game tails or locations of amphibian migration, those can be identified project specific as they can change in short time (or they should be identified as part of national or state specific monitoring programmes if those are repeated every five years).

The given indicator sets for different scales can only outline the general approach. Respective requirements for the level of detail and the work objectives may vary from project to project. Therefore, there may be a large overlap in content between the scale levels or planning instruments presented. For example, it may be appropriate to prepare a detailed, project-accompanying connectivity concept (see chapter “parity reconnection plans”) at the level of the EIA if no plausible or no sufficiently precise and up-to-date sectoral (defragmentation) plans are available and if only one or a few planning alternatives are to be compared - because then the feasibility of avoidance measures can become particularly relevant for decision-making. In the case of several alternatives that are spatially far apart from each other, at the level of the EIA a comparative framework sketch for project-specific reconnection concepts makes sense at best, while at the level of project approval a parity (equal) reconnection concept can in most cases lead to the efficient safeguarding of biological diversity despite the intervention. With regard to data collection, it is always necessary to clarify which data are needed and which of them are already available in sufficient quality and timeliness. The type of planning instrument does not necessarily determine the level of detail for environmental data or analyses: A SEA for a municipal development plan, for example, may require a level of detail that is only necessary in a road construction project for the section-related EIA.

As already mentioned, the EDM outlines areas where special diligence is needed in SEA on the one hand and on the other it identifies TI sections where detailed surveys in the scale > 1: 10,000 should be immediately started to decide on invests for defragmentation (e. g. large fauna passages, fencing or fence removal, landscaping the hinterland of crossing sites, strengthening populations in side areas of TI or improving TI-related habitats as verges etc.) and to outline applicable plans for concrete measures – see following table.

The working principle regarding indicators and indicator use is presented in the next tables by the example of necessary statement precision regarding eco-corridors and movement corridors for animals. Related r+d needs are integrated.

Table 21: Statement precision required for different planning scales by the example of the indicator "eco-corridors"

Scales for the assessment of - fragmentation - defragmentation - habitat corridors along/across TI	≤ 1: 300,000 SEA (TEN-T, ...)  + localisation of supra-reg. important conflict pts.	± 1: 200,000 SEA + EIA (NHP)  + regional important conflict points	± 1: 50,000 SEA + EIA  + important fauna passages	± 1: 10,000 EIA, IA of SAC  + necessary defragmentation	≥ 1: 5,000 impact regulation compens. balance  + avoidance/mitigation/compens.	**The EDM and the scales**
Existing plans or data *versus* Original field surveys	Small scale analysis Priority is on plans for green infrastructure and project-specific interpretation of landscape features			Larger scales: Priority is on project-specific field survey regarding species (further information and specification of green infrastructure plans)		The EDM defines priority sections for high-resolution defragmentation planning
Impact of the EDM* on TI planning *= currently based on national concepts that represent incoherent ecological approaches	Very high and to be used in context with Sites of Community Importance/ SCIs and other strictly protected areas	High but in need to be supplemented by existing or special developed regional eco-corridors	In need to be supplemented by existing or special developed local eco-corridors	... to be supplemented by TI project-specific, parity reconnection concepts */**	... to be supplemented by TI project-specific, parity reconnection concepts*/ **	**The EDM's scale-dependent role in impact assessment**
Further supplements in need (regarding ecological corridors and its function) **Additionally req. info:**	International + national migration corridors of migrating species ... See tables i1 and i2	+ regional migration corridors of species See tables i1 and i2	+ road- & railkill hotspots See tables i1 and i2	+ main game trails and amphibian or reptile migration paths See tables i1 and i2	See tables i1 and i2	
r+d needs concerning corridor maps and defragmentation priorities	e.g. European-wide methods to identify best corridors , based on habitat topology; criteria for prioritization.	e. g. methods (remote sensing, artificial intelligence) to identify best habitat corridors; methods to detect regional migration corridors, ...	e. g. methods for monitoring rail- and roadkill hotspots	* at the level of project approval an equal reconnection concept can in most cases lead to efficient safeguarding of biological diversity despite the intervention	** standard methods (minimum requirements) for the development of project specific but cross-sectional reconnection concepts must be developed	EDM-related r+d needs

The next table (Table 22) shows that the needed precision for information changes indicator-specifically with the planning scales. For the indicator taxa see tab. i5 and lastly tab. i7 gives an overview about all indicators with respect to different eco-regions.

Table 22: Aimed statement precision regarding scales, indicators and indicator use

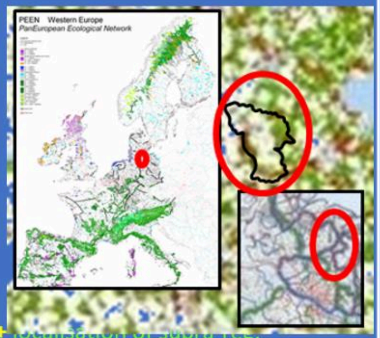
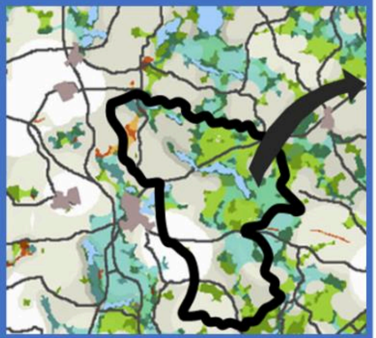
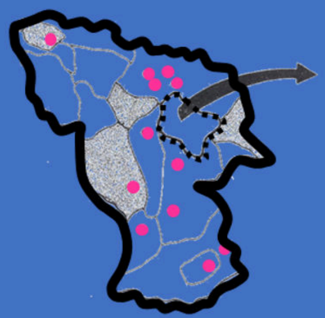
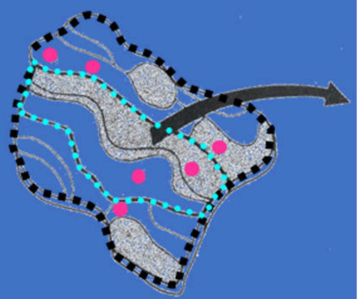
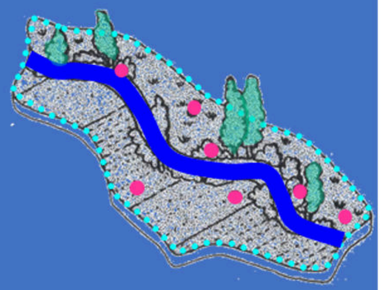
Scales for the assessment of - fragmentation - defragmentation - habitat corridors along/across TI	≤ 1: 300,000 SEA (TEN-T, …)  + localisation of supra-reg. important conflict pts.	± 1: 200,000 SEA + EIA (NHP)  + regional important conflict points
Indicators in need (additive)	= D1	= D1 + D2
Aimed statement precision regarding ecological corridors (only focal points; for details see supplementary texts and table i2)	Protected area systems and Europe-wide or nationally or state-wide important ecological corr.* *if possible based on the topology of ecosystem types in need or worthy of protection plus special migration routes; with respect to landuse-topology (e.g. CORINE data); *=> non-negotiable areas, high-risk comparison for different TI-corridors or needs for larger fauna passages and monitoring requirements.*	D1 plus county wide (supra-regionally) important corridors (e.g. application of up-to-date connectivity models for habitat networks) *=> detection of additional non-negot. areas, fine-tuned risk comparison for left-over or regionally developed TI-(corridor) alternatives and related needs for larger fauna passages and monitoring requirements.*

Table continuation: Aimed statement precision regarding scales, indicators and indicator use

± 1: 50,000 **SEA + EIA**  + important fauna passages	**± 1: 10,000** **EIA, IA of SAC**  + necessary defragmentation	**≥ 1: 5,000** **impact regulation compens. Balance**  + avoidance/mitigation/compensat.
… + D3	… + D4	… + D5
Plausibility check of and (if appropriate) adoption of D1 + D2 results plus: Sensitivity analysis of affected areas on the basis of existing and randomly checked (and supplemented) data, additional delineation of regionally important ecological corridors, area-wide "overview-field survey" by ecologists	Project-specific field surveys against the background of D3 are required as the main source of information;	Detailed project-specific field surveys (see next tables, e.g. locations of small-scale migratory movements); review of findings of the EIA;
=> roughly quantified differences between alternatives and main monitoring requirements.	*=> detailed balance also of impairments of locally important habitat connectivity or corr.; finely scaled differences between alternatives taking into account avoidability and compensability*	*=> effects on the biotope network and (meta-)populations of representative target species; type, location, efficiency and sustainability of avoidance and mitigation measures and respective monitoring requirements.*

3.2.4.3 Scale-related indicator taxa and indicator species for barrier assessment and for defragmentation plans

Figure 51 (below) shows why it is important to have (representative) information on the real species distribution and regional or local migration paths while planning TI on scales larger than ca. 1: 75,000: On the one hand, protected areas as a result of compromises and, often, insufficient data are not representing the real distribution of inhabited (stepping stone) habitats of species to be protected and they do not or only rarely represent eco-corridors. On the other hand, from the habitats distribution and size alone their colonisation by species cannot sufficiently be predicted due to population or habitat history and due to missing details on habitat quality (it is more efficient to map indicator species than habitat features and habitat dynamics to predict indicator species occurrence; see textbox 29.1 in van der Ree et al. 2015). The figure-related original EIA about upgrading the central highway to a motorway looked just around 50 m each side as impact area – totally missing fragmentation effects with the one exception, which was game migration that had been expressed as a roadkill hotspot within the area surveyed in the EIA.

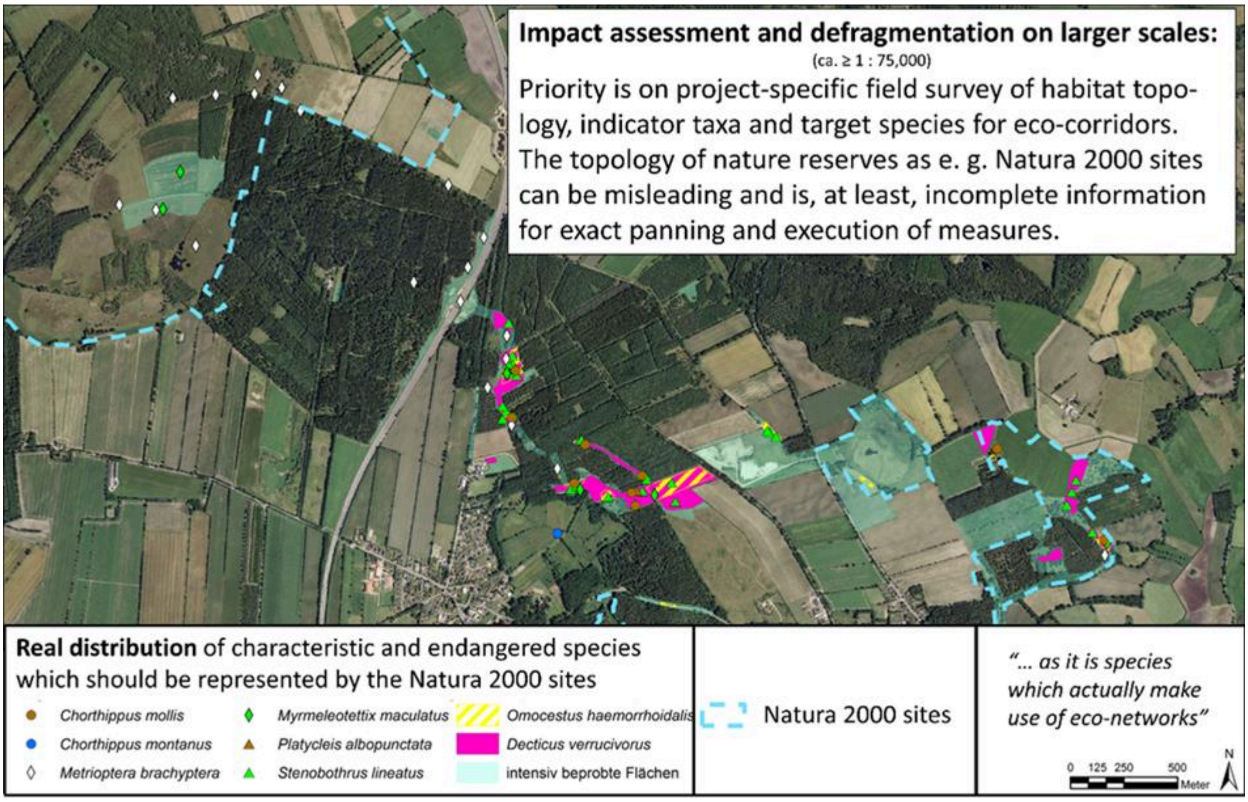


Figure 51: Distribution of indicative grasshopper and cricket species for heathland and dry habitats and the respective (inappropriate) Natura 2000 sites for the protection of heathland (and bogland) biodiversity

Obligatory ecosystem-specific taxa for impact assessment in scales > 1: 75,000 are proposed in tab. I5, but the needed survey intensity is scale-dependent too. While in the scale of ca. 1: 50,000 a combination of impact area-wide habitat mapping with random checks of existent data for plants and animals (see tab. I7) are sufficient, in the scale 1:10,000 representative mapping areas and sampling sites must be surveyed for both, animals and plants, with increasing number of sampling sites for plants and the small fauna in 1: 5,000 accompanied by area-wide mapping birds as e. g. shown in tab. i1.

*Table 23 = Tab. i1: Obligatory indicator taxa **for TI-related barrier and defragmentation assessment** at planning scales larger than ± 1: 75,000*

***Birds** are not listed in this respect, but would be obligatory indicators regarding habitat loss, habitat degradation, traffic-related mortality and especially if bottlenecks in flight long-distance migration corridors or if special resting sites are affected.*

? = while the taxa are tested for sufficient representation in temperate climates, the number of e. g. saltatoria in northern regions is too low (too less redundancy of species with similar demands on habitat connectivity) and the numbers of saltatoria (and ground beetles too) is too high in warm climate to be reasonable manageable with proportionate costs.

Regarding ports and coastlines there have been no tests about indicator taxa so far; most probably coast related reptiles, amphibians, saltatoria and ground beetles plus eventually dragonflies of brackish waters (if steppingstone habitat density can be of relevance) could sufficiently represent the hereby special demands for defragmentation.

Barrier-effect -Indicators in addition to (1) delineated eco-corridors and protected areas, (2) habitat topology or (3) migration routes and (4) fragm.-sensitive Annex II species of other taxa	**Barrier-effect -Indicators** for areas ◦ north of 55° latitude ◦ 47° to 55° latitude ◦ south of 47° latitude *57°N = Göteborg, 47 ° = Dijon*		
Obligatory indicator taxa for assessing fragment. effects	Lat.> 57°N (cold)	Lat. 47°- 57N	Lat. < 47° (warm)
regarding **sweet water bodies and banks**	mammals - amphibians fish* dragon flies ground beetles	mammals reptiles amphibians fish* dragon flies ground beetles	mammals reptiles amphibians fish* dragon flies ? large ground b.
regarding **arable fields**	mammals - ground beetles ?	mammals - ground beetles Saltatoria	mammals reptiles ? large ground btls. ? Oedipodinae
regarding **other open habitats and forest edges:**	mammals reptiles amphibians ? ground beetles	mammals reptiles amphibians saltatoria (ground beetles)	mammals reptiles amphibians ? Oedipodinae
regarding **tree dominated habitats (forests)**	mammals - - ground beetles	mammals - (amphibians) ground beetles (saltatoria)	mammals reptiles amphibians ? large ground btls.
regarding **coast lines**	?	?	?

*Fish don`t have to be surveyed **if, as a standard**, any watercourse crossings by TI are always designed to be passable for all aquatic and riparian species and no significant immisions (e.g. pollutants, nutrients, light) will take place neither in the construction nor in the operational phase. For other impacts than barrier effects and/or in exceptional cases additional, indicator taxa (as birds, bats, butterflies etc.) and target species are needed.

A short excursus about the eco-regional adaption of indicator use by the example of grasshoppers and crickets[82]

At a certain scale (mostly in ≥ 1: 10,000), there is need for information about the demands on ecological networks and the vulnerability of affected populations worthy of protection for guilds[83] as can be represented by saltatoria[84]. The indicator suitability of this taxonomic group is excellent in e. g. Switzerland, Austria or Southern Germany and sufficient in most parts of e. g. Northern Germany. However, in Sweden or Norway the natural species diversity is too low in most areas to deliver reliable results about ecosystem qualities and concerns of species protection while in Spain or Greece the species diversity is too high to be efficiently recorded if all genera would be regarded. Therefore, there is need for additional indicators for heliophile small flightless (or poor-flying) species of grasslands in the North and for a reduction of the number of grasshopper indicator genera in the South.

Like the saprobic system, the use of saltatoria as part of an indicator system for impact and defragmentation assessment has therefore to be regionally adapted and specified for its use in respective habitat types. The r+d-needs for true and useful indicator systems to represent biodiversity issues are still high (see Reck & Ree 2015) as especially the species listed in Annex IV and A FFG/BD are far from being representative (at least in Central Europe; Trautner et al. 2022).

Other impacts than barrier effects

Other most useful standard indicators with respect to habitat loss or degradation etc. are e. g. vascular plants, Characeae, birds, butterflies, wood inhabiting (xylobiontic) beetles, bees (at least in cities or in the North), macrozoobenthos, crayfish or molluscs (see table "impact type and indicators efficient to use; i. e. as well sensitive as feasible taxa). Ecosystem types like caves (with cave-crickets as perfect indicators for habitat quality in the South) or springs or groundwater are not affected by TI-related fragmentation effects and should be categorical preserved against any TI-related losses as a standard.

[82]Thereby always regarding that saltatoria are just one indicator group for only one important guild amongst other guilds that must be represented.

[83]Ecological guilds, mobility guilds, species types, important components of the food chain, …

[84]Grasshoppers and crickets

Table 24: Impact type and respective most efficient indicators to use (from Koch et al. 2011)

Taxa
● *most suitable*
○ *suitable due to mapping effort and indirect representation and /or relevance for decision making*

Standard taxa

Impacts	vascular plants	birds	reptiles	amphibians	ground beetles	butterflies	crickets and grasshoppers	large carnivore mammals	hoofed mammals
habitat loss by traffic infrastructure and traffic related fertilizers	●	●	●	●	●	●	●	○	○
pollutants	○				○				
nutrient loads	●					○			
change of local climate	●		○		●	●	●		
noise		●					○ (dotted)	○	○
roadkill, mortality at buildings and lamps		○	● (blue)	●	●	○	○	○	○
fragmentation t = **t**rivial range, m = **m**igration range, d = **d**ispersal range	○ d	○ t	● tmd	● md	● md	○ t	● md	● tmd	● tmd
change of key-functions as river dynamics or appearance of bioengineers	●		○	○	○	○	○		●

Special case taxa

Impacts	fungi	lichens	bats	flightless small mammals	snails	xylobiontic beetles	bees and wasps	ants	moths	spiders
habitat loss by traffic infrastructure and traffic related fertilizers	○	●	○	○	○	(r)	○	○		○
pollutants		●								
nutrient loads		○								
change of local climate	○	○			●	○	●	●	●	●
noise			○	○						
roadkill, mortality at buildings and lamps			○	○	○			○	○ (blue)	
fragmentation t = **t**rivial range, m = **m**igration range, d = **d**ispersal range			○ t	● d	● d	○ d				
change of key-functions as river dynamics or appearance of bioengineers					○	○	○			

Other

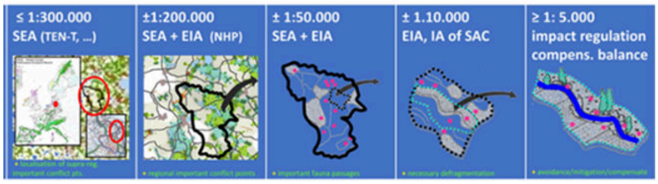
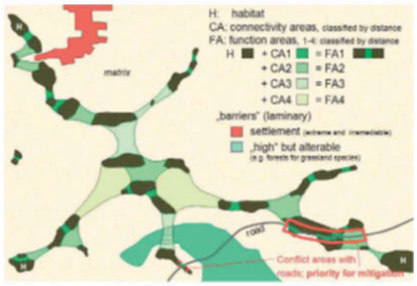
Impacts	mosses	soil and climate parameters	dry and wet deposition	biotope / vegetation types
habitat loss by traffic infrastructure and traffic related fertilizers	○	●		●
pollutants		○	●	
nutrient loads	○	○	●	○
change of local climate	○	○		○
noise				
roadkill, mortality at buildings and lamps				
fragmentation t = **t**rivial range, m = **m**igration range, d = **d**ispersal range				
change of key-functions as river dynamics or appearance of bioengineers	○			●

(r) = sufficiently represented by more cost-effective indicators as long as possibly important habitats are secured

3.2.5 Overview about all indicators of the indicator system with respect to different eco-regions

The next table (Table 25) lists the standard indicators with regard to scales and eco-regions. The specific indicator taxa are listed in tab. i1 and the principle of European target species for defragmentation is described in the subsequent chapter.

Table 25 / i2: Standard indicators for assessing barrier-related impacts and defragmentation needs - plus related r+d proposals

<table>
<tr><td rowspan="2">Decision–making indicators and relevant scales

</td><td colspan="3">for areas North of 55° latitude, 47°-55° lat., South of 47° lat. (57°N = Göteborg, 47 ° = Dijon)</td></tr>
<tr><td>Lat.> 57°N (cold)</td><td>Lat. 47°- 57N (temperate)</td><td>Lat. < 47° (warm)</td></tr>
<tr><td>Delineated Eco-Corridors and protected areas</td><td colspan="3">no cold-warm difference</td></tr>
<tr><td>EDF-corridors + other supra-regional important ecological corridors
(which should be improved asap by a European-wide analysis of habitat topology leading to integrative European eco-corridors and a compilation of long-distance migration routes of larger herbivore mammals)</td><td>≤
1:1,000,000</td><td colspan="2" rowspan="6">No differences (δ) between “cold”, “temperate” or “warm”
r+d needs 1: Best models for creating corridors from habitat topology-Info


r+d 2: guidelines for planning of parity defragmentation concepts</td></tr>
<tr><td>Topology of Wilderness Areas / SAC / National Parks / Nature Reserves (=strongly protected areas)</td><td>≤
1:1,000,000</td></tr>
<tr><td>TI-project specific update of supra-regional important ecological corridor (if appropriate) in the possible effect area of TEN-T projects</td><td>≤
1:200,000</td></tr>
<tr><td>Regionally important ecological corridors and spatially explicit species or habitat protection schemes on regional or supra-regional level</td><td>≤
1:50,000</td></tr>
<tr><td>Ecological corridors of local importance and/or elements (Art.10) or connecting elements (links) respectively between biotopes and spatially explicit species or habitat protection schemes on local level (at best developed in the framework of parity reconnection plans #chapter 3.5#) Thereby, it is essential to include the planning of municipalities and communities at this planning level (the acceptance of the measures by the local population is a necessary prerequisite for conservation and functionality)</td><td>≤
1: 10,000</td></tr>
<tr><td>Parity defragmentation concept</td><td>≤ 1: 10,000</td></tr>
<tr><td>Habitat Topology (HT) expressed as habitat network</td><td colspan="3">no cold-warm difference</td></tr>
</table>

Table continuation "Standard indicators" 1

HT expressed as habitat network of valuable and / or protected habitats (network of all valuable areas and network for different classes as limnic, wet, dry, woodland habitats)	≤ 1:50,000	r+d 3: mapping and evaluation methods (remote sensing?) and EU harmonization
HT expressed as habitat network habitats (for different habitat type classes) of all habitats but intensively used farmland or sealed areas (special habitat mapping in the effect area of planned TI)	≤ 1:10,000	r+d 4: automatic classification of habitat types from aerial photo and other remote sensing data
Water bodies	**no cold-warm difference**	
Streams, rivers and lakes	≤ 1:1,000,000	r+d 5: standards for underpass design
Creeks, ponds and springs	≤ 1:200,000	
Rivulets, ditches and pools	≤ 1: 10,000	
Migration routes and wildlife accident hotspots	**no cold-warm difference**	
Long Distance Migration Corridors of flightless mammals (incl. long distance transhumance) and of fish	≤ 1:50,000	r+d 6: EU- wide minimum monitoring standards
LDM Bottle necks (LDMR:BNS) for e.g., bats, birds and insects	≤ 1:50,000	
Main Deer path	≤ 1:10,000	r+d 7: guide for classification
Bat migration routes	≤ 1:10,000	
Amphibian migration routes	≤ 1:10,000	
Roadkill or railkill hotspots	≤ 1:10,000	r+d 8: min. monitor. standards
Game path densities	≤ 1:5,000	
TI-Project specific animal inventories	**partly high climate and eco-regional differences**	
Overview assessment: Faunistic expert opinion, based on a single site visitation (and interpretation of existent data) plus random species-checks	≤ 1:50,000 r+d 9: report guidelines	
Occurrence of indicator taxa (higher density of survey areas or points in 1: 5,000 than in 1:10,000)	> 1:10,000 (scale dependent survey intensities) climate-zone specific selection see table "taxa" r+d 10: representativeness of best indicator combinations	
Occurrence of target species (scale dependent survey intensities: higher density of survey areas or points in 1: 5,000 than in 1:10,000)	≤ 1:10,000 (scale dependent survey intensities) eco-region-specific selection see pre-selection of Central-European "target species" r+d 11: Selection of representative species for habitat corridors r+d 12: Test of representativeness of Habitat's	

Table continuation "Standard indicators" 2

Occurrence of target species (scale dependent survey intensities: higher density of survey areas or points in 1: 5,000 than in 1:10,000)	≤ 1:10,000 (scale dependent survey intensities) eco-region-specific selection see pre-selection of Central-European "target species" r+d 11: Selection of representative species for habitat corridors r+d 12: Test of representativeness of Habitat's directive Annex species and habitats for (a) biodiversity and (b) especially for habitat corridor or eco-network functions
Interpretations; e. g. ≤ 1:1,000,000: Needs for large fauna passages; e.g. ≤ 1:10,000: Needs and feasibility for all necessary passages and for compensation, if necessary PVA: Population vulnerability analyses/PVA (cf. Schöps & Reck 2002); e.g. ≤ 1:5,000: Detailed mitigation and compensation plans / *Parity defragmentation concept*, Sustainability of mitigation and compensation measures; e.g. ≤ 1:2,500: Detailed design of mitigation and compensation measures.	
Other impacts than barrier effects and/or exceptional cases	*Additional, indicator taxa and target species*

** Occurrence and distribution of indicator species of representative species groups*, spatial population structure of target species and valuation of the respective habitat qualities and habitat topology,

Regarding "best models for creating corridors from habitat topology-info", the next fig. shows an approach for the interpretation of the size, situation and mirrored fronts aiming for best eco-networks.

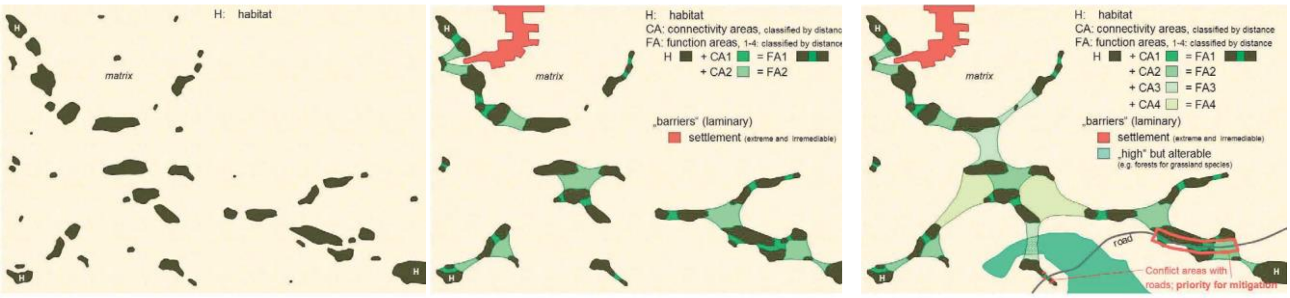


Figure 52: Habitat-Net - one[85] of different approaches for gaining integrative habitat networks and eco-corridors by (European-wide) analysis of habitat topology

[85] On the basis of habitat distribution and subsequent functional distances plus regarding effects of mirrored fronts, still realized or restorable eco-networks can be identified (if mirrored fronts of areas are large, connectivity for the small fauna, the majority of species, is realized across longer distances than between areas representing small mirrored fronts)

3.2.5.1 European-wide priority target species for eco-corridors

As it is species,
which actually make use of ecological networks or corridors

(and which create the living ecosystems) any approach to define an European network of eco-corridors, wilderness areas and protected areas for species and habitat should consider both

(1.) habitat-specific and site-specific aspects and even more and

(2.) the presence and the habitat or migration requirements of "management indicator species for ecological networks" or "target species for interlinking biotopes" respectively. (after Burkhardt et al. 2010)

In order to realize European and nationwide ecological networks of habitats as prescribed by the European GI strategy a European-wide system of criteria, which can be used to identify existing and prospective sites suitable for inclusion in such a network, should be produced.

Target species (see chapter "terms") thereby serve:

1. to represent the requirements of species for connectivity or functional connectivity of respective habitats or populations, as well as the habitat quality of respective core or stepping-stone biotopes

   and

2. as indicators for functional verification of the effectiveness of measures to secure habitat networks or reconnection.

For each local infrastructure project, target species should be selected individually on a site-specific basis and must be representative of the area in question as well as a compilation of representative species for larger areas (for eco-regions) should be the basis for the design of a functioning eco-corridor network of European importance. Accordingly, the compilation of particularly important target and indicator species of the biotope network from a European perspective is to be used for the development and functional protection of ecological corridors of Europe-wide importance. These include species that migrate over a large area and/or occur over a large area in Europe, but also species that are of particular importance in individual countries or natural regions and that are at the same time dependent on functioning ecological networks.

The species listed in Annexes II and IV of the Habitats Directive which are dependent on defragmentation and species of the Bonn and Bern Conventions must be included but also the many more species whose requirements and occurrences must be given high priority, such as e. g., the European adder (*Vipera berus*), which is highly endangered in most of its European range and often relegated to isolated remnant populations. The species of the Habitats Directive or the Bonn and Bern Conventions alone do not adequately represent the requirements of European ecological networks.

For the individual states and/or the eco-regions (which may be further differentiated according to latitude), suitable species lists still have to be compiled (with the exception of the largely developed list for Central Europe) and a representativeness check is required for all regions. As e. g., red deer would be a suitable target species nearly all over Europe the Bison or Moose are restricted to more northern areas, chamois to more alpine areas or gopher (*Spermophilus citellus)* to more pannonic or southern areas. The small fauna as e. g. grasshoppers are often restricted to a few of member states or even to parts of them as e. g. Willemses' Stone Grasshopper *Prionotropis willemsorum,* Predatory bushcricket*, Saga pedo,* Wart biter*, Decticus verrucivorus or the* Mountain grasshopper *Podisma pedestris.*

Target species lists should not be excessively long to be manageable, but also not too short in order to remain representative. The list developed for Germany according to Burkhart et al. 2004 (supplemented mainly for the guild of ground living, flightless insects by Reck et al. 2008 may serve as an orientation.

Table 26: Exemplary List of Central European "priority target species for interlinking biotopes"

Mammals	
Beaver (*Castor fiber*)	European hamster (*Cricetus cricetus*)
Moose (*Alces alces*)	Common bottlenose dolphin (*Tursiops truncatus*)
Eurasian otter (*Lutra lutra*)	Wild horse (*Equus ferus*)
Brandt's bat (*Myotis brandti*)	European bison (*Bison bonasus*)
Greater horseshoe bat (*Rhinolophus ferrumequinum*)	Bechstein's bat (*Myotis bechsteinii*)
Grey seal (*Halichoerus grypus*)	Red deer (*Cervus elaphus*)
Lesser horseshoe bat (*Rhinolophus hipposideros*)	Chamois (*Rupicapra rupicapra*)
Common bent-wing bat (*Miniopterus schreibersi*)	Hazel dormouse (*Muscardinus avellanarius*)
Eurasian lynx (*Lynx lynx*)	Badger (Meles meles)
Western barbastelle (*Barbastella barbastellus*)	Pine marten (*Martes martes*)
Harbor seal (*Phoca vitulina*)	Wild boar (*Sus scrofa*)
Alpine ibex (*Capra ibex*)	Eurasian water shrew (*Neomys fodiens*)
European wildcat (*Felis sylvestris*)	Bicolored shrew (*Crocidura leucodon*)

Geoffroy's bat (*Myotis emarginatus*) Wolf (*Canis lupus*) Brown bear (*Ursus arctos*)	Eurasian harvest mouse (*Micromys minutus*) European rabbit (*Oryctolagus cuniculus*) European edible dormouse (*Glis glis*) livestock (large herds within systems of transhumance)
Reptiles	
Aesulapian snake (*Elaphe longissima*) European pond turtle (*Emys orbicularis*) European green lizard (*Lacerta viridis*) Western green lizard (*Lacerta bilineata*) Common European adder (*Vipera berus*) Dice snake (*Natrix tessellata*)	all snake species including the grass snake but especially Sand lizard (*Lacderta agilis*) (only Northeren areas) Common wall lizard (*Podarcis muralis*)
Amphibia	
Yellow-bellied toad (*Bombina variegata*) Common spadefoot (*Pelobates fuscus*) European tree frog (*Hyla arborea*) Moor frog (*Rana arvalis*) European fire-bellied toad (*Bombina bombina*)	European green toad (*Bufo viridis*) Italian crested newt (*Triturus carnifex*) Common midwife toad (*Alytes obstetricans*) Nothern crested newt (*Triturus cristatus*)
Fish	
Ide (*Leuciscus idus*) Common barbel (*Barbus barbus*) Brook lamprey (*Lampreta planeri*) Twait shad (*Alosa fallax*) European river lamprey (*Lampetra fluviatilis*) Atlantic salmon (*Salmo salar*) Allis shad (*Alosa alosa*) May fish (*Alburnus mento*) Sea trout (*Salmo trutta trutta*)	Sterlet (*Acipenser ruthenus*) European sea strugeon (*Acipenser sturio*) Zope (*Ballerus ballerus*) River trout (*Salmo trutta fario*) European flounder (*Platichthys flesus*) Huchen (*Hucho hucho*) Houting (*Coregonus oxyrinchus*) Weatherfish (*Misgurnus fossilis*) Schneider (*Alburnoides bipunctatus*)

Sea lamprey (*Petromyzon marinus*) Common nase (*Chondrostoma nasus*) Brown trout (*Salmo trutta lacustris*)	Streber (*Zingel streber*) Souffia (*Telestes souffia*)
Dragonflies	
Bileks damselfly (Coenagrion hylas) Large white-faced darter (*Leucorrhinia pectoralis*) Green snaketail (*Ophiogomphus cecilia*) Green hawker (*Aeshna viridis*) Southern damselfly (*Coenagrion mercuriale*) Subarctic darner (*Aeshna subarctica*) Dark whiteface (*Leucorrhinia albifrons*) Ornate bluet (*Coenagrion ornatum*)	Small red damselfly (*Ceriagrion tenellum*) Pygmy damselfly (*Nehalennia speciosa*) Smale pincertail (*Onichogomphus forcipatus*) Yellow-winged darter (*Sympetrum flaveolum*) Spottet darter (*Sympetrum depressiusculum*) Lilypad whiteface (*Leucorhinia caudalis*) Northern damselfly (*Coenagrion hastulatum*)
Grasshoppers and circkets (Saltatoria)	
Gravel bank grasshopper (*Bryodemella tuberculata*) Long-winged grasshopper (*Aiolopus thalassinus*) Italian locust (*Calliptamus italicus*) Gravel grasshopper (*Chorthippus pullus*) Red-winged grasshopper (*Oedipoda germanica*) Saddle-backed bush cricket (*Ephippiger ephippiger*) Alpine groundhopper (*Tetrix tuerki*) Bull Bush-cricket (*Polysarcus denticauda*)	Short-horned grasshopper (*Podisma pedestris*) Large banded grasshopper (*Arcyptera fusca*) Lesser mottled grasshopper (*Stenobothrus stigmaticus*) Black-spotted toothed grasshopper (*Stenobothrus nigromaculatus*) Water-meadow grasshopper (*Chorthippus montanus*) Wart-biter (*Decticus verrucivorus*)
Ground beetles	
Abax ovalis *Abax parallelepipedus* (for the northern central European areas) *Amara infima* *Bembidion foraminosum* *Calosoma reticulatum*	*Carabus nitens* *Cicindela arenaria* *Cicindela germanica* *Cicindela maritima* *Cicindela sylvatica*

Calosoma sycophanta *Carabus clathratus* *Carabus convexus* *Carabus glabratus* *Carabus intricatus*	*Cychrus attenuatus* *Cymindis axillaris* *Cymindis humeralis* *Nebria livida* *Platynus livens*
Xylobiontic beetles	
Bupestis haemorhoidalis *Cerambyx cerdo* *Ischnodes sanguinicollis* *Lucanus cervus*	*Megopis scabricornis* *Osmoderma eremita* *Rosalia alpina* *Strangalia aurulenta*
Other (spiders, molluscs plants), exemplary	
Arctosa cinerea *Pardosa fulvipes* *Margaritifera margeriti-fera* *Pseudanodonta com-planata* *Unio crassus* *Unio tumidis* *Candidula unifasciata* *Trochoidea geyeri*	*Angelica palustris* *Jurinea cyanoides* *Parnassia palustris* *Pulsatilla spec.* *Splachnum sphaericum* *Splachnum. ampullaceum* *Stipa spec. …* Many of the spring geophytic plant species
Butterflies and burnets	
Damon blue (*Agrodiaetus damon*) Cranberry fritillary (*Boloria aquilonaris*) Scarce heath (*Coenonympha hero*) Large heath (*Coenonympha tullia*) Moorland clouded yellow (Colias palaeno) Marsh fritillary (*Eurodryas aurinia*) Grayling (*Hipparchia semele*)	Purple-edged copper (*Lycaena hippothoe*) Poplar admiral (*Limenitis populi*) Alcon blue (*Maculinea alcon*) Large blue (*Maculinea arion*) Scarce large blue (*Maculinea teleius*) Glanville fritillary (*Melitaea cinxia*) Apollo (*Parnassius apollo*)

Scarce fritillary (*Hypodryas maturna*) Woodland brown (*Lopinga achine*)	Clouded Apollo (*Parnassius mnemosyne*) Coronilla burnet (*Zygaena fausta*) Scabios burnet (*Zygaena osterodensis*)
Birds	
Black grouse (*Tetrao tetrix*) Osprey (*Pandion haliaetus*) Eurasian curlew (*Numenius arquata*) Great bustard (*Otis tarda*) Ural owl (*Strix uralensis*) Hen harrier (*Circus cyaneus*) Common crane (*Grus grus*) Ortolan bunting (*Emberiza hortulana*) Great grey shrike (*Lanius excubitor*) Eurasian bittern (*Botaurus stellaris*) Red kite (*Milvus milvus*) Short-toed snake eagle (*Circaeetus gallicus*) Lesser spotted eagle (*Aquila pomarina*) Black stork (*Ciconia nigra*) White-tailed eagle (*Haliaeetus albicilla*) Golden eagle (*Aquila chrysaetos*) Black tern (*Chlidonias niger*) White stork (*Ciconia ciconia*) Montagu's harrier (*Circus pygargus*)	Western capercaillie (*Tetrao urogallus*) Hazel grouse (*Bonasa bonasia*) Eurasian stone-curlew (*Burhinus oedicnemus*) Rock ptarmigan (*Lagopus muta*) Whinchat (*Saxicola rubetra*) Spotted crake (*Porzana porzana*) Collared flycatcher (*Ficedula albicollis*) Western bonelli's warbler (*Phylloscopus bonelli*) Middle spotted woodpecker (*Dendrocopos medius*) Common sandpiper (*Actitis hypoleucos*) Gull-billed tern (*Gelochelidon nilotica*) Little tern (*Sternula albifrons*) White-backed woodpecker (*Dendrocopos leucotos*) Barred warbler (*Sylvia nisoria*) Eurasian hoopoe (*Upupa epops*) Great reed warbler (*Acrocephalus arundinaceus*) Cirl bunting (*Emberiza cirlus*) Rock bunting (*Emberiza cia*) Garganey (*Anas querquedula*)

3.2.5.2 Aimed minimal average densities or target densities for ecological corridors (as an indicator)

The current EDM is mainly based on the compilation of national delineations of ecological corridors and on special protected areas. The future EDM should include:

- the analysis for habitat topology[86] (and habitat connectivity) with regard to more stenotopic (often small) species and
- long-distance migration paths of larger but often comparatively eurytopic species,

both with regard to TI-related barriers[87] and with regard of large areas with intensive industrial land use.

Such analysis will lead to improved national eco-corridor systems.

As a reference for existing corridor systems and as orientation for further development ideas for necessary corridor densities are needed. Target parameters are required to establish or secure a coherent network of ecological corridors and to check implementation. They are a background information:

(1) for TI-related impact assessment and

(2) for, in future hopefully obligatory, “parity reconnection concepts” which shall be part of any TI-plans in scales larger than ± 1: 25,000 (1: 2,500 - 1: 50,000).

For any target values, in turn, a prognostic control of success is helpful in order to be able to depict what contribution successful implementation would have for safeguarding biodiversity. The need for ecological corridors changes depending on the intensity of land use, and the assessment of need depends on the knowledge gained about effectiveness. For the latter, monitoring of representative pilot projects is helpful.

Because the realization (or, where it still exists, the safeguarding) of a coherent ecological network that also functions across transport infrastructures is essential for the protection of species and ecosystems, and because the network-based EDM (especially of the next generation) is an essential planning indicator, minimum requirements (to be examined) are formulated in the following, which on the one hand represent an expert opinion, but which on the other hand are also derived from current planning principles and from corresponding requirements for the density of fauna passages (cf. Hlavac et al. 2019 and chapter 3.5.3:”Thresholds for the dimension and for maximum distances of fauna passages or ecoducts at strong barriers”).

[86] Using remote-sensing, automatic, AI-based identification of habitats, interpretation of mirror fronts and of matirs-related barrier effects

[87] The establishment of a public database showing, on the one hand, (1) all permeable TEN-T sectors and, on the other hand, (2) all critical fragmentation sections as well as (3) relevant defragmentation measures (incl. their dimensins and history) should be started immediately to monitor defragmentation progress

Aimed corridor densities

European corr. systems:

5 km/100 km²

(equivalent to a 30-40 km corridor grid)

Motorways (FRG): ca. 3.7 km/100 km²

National corridor systems:

10 km/100 km²

(equivalent to a 20-25 km corridor grid)

Motor- + highways (FRG): ca. 14 km/100 km²

State corridor systems:

20 km/100 km²

(equivalent to a 10 km corridor grid)

≥ State roads (FRG): ca. 39 km/100 km²

Regional/county corridor systems:

40 km/100 km²

(equivalent to 3-5km corridor grid)

≥ County road: (FRG) ca. 60 km/100 km²

Plus:

Local minimal densities of compound habitats within fields or forests

For comparison of the proposed corridor densities see the densities of different corridor network plans below (1st figure) as well as the planned density for fauna passages for a new motorway (and see also chapter 3.6.2).

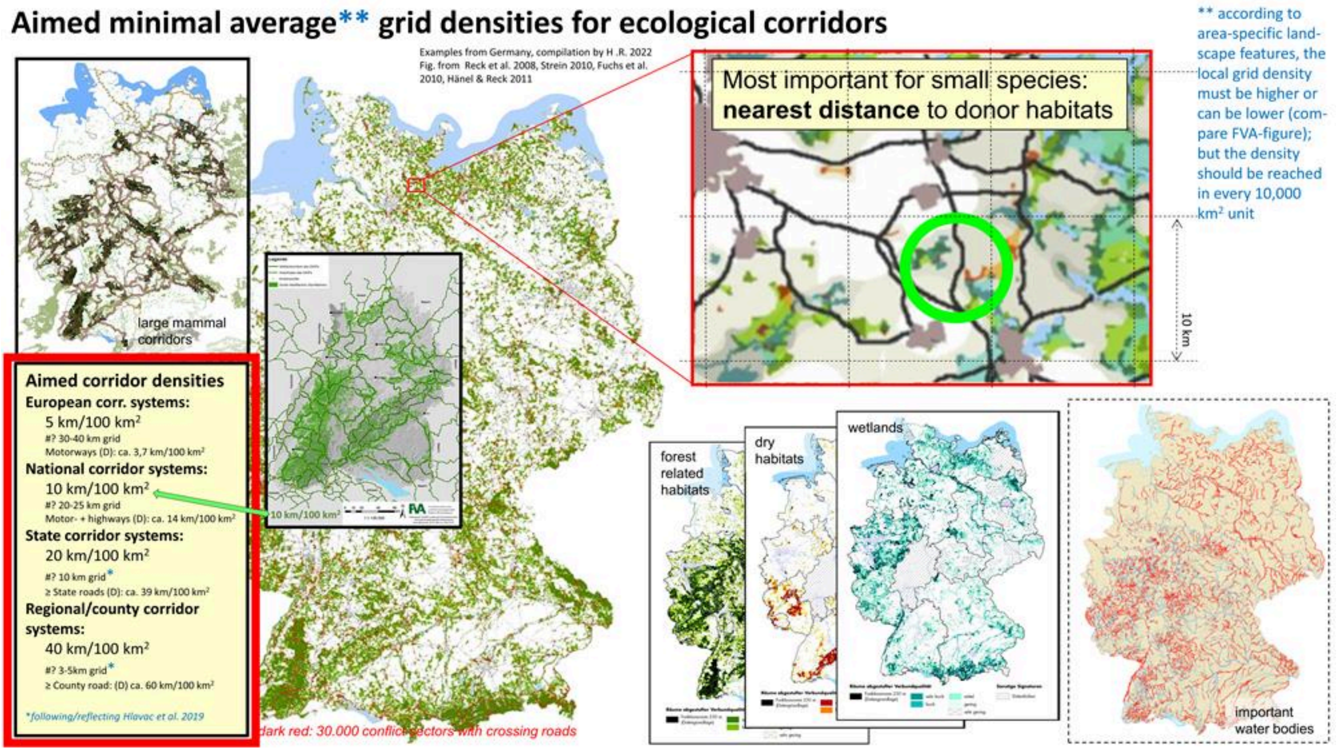


Figure 53: for comparison with the proposed corridor densities: National and state (Baden-Württemberg; = FVA-figure) large mammal corridor system and national habitat networks (integrative and sectoral for woodland, for dry ecosystems, for wetland and for the watercourse network)

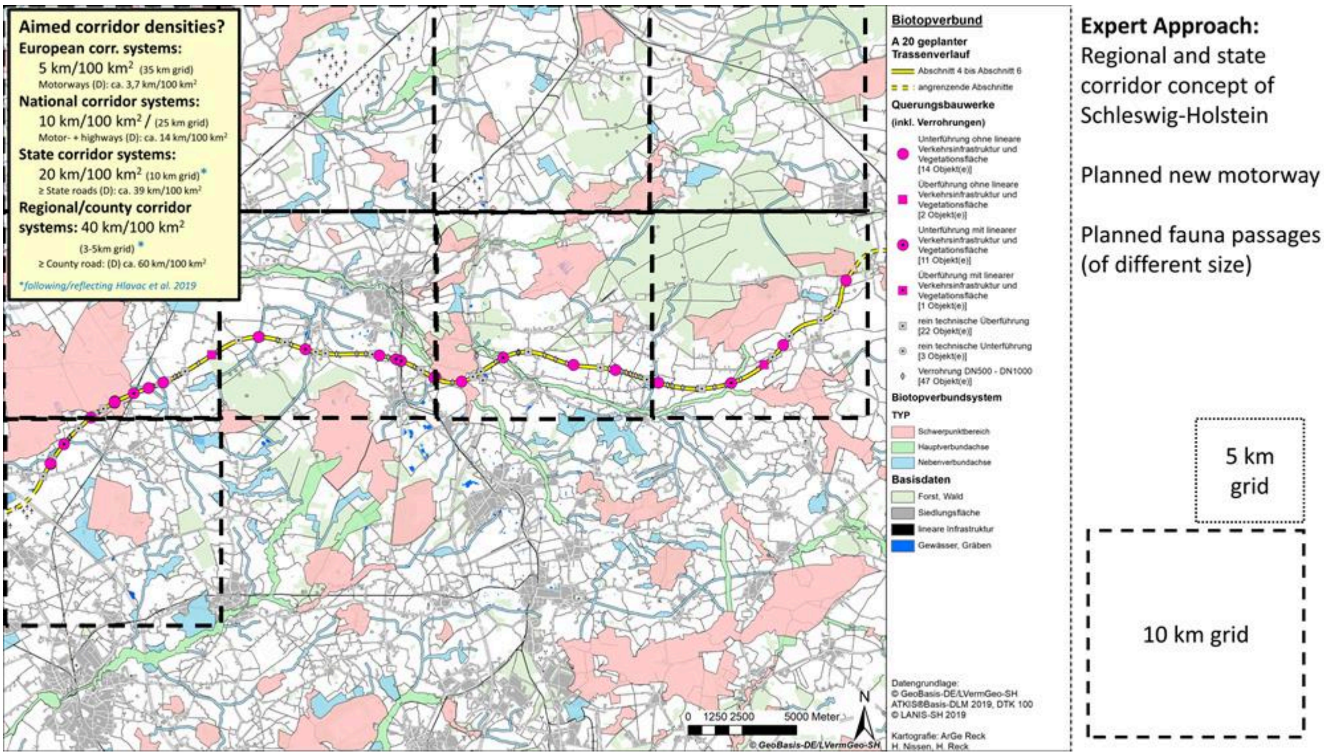


Figure 54: for comparison with the proposed corridor densities: State (Schleswig-Holstein) eco-corridor system and its representation in planned fauna passages along a newly planned motorway (*preliminary meanwhile improved approach)*

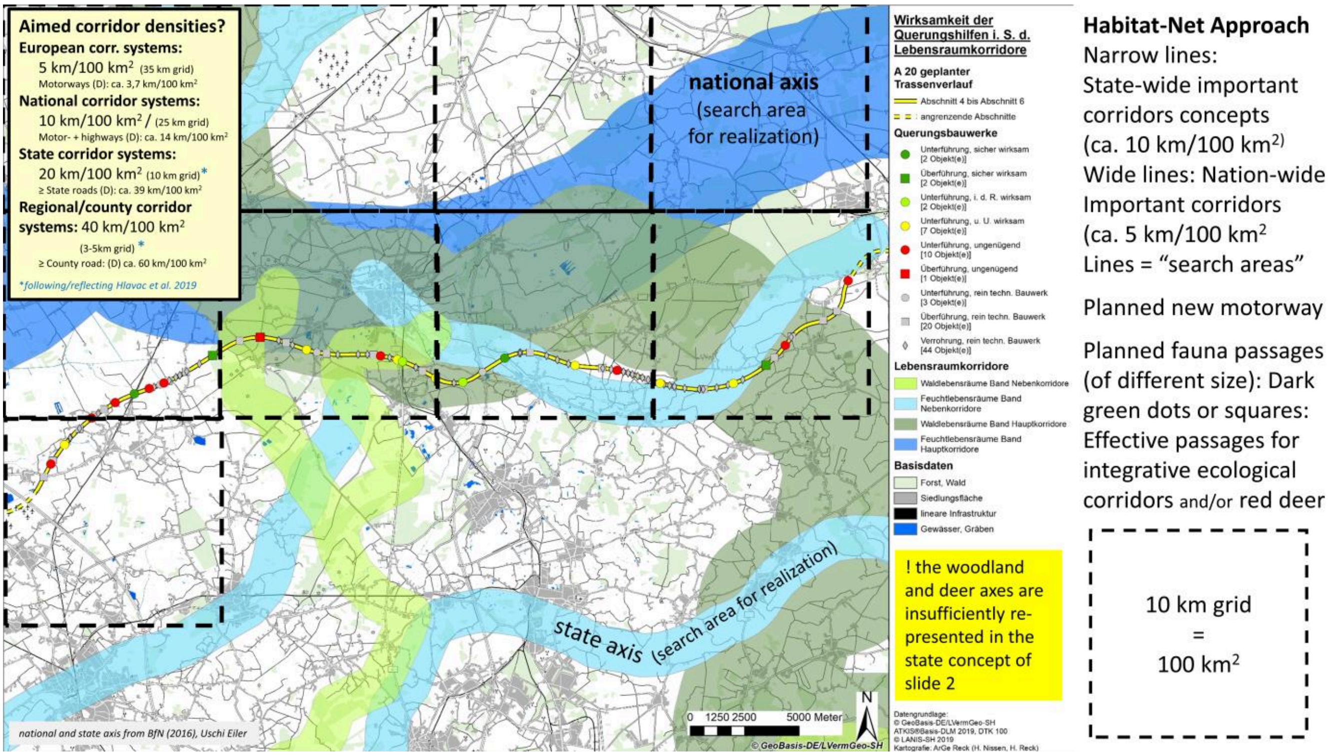


Figure 55: for comparison with the proposed corridor densities: National eco-corridor system (approximate indicative axes for realization) and its representation in planned fauna passages along a newly planned motorway (*preliminary meanwhile improved approach)*

In highly fragmented landscapes (i. e. the majority of European landscapes), the network density or coherence of ecological corridors must be restored (especially by overcoming traffic-related barriers). In the few coherently near-natural landscapes, at least the minimum density must be maintained from a strategic perspective).

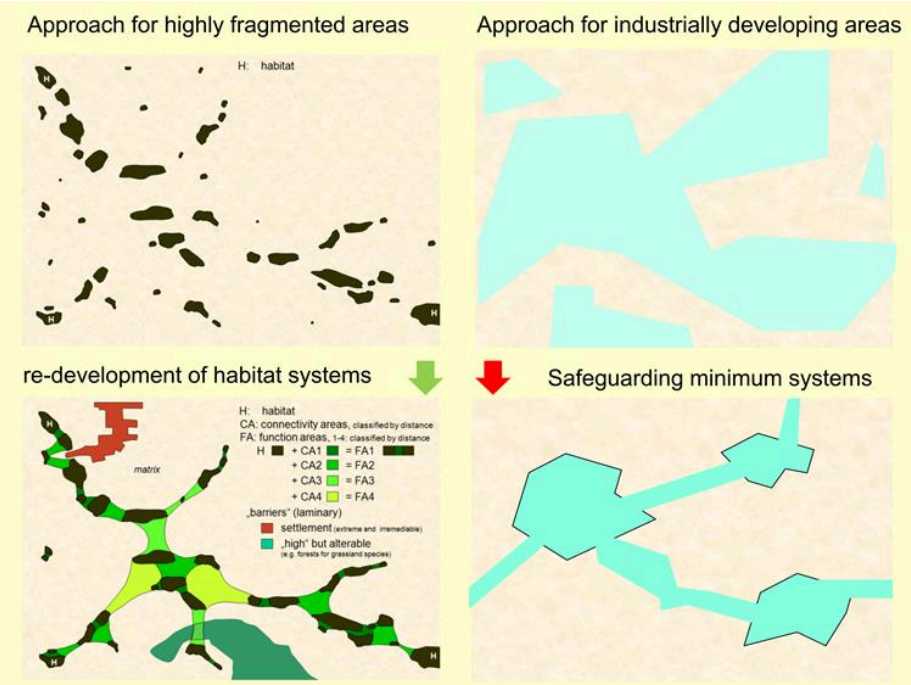


Figure 56: Principles for safeguarding connectivity while developing TI

Left: Central European lowland approach = redevelopment of a sufficient corridor network,
Right: Approach for still coherently near-natural landscapes = securing savely functioning eco-networks (thereby not included: the need for designation or large TIH-free reserves)

Under current land use at least 2/3 of the EU 30 %-requirement for protected areas is needed for ecological corridors (roughly 10 % for core areas and 10 % for corridor areas.

3.2.5.3 As a summary, the r+d needs in a nutshell

∑

The presented preliminary, scale-related indicator system should be applied to guarantee the minimum of needed information for decision-making. It should be continuously improved by testing its representativeness and its

Related r+d needs concern

- Implementation of the standard indicator system into every stage of TI-planning and continuous improvement of the system by critically testing its representativeness and its relevance for decision-making.
- Regulations for obligatory implementation of the EDM* (and respective state corridor systems and national defragmentation priorities along TI) into TI planning for imperative safeguarding or restoring the ecological function of identified eco-corridors.
- Programmes for further identification and monitoring of supra-regional eco-corridors by (1) using remote sensing data on habitat topology (automatic classification using artificial intelligence) and analysis of habitat distance, e. g. Habitat-Net, (2) compiling expert information on large-distance migration corridors and transhumance corridors plus further identification by individual tracking using methods as developed e. g. in the ICARUS-project (International Cooperation for Animal Research Using Space) plus developing guidelines to classify and identify main deer paths on local level.
- European-wide monitoring of WVC or compilation from national projects
- Regulations and manuals for the integration of cross-sectional parity reconnection concepts.
- Development of standards for watercourse underpass design that saves any migration needs for limnic and bank species and insofar prevent needs for project-specific mapping.
- Implementation of the standard indicator taxa system for moderate climate zones and eco-regional adaption to the warm and cold ecoregions of Europe.
- Development of guidelines for “overview assessment” regarding indicator taxa in the scales of ca. 1: 50,000 (report guidelines for: faunistic expert opinions, based on a single site visitation, interpretation of existent data plus random species-checks).
- Testing the representativeness of best indicator taxa combinations with special regard on the representativeness of Annex II/IV species for defragmentation issues
- Selection and test of regionalized representative European target species for planning habitat or eco-corridors and for effect monitoring.
- Implementation of the target densities proposed by BISON D5.3 and comparison to the respectively current densities of national and/or state corridor systems.
- Prognostic success controls of different implementation variants for eco-corridors (inter alia looking for tipping points of effectiveness regarding corridor densities) by using the example of the effects on representative target species (population viability analyses, examination of the influence on the distribution or recolonisation of abandoned areas under different land use or climate scenarios).
- Development and monitoring of pilot projects or monitoring of existing measures for the realisation of supra-regional connectivity / eco-corridor projects.

3.3 Better impact assessment 2: The neglected role of TIH as habitat corridor

3.3.1 Verges as habitats and corridors

Habitat functions

Roadside vegetation in comparison to the surrounding countryside (including commercial forests) can be species rich. That, concisely, is the result of a comparative study on vascular plants in Schleswig-Holstein (Müller et. al 2016). The cause is not the particular species richness along the roads, but the impoverishment of the intensively used surrounding landscape in large areas. Similar results are provided by e. g. Kaiser 2022, Daniel-Ferreira et al. 2021, or, eye opening, already by Verstrael et al. 2000).

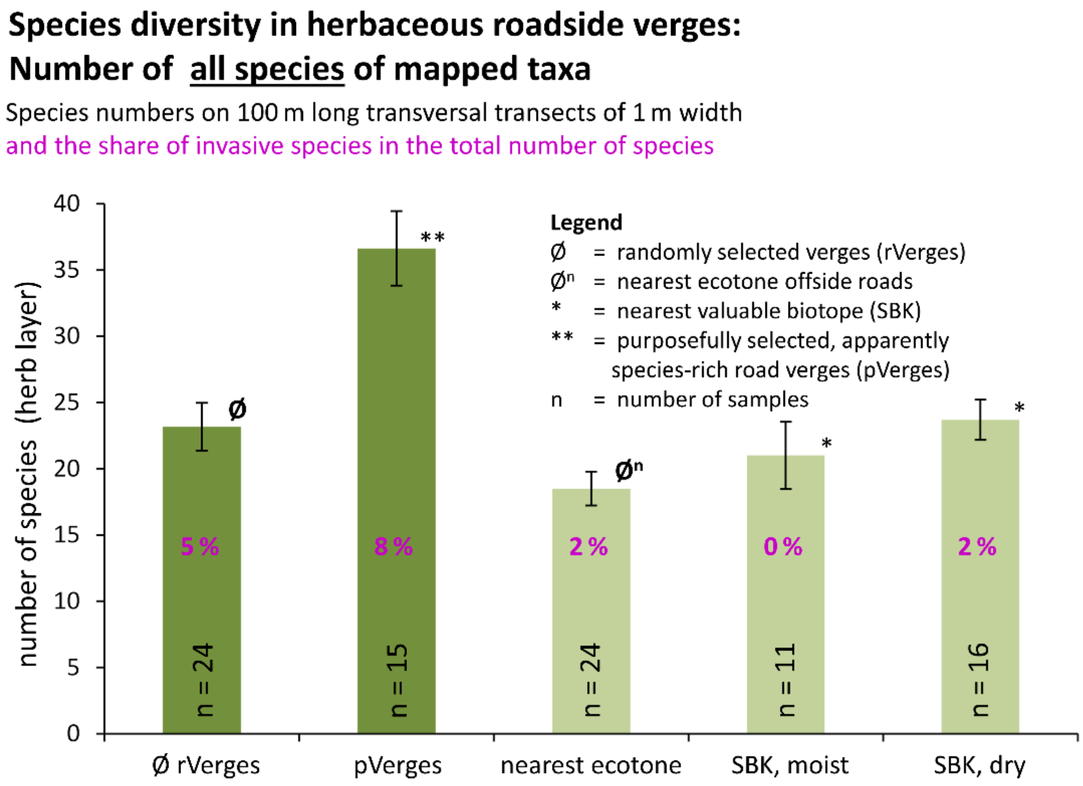


Figure 57: Comparison of plant species diversity of road verges and (valuable) hinterland habitats For more details see Müller et al. 2016, DOI 10.13140/RG.2.2.30321.25442

For small animals, especially butterflies, burnets, grasshoppers and ground beetles, but also dormice, sand lizards and wild bees, verges can make a significant contribution to safeguarding biodiversity and can be developed as a component of Europe's green infrastructure since lead (Pb) as fuel additive is forbidden and other traffic-related pollutants are largely reduced (Reck 2002).

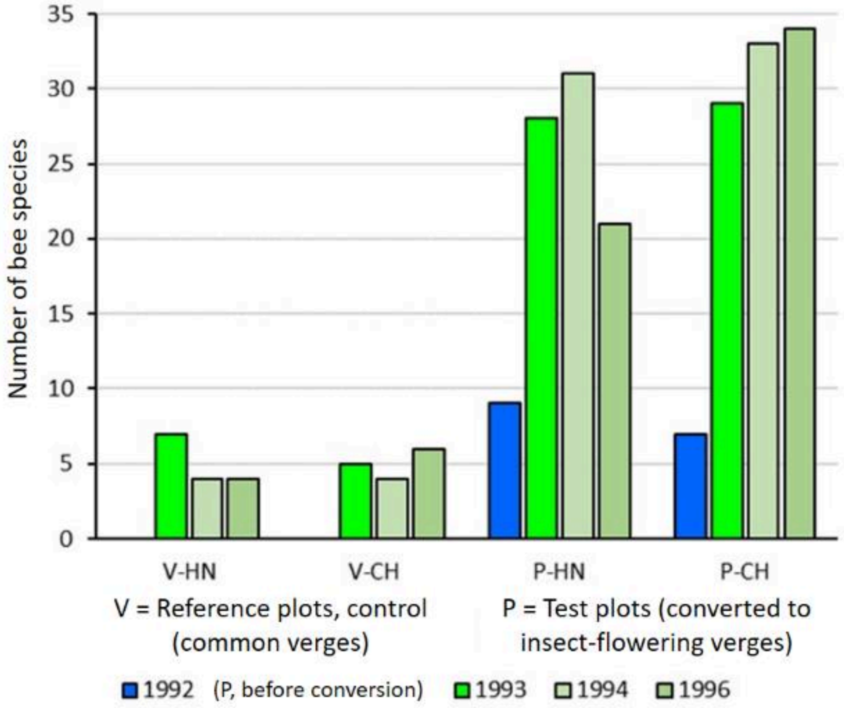


Figure 58: Number of wild bee species in inner-city road verges (left, V: Conventional verges; right, P: 1992 = verges before redesign to flowery areas, 1993 ff after redesign)—for wild bees a considerable and sustainable increase in species can already be measured from the first year after redesign (data: Schwenninger & Wolf-Schwenninger 1998)

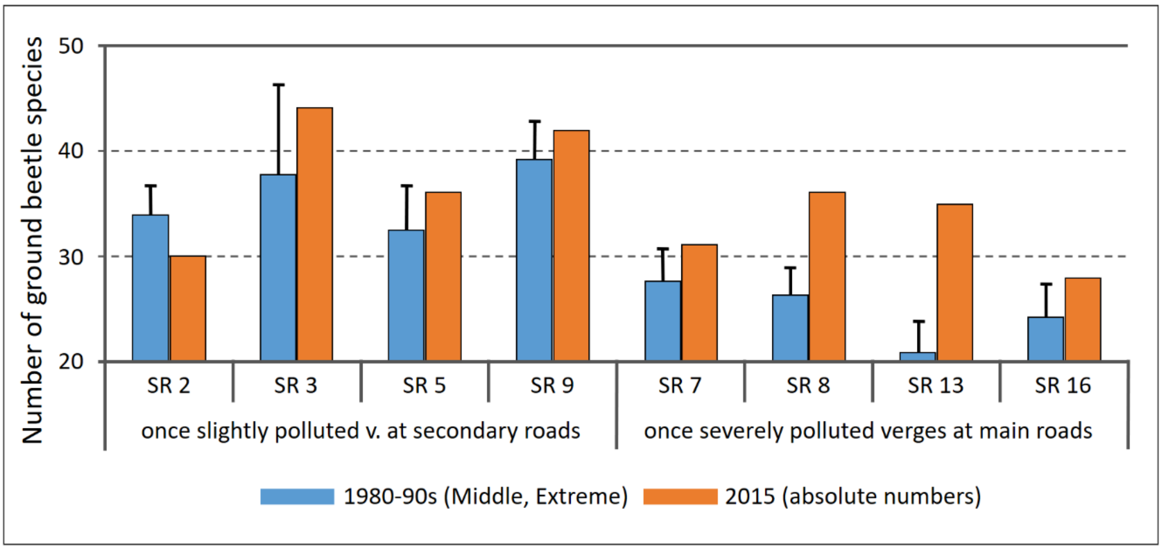


Figure 59: Mean ground beetle species numbers of repeatedly examined roadsides (SR) Numbers in the 1980 – 90s (blue) compared with 2015 (red); left side: previously lowly-polluted verges, right side: previously highly-polluted verges (from Peix et al. in prep.).

While verges are not a substitute for large-scale semi-natural and/or species-rich ecosystems, they can be a supplement to such areas and support their functions. In intensively used landscapes, the verge network can provide a minimum supply of biodiversity (Zinner et al. in prep.). However, the great potential of traffic verges for the promotion of biodiversity has so far only been used marginally (Reck & Müller 2018)

In the Czech Republic a promising integrative project, the project “butterfly highways” has been implemented (Mladek & Sikula 2016). ”Integrative” means to create species-rich verges on the one hand and reducing biomass and costly maintenance on the other at the same time, by using nutrient poor substrate or (in Czech Republic) by using the semi-parasitic plant yellow rattle to increase plant-diversity. The yellow rattle experiment in Czech Republic started successfully, could be repeated in Germany too (Zimmerbeutel et al. 2002) and should be applied in any poor verges and in (poor) compensation grassland at least in moderate European climate zones, but it needs biodiversity friendly maintenance (late mowing and strip or section-wise mowing and it has to be complemented in largely impoverished landscapes with species-rich additional seed mixes). By now, further methods to change species-poor verges to species rich habitats should be developed as well as appropriate applications and design (e. g., Rosell et al. 2022) and special solutions for dry and warm areas in e. g., the pannonic or Mediterranean regions in Europe.

Critical for the habitat function is inappropriate or contradicting verge management as is exemplary highlighted for the lucky burnet:

Figure 60: Lucky burnet (Zygaena fausta suevica), photographed at a landslide near Neuffen

Far from the road, but still in the vicinity of the site of the holotype (= former occurrence on the state road L1250), an occurrence rich in individuals was still found there in 2017.

Figure 61: Serious maintenance errors on the Neuffen roadside

The rising road on the edge of the Swabian Alb was the type locality of the Lucky burnet (Zygaena fausta suevica). The monophagous caterpillars of the Lucky burnet lived there for decades in the stands of mountain vetch (Coronilla coronata) growing on disturbed/moving soils and thus found an ideal habitat in the dynamic roadside greenery, especially as the flower supply was very high during the moth flight period. The unfavorable and uniform roadside maintenance and ultimately the complete mowing of the caterpillar food plant at the time of oviposition led to the disappearance of the species at the site where it was recorded for the first time about a hundred years ago (photos 2015; for improved maintenance approaches see Rosell et al 2022 or Reck & Müller)

Verges as ecological traps

The potential trapping effect of TIH must be distinguished from the effects of road mortality or the road traffic death trap itself.

Zinner et al. (in prep. b) did not find any evidence of a trapping effect of improved roadside vegetation (in the extensive zone), especially of flower-rich vegetation, for small animals and Schleicher et al. 2021 report the same while species such as sand lizards and dormice have been shown to thrive in roadside vegetation. It could be critical for small birds if woody plants reach very close to the roadside (see e. g. Steiof 1996). This may cause disproportionate mortality, as already described by Bay and Rodi (1990) for the yellowhammer: The road space was apparently so attractive for yellowhammers in the breeding season that territories orphaned due to road mortality were immediately reoccupied. It can be assumed that, compared to eutrophic margins, nutrient poor verges rich in insect-flowering plants may even reduce the mortality risk of owls and birds of prey, because they no longer have to grab their prey on the road or at the immediate roadside and because mice density could be lower. However, this opinion is discussed controversially and data are lacking.

For game, too, nutrient-poor margins are presumably less attractive than nutrient-rich vegetation or herbs (Petrak in lit.). However, reliable studies on this are not available (neither mortality-reducing nor mortality-increasing factors are sufficiently known). How wide the distance between woody plants and the roadside must be in order to avoid an increased risk of accidents for game also needs to be investigated in more detail. So far, it is only possible to show that the risk of accidents on road sections with dense shrubbery and trees very close to the road is increased for both - for game and for motorists (Gercken 2021). The altitude of roads in relation to their surroundings, the protein content of herbaceous and grassy vegetation, fruiting fruit trees, the presence of crossing aids (fauna passages) and the state of maintenance of wildlife protection and amphibian fences (small animal deflectors), which can reduce mortality but increase the barrier effect, also play a significant but so far hardly quantifiable role.

Corridor function of verges

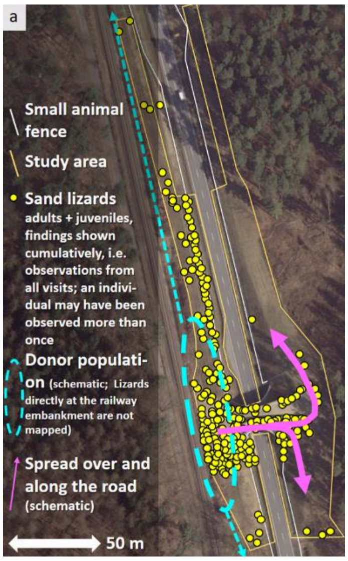
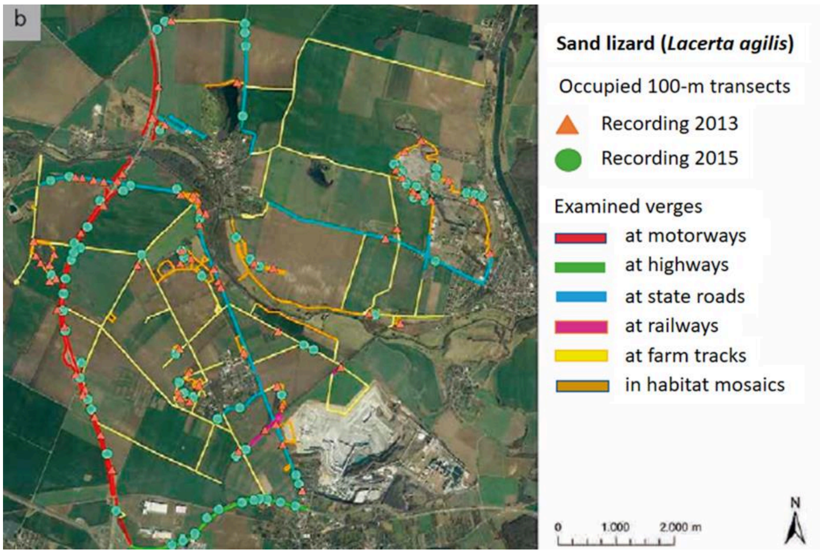
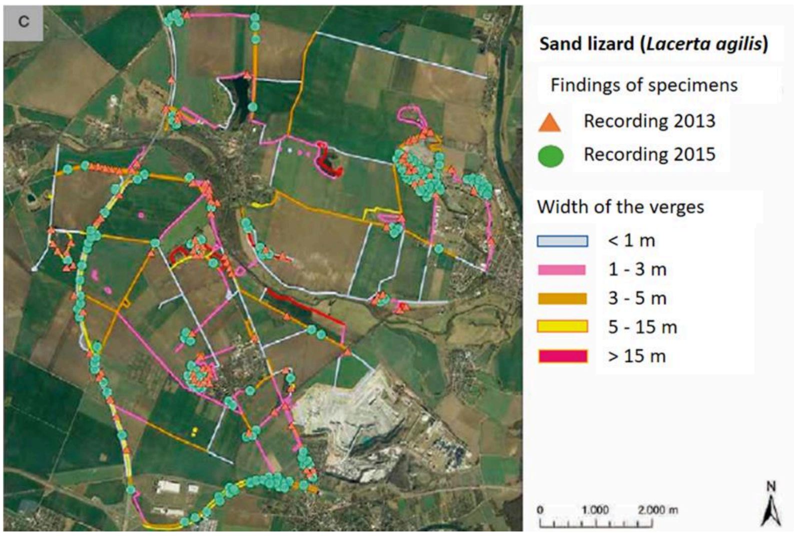


Figure 62: Colonization and use of roadsides by the sand lizard (Lacerta agilis) a-c

For sand lizards, TIH or verges respectively (extensive maintenance area and border to the intensive maintenance area) is a habitat and dispersal area and, in contrast to the surrounding agricultural landscape, has become an important refuge in many landscapes.
a) After the construction of a new federal road, a sand lizard population near Lübeck expanded from a railway verge across a fauna overpass into the road verges (data 2011: V. Daunicht, 2015: F. Widdrich).
Much more striking and spatially extensive is the colonization of motorway side areas near Bernburg (b, c).



b) illustration of colonized 100 m transects records of 2013 and 2015 after fast colonization of the verges



c) of recorded individuals in the investigated road verges; records of 2013 and 2015

(b, c, from Fritzsch et al. in prep., basic geodata: Web Map Service [WMS] of digital orthophotos [DOP100], © GeoBasis-DE/Saxony-Anhalt State Office for Surveying and Geoinformation [LVermGeo LSA] 2016).

(Wide) Verges can have great potential as corridors which was already proved by Vermeulen in 1994 on local scale (see also Noordijk et al. 2011). Also at local scale, the role of **verges as important feeding elements** to fauna passages is positively tested too (see chapter "bundling", Schulz & Reck 2017, Rietze & Reck 1998). It must be regarded, that too dense vegetation near the ground in verges acts as barrier, sparse vegetation near the ground as corridor (Richter et al.2013 … or Figure 68). Critical for the function of verges as supra-local habitat network could be intersections; especially intersections by roads with curbs. As the contribution to the supra-local habitat network is (with the exception of dormice, Friebe et al. 2018) not yet sufficiently assessable (cf. Ouédraogo et al. 2020 or Villemey et al. 2018) best practice for verge design and effects on the function of supra-local habitat networks should be closer surveyed because of the great opportunities for safeguarding biodiversity in combination with TI.

Green strip or Grass verge overpasses and underpasses

Verges can and should be used as feeding corridors for fauna passages (fp) but grass verge fp (that means near natural verge design along TI on traffic bridges or traffic underpasses – or even alone) could furthermore be a part of defragmentation concepts. They will never replace large fp but could be a necessary supplement and even reduce the needed numbers of large fp.

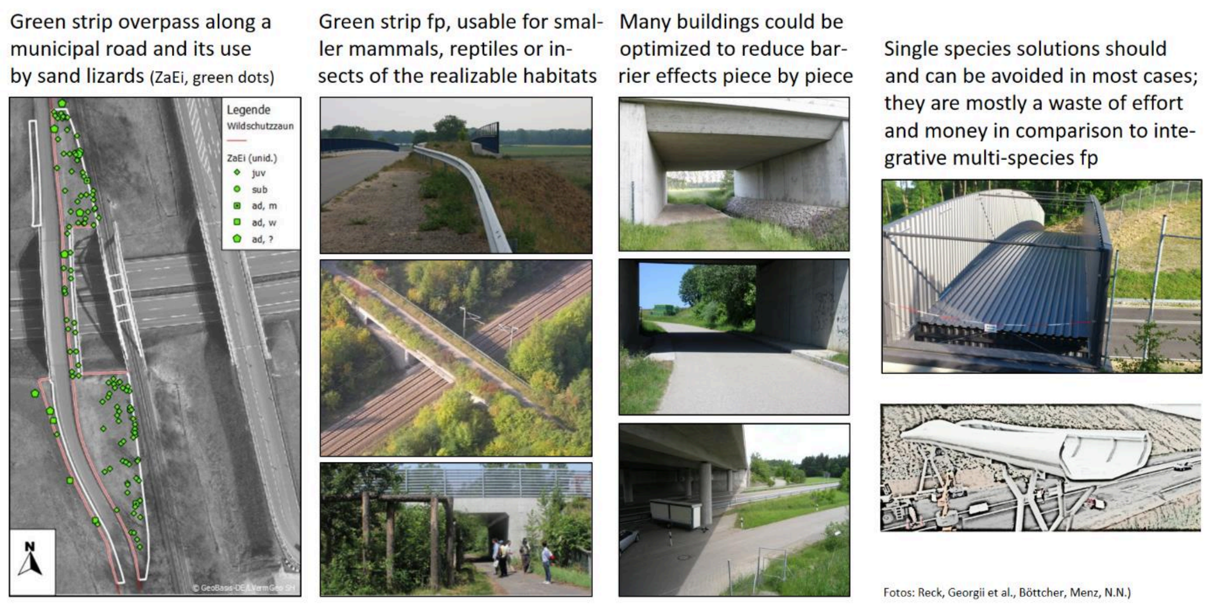


Figure 63: Green strip fauna passages as supplement to larger buildings

The sum makes the difference: As dispersal is mostly a stochastic process, regarding the small fauna, each possibility to mitigate the barrier effects must be used in addition to larger designated fauna passages according to chapter 3.5.3. If appropriately designed green strip fp are frequently used by rodents and shrews and, as overpasses, by dormice and lizards but also by single species of amphibians and ground beetles or grasshoppers of surrounding areas (at least by some of the species of the respective surroundings) but the effects cannot be quantified so far, for most of the relevant guilds.

As the "catchment area" of fp for small animals is small, all possibilities to create fp near the habitats of species in need of protection should be used. Thereby it has to be remembered that larger animals do not go through the eye of the needle, that many (helio- or xerothermophilic) small animals do not or barely pass through underpasses and even amphibians do not or hardly use amphibian tunnels smaller the 2 m in diameter if they are more than 20 m long. As for the small fauna, which consists mostly of stenotopic species, the specific habitats have to be developed on or in fp. Therefore, large multi habitat fp are necessary at supralocal eco-corridors and smaller fp have to be supplemented where rare habitats are localized. The SLASS* discussion has to replace the SLOSS* debate because no single fp will ever carry all the species affected by any specific TI section.

Only integrative (parity) defragmentation plans and measures (chapter 3.5.1) will safeguard spatial ecological functions as needed for sustainably safeguarding biodiversity.

*SLASS = single large AND several small, SLOSS = single large OR several small.

3.3.2 Safeguarding the corridor function of verges and its representation in EIA and IR

The role as habitat and corridor of TI side areas is rarely explicitly planned or described on EIA-level and the design is often not executed in a way that is conducive to safeguarding biodiversity (but often counterproductive). TIH are also rarely part of the impact balance; nevertheless, they should. Careful design, clear rules for maintenance of the side areas as best habitats should therefore be developed while planning and especially the role as feeders for fp needs detailed planning.

The design and topology of TIH is an important part of the project description (see chapter 3.3) influencing mortality and barrier effects as well as habitat and population connectivity. The quality of the verges which can increase negative impacts (if wrongly designed) or significantly contribute to the ecological network (if purposefully designed and maintained for the local target species or ecosystems) must be integrated into the impact balances and the possibility for biodiversity-friendly verges can be even be decisive for finding best alternatives.

The principle how existing verges should be safeguarded while upgrading, building or bundling TI is shown in chapters “livable ways and roads”, “curbs & co” and “bundling”). In the same way optimization of verges as eco-corridors should be planned and executed for existing TI and with priority for feeding fauna passages. The verges should be created as insect-flowering, diverse habitats and best be part of defragmentation concepts (chapter “parity reconnection”). In **EIA**, the area consumption for side areas can be differently weighed if biodiversity-friendly verges or if just spacing-areas or even critical designed verges with non-local species are planned. The same is for assessing barrier effects.

Accordingly, a clear idea must be developed in the project description as to how the side areas are to be designed (size, location in relation to biotopes, substrate management, type of vegetation).

For **IR** (mitigation and compensation), biodiversity-friendly verges can compensate for losses of species-poor intensively used land. Otherwise, such verges reduce at least negative impacts and so respectively reduce the compensation efforts.

As verge design has, beside the negative effect of shrubbery too close to TI, many more but more or less unknown effects on the mortality of birds, bats and larger mammals more information is needed for impact assessment as well as for impact mitigation.

3.3.3 r+d needs

By now, further methods to change species-poor verges to species rich habitats (e. g. by 1 sowing selected herbs or woody species – if appropriate in combination with hemiparasites like yellow rattle for reducing biomass and overgrow and/or 2 by soil treatment and/or 3 harrowing etc.) should be developed as well as appropriate applications and design (e. g. Unterseher 2015, Reck & Müller 2018, Rosell et al. 2020, Zmmerbeutel et al. 2022). Thereby special solutions for dry and warm areas in e. g., the pannonic or Mediterranean regions in Europe are probably needed. The goal is a guidance for Eco-region-specific design of verges and other TIH as habitat corridor and eco-region and ecosystem-specific rules for sowing or planting goal-oriented plants*** and for the substrate management in TI-side areas.

For EIA and IR, a survey of (positive and negative) verge impacts on representative guilds or taxa or representative target-species respectively is necessary to permit appropriate impact balances. Especially the role as feeding corridors to fp and as supra-local habitat corridors and the supporting TI and TIH features have to be closely examined (dispersal distances of representative target species from different small-animal guilds, influence of vegetation density).

As for reducing traffic-kills the effects the two main fields for research are:

1. Quantifying the mortality risk or, more probably, the opportunities for risk-avoiding by insect-friendly verge design and maintenance and

2. Finding appropriate distances for shrubbery to TI edges (different distances of shrubbery should be examined to define minimum distances of shrubs to reduce bird and game kill and methods for compensation for the therewith connected increased barrier effect for woodland species should be developed).

***Lists for seeds or plants

3.4 Better impact assessment 3: Some Opportunities for impact avoidance

Σ

Impact avoidance is insufficiently regarded in impact assessment

Especially the avoidance of

- bundling risks
- impacts due to (too) high design speed and
- impacts by curbs, protection walls/concrete guards and fences

are neglected and environmentally better alternatives are not compared. Even completely unnecessary impacts are too often not avoided. While obvious mistakes should be mitigated by obligatory subsequent damage repair other should be solved in the context of more detailed considerations for renovation work or upgrading. Therefore, the too often unnoticed risks are presented, solutions outlined and recommendations for r+d compiled.

3.4.1 The critical role of bundling

Standards for safeguarding biological diversity and for accelerating planning procedures regarding

A) bundling of transport infrastructure (TI) with photovoltaic facilities and

B) bundling of TI with one another

A contribution to the Bison WP5 T5.2 D5.3 report. Part A is adapted for BISON from some chapters of a manuscript by Franziska Peter, Heinrich Reck, Jürgen Trautner, Marita Böttcher, Martin Strein, Mathias Herrmann, Holger Meinig, Henning Nissen and Manuel Weidler; Part B is authored by Heinrich Reck und Marita Böttcher based on discussions with the PartA-authors

Key words:

Bundling - Roads - Railways - Canals - Photovoltaics - Biodiversity - Habitat networks - Habitat protection - Wildlife - Barrier effects – Habitat fragmentation – Ecological permeability

Key hypothesis

“Not all bundling routes and not every bundling of TI with other infrastructure are ecological errors but many”

3.4.1.1 Abstract: Bundling can be an ecological error

Bundling is not automatically a mitigating precaution against increasing fragmentation, although if the interspaces or facilities are suitably designed, there may even be advantages in terms of safeguarding habitat networks. At first glance, bundling projects reduce landscape fragmentation, but when looking at a larger scale, it often becomes apparent that fragmentation effects are intensified by bundling and that reconnection measures can become impossible or very costly due to bundling.

Instead of minimising negative effects on nature, bundling can lead to excessively increased land and material consumption, higher emissions, enormous barrier effects and excessive costs. Therefore, a comprehensive ecological and economic balance of bundling options and alternatives is always required.

In any bundling, it must be ensured that ecological networks (biotope network / biotope connectivity / migration corridors) or their restorability are sufficiently safeguarded. For this purpose, preliminary standard requirements and proposed solutions are formulated and the corresponding need for research is outlined.

3.4.1.2 Part A/B: What is bundling?

In this paper, we do not consider 'bundling' as a procedural term, but rather as a spatial-functional concept. The limits of advantageous bundling are reached when non-bundled projects "prove to be more spatially and environmentally compatible in individual cases," or when "an unreasonable or unlawful additional burden arises from the bundling of existing and new effects" (BNetzAG 2019)."

Bundling and respective standards as part of accelerated planning

Spatial-functional bundling, understood as aiming for solutions with minimal conflicts, can not only contribute to conflict avoidance and mitigation as a planning approach, but also to accelerated planning when consistently applied. The same applies to the use of sound and task-appropriate standards. Compliance with such standards (see following texts) shortens planning and decision-making processes and often reduces the need for specialized analyses in individual cases.

Part A: Bundling of transport infrastructure (TI) with photovoltaic facilities (PV-F)

3.4.1.3 Part A (TI/PV-GMS): Introduction

Solar power plants can be significant barriers to habitat connectivity. Especially critical is their installation over long distances parallel to transport infrastructure.

Although the roof and building potential for solar energy is high[88], photovoltaic ground-mounted systems (PV-GMS) are increasingly being installed, mainly along transport routes, partly for cost reasons partly because the areas adjacent to traffic routes are considered to have above-average pollution levels and are therefore of inferior habitat quality. This assessment is based on experiences from the last century when the pollution along transport routes was very high and the habitat potential in the hinterland of transport routes was still large. However, this is outdated (Reck 2022). It is not clear how today's political statements on existing pollution are justified. Pollution of areas far from traffic routes e. g. by agricultural inputs (fertilisers, pesticides) or by soil tillage may be weighted less heavily than pollution by noise or tyre wear, for example.

The spatial bundling of transport routes and freestanding photovoltaic systems has enormous potential to disproportionately increase the barrier effect of linear infrastructure and to intensify functional fragmentation effects, so that habitat connectivity and wildlife routes in particular can be impaired. In addition, high-quality habitats and refuges for species worthy of protection may be located on both sides of the transport routes (e. g. Verstrael et al. 2000). The occupation of which may result in the loss of habitats and populations and thus jeopardise the habitat network. For animals crossing roads in bundled areas, for example, the stress situation can become critical if possible resting areas or areas for reorientation on the opposite side of the road are missing and the risk increases that animals turn back into the traffic (Xu et al. 2020), thus increasing traffic mortality.

It is particularly important in this respect to note that both on national levels and at the European level, e. g. through the Biodiversity Strategy of the European Union, all countries and Member States are called upon to create ecological corridors and to ensure the connectivity of the various habitats (EU Commission, Proposal for a Directive COM (2020), 0380, p. 6).

[88] in Germany, for example, more than twice as high as the total area required for PVF, Günnewig et al. 2022

In the following, this paper only refers to the planning and design of PV-GMS, in the context of linear transport infrastructure (roads, railways and waterways). Transportation infrastructure (TI) associated with pipelines and other photovoltaic facilities (PVF), as well as floating PVF, are not addressed.

Figure 64: Examples of until now still initial bundling of PV-GMS and transport routes.

Improper bundling of PV-GMS and transport routes can prevent biotope and population connectivity on a large scale and thus excessively impair the mobility of species, which is essential for safeguarding biodiversity. Sources: Aerial photograph Mecklenburg-Western Pomerania (No. 1): Map data © 2015 Google; Orthofotos Brandenburg (No. 2 – 6): GeoBasis-DE/LGB, dl-de/by-2-0

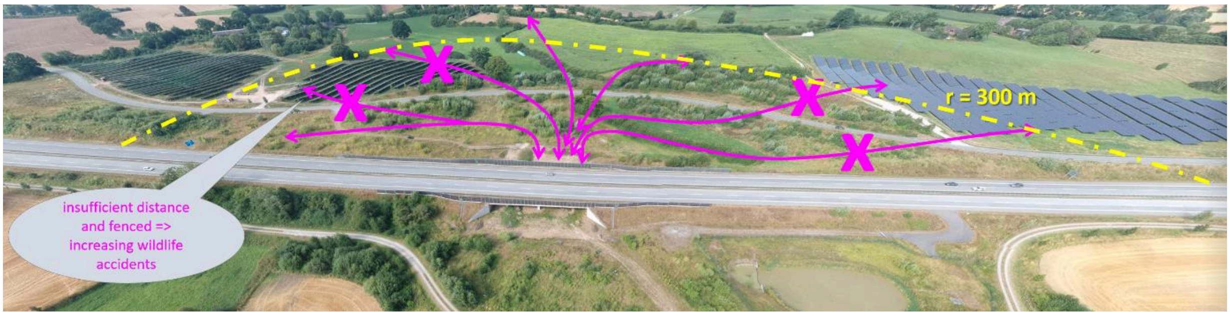


Figure 65: PV-GMS at a fauna underpass.

If PV-GMS are fenced and built too close to wildlife crossings or unfenced roads, the functionality of the wildlife crossings can be significantly impaired or completely prevented and/or the risk of accidents can increase. Aerial photo "Stolpe wildlife underpass" by Björn Schulz; for orientation purposes regarding Figure 66, a radius of approx. 300 m west of the underpass is drawn in.

3.4.1.4 Bundling PV-GMS and TI and the spatial reference of the proposed standards

Although bundling cannot be expressed uniformly with a single distance value for every case, it is necessary (for practical reasons) to establish a magnitude for the following recommendations. In this context, we consider:

- In general, PV-GMS that are less than 100 to 110 meters away from TI. If the distance is more than 110 meters, there may be sufficiently large areas with independent habitat functions between TI and PV-GMS.
- As a special case the surroundings of specific, integrative wildlife crossings; in this case, a radius of 300 meters must remain barrier-free (see figure in the following text).

3.4.1.5 Goals, benefits, and limitations of bundling PV-GMS and transportation routes

In contrast to spatially separate facilities, the bundling of PV-GMS and transportation routes (and also TI with TI) is expected to result in obvious benefits for the natural environment, particularly in terms of reducing functional fragmentation and improving functional habitat connectivity in landscapes. However, bundling must never lead to a significant ecological barrier effect that cannot be sufficiently avoided or functionally compensated, especially due to the close proximity. Accordingly, suitable spaces or corridors for habitat connectivity and animal movements, as well as special development potentials for eco-corridors, must be secured. Such include international/European and national habitat networks, state-wide and regional habitat connectivity systems or wildlife corridors, and other ecological corridors (that means particularly suitable areas, as well as linear elements in the landscape that enable the movement of individuals, genes, and ecological processes; see Drobnik et al. 2013, Chetkiewicz et al. 2006).

Under no circumstances should the bundling of PV-GMS and transportation routes (or TI with TI) impair the (future) implementation and/or effectiveness of habitat connectivity measures across existing transportation routes. In particular, the functionality of animal crossing aids and underpasses for water bodies, as well as their access areas (or corridors for large animals), must be ensured. This also applies to particularly suitable areas for the development of green infrastructure (e. g. critical sections in the European defragmentation map or in national or regional defragmentation concepts or suitable areas for implementing the needed minimum density of fauna passages - see chapter 3.6.2 "Thresholds for the dimensions and for maximum distances of fauna passages and ecoducts" or Hlavac et al. 2019).

The preservation of habitat connectivity axes / habitat networks is particularly important and is required, for example, by the Schleswig-Holstein PV-GMS decree (MI/MELUND 2021). However, migration routes of, for example red deer and other large mammals are often not adequately represented by these axes. Therefore, important migration corridors must be identified and preserved on a project-specific basis in addition to the habitat connectivity corridors. In accordance with the EU Biodiversity Strategy (EU Commission, Proposal for a Directive COM (2020), 0380, p. 4 ff), all supra-local connectivity axes as depicted or planned on European or state-wide or regional levels must be kept free.

In any case bundling should never be achieved through a one-sided consideration of poten-tially less important nature conservation benefits, such as less general landscape fragmenta-tion. A usually undifferentiated perspective only with regard to undissected areas despite their quality, or only with regard to the landscape scenery. Such can lead to habitat frag-mentation, i.e., the consumption of ecologically important habitats or corridors or recrea-tional areas. **If less conflicting alternatives are available through spatial distancing of PV and TI (or TI and TI), it is no longer ecologically sensible bundling, regardless of the spa-tial proximity.**

The corridor function of roadside green infrastructure, for example, for hazel dormice (Friebe et al. 2018), sand lizards (Fritzsch et al. in print), and many species of invertebrates (e. g., Vermeulen 1994), must also be taken into consideration. Verge areas (accompanying greenery) can be ecologically significant habitats or have high potential as habitats and ecological corridors. So far, verge areas have mostly not been commercially exploited, allowing for ample opportunities for conservation-oriented enhancements to secure biodiversity. Accordingly, the ecological potential of verge areas must be considered in decision-making processes for bundling.

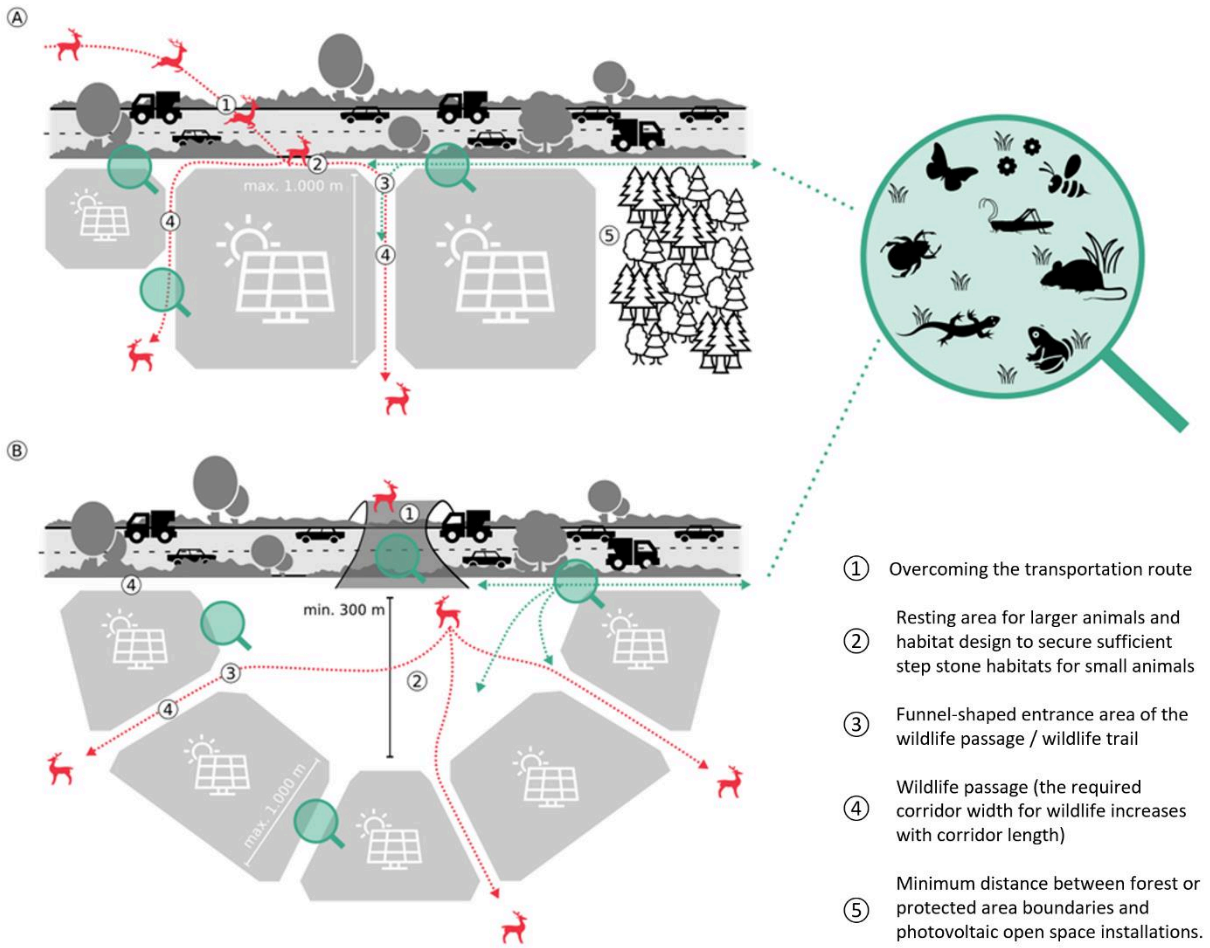


Figure 66: Standards for the positioning of PV-GMS

(A) along transportation routes and (B) along transportation routes with special integrative crossing aids as *green bridges/underpasses, fauna overpasses/underpasses, water underpasses*
The illustrated principle also applies to the construction of parking or resting areas and other infrastructure along transportation routes in the open countryside.
Expansion projects (upgrading), i. e. widening of traffic routes, must not be carried out at the expense of parallel green corridors (species-rich verges); in case of conflict, these must be relocated to the outside.
In the special case of long-term fenced traffic routes, corridors parallel to roads and intersecting PVF can become non-functional. If necessary, animal crossing aids must then be built at suitable locations, at least at intervals of around 2.5 km (cf. chapter passage densities). Feeding corridors to existing or future animal crossing aids / animal crossing points must be secured or kept free for this purpose.

3.4.1.6 Standards for bundling PV-GMS With TI

Standards
for fencing and sizing of PV open space installations,
for keeping areas free of PV-GMS and
for the design of wildlife passages between PV-GMS and between PV-GMS and TI

1. **No wildlife fences around PV-GMS**

   Wildlife-proof fencing is generally not considered necessary for the operation of PV open space installations and constitutes an intervention in nature and landscape that affects the mobility of keystone species (vector and habitat formation function of large mammals), among other things. Wildlife-proof fencing without reasonable cause represents avoidable impacts that should be avoided using proportionate means.

2. **No eutrophic and/or dense and tall border vegetation**

   Bordering grass and herbaceous verges should not be too dense and thereby hinder or restrict the mobility of smaller ground-dwelling animals. Very dense vegetation bands can arise from improper substrate selection or soil-bound wire mesh. They can prevent the spread of flightless small animals to a similar extent as heavily trafficked roads. In combinations with other barriers, they can hinder the necessary supra-local exchange of individuals between different habitats.

   By choosing nutrient-poor substrates and suitable seed mixtures, barrier effects can be prevented and maintenance efforts reduced. Therefore, intentional or accepted development of dense border structures without reasonable cause generally contradicts the objectives of nature protection.

3. **Mandatory taboo areas for PV-GMS installation**

   Designated areas of the ecological network, such as regionally important habitat corridors and wildlife corridors, must be kept free from PV-GMS installations. In addition, planned reconnection measures as part of reconnection programs should be taken into account, and priority areas for reconnection should be excluded from PV-GMS development. Consideration should be given to European concepts or plans, as well as such on national, regional and even local levels, including special areas with a high suitability for creating eco-corridors in already highly fragmented landscapes. The latter, especially migration corridors for large mammals, must be identified on a project-specific basis, for example based on habitat network analyses (analysis of habitat topology), based on wildlife accident hotspots on roads, or through consultation with hunting rights holders.

4. **Mandatory establishment of wildlife passages through PV-GMS**

   PV-GMS installations, especially in situations where they are concentrated, can disrupt or hinder individual movement between populations, wildlife migration, or colonization and recolonization processes, which may occur independently of specific ecological network axes, on a large scale. Therefore, a minimum level of permeability must be maintained, which also defines the size of spatially contiguous units of PV-GMS.

To ensure sufficient wildlife mobility, a passage corridor with a minimum width of 100 m must be kept free at least every 1,000 m (Fig. 3). The exact location should be derived based on the ecological conditions on site. Obligatory network corridors along water bodies, etc., can support habitat connectivity and serve as wildlife corridors. All main and secondary corridors of connectivity systems (habitat networks), etc., must be fully secured even if they are realized with narrower spatial distances than the 1,000 m spacing, for example.

The minimum width of 100 m for passage corridors is necessary to allow large animals to use these corridors between PV-GMS without significant restrictions and at the same time allow for the design of sufficient stepping-stone habitats for small animals. The otherwise stochastic and extensive dispersal of small animals and the connectivity of their habitats are narrowed by PV-GMS to the passage corridors, which requires an increase in habitat suitability for such species in the corridor. Therefore, 10% of the area of any PV-GMS is required for connectivity functions, either in the form of passage corridors between otherwise closed blocks of PV-GMS and/or, in the case of PV-GMS outer edges < 1 km, for the edge design of PV-GMS as habitat bands. It is a prerequisite that no road use takes place in the passage corridor (short crossings are possible) and that the passage corridor remains free from sealing and technical infrastructure. This, along with ecologically sound area design, is at the same time sufficient for compensating habitat loss on formerly intensively used and ecologically low-value areas.

Furthermore, in order to maintain habitat connectivity parallel to traffic routes, a minimum distance of 30 m must be kept between traffic routes and PV-GMS. This minimum distance, when appropriately designed, provides a resting area between traffic routes and PV-GMS and reduces the risk of wildlife accidents after crossing a road (rebound effect), and it also serves as a connecting corridor between passage corridors through PV-GMS. For fenced traffic routes, this distance is not required if there are no worthy-of-protection stepping-stone biotopes present, and if the wildlife fence in question is likely to remain permanently installed. However, wildlife or traffic protection fences should always be removed when, for example, no significant wildlife accidents are expected due to a reduction in maximum speed, or when they constitute disproportionate barriers in the biotope network.

5. **Taboo areas for PV-GMS installation around integrative crossing aids like ecoducts, multi-species fauna overpasses/underpasses or water course underpasses**

Crossing aids are intended to maintain or restore ecosystem connectivity along traffic routes, but they can only function effectively if their access area and at least the immediate surroundings are obstacle-free, and stepping-stone biotopes in this area are not compromised in their function. Accordingly, no PV-GMS should be established within a radius of 300 m around existing green bridges, green underpasses, fauna bridges, fauna underpasses, as well as viaducts, water underpasses, and access corridors to crossing aids (Figure 66). Outside the 300 m radius, or into the taboo zone, 30 m wide connection corridors must be kept parallel to the traffic route (as mentioned above and shown in Figure 66). In addition, within a wider radius of 900 m, at least three continuous wildlife corridors, each 100 m wide, must be kept clear on each side of the road, to ensure access to the crossing aids from different directions and minimize disturbance. Deviations may occur depending on specific circumstances such as the location of settlements, special land use, local or regional important deer paths or special habitat topology (location of particularly worthy-of-protection habitats / stepping-stone biotopes) (cf. Reck et al. 2019).

6. **Minimum distance of PV-GMS from water bodies, forest edges, and small or minor crossing aids**

Due to the high importance of watercourses (natural or formerly natural, including straightened water bodies, as well as main ditches with a minimum width of 1.5 m) and standing water bodies for habitat connectivity and as wildlife habitats, PV-GMS must maintain a distance or buffer zone of 50 m from these water bodies. The same applies to a buffer zone of 50 m around minor crossing aids (e. g. small animal passages, green strip bridges, etc.) and bridges or underpasses for e. g. agricultural and forestry traffic cyclists or pedestrians, if they are unsealed or known to be used as crossing points by wildlife.

Forest edges, like water bodies and their surroundings, are particularly important habitats and migration corridors for various species in the habitat connectivity network. Because they can be utilized by animals both, in the open land area and within the forest stand, a distance of 30 m from PV-GMS is sufficient.

7. **Quality of the wildlife passages or the habitat linkage corridors through solar power plants (and similar facilities) // connectivity corridor**

The quality of the passage corridors should, according to recommendations for the design of crossing aids (Iuell et al. 2003, Kruidering et al. 2005, Reck et al. 2019), primarily consist of open land with occasional individual bushes and groups of shrubs, which together do not exceed 10 % - 20 % of the area. Only in cases where roadside areas are designed in a gallery forest-like manner and the passage corridor is oriented towards a woody stand, the woody cover in the corridor (patchy or strip-like) should be 50 to 70 %. The vegetation development in the passage corridors should primarily take place on poor soils preserving, if species-rich or natural, existing vegetation or based on adapted seeding and appropriate maintenance. The aim is to develop mainly insect-pollinated, sparse herb and grass layers with usually significant proportions of bare ground structures on one hand, and perennial plant structures on the other hand. The species composition and design of the passage corridors should be oriented towards the primary nature conservation goals and site potentials in the respective natural region (see Finke & Werner 2020, Reck 2022, Rosell et al. 2020, Unterseher 2015, Werner 2014 for Central Europe).

8. **Avoidance of lighting**

Special requirements exist for avoiding lighting that may deter, disturb, or attract wildlife. Lighting can impede or disrupt the use of the elements of the ecological network, in addition to causing individual losses. Negative effects of lighting can be minimised (Schroer et al. 2019) and therefore should be actively avoided.

Part B: Bundling of Transportation Routes

3.4.1.7 Part B (TI/TI): Introduction

The same principles as those described for the bundling of transportation routes with large-scale (or long) parallel other technical infrastructures that affect the shape or use of areas as PV-GMS apply to the bundling of transportation routes with one another. Only additional specific features will be described below.

3.4.1.8 Effects of close bundling of transportation routes (impact factors and impacts)

As already mentioned in Part A, unlike spatially independent TIH, the bundling of transportation routes is expected to result in apparent benefits for the natural environment, particularly in terms of reducing functional fragmentation and improving functional connectivity of habitats in landscapes and at a scale of < 1: 50,000, this appears to be the case. However, in reality, this impression is often not true, except in large natural and underutilized areas where bundling can regularly reduce additional burdens. Otherwise, in most European areas, it should be considered that there could be disproportionate additional burdens by TI bundling.

Critical factors of bundling

- Disproportionate effort for maintenance roads, emergency roads, forestry roads or agricultural roads, crossing structures, drainage and rainwater retention basins, as well as for the development of stops or stations, rest areas, and agricultural areas.
- Disproportionate (area) requirements for the dimensions of crossing structures for traffic and even more so for necessary fauna passages (see below), with disproportionate material consumption and therefore disproportionately high emissions, including CO_2.
- Significant intensification of barrier effects, as bundling roads can be absolute barriers for many species. This is due to the frequent use of protective walls (or concrete guards respectively) in close bundling, as well as the cumulative and potentially multiplicative effects on fragmentation and mortality (resulting high distance of stepping-stone habitats, psychological barrier, cumulative filtering effect due to higher risk of collisions and the possibly enhanced need for construction of wildlife fences).
- The effort for ecological crossing aids increases, as longer crossing aids may need to be disproportionately wider in close bundling, and some solutions may become impossible (long underpasses may no longer be usable by many species or wildlife warning systems at crossing points may be ineffective due to the higher collision risk by rebound effects).
- Implementation of measures for reconnection of habitats can be significantly hindered by conflicts of jurisdiction due to different administrations or responsibilities for different transportation modes, and higher planning and construction costs arise due to the high need for coordination and necessary separation devices as protection walls or concrete guards etc.
- Overall, the land consumption can be considerably higher (see points above - but also, due to the different possibilities of different transports to overcome gradients, large intersecting areas may arise) and thus the competition for land between nature conservation and commercial land use is increased. In addition, bundled TI are less able to avoid biotope losses due to fewer possibilities for swivelling the respective routes.

Figure 67: Bundling of a motorway with a high-speed railway
Highlighting disproportionately high expenditure for bridges, maintenance and rescue routes, protective walls/concrete guards, separating strips, etc.

Potential positive factors of bundling

- Potentially lower landscape fragmentation e. g. affecting the effective mesh size indicator, M_{eff} after Jäger 2002 if applied to areas without differentiation of habitat qualities or land use (regarding only pure area fragmentation). A different effect occurs when the fragmentation effects or the M_{eff} is related to recreational areas or valuable habitats, or ecological networks and when different barrier strengths are considered. Nota bene: Habitat fragmentation and landscape or area fragmentation are ecologically different phenomena.
- Reduced need for the number of crossing aids for vehicles, people, or animals (if very close bundling is executed) but with disproportionately higher requirements for their size and construction effort.
- Overlapping and therefore overall smaller impact bands (when only operational emissions are considered, while construction emissions and construction site areas or impact bands of barrier effects are ignored).
- The creation of large intermediate spaces (technical offset areas) that could be used as habitats and parallel ecological corridors (if there is no competition with solar plants or other land uses privileged in the traffic area).

**The basic assumption
and often pursued planning premise
that bundling is the most environmentally friendly solution
is incorrect.**

Both scenarios are possible, i.e., mutual reinforcement of the impact intensity (presumably in many cases), but also a reduction of the overall burden (presumably in more exceptional cases). Therefore, an individual case examination of the advantages and disadvantages is always required. Any pre-determination of bundling options as "more environmentally friendly alternatives" leads to planning errors.

The crucial factor here is the "tightness" of the bundling and the utilization of the intermediate space e. g. as stepping-stone biotopes.

**Any new construction or expansion of two different modes of transport in close proximity must be evaluated in a cross-modal manner with regard to fragmentation effects and approved with reference to each other.
Pre-existing impacts from one mode of transport cannot lead to the subsequent mode having no obligation to mitigate.**

Otherwise, necessary reconnection efforts are hindered and the intention of the EIA directive to consider cumulatively or synergistically acting impairments is disregarded.

The consequences of bundling can only be evaluated and addressed in a cross-modal manner.

3.4.1.9 Standard requirements for the bundling of transport infrastructure

Standard requirements for bundling of TI are:

- A comprehensive and careful life cycle assessment (ecological and economic balance) must be conducted, weighing all the advantages and disadvantages of bundling.
- The needs for safeguarding eco-networks and ecological reconnection must not be considered individually for each mode of transport but must always be assessed and addressed in a cross-modal manner for the entire bundling sections.
- In accordance with the minimum requirements for the density of fauna passages from page 210ff and regarding habitat-networks and migration corridors, fully functional crossing aids or combinations of crossing aids must be installed across all bundled transportation modes. Due to the restricted access areas caused by bundling and the potentially limited functionality of fauna passages due to their length, their hinterland connection must be carefully designed and secured (see also chapters on parity reconnection).

With regard to landscape fragmentation, it must be emphasized that there is a significant difference between landscape fragmentation and habitat fragmentation. Natural or species-rich habitats are limited to small proportions of most European landscapes, and functional habitat corridors are only preserved or restorable on a few axes. These must be prioritized for functional connectivity. Therefore, it must be ensured that transport infrastructures can be safely crossed at a sufficient density (chapter 3.5.3, Hlavac et al. 2019) in any bundling scenario, even if this leads to significantly higher requirements for structures as overpasses or underpasses or for land provision for wildlife corridors or stepping-stone biotopes.

3.4.1.10 r+d needs related to bundling T/TI or TI/PV-GMS

Regarding the poor knowledge about bundling effects and the contradicting hypotheses about positive and negative impacts of bundling the following r+d needs should be answered:

- Initiating representative case studies to get comprehensive ecological and economic assessments for typical bundling projects in comparison to typical alternatives as an orientation for strategic environmental assessment (and/or creating guidelines for conducting individual life cycle assessments (relevant factors include land use, energy and material demand, total costs including planning and administrative efforts, barrier effects and possibilities for ensuring sufficient ecological connectivity).
- Conducting research on ecological function of buffer areas or the minimum required distance between bundled transport infrastructure and/or technical facilities accompanying transport infrastructure.
  The distance between traffic areas and parallel intensive land use, and especially parallel bundled transport routes, has a decisive influence on the behaviour of animals in terms of rebound effects, and thus on the risk of accidents or the barrier effect. Necessary stepping-stone biotopes must be designed in the intermediate spaces for small animals. Therefore, it is necessary to determine the dependency of the barrier or connectivity function on the width (and design) of resting or intermediate spaces for different indicator species (e. g., lynx, red deer). For small animals, the minimum width is determined by the required size and density of stepping-stone biotopes. Better data on the surmountable distances between stepping-stone biotopes depending on the sizes and frontages (mirrored fronts) of habitats, as well as the resistance to movement of interstitial land uses, would be desirable.
- Conducting research on the ecological function of wildlife passages through technical areas as PV-GMS related to TI. What is the optimal or most efficient length and width ratio of such passage corridors?
  When large marshalling yards, resting and parking areas, ports, or industrial facilities, such as photovoltaic systems, are designed to be traversable for animals the question arises as to the necessary minimum width depending on the length.
- Conducting research on the resistance of dense herb and grass strips on small animal movement and thresholds for verge vegetation or green strip vegetation densities.
  Because overly dense strips can significantly hinder the dispersal of epigeic small animal species and thereby impair the connectivity function of passage corridors or green infrastructure alongside transportation routes, the difference between species-rich, sparsely growing strips versus dense overgrowth should be investigated in terms of animal mobility. This will also allow an estimation of how far small animals can be steered towards green bridges or stepping-stone biotopes.

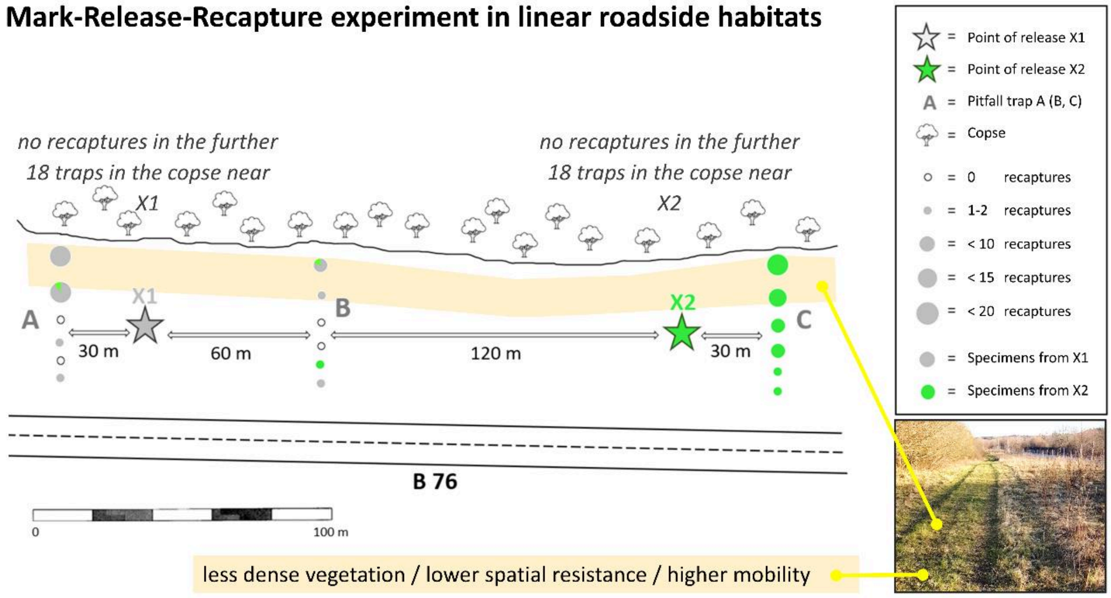


Figure 68: Ground beetle mobility along the highway B76
Mark-recapture experiment 2022 from D. Bockwoldt. The topology of the verge habitats leads to a clear corridor effect for species of open habitats (as described by Vermeulen 1994, Rietze & Reck 1998 or Noordijk et al. 2011). In less dense vegetation, mobility (and dispersal) seems to be decisively higher.

3.4.2 Reducing traffic velocity (design speed and operational speed)

Problem outline

Many of TI-related barrier effects could be avoided without negative effects on the respective TI function.

TI design for unnecessary high traffic velocities and respective realized speeds are affecting:

(1) barrier relevant area and habitat consumption
(e. g. due to the related carriageway width or due to velocity-related bend standards and the impossibility to adapt the traffic line by circumventing valuable biotopes)
(2) mortality
(which is probably exponentially/logistically increasing with faster vehicle speed for most species, especially birds, bats and larger mammals) -
(3) needs for (barrier-effective) fences or
needs for protective walls or
for solid railway tracks instead of ballast beds which are permeable for the small fauna,
(4) eutrophication of stepping-stone habitats (the higher the velocity, the higher e. g. the NOx emissions)

and many more (see fig.29, chapter “deficits”).

Situationally adapted, slower driving speeds (e. g. 90km/h on highways and 110 km/h on motorways) and the associated reduction of high design standards, however can reduce impacts as they reduce:

- rolling noise (which becomes louder with speed), i. e. unnecessary noise, which not only impairs the well-being but also the health of many people (in favor of the speed kick of a few high-speed drivers) and which devalues unnecessarily large areas as habitat, e. g. for songbirds,
- unnecessarily wide bands of nutrient and pollutant emissions in neighboring areas and sensitive habitats, as well as CO2 emissions (also due to the quantities of concrete and building materials saved),
- unnecessarily high land requirements for motor vehicles, including unnecessarily high requirements for paved verges and unnecessary land sealing or land competition (the higher the speed, the wider the roads have to be), and they avoid
- unnecessarily high barrier effects by construction or operation and (complementing driver assistance systems) serious accidents or unnecessary death and suffering of humans and animals (bird and bat strikes are reduced as well as losses of ground beetles, grasshoppers, toads, snakes, dormice, hares and deer).

It also reduces avoidable stress for motorists and unnecessary costs for large construction sites and buildings and their maintenance.

R+d needs

As lower design speeds and travel velocities have an enormous potential to reduce barrier effects (and the many other negative impacts on the environment as well as traffic costs) without compromising mobility goals for people and the economy the relation between environmental and social costs and economic or timesaving (often only pretend) benefits must be scientifically examined. Best tipping points for cost-benefit balances must be found for decision-making. Of great relevance thereby is the comparison of habitat consumption and the efforts for emerging needs for larger TI-buildings as subways etc., the comparison of barrier effects or the comparison of remaining possibilities and the costs for the mitigation of barrier and other impacts, the comparison of noise levels, exhausts and related human health and real time budgets regarding not only design speeds but also traffic jams due to speed-related higher risk of accidents or concertina effects. Furthermore, research is recommended on enhancing travel speed by optimizing traffic flow instead of high speeds or enhancing travel speed by optimizing boarding and disembarkation times.

Immediate balancing requirement

Regardless of large research gaps the effects of lower velocity or different design speeds have obligatory to be compared as alternatives in SEA and EIA using the current state of knowledge.

3.4.3 Curbs, protection walls, fences & Co. as barriers and r+d-needs to overcome its adverse effects on biodiversity

Roadside elements can multiply the barrier effect of traffic routes and are often deadly traps.

Obvious (because intended) is, that fences are barrier elements. They are deadly only if they are built on one side in the open landscape or if they are designed incorrectly. The ugly picture of strangled deer in bent up bar fences is easily avoidable. It is more difficult to avoid the intrusion of large animals at the ends of the fence and correspondingly panic-stricken escape attempts. In addition, it is difficult to decide when fences as barriers do more harm than good.

Many lives can be saved with favorable edge design:

- Avoidance of visibility-restricting vegetation at the roadside (Gercken 2021), - perhaps distances of more than 5 m between trees are sufficient, or the
- Development of attractive crossings at clear road sections as well as by a
- Reduction of the maximum permissible speed (e. g. Seiler 2003)].

Less obvious are the effects of unintended barriers. Dense verge vegetation can prevent or hinder crossing of lanes by, for example, large ground beetles (Zinner et al. 2018: 90, 95) or juvenile amphibians (Anstoetz 2018). The general requirement to use meagre substrates and to promote sparse (not too dense) vegetation in the verges (Reck & Müller 2018) helps to reduce barrier effects.

Largely unnoticed is the need to avoid, as far as possible, the use of curbs that protrude significantly above the road surfaces.

3.4.3.1 The role of curbs[89]

Cyclists who want to change sides or everyone who pushes strollers or wheelchairs or uses walkers know the problem - just not, it seems, the street planners. For small animals, curbs have a devastating effect. They explain the species deficiencies of flightless large ground beetles in cities (cf. Trautner 1993: 227), they lead to the death of amphibians, reptiles or shrews, and they may prevent roadside vegetation from contributing to habitat connectivity e. g. through settlements, because an additional obstacle is created at each junction. Even if they are not insurmountable for all species, they increase the length of stay on roads many times over, thus increasing the risk of killing and they lead to reversal movements.

[89] after Reck 2022

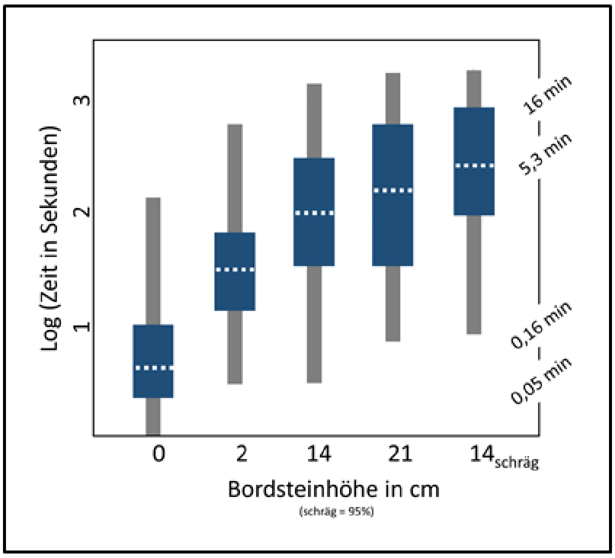


Figure 69: Retention time of large ground beetles at curbs of different heights

Laboratory experiment by Wellner 2019 (n = 317 observation data, logarithmic scaling). The influence of curb height is statistically significant, but the dwell time at high curbs is still underestimated because observation units with a dwell time of respective beetles of more than 30 minutes were not integrated into the data set (experiment terminated after 30 minutes of inactivity at the curb).

Legend:
Log (Zeit in Sekunden) = Log (time in seconds)
Bordsteinhöhe in cm = curb height in cm

Figure 70: Slow worms at curbs

Even beveled curbs are not or only with difficulty surmountable for many specieshere: Unsuccessful climbing attempt of a slow worm on the county road L410 (at least until the observer intervened); close by were found dead specimens.

Unnecessary and unnecessarily high curbs must be avoided completely. Only explicitly identified, explained need in individual cases justifies their use. And even where there is an apparently justified need, e. g. as a rainwater barrier or to safely separate motor vehicle and slow-moving traffic, there are more suitable, life-friendly solutions: Speed limits and associated lane narrowing and/or the creation of intervening, colorful herb and grass strips and, as ultima ratio, differently shaped curbs or curbs placed on gaps and thus climbable.

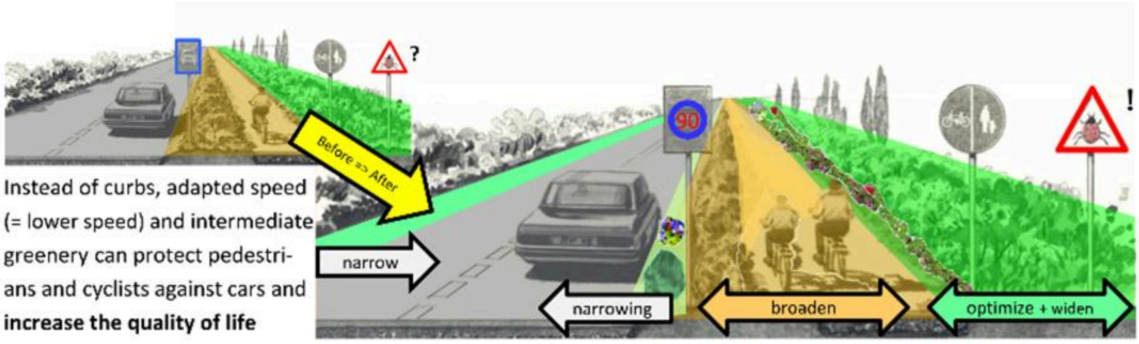


Figure 71: Replacing "TI as barrier" with "TI for life"
(from Reck 2022). Instead of curbs, adapted (lower) speed and intermediate greenery can protect pedestrians and cyclists against cars and increase the quality of life.

Avoidance of unnecessary protection walls or concrete guard barriers

The continuing trend towards the use of concrete crash barriers (as a mostly unfounded substitute for crash barriers) should be stopped immediately against this background. The use of concrete crash barriers is predominantly (there are always exceptions) an unnecessary, avoidable and therefore in principle prohibited intervention in the natural balance. The barrier effect of the walls is absolute for many flightless small animal species; for others, including large animals, unnecessary, deadly traps are created.

Figure 72: Mice at curbs

Shrews (left, S. araneus) can at best get over curbs no higher than their head-torso length; the common vole (M. agrestis) presumably likewise (all available pictures show turning around at the edge) and wood mice (photo: Apodemus spec.) are also limited. Only the Norway rat (R. norvegicus, right) overcomes all curbs.

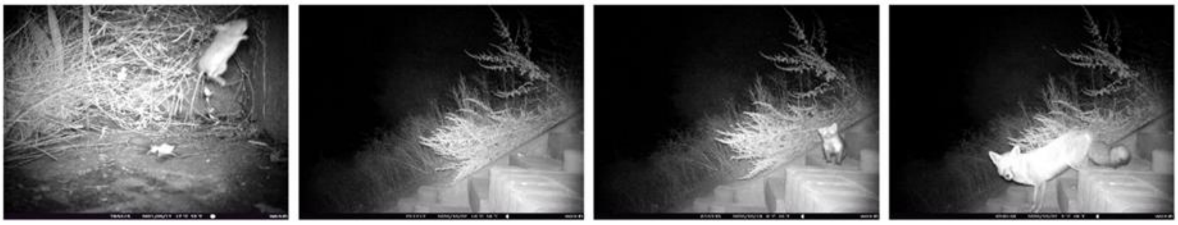


Figure 73: Jumping mouse and predators at curbs or stairs

Only a few small mammal species can jump up like the yellow-necked mouse, others are trapped on the curb (all photos: Henrik Schulz as part of the BMU-funded BfN project "Bio-ecological effectiveness of underpasses for insects, reptiles and flightless small mammals")

Necessary protection walls as e. g. noise barriers can be constructed in a way that the small fauna can cross at any place by a gabion foundation of large stones or due to regular passage holes.

Unnecessary barrier effects of rails

Along railways, curb-like cable shafts and the like protruding high from the ground must and can be avoided and the same is with unsurmountable parallel ditches (natural bank design). Even the rails itself are no longer a barrier e. g. for amphibians if gaps between rail and ballast are left.

Figure 74: Deeply levelled ballast reduces Railkill of amphibians
While tracks lying directly on the ballast or close to it are deadly barriers, deeply levelled ballast is a cost-free alternative that makes it possible for small vertebrates to cross railway lines.
(Photos: E. Krummenacher in Rieder et al. 2006)

3.4.3.2 Gullies as traps: r&d-needs to overcome its adverse effects on biodiversity

The trapping effect of gullies for small animals (e. g. amphibians or ground beetles) is well known. For this reason, gullies must never be built along amphibian protection fences or at fauna passages, at least never without special protective measures.

Because unnecessary animal losses (especially of strictly protected species) can and must be avoided elsewhere, it is necessary to develop and order standard gully designs that ensure the escape of small animals like ground beetles, amphibians, reptiles, shrews etc.

3.4.3.3 The role of fencing

Fencing (in relation to a sufficient number of fauna passages[90]) is a useful measure to reduce both human and wildlife mortality or injuries. Recommendations on good practice are available (e. g. IENE handbook, Brieger et al. 2021). However, costly fencing is applied far too much and escape devices are far to few installed.

Fencing is a stopgap solution. Fencing can critically enhance barrier effects and fences can be deadly traps. So, fencing should be avoided as far as possible.

Alternatives for fencing can be:

- better (broader) sightlines along TI,
- attractive fauna passages,
- habitat corridors that lead (larger) animals away from risky dam situations and/or to fauna passages,
- slower traffic speed
- or, at rails, wildlife warning systems (in combination with facilitated traversing over the ballast bed with e. g. the aid of tread mats).

All planned and existing fences should undergo an assessment if barrier risks and/or accident risks at the fence's end are higher than accident risks without fences and/or with improvement of the side areas. And species-specific fencing (e. g. only regarding bats) without conflating, integrative optimization for all affected species or guilds often create unnecessary conflict of goals or contradicting solutions regarding biodiversity in total. In many cases lower velocity and adequate verge structure can reduce traffic accidents with larger mammals (and also birds, bats, insects) and collision impacts so that costly and isolating fences can be spared. So, tipping points for cost-benefit balances must be found for decision-making.

[90] See chapter 5.2.2, “Thresholds for the dimension and for maximum distances of fauna passages”

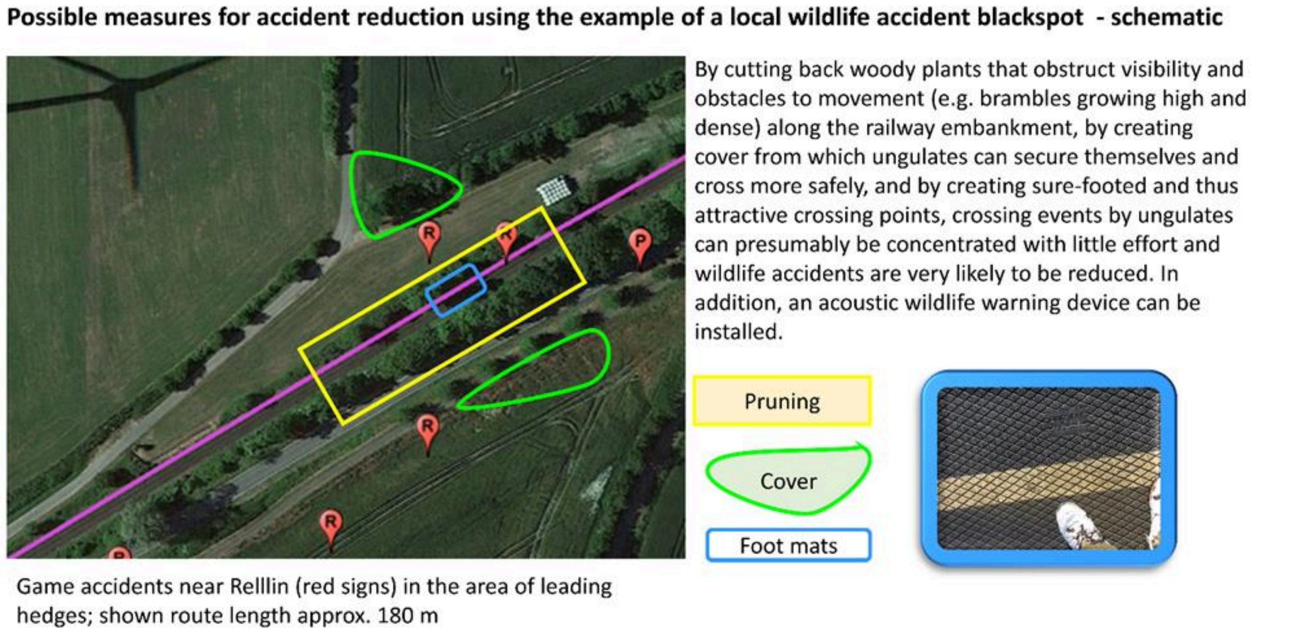


Figure 75: Railkill reduction for larger mammas by warning signals, verge design and tread mat solution

Tread mat solution to be tested (sketch from Reck & Fehlberg in prep. of a route section that can be optimized as a wildlife crossing point). In combination with automatic warning signals for approaching trains (e. g. Babinska-Werka et al. 2015, Backs et al. 2017), attractive crossing points could reduce ungulate mortality and barrier effects. While studies on warning systems are available, is not known whether optimized crossings (attractive tread mats for ungulates) can concentrate large animal crossings and significantly reduce mortality.

3.4.3.4 Research and Development needs (r+d) concerning protection walls, fences, curb stones and verges as barriers

Abbreviations: **r** = Research, **d** = Development, **EDM** = European defragmentation map, **TI** = Transportation Infrastructure, **WVC** = Wildlife vehicle collisions

d Implementation of a general rule that curbs & co. are forbidden in TI construction or TI renovation if not individual case-specific justified (case-specific assessment

d Guidelines (standards) for easily surmountable curbs or curbs placing on gaps and thus climbable that are useful as rainwater barrier (as alternative for precipitation water steering by curbs) / Development of curb designs that guarantee directed rainwater drainage that is no barrier for the small fauna (e. g., specially designed grating stones or kerbs placed on gaps and thus climbable)

d Guidelines (standards) for gully design which ensures the escape of small animals like ground beetles, amphibians, reptiles, shrews etc.

d Implementation of standards for mortality safe wildlife fences

r Quantifying negative and positive effects of wildlife fences related to typical environmental situations and to traffic characteristics (rules for application or avoidance, tipping points for decision-making)

- Quantifying the impact of different distances of woody plantations on WVC
- Quantifying the impact of different densities of fauna passages on WVC
- Survey of the effects of more or less ungulate-nourishing roadside or rail side vegetation and related WVC
- Survey of the effects of herb and grass density in verges (a) on the migration of the small fauna, (b) on the habitat quality for the small fauna and (c) on the traffic mortality of birds of prey
- Quantifying and balancing negative and positive economic and ecological effects of different traffic velocities on different TI types with regard to the total ecological footprint and especially WVC or the avoidability of fences or protection walls or curbs
- Survey of existing TI where curbs & co. should be deconstructed or de-fencing should be applied (primarily along defragmentation areas due to the EDM or regional eco-corridor or defragmentation concepts if no or too few fauna passages are realized).

Figure 76: Fences and plastic nets against erosion can be deadly traps
Badly designed fences, even special fences against wildcat mortality, can lead to the opposite, which is more mortality, and promote accidents. The unnesseecary plastic nets against erorsion affect strongly protected species and end as micro-plastic. Regarding nature protection laws they can be assessed as illegal devices.

3.5 Better impact avoidance and mitigation

3.5.1 Parity reconnection or, respectively, defragmentation plans as obligatory component of TI development and as pre-condition for accelerated planning

Heinrich Reck & Marita Böttcher

New construction – bundling – upgrading – fencing – renovation:

Parity defragmentation concepts as an obligatory precondition for planning acceleration and as a basis for multi-objective optimization

Provided that measures to safeguard biodiversity through the parallel development of habitat networks are integrated from the outset into the new planning of transport infrastructure and if appropriate avoidance and compensation measures are defined proactively (and not only as a reaction to objections or lawsuits), planning delays due to nature conservation concerns can be avoided.

Where appropriate, cross-sectional identification of priority sites for eco passages and eco corridors (habitat networks and animal migration routes) on regional scale form a suitable framework for renovation and upgrading as well as for defragmentation projects, which reduce overly fragmentation by the already existing TI network.

r+d needs

- Manual for practical implementation
- Scale-specific list of target species for defragmentation [91]
- Integration into EU-regulations

[91] As it is species, which actually make use of ecological networks or corridors and, as plans and measures have to be evaluated, representative target species should be used for prognostic and in situ success control.

3.5.1.1 What are parity defragmentation plans, what are the benefits for TI development and biodiversity, how can they be implemented?

Introduction and outline of the most appropriate planning levels

Parity reconnection plans (and liveable roads and rails[92]) can be the silver bullet to biodiversity friendly TI development. They will lead to better planning, less conflicts and accelerated realisation. Therefore, in future, any planning of TI must be coordinated with habitat reconnection plans developed on an equal basis and jointly implemented.

The most relevant planning levels for parity defragmentation plans (pdp)[93] are:

1. **for (1) new development and (2) for upgrading or (3) for bundling[94] or (4) for fencing of TI** (i. e. SEA, EIA and IR on local and regional scale)**:**
   Whereas in the case of several TI-corridor or route alternatives that are spatially far apart, at the level of the EIA at best a comparative framework sketch for project-specific, possibly cross-section reconnection concepts make sense. In the case of spatially narrow route alternatives and at the level of project approval, a detailed parity reconnection concept[95] can in most cases lead to efficient safeguarding of biological diversity despite the impact. Exceptions can be small-scale / small area projects),
2. **for (5) renovation of TI**: The fulfilment of standards for ecological passages[96] by retrofitting must lead to at least ecological surmountability. Therefore, an integrative pdp (regarding more than single spots) on regional scale is helpful to find the most efficient solutions.

For compensation of ecological fragmentation due to TI construction in the past (6), mainly regional, or state or national or European defragmentation programmes can stimulate action.

Rationale

Existent biotope network planning at the superregional level usually only needs to be adapted locally when new TI is developed. The given large-scale, e. g. state-wide ecological relationships remain in place. At the regional and local level, things are different: On regional and local level upgrading or new installation of TI can alter both, habitat topology and connectivity in a way that reformation of planned or realized habitat networks is necessary on the one hand – and, on the other hand, the improvement of habitat networks and connectivity[97] is the most efficient compensation measure.

---

[92] see chapter liveable roads
[93] but always with regard to the strategic EDM and/or strategic plans for eco corridors on superregional level
[94] bundling of different TI or bundling of TI with fenced or large-scale technical infrastructure such as photovoltaic systems
[95] Following a cross-sectional approach
[96] density and quality according to chapter “thresholds for dimension and maximum distances of fauna passages”
[97] cf. Iuell et al. 2003*, Herrmann & Jennewein 2018, Reck 2013 or the “Hamburg A26 parity habitat corridor and TI development” as explained in this chapter (approaches for integrative reconnection plans can also be found, for example, in the DEGES “motorway A11 environmental concept” for the sectors between Jarmen and AK Uckermark, 120 km, with copmensation area pool "Koblentzer Seewiesen") or the defragmentation plans of the German Autobahn GmbH for the A20 in Lower Saxony or for the A39 project.

Planning acceleration

Provided that measures to safeguard biodiversity through the parallel development of habitat networks are integrated from the outset into the planning of new or expanded transport infrastructure, and if appropriate avoidance and compensation measures are defined proactively (and not only as a reaction to lawsuits), planning delays due to nature conservation concerns can be avoided. Precautionary planning for reconnection, if necessary, across several TI sections or respectively the identification of priority sites for eco passages, biotope corridors and wildlife migration routes on regional scale also provide a suitable framework for best restitution while renovations.

A possible lighthouse project

In the state of Hamburg, lawsuits with respect to the closing of a missing section in the motorway network in and around the state were avoided due to the development of a parity reconnection plan involving an eco-corridor and its improvement as well as building fauna passages. The basis in this case was an agreement between state authorities and NGOs. The following is an abridged excerpt (mutatis mutandis) from the agreement on the construction of the A26 federal motorway (west section) and on the biotope corridor between various NGOs and the state Free and Hanseatic City of Hamburg: *The Süderelbe area is currently a planning area. The NGOs object to the fact that the various projects will result in the loss of significant parts of the Süderelbe area as a habitat for animals and plants and that the Süderelbe natural area will be permanently separated from the Moor Belt natural area. Talks have been held between the parties involved to integrate nature conservation concerns into the TI development with the aim of finding a mutually agreeable overall solution. As a result, the parties involved agreed on the following: The state Hamburg undertakes to establish a biotope corridor that ensures* ***the preservation and development of functioning ecological interrelationships*** *between the moor belt in the south and the nature conservation areas in the north. The biotope corridor serves to maintain and promote biodiversity, in particular viable populations of wild animals and plants, and enables exchange between populations as well as migration and colonization. The aim is to exploit the potential of the biotope corridor as a habitat for existing and future animal and plant species typical of the natural area. ... The function of the biotope corridor as a system of interlinked biotopes and TI permeability are ensured in the area of the motorway by constructing suitable mutually complementary fauna passages.*

The area of the corridor and the respective road section as well as the planned fauna passages are shown in the following g figure.

---

* From Iuell et al., chapter 7.1.3, Fauna passages as part of a general landscape permeability concept:
“Fauna passages and other structures adapted to increase the crossing of transport infrastructure by animals should never be considered in isolation. They should be part of a general 'permeability concept' to maintain connectivity within and between populations of animals. This concept emphasizes connectivity between habitats at least at a regional scale and considers not only the transport infrastructure but also the distribution of habitats and other potential barriers such as built-up areas. Fauna passages can then be regarded as small but important elements used to connect habitats by enhancing the movements of animals across transport infrastructure. At a more specific level, a permeability concept can be produced for a particular road or railway project. All connecting elements, such as tunnels, viaducts or elevated roads, stream and river crossings, culverts, and passages designed especially for animals should be integrated into the permeability concept. Again, the primary objective must be to maintain the permeability of the transport infrastructure for wildlife to ensure the connectivity of the habitats at a larger scale.”

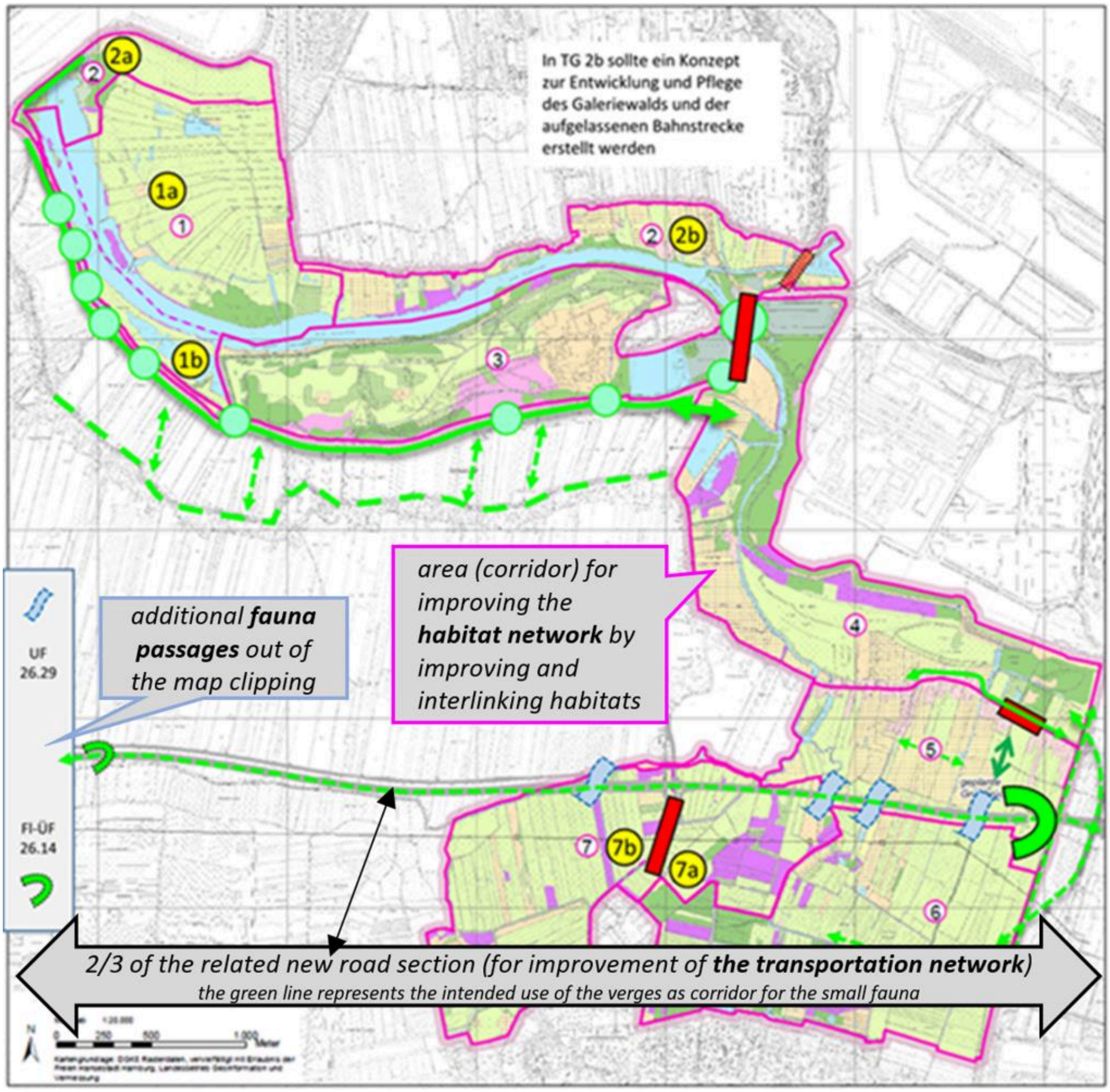


Figure 77: Area of the parity reconnection plan "Hamburg wetland corridor"

The symbols for fauna passages (ᵔ overpasses and ˜ underpasses) mark two third of the road section which effects on biodiversity are mitigated and compensation by the development of a functioning Hamburg wetland corridor within the magenta bordered area (plan by Tesch et al. 2020 in mutual agreement with the state authorities and NGOs as well as with independent reviewing experts. The related "prognostic success control" according to the idea of Marti & Stutz (1993) has shown a probably high effectiveness of an implementation for most ecological guilds which were represented by appropriate target species for defragmentation. Currently (2022) both, the transport infrastructure construction, the construction of the fauna over- and underpasses and the realization of measures for improving the habitat network have begun.

3.5.1.2 r+d needs regarding parity reconnection

Development

As the approach is very promising for safeguarding biodiversity and for acceptance of TI, a European guidance for best practice and legal implementation should be developed.

Three related subtasks would be:

a) creating a manual for practical implementation and for advertising by compiling and analysing case studies,
b) a call for lighthouse projects and
c) a compilation of legal conditions and administrative ways for integration into EU-regulations or other planning law or procedures and into European and national development programmes that allow or assist parity defragmentation as obligatory part of TI improvement.

Research (or effect monitoring respectively)

Monitoring in selected case studies, regarding achieved and achievable economic, social and ecological benefits, should be used for critical justification (e. g. effect on mitigation and compensation quality, effects on planning acceleration).

3.5.2 Needs for Fauna Passages (FP): Seven rules on "when FP are necessary"

after Reck et al. 2019

3.5.2.1 When do we mandatorily need fauna passages (FP): Instructions for the planning and maintenance of TI with regard of the EDM

Because FP are (should) always be questioned due to their costs[98], guidelines are helpful when they should generally be built. Therefore, and although there can always be justified deviations in individual cases, an agreement on minimum standards is helpful. Such minimum standards are presented and the need for their implementation is outlined. The standards are based on the preliminary proposal by Reck et al. 2019. In addition, there are clear requirements for a general minimum density of FP in the landscape (subsequent chapter, based on Hlavac 2019).

[98] As well as the goals, dimensions, or density or type of the TI itself should be questioned too.

Seven rules on when FP are necessary

Wildlife crossings are always needed:

1. If ecological networks of Europe-wide significance (in particular critical TI-sectors indicated by the EDM) or of national or state-wide significance[99] are bisected by transport infrastructure with strong barrier effects.
(A preliminary approximation or definition of the term strong barrier for roads, rails, canals and bundled TI is given in the subsequent chapter. Regarding roads strong barriers are such which are used by more than approx. 10,000 vehicles a day or, at bottlenecks in ecological networks,[100] roads which are used by more than approx. 5,000 vehicles a day and in general all road sectors with associated insurmountable structures as e. g. sheet-pile walls, fences, concrete guide barriers, curb stones or high, vertical plinths);
2. if national parks or wilderness areas or other nature conservation areas, Natura 2000 sites or protected woodlands, natural woodlands and/or conservation woodlands are bisected, and if characteristic rare or endangered species no longer have a sufficient range of habitats at their disposal on the one or other side of the TI as a result of this;[101] *exceptions: if compensatory habitat enlargement and/or habitat optimisation are envisaged and possible, wildlife crossings are not required*;
3. if severely endangered biotope types (individual sites or agglomerations of homogeneous biotopes located less than 1,000 m apart[102]) are effectively so fragmented that, as a result, characteristic rare or endangered species no longer have a sufficient range of habitats at their disposal;
exceptions: if compensatory habitat enlargement and/or habitat optimisation are envisaged and possible, wildlife crossings are not required;
4. if habitats, populations or metapopulations and/or functional areas or migration routes of very rare or severely endangered species, independently if the affected species are large as bears or small as grasshoppers, are effectively bisected in such a way that their ranges or populations are less than the necessary minimum sizes;
exceptions: if compensatory habitat enlargement and/or habitat optimisation are envisaged and possible, wildlife crossings are not required;
5. if important migration routes of migrating species that are not severely endangered, if at all, are bisected in such a way that the populations in question come to be endangered. The significance (importance) of migration routes derives from the relative significance of the populations affected (= population far larger than average, density of wildlife paths far above average or populations

---

[99] E. g. target areas for supraregional habitat-corridor and/or ecological-network plans, e. g. priority areas or main network axes of state-wide significance, cross-state or cross-nation ecological-network axes or national wild-animal corridors (see figures in chapter "minimum densities for ecological corridors").

[100] The width of one of the relevant biotope types is less than approx. 30 m (and it is not possible for such to be expanded).

[101] Relates to: (a) minimum range and/or MVP90/50 (MVP90/50 means there is a 90% probability the population will still exist in 50 years) or (b) for severely endangered large mammals: home/activity ranges of reproduction groups as well.

[102] Undissected functional areas, see Naturschutz und Biologische Vielfalt, no. 62. or
https://www.bfn.de/themen/planung/eingriffe/wirkungsprognosen/zerschneidung-wiedervernetzung.html

important in terms of the geography of animal ranges);
exceptions: if compensatory habitat enlargement and/or habitat optimisation are envisaged and possible, wildlife crossings are not required; e. g. substitute spawning grounds for amphibians;

6. if waters are crossed. All water crossings are to be designed in such a way that species living in the water body or the bed of the water are able to cross the infrastructure and at least one ledge along the bank is present as well. Needs with further-reaching implications concerning passages/underpasses arise if the above-mentioned criteria are fulfilled;
7. if coherent ungulate populations of far above average size are bisected by transport infrastructure and the transport infrastructure is used by more than 5,000 vehicles a day or insurmountable built structures are associated with the transport infrastructure.

3.5.2.2 Development needs regarding standard rules for the implementation of large fauna passages across Transport Infrastructure (TI)

Due to excessive fragmentation, the construction of large fauna passages is a priority. As a first step, it is therefore recommended that the seven rules be immediately regarded by the transport administration. At the same time a broad discussion and improvement of the proposed convention should be started. Third step is the adoption of the resulting best practice recommendation by legal boards and the implementation in respective European directives and strategies (Impact assessment and regulation, defragmentation, safeguarding the functionality of protected habitats and of wilderness areas, green infrastructure, eco-corridors, natura 2000 network.

3.5.3 Thresholds for the dimension and for maximum distances of fauna passages or ecoducts at strong barriers

Heinrich Reck, Vaclav Hlavac, Martin Strein & Marita Böttcher

Summary and policy implications

Meeting the presented standards for minimum dimensions and minimum density of fauna passages is crucial for reducing the impact of transport infrastructure on ecological networks and animal populations due to barrier effects. Compliance with these standards is essential for the success of the EU's biodiversity and green infrastructure strategies, as well as for the approval of new TI projects and TI renovations. Fulfilling the standards reduces the risk of delays in TI execution due to incorrect impact mitigation, which could result in legal challenges. Although deviations from the standards may be necessary in some cases due to local particularities or special project characteristics, they must be well-defined and justified on a case-by-case basis.

Meeting the standards could furthermore serve as a main indicator, among others, for assessing the fulfilment of the EU biodiversity and the EU Green Infrastructure strategies, particularly in critical sections of the European Transportation Network as e. g. identified in the European Defragmentation Map developed within the BISON-project.

However, the standards need to be regularly updated since knowledge about functioning fauna passages and the requirements for their successful integration into the hinterland are still being improved. Therefore, research and development needs are outlined to enhance the effectiveness of fauna passages and ensure their successful integration into ecological networks.

3.5.3.1 Thresholds for guild-specific minimum size of fauna passages (FP)

State of knowledge

It is important to continuously update our understanding of the effectiveness of fauna passages (FP) or ecoducts, as there are relatively few quantifiable scientific studies that compare the activity density of animals on and in FP with the activity density in portal or access areas. Additionally, previous results have high variance due to interactions between the dimension requirements and the type of disturbance or location in relation to different types of land use and habitats. It is important to note that experiences made in one country may not be directly transferable to another country without further consideration.

In the following, threshold values for orientation (as of 2022[103]) are compiled on requirements for the dimension of FP regarding wide and heavily trafficked (or wide and fenced) roads and other strong TI-related barriers (TI = Transportation Infrastructure).

Technical standards and ecological flexibility

In e. g. Germany, the FGSV instruction on ecological passages (= MAQn, Attermeyer et al. 2022) defines the standard requirements for the dimensions of ecological passages (FP) with legal implications. In e. g. Czech Republic, we find the strong recommendation of Hlavac et al (2020). While requirements for the density of crossing aids are not included in the MAQn, the Czech paper and similar publications for the Carpathians (Hlavac et al. 2019) provide guidance on this matter.

Because the ecological effectiveness of FP is not only dependent on the dimension, but on several interacting factors, which in turn have different taxon-specific or guild-specific effects[104], standard ecological measures can at best be derived as a framework.

The most important interacting factors are:

- the integration and connection (stepstone biotopes, guiding elements) to the surrounding landscape or to habitat networks (hinterland integration),
- the density of individuals of the respective target species in the access area,
- the orographic and microclimatic conditions (especially terrain and respective exposure or sunlight as well as soil moisture),
- the freedom from disturbance or the extent of disturbance (for larger mammals, the absence of hunting at FP and the type of hunting in the hinterland are of decisive importance), or
- the density or combination of different neighboring FP.

Tab. 1 of Reck et al. 2019 contains a detailed list of important factors with information on the different importance of the factors depending on species or ecological guilds. Depending on how a certain factor

[103] And with regard of recommendations by Attermeyer et al. 2022, Fuhrmann & Tauchert 2010, Helldin 2022, Hakansson 2020, Hlavac et al. 2019, Iuell et al. 2003 / Rosell et al. 2022 (with respect to IENE 2022), Kruidering et al. 2005, Struijk et al. (2014), U.S.DT 2022, Weber 2011, Zinner et al. 2018 as well as of results from the ongoing project "monitoring of fauna passages in Schleswig-Holstein" (data of Schulz, B., Schulz, H., Jordan, N. & Petersen S.)

[104] Thus on ungulates differently than on e. g. pawed animals or on e. g. grasshoppers.

is developed, another can or must be changed and, especially for mammals, habituation plays an important role. Thus, the behavior of resident individuals familiar with the locality or guided by an experienced lead animal differs considerably from the behavior of non-resident, dispersing individuals. If, for example, resident deer are the main target species of a FP at a quiet site, free of hunting over a large area and if solutions have been created elsewhere for other target species (e. g. grasshoppers, lizards or dormice), relatively narrow underpasses may be sufficient for the ungulates. Depending on height and length, relatively narrow underpasses, e. g. 30 m wide, may be sufficient even for red deer, whereas in the average landscape and with regard to migrating deer, underpass widths according to e. g. MAQn may be required (i.e. widths of up to 80 m). If several FP for ungulates are built complementarily in close spatial proximity to each other, smaller FP are again sufficient, at least in part (cf. Helldin 2021, Herrmann & Jennewein 2019). **This does not raise the so-called SLOSS question (single large or several small), but the question of the most favorable sequence of large and small crossing aids (the SLASS question: some large and several small).**

Unless deviations can be suggested because of requirements of individual cases (also with regard to the interaction of several structures), the standard dimensions of the MAQn (see below) should be used or dimensions that are rated "reliably usable" according to the following table. In the case of a FP density according to Table 2, however, the requirements for the dimension can often be reduced (the category "generally usable" according to the following table can then suffice, with e. g. the exception of important long-distance migration corridors for larger mammals).

Still unclear is the role of green strip buildings (passages built of narrow strips of soil or vegetation along TI or even as standalone passages). It is possible that a high density of green strip buildings / green strip passages can replace some larger fauna passages or at least increase connectivity or help single species. While, as underpasses, they seem to be effective for small mammals, there are no data available to assess the effects on other taxa.

Traffic light evaluation of FP function on wide traffic routes or route bundles

Threshold values for orientation to check the suitability for

- integrative habitat corridors,
- aquatic and riparian ecosystems and
- vertebrates[105].

The ratings "insufficient", "possibly usable", "usually usable", "reliably usable" and "standard according to MAQn" refer to regular usability by the respective animal species and, with regard to the

[105] The necessary dimensions for invertebrates (as far as they are not adequately represented within the framework of habitat corridors - see following table section C) are strongly dependent on the habitat or habitat requirements of any species in need of special protection that may be affected. The dimensions of FP must be chosen in such a way that the habitat characteristics in or on and in the portal area of the FP can be adequately established except for very short gaps - this is often difficult or impossible to achieve in underpasses, especially for diurnal species of dry-warm habitats (high, sunlit structures); in this case, only overpasses can help. Due to sometimes very restricted occurrence of specialized species along TI, green strip passages should be tested for suitability as complement.

category "reliably usable" / "standard according to MAQn", in particular also to non-resident individuals, i. e. dismigrating individuals without local experience.

Under particularly favorable circumstances, single individuals, e. g. single roe deer, occasionally use tunnels, which are rated as "insufficient" in the following table (cf. e. g. Weber 2011). For many reptile species and even more so for flightless, diurnal and heliophile insects, the attractiveness of the access area as well as substrate quality and moisture, vegetation structure and hiding places as well as warmth or illumination play the decisive role. Therefore, the indirectly substantiated demands of small animals on the dimensions of underpasses can be greater than those of some large animals.

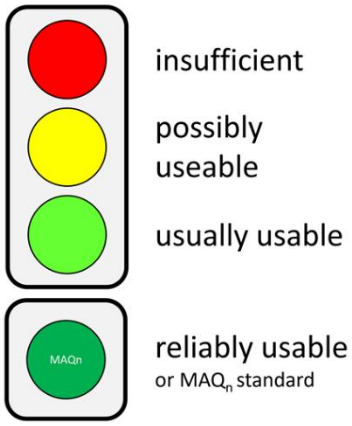


Table 27: Dimensions and resulting usability of fauna or eco passages (FP) in Central Europe[106]

Information and legends to the table

Editors and structure

Interpretation of recent monitoring results and recommendations with special reference to Hlavac et al. 2019 by H. Reck & M. Strein, as of 2022[107]

The assessments are divided into 3 table sections: Section A: Mammals (excluding bats), Section B: Herpetofauna/invertebrates, Section C: Aquatic and riparian ecosystems and habitat or eco-corridors

General conditions

1. The information on height and width applies to underpasses of about 30-40 m in length and overpasses of about 60-80 m in length (corresponding to traffic routes of about 30 m in width; with route widths of e. g. 15 m, on the one hand the necessary width for vertebrates can be significantly reduced, while on the other hand the necessary width for invertebrates or for biocoenoses of habitat networks always results from the number of habitat types to be bridged or underpassed, whereby the relevant minimum widths or, in the case of an underpass, special requirements for brightness are added).
   With regard to overpasses, the requirements for widths presumably increase rather linearly with increasing length, whereas for underpasses the requirements for opening widths increase exponentially.

2. The "effective width" does not have to be interpreted as a "usable width" in the sense of full accessibility; for example, the effective width of a wide watercourse passage for ungulates can correspond to the total width, even if only a part of the underpass in the form of flat berms is available as a walking surface.

[106] Eco-regional deviations are to be expected for the small fauna in warmer climate and for larger mammals due to regionally different hunting systems and population densities or for northern species like reindeer.

[107] Prepared within the framework of work on the projects (1) "Habitat networks and the avoidance of habitat fragmentation" on behalf of BfN, (2) "Biodiversity and Infrastructure Synergies and Opportunities" funded from the European Union Horizon 2020 programme, (3) "Bio-ecological effectiveness of underpasses for small animals" on behalf of BfN, (4) "Monitoring of the green bridges at Kiebitzholm, Brokenlande, Clashorn, Strukdorf and Gudow as well as the Stolpe wildlife underpass" on behalf of the Foundation for Nature Conservation and Via Solutions Nord, and in particular (5) in the context of the planning of the new construction and upgrading of the A20 and A23 motorways in Schleswig-Holstein on behalf of Deutsche Einheit Fernstraßenplanungs- und -bau GmbH (DEGES)

3. Assuming that the design and connectivity are appropriate.
4. The (unclear) effect of splaying (light gaps between traffic lanes) is not taken into account.
5. The requirements for large mammals result from the general disturbance regimes currently prevailing in Germany, such as territorial hunting (Revierjagd), but at the same time also under the assumption of local quieting and obstacle-free connection to the surrounding landscape.
6. The newly revised instruction sheet for FP (MAQn, Attermeyer et al. 2022) is obligatory for approval of new roads in Germany and used as a decisive framework; the MAQn requires a high usability of the passages also for non-resident individuals (individuals that are of high importance for recolonization processes or large-scale metapopulation systems, but which are not familiar with the locality and for which it is assumed that they show a strong avoidance behavior towards unknown narrow FP); it is assumed that FP that meet the requirements of the MAQn are fully effective for flightless vertebrates. Restrictions apply to heliophile and/or xerothermophile small animals in underpasses, for which it is not yet possible to determine to what extent or in what dimension those are actually effective. For this purpose, the MAQn data may be unsuitable and relative passage widths (w*h/2l) of more than at least 2.8 are probably necessary.

Legend

MAQ_n = Guidelines for FP along roads, new version (Attermeyer et al. 2022). For larger mammals, the MAQn data on dimensions generally assume considerable freedom from disturbance and nearby stepping stone biotopes (closer than 100 m).

% = required and, where data are available, measured activity densities in the structure compared to activity densities in its immediate vicinity.

n.p. = not provided.

* = Height above solid ground/above the berm (in low structures ungulates also cross in the water as long as the water depth is not too high and the riverbed is sufficiently firm).

Measures w = width, h = height, l = length ((each from the point of view of a crossing animal, MW = mean water level, HW_{10} = water level of an average 10-year flood).

Explanations on small mammals and herpetofauna

In contrast to the MAQn, no specific information is provided on predominantly ground-dwelling small mammals. All FP suitable for foxes are certainly suitable for them in terms of dimensions, and the same applies to marten species; - with one possible exception, insofar as the MAQn (Attermeyer et al. 2022) is to be taken into account: For the pine marten, the MAQn requires considerably larger dimensions than for fox or badger, deviating from the following information. The decisive factor for small mammals is the provision of structural elements and hiding places at the respective FP and - especially - the design of an access and portal area that is attractive as a habitat.

On dormice: All FP suitable for brown hares are suitable in terms of dimensions, but only if there are almost no gaps in the branch cover.

On bats: Special guidelines have been developed for this; bats are not dealt with here; if necessary, the widespread 36 m^2 requirement (FRG) or > 24 m^2 (NL) for the opening width of underpasses for sensitive bat species should be taken into account.

On reptiles: Existing data on underpasses are still very different or controversial. Observations on the interaction of dimensions and use of underpasses are lacking; it is possible that long, shaded subways are generally unsuitable for most species (at least for lizards in moderate and cold climate).

On amphibians: Specially designed small animal protection facilities (MAQn, Figure 30) are often required at special migration corridors (spawning migrations). ....
According to Fuhrmann & Tauchert (2010), small sized culverts (width < 2m, height < 1.5 - 2m) will probably not work for frogs and toads if the culvert is longer than 15-20 m and for newts if the culvert is longer than 10-15m.

As a rule: The quality of the design of the access area, including guiding elements and, if necessary, protection against irritation, is always particularly relevant.

Table section A: **Mammals** (without bats)

Affected acceptor (species type)	**Assessment for underpasses or culverts with a length of approx. 25 to 35 m** [or la length of about 15 m (e. g. 2-track railways), approx. half to two thirds of the specified width is sufficient for vertebrates; - for l > 35 m, the underpass must be dimensioned larger (presumably disproportionately larger)]					**and for respective overpasses**
	Usability	%	Effective width in m	Minimum berm, width in m, each	Height in m*[108]	Effective width in m
fox, badger marten, beaver, epigeic small mammals	insufficient	≤ 20 %	< 0.5	< 0.5	< 0.5	< 0.5
	possibly useable	up to 45 %	0.5 to < 1	0.5 to 1	0.5 to 1	0.5 to < 2
	usually useable	up to 90 %	> 1 to 2.5	> 1 to 2.5	1 to 2	> 2 to 5
	reliably usable	> 90 %	> 2.5	> 2.5	> 2	> 5
	at main game paths after MAQn		≥ 20		≥ 2.5	≥ 20
Otter (beaver) ! Specific demands at high watermarks	insufficient	≤ 20 %	< 0.5	< 0.5	< 0.5	at running waters: for overpasses like fox or badger
	possibly useable	up to 45 %	0.5 to < 1	0.5 to 1	0.5 to 1	
	usually useable	up to 90 %	> 1 to 2.5	> 1 to < 3	1 to 1.5	
	reliably usable	> 90 %	≥ 2.5	3.0	> 1.5 *[109]*	
	Along water bodies according to MAQn (data for lengths from 25 m; for further differentiations see MAQn)		watercourse plus double-sided berms 1*MW, 1*HW_{10}	each ≥ 2.5 at MW, and one ≥ 1.5 at HW_{10}	≥ 2,25 m higher than HW_{10}	
	For overland dispersal according to MAQn		Dry culverts (between e. g. lakes): h ≥ 2, w ≥ 3.5			over land
Wolf, Lynx, Wildcat, pine marten			*So far, only few usable data are available and expert opinions differ considerably; the recommended author's opinion of **2-3 times the width and 1.5-2 times the height as given for "fox"** is not shared by many colleagues, especially with regard to the wolf (they often demand larger dimensions, see also MAQn).*			
	MAQn for dispersing for resident		≥ 80 ≥ 30	n.p. n.p.	≥ 5 ≥ 5	≥ 50 ≥ 30
European hare dormice	insufficient	≤ 20 %	< 6	< 1.5	< 1	< 3
	possibly useable	up to 45 %	6 to < 12	≥ 1.5	1 to < 2	3 to < 6
	usually useable	up to 90 %	12 to < 20	≥ 1.5	2 to < 5	6 to < 10
	reliably usable	> 90 %	≥ 20	≥ 1.5	≥ 5	≥ 10
	MAQn-for hare Attermeyer et al. 2022		≥ 20		≥ 5	≥ 20
	MAQn-for dormice (here greatly simplified)				≥ 5	

108 Height above solid ground/above the berm for mean water level MW (in low structures ungulates also cross in the water as long as the water depth is not too high and the riverbed is sufficiently firm)

109 If, at roads, there is an otter-safe fence above; if not, a berm above HW_{10} seems to be necessary to avoid roadkill

Continuation of table section A: **Mammals** (without bats)

Affected acceptor (species type)	**Assessment for underpasses or culverts with a length of approx. 25 to 35 m** [or la length of about 15 m (e. g. 2-track railways), approx. half to two thirds of the specified width is sufficient for vertebrates; - for l > 35 m, the underpass must be dimensioned larger (presumably disproportionately larger)]					**and for respective overpasses**
	Usability	%	Effective width in m	Minimum berm, width in m, each	Height in m*[110]	Effective width in m
Fallow deer, roe deer* and wild boar[111]	insufficient	≤ 20 %	< 10	< 3	< 1,8	< 2
	possibly useable	up to 45 %	10 to < 15 20	≥ 3	1,8 to 3.5	2 to < 10
	usually useable	up to 90 %	15* 20 to < 20* 30	≥ 3	3.5 to 5	10 to < 20
	reliably usable	> 90 %	≥ 20* 30	≥ 3	≥ 5	≥ 20
	MAQn		≥ 30 m		≥ 5 m	≥ 30
Red deer[112] (and other, larger ungulate species)	insufficient	20 %	< 10?	< 5	< 2.5	< 10
	possibly useable	up to 45 %	10 to < 30?	≥ 5	2.5 to < 4	10 to 30
	usually useable	up to 90 %	30 to < 80?	≥ 5	4 to < 5	30 to 50
	reliably usable	> 90 %	≥ 80	≥ 5	≥ 5	≥ 50
	MAQn- Attermeyer et al. 2022		≥ 80	n.p.	≥ 10, (≥ 5°); resp. °*w*h/l* ≥ *1.5*	≥ 50 m

[110] Height above solid ground/above the berm for mean water level MW (in low structures ungulates also cross in the water as long as the water depth is not too high and the riverbed is sufficiently firm)

[111] For these species, Hlavac et al. 2019 call for similar dimensions. *For roe deer, current, unconfirmed data suggest that (depending on disturbance) smaller dimensions may be sufficient (data from Jordan 2019 and Petersen 2022, fauna passage monitoring in Schleswig-Holstein; see also Hakansson 2020 or Fehlberg & Pohlmeyer (1994) which report successful roe deer crossings of 0,5 per observation day in an underpass of w=1,3m * h=8,7m / l=30m).

[112] Hlavac et al. 2019 demand 1.5 to 2 times the width for red deer overpasses, depending on the assignment of the effectiveness rating, if the effectiveness rating "very good" by Hlavac et al. is equated with "reliably usable"; if the rating "good" is equated with "reliably usable", the values correspond; the values given for underpasses are similar to Hlavac et al.

Table section B: Herpetofauna

Affected acceptor (species type)	Assessment for underpasses or culverts with a length of approx. 25 to 35 m [or la length of about 15 m (e. g. 2-track railways), approx. half to two thirds of the specified width is sufficient for vertebrates; - for l > 35 m, the underpass must be dimensioned larger (presumably disproportionately larger)]					and for respective overpasses equipped with guiding elements and hiding structures
	Usability	%	Effective width in m	Minimum berm, width in m, each	Height in m*	Effective width in m
Amphibians Not all species are represented; e. g. observations on the yellow-bellied toad are missing		n.p.	*For amphibian culverts longer than 20 m, the authors did not have reliable information*			
	insufficient	n.p.	*< 0.5?*	*< 0.5?*	*< 0.5?*	< 0.5
	possibly useable	n.p.	*0.5 to < 1?*	*0.5 to < 1?*	*0.5 to 0.8?*	0.5 to < 2.5
	usually useable	n.p.	***According to Fuhrmann & Tauchert (2010) small sized culverts (width < 2m, height < 1,5-2m) will probably not work for frogs and toads if the culvert is longer than 15-20 m and for newts if the culvert is longer than 10-15m;*** *Sinsch & Stamann in turn report from a single site in 2023 that a culvert of w=2m*h=2m and l=42m was usable at least occasionally for Anura*			≥ 2.5
	reliably usable	n.p.				≥ 2.5
	MAQn	n.p.	*Up to l=20 m w ≥ 1 m, h ≥ 1m*	*much larger dimensions if l > 20 m*	*≥ 1 m, higher if l > 20 m*	n.p.
Reptiles		n.p.	*Data insufficient; species-specific use very different (unlike grass snakes, lizards in temperate and cool climates seem to use only very short or very large underpasses at best* *(cf. Struijk, et al. 2014)*			*Vegetated or richly structured overpasses are excellently used*
	MAQn (2022	n.p.	*the sun exposure defines the necessary width*	*2.0 to 5.0 in width, vegetated and intermittently sunlit*	n.p.	≥ 5

Table section C: Watercourse and riparian ecosystems and habitat corridors

Affected acceptor (species type)	**Assessment for underpasses or culverts with a length of approx. 25 to 35 m** [or la length of about 15 m (e. g. 2-track railways), approx. half to two thirds of the specified width is sufficient for vertebrates; - for l > 35 m, the underpass must be dimensioned larger (presumably disproportionately larger)]				**and for respective overpasses**
	Usability	Effective width in m	Minimum berm, width in m, each	Height in m*	Effective width in m
Ditches and ditch edge species (without large animals and without heliophile species)	insufficient	< ca. 1,5	< 0.5	< 0.5	/
	possibly useable	ditch width plus berms 0.5 to < 1		0.5 to < 0.8	/
	usually useable	ditch width plus berms 1,0 to < 1.5		0.8 < 1.5	/
	reliably usable	ditch width plus berms ≥ 1.5		≥ 1.5	/
Originally natural water bodies but not such within habitat corridors as listed below, usable for limnic species and many riverside species but without red deer and the heliophile small fauna	insufficient	≤ ca. 10	< two times 4	< 2	/
	possibly useable	Watercourse width plus berms	two times 4 to < 8	2 to < 3.5	/
	usually useable	Watercourse width plus berms	two times 8 to < 20	3.5 to < 5	In mountainous areas (TI routes along slopes) streams may be routed over tunnels; here, no transverse construction may take place in the water and at least 5 m bank strips are required on each side
	MAQn Reliably usable for limnic species and many riverside species but without red deer and the heliophile small fauna (cf. thresholds for otter)	Watercourse width plus berms (berm width see on the right)	Watercourse width plus 2*watercourse width or, from watercourse width 8m: watercourse width + 2*20m	Minimum ≥ 1.5m above mean high water level and, for creeks up to 5m width: height = width; for rivers and streams: h = 5 m minimum, better 10 m above mean high water level	
Habitat corridors[113] regarding a single, Individual structure, for combined structures smaller dimensions each can be sufficient	insufficient	< 20	< 30	< 2.5	< 30
	possibly useable	20 to < 40	30 to < 40	2.5 to < 4	30 to < 40
	usually useable	40 to < 80	40 to < 50	4 to < 5	40 to < 50
	reliably usable	≥ 80	≥ 50	≥ 10 (? ≥ 5)	≥ 50

[113] Hlavac et al. 2019 request 1.5 to 2 times the width for overpasses, depending on the degree of effectiveness, if the effectiveness rating "very good" is equated with "reliably usable"; if the rating "good" is equated with "usually usable", the values correspond; for subways, Hlavac et al. do not provide information on the effectiveness for habitat corridors.

***For further comparison** see, e. g. U.S.D.T. (2022), Kruidering et al. (2005), IENE (2022) and particularly WILDLIFE AND TRAFFIC a European Handbook for Identifying Conflicts and Designing Solutions hosted by IENE: https://handbookwildlifetraffic.info/. **Besides placement** which is decisive for both, for larger animals the size and freedom of disturbance is most important while it is biotope quality, habitat topology and respective mirror fronts for the small fauna (compare table 1 and fig 54-56 in https://www.researchgate.net/publication/331546583_Green_Bridges_Wildlife_Tunnels_-and_Fauna_Culverts_The_Biodiversity_Approach_Grunbrucken_Faunatunnel_und_Tierdurchlasse_-_Anforderungen_an_Querungshilfen).*

Figure 78: Recent construction site of inadequate fauna passages at an important corridor/watercourse in the Rhine valley

Photo. M. Strein 2021. There is a great need to avoid useless or inadequate solutions (and/or inappropriate mono-species solutions too). The ecosystem or multi species approach should always be in the foreground.

Figure 79: Wolves in an underpass (1)

Wolves (C3) crossing the motorway A7 in Schleswig-Holstein (SH) on the right berm (l = 39 m, berm width = 1.6, h = 0.9 m) of a watercourse (total FP width = 7 m); photos: Wolf caretakers SH / W. Springborn

Figure 80: Wolf in an underpass (2)

*Wolf crossings below the motorway A21 in Schleswig-Holstein
(watercourse underpass with berms; dimensions: l = 34,5 m, berm width ca. 1.5 m each, h above berm ca. 1, 5 m at its lowest point); one of the known two wolves in the area was overrun in March 2023 on a nearby highway in a section without fauna passage or fence; photos: Wolf caretakers SH*

No scheme for invertebrates yet

The necessary dimensions for invertebrates (as far as they are not adequately represented in the framework of habitat corridors) are strongly dependent on the demands of affected species on the respective habitats. The dimensions of FP must be chosen in such a way that the habitat characteristics in or on as well as in the portal area of the FP can be adequately established except for very short interruptions each when multiple habitats intersect. This is often difficult to achieve in underpasses, especially for diurnal species of dry-warm habitats. For general rules for the necessity of FP, see Reck et al. 2019, p. 24). Further information on minimum requirements on underpasses for insects but also reptiles and arboreal mammals is urgently needed.

Sketches of a preliminary test application

The next figures show results of a preliminary assessment of mitigation measures (underpasses and overpasses) for their usability to safeguard eco-corridors and the migration of some selected taxa[114]. Therefore, the traffic-light criteria were translated into a GIS-Algorithm, so that any changes in the construction plans can immediately be represented in the overall assessment map. If standards for avoiding fragmentation (or, in case of an existing TI, standards for defragmentation) are not met then, there is a need to give overriding reasons in very detail or projects can no longer get approval.

[114] The represented defragmentation concept (the arrangement and mostly the dimensions and landscape integration of the fauna passages (FP) are meanwhile adapted in a still ongoing improvement procedure as are the used thresholds; not all surveyed taxa are shown.

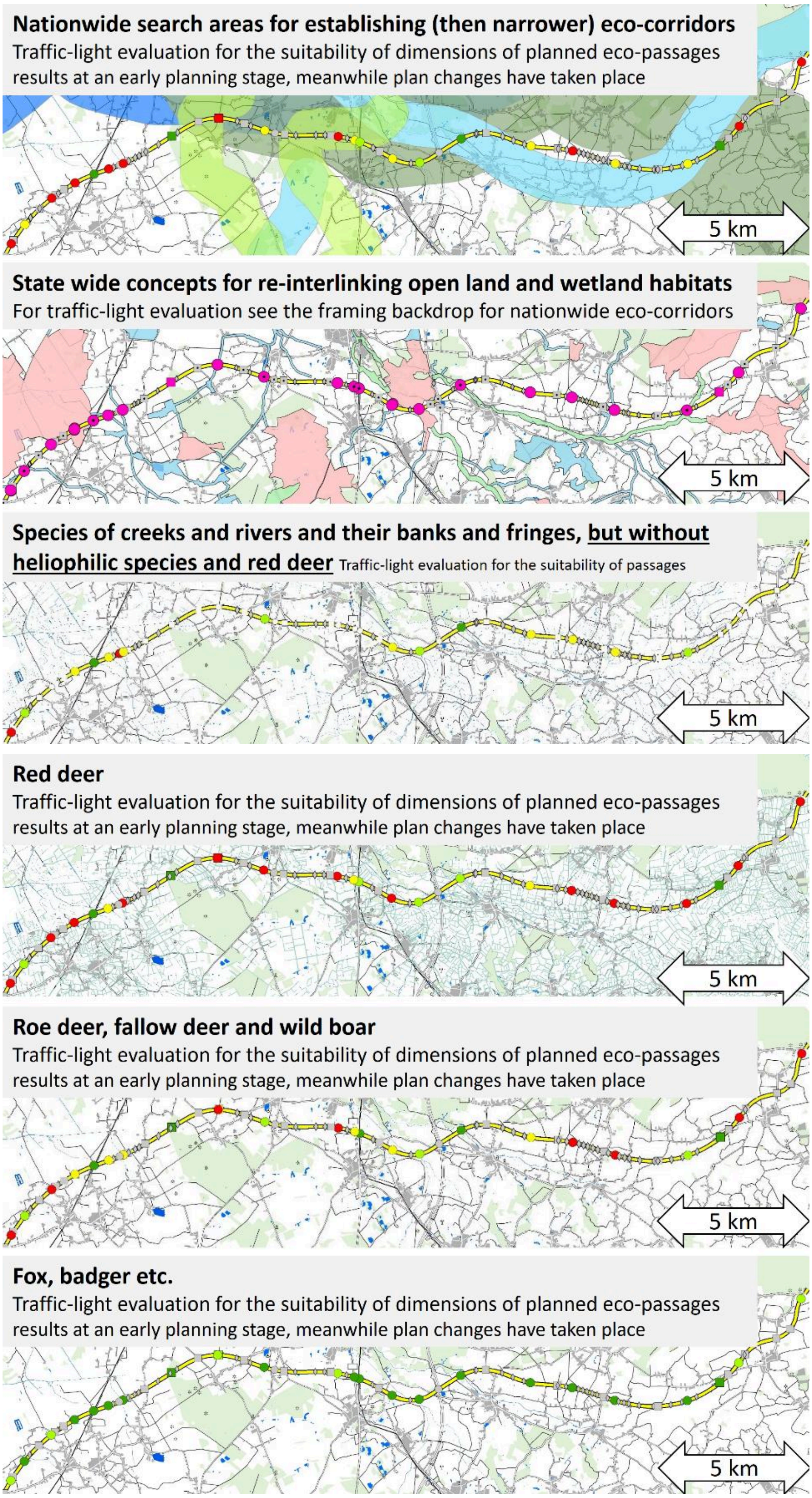


Figure 81 a-f: Application of FP assessment for estimation of the resulting connectivity of ecological corridors, habitats, and populations on regional level

The results can be tested against the framework for minimum demands on the densities for functioning passages (FP) as described in the following chapter “Thresholds for maximum distances of fauna passages / eco-ducts at strong barriers - a standard based on the proposal by Hlavac et al. 2019”.

3.5.3.2 Thresholds for maximum distances of fauna passages / ecoducts at strong barriers: Standards, based on the proposal by Hlavac et al. 2019

Note on the application

Experience and recommendations on the necessary density of fauna passages or ecoducts respectively depend on the strength of the barriers under consideration and their location in relation to habitat and land use topology and wildlife routes on the one hand, and on the current state of knowledge on the other.

In the following, a simple overview or a standard requirement for minimum densities at strong barriers is given with the state of knowledge in 2022. Deviations from the standard may be possible due to local peculiarities or new findings. However, this must be justified in individual cases (e. g. if measures for improving or reestablishment of biotope networks are implemented in connection with the upgrading or new construction of transport infrastructure, or if habitat corridors are created within the framework of a parity-developed connectivity concept, or if large-scale settlement structures make a sensible design of fauna passages impossible).

The following standard is closely based on Hlavac et al. 2019. However, before it can be applied, important wildlife routes and biotope corridors must always be identified locally and, if necessary, secured in their functions as a whole. The standard itself only defines the minimum density of passages as a reference. In individual cases, a higher density may be required.

The terms "fauna passage or ecoduct" in the context of this chapter usually refer to integrative multispecies overpasses or underpasses as also described by Attermeyer 2022, Reck et al. 2019 or by Kruidering et al. 2005 (“ecoducts”, p 75 ff). However, depending on the barrier type, alternative passages may be appropriate in individual cases. Along railway lines, passages can be created for small animals through suitable design of the accompanying habitats and verges, the railway embankments and through deeply levelled ballast or, for large animals, through the design of attractive crossing areas (well-placed cover nearby as well as tread mats on the ballast) which are coupled with wildlife warning systems (warning systems that warn the wildlife immediately before the arrival of a train[115]). Special features such as amphibian migrations may require additional measures.

[115] Babinska-Werka et al. (2015), Backs et al. (2017), Eilertsen et al. (0221), Seiler & Olsson (2017), Shimura et al. (2021), Zylkowska et al. (2021)

The standard density requirements - tabulated

Table 28: Comparison values for estimating the necessary densities of effective passages across strong, linear barriers (based on Hlavac et al. 2019)[116]

Functioning passages for or according to the requirements of:	Large mammals as e. g. red deer	Larger herbivores as e. g. roe deer or hare and wolves and lynxes as well	Medium-size carnivores as e. g. badger, fox or marten	Supra-regional important habitat corridors,[117] or: small fauna / special guilds	Recommended proportion of functional fauna passages from the total length of the infrastructure Share of eco-corridors/passages with respect to the length of strong-barrier TI
in/at					
Forests	In core areas: Every 5 km. Outside of such areas: At long-distance migration routes (but not necessarily more than 1 passage per 5 km TI).	Every 2-3 km: Suitable smaller passages that are also usable for the smaller fauna	Every 1-2 (3) km	At eco-corridors: larger integrative passages; plus every 2.5 km (or at bat pathways) smaller but still integrative passages and/or culverts for amphibian migration	If mostly overpasses: 1-2 % or, if mostly underpasses: 2-3 %
Near natural or species rich (semi-) open landscapes				At eco-corridors: larger integrative passages; plus every 2.5 km (or at bat pathways) smaller but still integrative passages plus culverts at amphibian migration paths	If possible overpasses: 1-2 %; if underpasses: 3 % or more
Near natural wetlands					Preferably 10 %
Running waters	At long-distance migration routes, but not necessarily more than 1 passage per 5 km TI	At all (at least formerly) natural watercourses and main ditches in eco-corridors: Larger underpasses; at other sites due to minimum standards as described in Attermeyer et al. 2022 or preceding chapter respectively[118]			100 % of the water body plus wide berms

[116] Compiled within the framework of work on the projects "Habitat networks and the avoidance of habitat fragmentation" on behalf of BfN, "Biodiversity and Infrastructure Synergies and Opportunities" funded from the European Union Horizon 2020 programme, and in the context of the planning of the new construction and upgrading of the A20 and A23 motorways in Schleswig-Holstein on behalf of Deutsche Einheit Fernstraßenplanungs- und -bau GmbH (DEGES).

[117] Factual corridors and special potentials for reconnection as well as concepts or plans of the European Communities, national or state governments or regional planning authorities.

[118] Exceptions may be made in the case of very high densities of smaller watercourses; in this case, however, special habitat corridors or ecosystems are usually affected, for which special solutions are required (viaducts etc.); main ditches whose water level at mean water level is wider than 1 m are considered as relevant ditches.

ff: Table continuation on the next page

Table 28, continuation

Functioning passages for or according to the requirements of:	Large mammals as e. g. red deer	Larger herbivores as e. g. roe deer or hare and wolves and lynxes as well	Medium-size carnivores as e. g. badger, fox or marten	Supra-regional important habitat corridors,[119] or: small fauna / special guilds	Recommended proportion of functional fauna passages from the total length of the infrastructure Share of eco-corridors/passages with respect to the length of strong-barrier TI
in/at					
Intensively used farming landscapes	Every 10 km and/or at long-distance migration routes, but not necessarily more than 1 passage per 5 km TI	Every 4-5 km	Every 2-3 (4) km	Every 5 km (or at bat pathways) one smaller but still integrative passages plus culverts at amphibian migration paths	1-2 %
Settlements	At long-distance migration routes (if), but not necessarily more than 1 passage per 5 km TI	At supra-regional eco-corridors		At eco-corridors; and (if affected) special bat or amphibian passages	dependent on the specific structure of the affected settlement area

***integrative** = suitable for small animals and large animals of the respective habitat type but dimensioned according to the requirements of the respective large animals, i.e. not the entire spectrum of small animal habitats is included in the underpass or overpass, the usable width is small, such as at grass verge overpasses; **for specific dimension requirements**, see preceding chapter; **for design, see** Attermeyer et al. 2022 and Reck et al. 2019; **for special cases** such as two-lane railway tracks, see text.*

What are strong barriers in relation to habitat corridors or axes of the supra-local biotope network? - A list of preliminary criteria

The following criteria are a preliminary approximation. Scientific studies on population-biological or areal-geographical interactions with different barrier types are lacking. As strong barriers for flightless species with active dispersal in relation to the aforementioned standards can be considered (as of 2022, non-exhaustive list):

1. in habitat corridors or biotope networks outside confined spaces or bottlenecks respectively [120]

[119] Factual corridors and special potentials for reconnection as well as concepts or plans of the European Communities, national or state governments or regional planning authorities.

[120] The term bottleneck is defined differently in different contexts. **Definition 1** is related to habitat networks meeting settlement zones (Hänel et al. 2015): A bottleneck is a specific section of the landscape where one or more habitat networks could potentially be blocked by the growth of settlements. Bottlenecks in this context are roughly gaps < 1,000 m between settlements. **Definition 2** is related to de facto habitat corridors: Here, bottlenecks are areas where stepping stone biotopes in stepping stone corridors of less than 300 m in width or, as the case may be, landscape corridors narrower than 300 m hit linear TI –related barriers.

a) Roads with a vehicle density of ≥ 10,000 vehicles/day,
b) Railway lines with more than approx. 300 to 360 trains per day or with more than 4 parallel tracks or, depending on the type of construction, railway lines with a fixed track or

2. at confined habitat corridors (bottleneck situations):
   Roads with a vehicle density of ≥ 5.000 vehicles/day or
3. all railway lines bundled with roads that are used by more than ≥ 5.000 vehicles/day (narrow bundling)[121] or
4. any canal or body of water with unnatural banks, sheet piling, concrete embankments and the like; or
5. all traffic routes with conventional protective walls.

Other barrier types or barrier features can only be assessed on a species-specific basis: For example, a 10 cm high curbstone is a strong barrier for a slow worm but not a barrier for a wolf[122].

In the area of concentrated amphibian migrations, roads with a traffic density of ≥ 1,000 vehicles per day are already very strong barriers (however, taxon-specific special solutions are justified here). Otherwise, and **only for cases outside habitat corridors**, a) any transport infra-structure (TI) with a barrier effect of more than approx. 95% for large animal species or for small animal species related to very small populations on the one hand, and b) TI with a barrier effect of more than 99% for small animal species related to large populations on the other hand, are considered to be very strong barriers. The consequences of traffic-related mortality on local and metapopulations are not considered in this context and must be included additionally in assessment procedures.

3.5.3.3 r+d needs regarding the dimension and density of fauna passages

Underpass use

- Evidence-based assessment of the maximum length of amphibian culverts narrower than 2 m. *An ongoing poll has so far produced the following result: There seems to be no evidence that amphibian culvert, narrower than ca. 1.5 m in diameter and longer than about 20 m are reliably effective – but quite the opposite. Nevertheless, they are built for a lot of money and are considered a functioning mitigation measure. Research is needed to find thresholds for culvert use and to test the hypothesis, that, at TI wider than 20 m, the construction of additional ponds in combination with integrative fauna underpasses every 500 m in valuable amphibian habitats is much more effective from an ecological perspective as well as from an economic perspective than constructing a series of smaller culverts.*

- Interrelationship between openness index (w*h/l) and the use of underpasses a) by insects (especially diurnal species or species of warm or dry habitats) and b) b< amphibians and

[121] see also Baierl et al. 2023 and Vilmer notes on the bundling of transport infrastructure and of transport infrastructure with photovoltaic lines (Böttcher et al. in prep.); whether e. g. 15 to 25 m wide, near-natural or otherwise suitable green spaces between the modes of transport can sufficiently minimise bundling effects, so that modes of transport can then be assessed individually, is controversial for larger mammals and has not been investigated.
[122] it is unclear whether conventional game protection fences keep wolves away from traffic areas or whether they are frequently overrun or bypassed (Reck & Schmüser 2022).

reptiles. Dimension thresholds for the usability of underpasses by flightless insects of dry open habitats (e. g. flightless grasshoppers and crickets) and for reptiles (especially lizards) are nearly not calculable. Therefore, the correlation between openness (width and height with respect to the length of underpasses) and its use by those guilds is of prior interest. The question is, which kind of correlation (which curve type, probably a sigmoidal) exists between the use of underpasses and the respective openness and where (if) are the knees of the curves, indicating function on the one hand and efficiency on the other. Such should especially be identified e. g., for exemplary indicator insect and reptile species as could be *Saga pedo*, *Chorthippus apricarius* or *Lacerta bilineata* or *L. agilis*.

- Better estimations (better evidence) for dimension thresholds for the usability of underpasses by ungulate species, esp. red deer, chamois, reindeer as probably most demanding and sensitive mammal species (see chapter target species for European defragmentation and ecological corridors). Although there is some information for some species, the given, preliminary thresholds should be better founded or, if misleading, adapted.

- Improvement of underpass use below four- or six lane TI by tight light gaps (width < 3 m) between traffic lines. *For ungulates, the benefit (with the given dimensions) is controversially discussed because some experts even expect negative effects. So, the effects cannot be assessed at present on basis of current observations. For small animal species of the vegetation fauna and reptiles, a light gap within the given dimensions of the structure will most likely result in a (considerable?) optimization - however, whether relevant species are affected is unclear. Under the given conditions, no considerable optimization of fish passage is to be expected, but this is different for e. g., dragonflies.*

- What (if) are eco-regional differences of underpass use? (1) e. g., better use of underpasses in warm climate by the small fauna (2) different use of passages in dependence on the region-specific hunting systems (better use of small underpasses by larger mammals if e. g., hunting is limited to very small-time intervals over the year and / or if larger hunting-free zones are set up).

- Use (preconditions for use) of water bodies by land mammals. *In case of low culverts with suitable substrate at the bottom of the watercourse and rather shallow water depth < 1 m, e. g. roe deer often cross in the watercourse; it is assumed that they seek the greatest possible distance from the structure cover. Therefore, in plain lowlands low underpasses could be improved by shaping the waterbed.*

Green strip buildings or passages

- While there are some observations about regular use by roe deer or foxes, single reptiles, amphibians or grasshoppers, there are no data available to assess the effect and the range of species that could use such strips in a way to effectively reduce barrier impacts. The effects of dimensions, design and density should be closer examined.

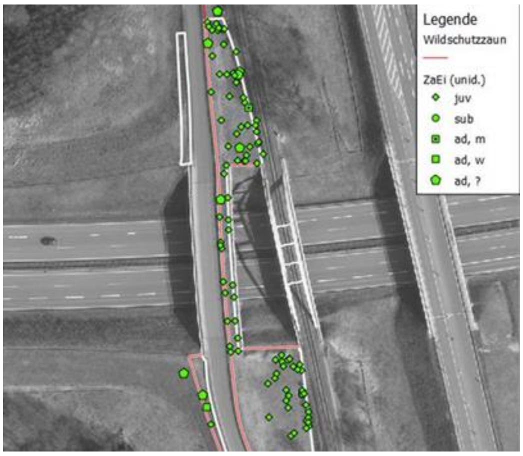


Figure 82 a, b: Green strip passage over a motorway

Along a municipal road near Lübeck and its use by sand lizards (survey area within the white lines). While at least juvenile sand lizards used the passage regularly and even single roe deer tracks could be identified it was insufficiently used by grasshoppers (only 3 of 11 species from the entrance area could be found on the passage); photo: H. Reck, photomontage: V. Daunicht, using a photo by GeoBasis-DE/LVermGeoSH; data: V. Daunicht, K. Hänel, H. Reck. An integrative assessment of the efficiency of green strip passages against the SLASS (single large and several small) debate is urgently needed.

Passage economy – research on construction

- It is highly probable that fauna crossings could be built in a more cost-efficient way than has been the case up to now if standard constructions were available (e. g. on the basis of wave steel profiles). Therefore, low-cost construction types for overpasses and underpasses with prefabricated elements should be developed. Such could even replace expensive wildlife warning systems at roads which are difficult to maintain and only useful for lager animals instead of all affected species.

Rating passage effects on population level: Establishment of harmonised conventions

- Thresholds for passage effectiveness
  Looking at the use of passages (e. g. by calculating the activity index “AI”, Yanes et al. 1995) we need thresholds (expert opinions, effect models) to decide which “AI” would be sufficient for larger mammals (e. g. AI = 0,3), for dismigration of small animals (e. g. AI = 0,05) or for amphibian migration (e. g. AI = 0,45). For a rough hypothesis, see table below. Further establishment (and periodic review) of harmonized conventions on thresholds of effectiveness for differently sized passages and for minimum densities of FP, based on (model) studies regarding effects on population level, would be a contribution to a more expressive European defragmentation index which is necessary for the monitoring of green infrastructure success.

Barrier strength and effects

- Promotion of coordinated studies for the better understanding of barrier strength for different indicative species types, regarding the impact factors (1) TI-width, (2) protection walls, (3) curb stones, (4) density and height of verge vegetation, (5) traffic velocity and (6) traffic density is recommended for better impact assessment and mitigation

- Because the (guild-specific) severity of barrier effects is not only depending on the barrier strength the effect of habitat topology or metapopulation structure is needed to develop conventions for assessment procedures and best solutions for mitigation (balancing fauna passage effects against habitat development effects).

Table 29: Assessment of (rating classes for) the use of FP by animals

Legend:
Preliminary testing thresholds (to be falsified or verified or adjusted) for rating the use of fauna passages (FP) by respective species with regard of effects on population level (but for closer rating of the real effectivity on population level, further criteria are needed, especially the number of FP in relation to the TI sector under consideration and the habitat topology around that sector)

On the right: Rating classes for the use of FP by various indicator species or taxa.

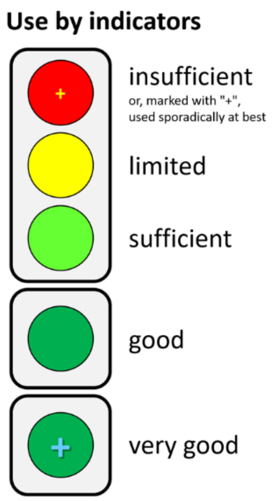


Table 29 ff:

Preliminary test values for rating classes related to the relative permeability (rel PM)

The rel PM is referring to the survey of activity densities: ADFP/ADRS = "activity density in or on a fauna passage, FP" / "activity density at an explicitly named reference site, RS"; values of the rel PM are about twice as high as values of the activity index (AI) after Yanes et al. (1995)

	rating monitoring results of fauna passage (FP) use demands on the relative permeability (rel PM) with respect to		
on the right: rating objects Below: Rating classes	**• dismigration of <u>flightless</u> species of the small fauna**	**• use by larger animals** or **• safeguarding of fragmented small populations of small fauna species**	**• safeguarding of concentrated migration** of e. g. amphibians (then, if appropriate, also related to amphibian protection facilities as a whole)
insufficient	**rel PM < 1 % of the comparative activity density** or, if no comparative data are available, no relevant activity, at most individual observations	Reference site:* Portal / cl. ac. area => **rel PM < 20 %** Ref.site „Surroundings“ => rel. PM < 40 %?	Reference site: Portal / closer access area => **rel PM < 70 %?**
limited	**rel PM 2-5 % of the comparative activity density** or, if no comparison data are available, only a few observations of individuals of the respective taxa	Reference site: Portal / cl. ac. area => **rel PM 21-45 %** Ref.site „Surroundings“ => rel. PM 41-80 %	Reference site: Portal / closer access area => **rel PM 71-80%**
sufficient	**rel PM 6-30 % of the comparative activity density** or, if no comparison data are available, few specimens of the respective taxa, e. g. > 5 in a series of 6 pitfall traps	Reference site: Portal / cl. ac. area => **rel PM 46 -90 %** Ref.site „Surroundings“ => rel. PM 80-180 %	Reference site: Portal / closer access area => **rel PM 81- 90 %**
good	**rel PM 31-90 % of the comparative activity density** or, if no comparison data are available, some specimens of the respective taxa, e. g. > 6 - 10 in a series of 6 pitfall traps	Reference site: Portal / cl. ac. area => **rel PM 91 -95%** Ref.site „Surroundings“ => rel. PM 180 -260 %?	Reference site: Portal / closer access area => **rel PM 91-95 %?**
+ very good	**rel PM > 90 % of the comparative activity density** or, if no comparison data are available, many specimens of the respective taxa, e. g., > 10 in a series of 6 pitfall traps:	Reference site: Portal / cl. ac. area => **rel PM > 95 %** Ref.site „Surroundings“ => rel. PM < 260 %	Reference site: Portal / closer access area => **rel PM < 95 %**

** Reference sites => closer access area: r < 25 m; surroundings: r > 150 m – 500 m;*
precondition for using the thresholds given with respect to the surroundings is a FP-density according to table 2 “Standard density for FP after Hlavac 2019”

3.5.4 How to handle ports

Introduction

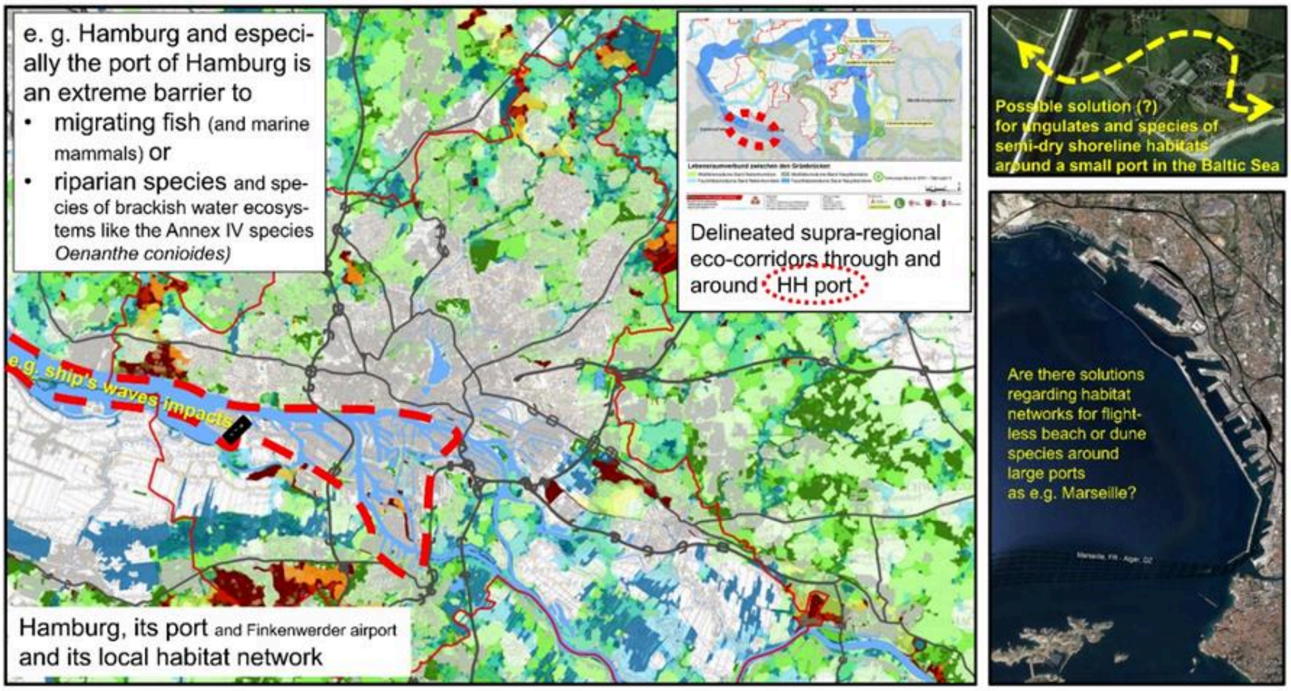


Figure 83: Hamburg port as prop in the Elbe river continuum and the Elbe floodplain eco-corridor

Main picture: Coloured (green, orange, blue) areas around Hamburg: Left over habitat networks (core areas and nearest distances regarding mirrored fronts; the wetland habitat continuum is completely interrupted by the Hamburg port area
Picture top, right: How to circumvent a small port and how to undergo the upgraded traffic magistral to Denmark at least for dry coastal habitats and for larger mammals on the island of Fehmarn
Picture left, below: How many stepping stone habitats are needed to restore the coastal corridor for beach and dune species in the Marseille harbour area?
Picture top, middle: Location of the Hamburg (HH) port regarding supraregional eco-corridors

Barrier effects of ports (and other non-linear TI) are not considered closely in the D5.3 report, but such can be severe props in bottleneck situations of naturally connected habitats of rivers and floodplains or of coastlines. As those structures are natural corridors, the related stenotopic species are adapted to continuously connected step stone habitats as e. g. wingless dune or gravel bank crickets (like *Bryodemella tuberculata*) or to largely undissected linear migration lines as e. g. fish. Thereby even small fish species like brown trout (*Salmo trutta*) or spirlin (*Alburnoides bipunctatus*) migrate across large distances and need (on the long run) large networks of running waters for their survival as well as the mussel larvae which fish transport as obligatory vectors and as many other inverts or of course the well-known long-distance migrators as huchen (*Hucho hucho*) or European eel (*Anguilla anguilla*).

Fragmentation impacts by ports are doubtless of great importance but not quantified for terrestrial and semi-terrestrial species by now. Therefore, ad hoc solutions against the barrier effect are as urgently needed as research on the effects and on most efficient mitigation.

Even for limnic species and ecosystems, the barrier effects and causes are too often not adequately addressed in planning. Sediment modification, sedimentation and water-chemical pressures due to permanent dredging to clear and deepen shipping channels in and around ports are a particularly large problem that has not been investigated in this respect.

Ad hoc mitigation possibilities

- For ecosystems and species which are independent of the waterbodies and of banks or of habitats, which depend on flood (and wind) dynamics: Habitat corridors (circumventing bypass corridors) must be developed around the ports (at least if designated eco-corridors are affected).
- The river continuum for fish and other limnic species must be fully restored by rows of fish passages and by at least densely scattered step stone areas of near natural riverbed structures (which is also requested by the European water directive).
- For bank or beach related species, near natural bank/beach habitats must be installed at least as close stepping-stone habitat chain within the port areas.

Figure 84: Nation-wide main and secondary eco-corridors around and through (the port of) Hamburg

The Elbe flood plain is a designated main eco-corridor in Germany, but the bottleneck situation of Hamburg is unsolved, especially for riparian species. The same conflict is typical for many European port areas.

Airports

Airports can have similar effects as ports. The originally planned upgrading of the Lübeck airport is dissecting one of the few Schleswig-Holstein populations of the threatened wartbiter *D. verrucivorus*, which is one of the indicative target species of the local habitat network as well as of the national defragmentation concept. The local functional dissection of the (indirectly) affected Natura 2000 site is solved by a planned bypass eco-corridor system and solvable for the wartbiter by appropriate insect-friendly grassland management inside the airport area. As many Natura 2000 sites are not functionally but administratively bounded and designated it's the real habitat topology or population structures that must be assessed for impact regulation instead of simply looking at impacts on protected area shapes alone.

R+d needs

The minimum density (dependent on habitat size, quality and mirror front situations and also dependent on matrix qualities) for sufficient step stone bank/coast elements within ports have to be explored as well as the long-term effects of ports on the occurrence and survival of representative target species (indicator species) by both, population vulnerability models and by interpreting comparative inventories.

3.6 Better future: Transportation networks as corridors for life by the example of landscape roads

3.6.1 Introduction

In the foreground of discussions on the further development of TI is usually the question: Either life and living spaces or new construction and expansion of roads, railways & Co. The "both/and" is usually neglected and it is the task of the BISON project to point out possibilities in this regard and to outline the corresponding development needs.

The fact that the "either" is so often the focus is very often the result of supposedly immovable requirements or standards set by traffic route construction, which include many parameters that are hardly questioned and seem to have no alternatives, such as high design speeds or the shortest possible travel times, insurmountable curbs and retaining walls, non-negotiable wide curve radii, wide carriageways or waterway subways reduced to the hydraulic minimum, and much more. If traffic routes were considered from the outset not only as transport routes but also as lifelines for people and animals, the conflicts between TI and the well-being of residents and travelers and conflicts between TI and biodiversity would be far fewer. The following example "Roads for Life" is intended to point to possible research and development tasks that could promote a higher quality of life. It is based on an essay (Reck 2022) that has already been published in German.

3.6.2 Seizing Opportunities – Roads for Life - or - Transportation networks as corridors for life: Landscape roads

3.6.2.1 Rationale

People spend a great deal of their lives "on the move", i. e. on roads and paths. Slow-moving traffic, i. e. cyclists and pedestrians (with and without baby carriages etc.), thereby experience noise, spray or danger just as directly as they can (or could) experience blossoming verges and pleasant places to meet, talk, stroll or pick flowers. Maybe not necessarily on motorways - but why not at least on the other types of roads? Older people still know this: many social activities took place on and oriented towards the street. But slow-moving traffic is currently overly or unnecessarily burdened by fast-moving traffic, and this also creates unnecessary barriers and death traps for animals.

3.6.2.2 Goals - or: “One step back and two steps forward”

The (expected) great progress in vehicle construction and in the development of warning systems will in any case reduce pollutant emissions, engine noise and the risk of accidents. The first step forward has almost been taken.

Situationally adapted, slower driving speeds (the needed second step) and the associated reduction of high design standards, however, reduce impacts far more, as they mitigate:

- rolling noise (which becomes louder with speed), i. e. unnecessary noise, which not only impairs the well-being but also the health of many people (in favour of the speed kick of a few high-speed drivers) and which devalues unnecessarily large areas as habitat, e. g. for songbirds,

- unnecessarily wide bands of nutrient and pollutant emissions in neighbouring areas and sensitive habitats, as well as CO_2 emissions (also due to the quantities of concrete and building materials saved),
- unnecessarily high land requirements for motor vehicles, including unnecessarily high requirements for paved verges and unnecessary land sealing or land competition (the higher the speed, the wider the roads have to be),
  and they avoid
- unnecessarily high barrier effects by construction or operation and, complementing driver assistance systems, serious accidents or unnecessary death and suffering of humans and animals (bird and bat strikes are reduced as well as losses of ground beetles, grasshoppers, toads, snakes, dormice, hares and deer).

It also reduces avoidable stress for motorists and unnecessary costs for large construction sides and buildings and their maintenance.

The step backwards would then be the retrieval of living paths, which, when considered closely, is actually another step forward.

3.6.2.3 Liveable ways and roads - or: “Less Road is More Life”

Adapted, i. e. reduced vehicle speeds and lane widths in favour of slow traffic (space for pedestrians, cyclists) facilitate greening (colourful verges and avenues), which make the necessary use of ways by people more liveable and provide habitats for flowers, insects & Co, thus contributing to the development of green infrastructure.

But also, because e. g. subways are expensive and yet mostly not suitable for heliophile small animal species, because only large subways are usable for wildlife and because green overpasses are mostly even more costly, all roads must be designed in such a way that they do not represent a significant barrier or in such a way that the barrier effect and mortality is at least strongly reduced. Designing wide spaces between vehicle lanes, bicycle lanes, footpaths and/or service roads as habitat can contribute significantly to this. For this purpose:

- all protruding curbs must be removed or avoided (lawn-like but species-rich margins with rosette plants and sub-grasses serve as a safety element and hard shoulder directly adjacent to traffic lanes) and, where unavoidable, gullies must be converted or redesigned to make them amphibian-proof and
- the dense overgrowth of herbaceous and grassy margins parallel to roads and paths must be avoided by using nutrient-poor substrates (ensuring low spatial resistance by developing sparse vegetation) and by growing insect-flowering plants or, at places where e. g. high grasses are dominant, by e. g. sowing the hemiparasitic key species “yellow rattle” (Zimmerbeutel et al. 2022)

At the same time, the herbaceous strips serve as a reaction distance (to avoid accidents with game) to accompanying woods or forest edges. However, in clearly visible sections, woody vegetation interconnections are then necessary by means of guiding copse for small animals and as game crossings).

The development of "landscape roads" is an older design principle that was (and is) in use at some places. Important features are:

- Limitation of the lane width for motor vehicles as far as possible with simultaneous separation of the lanes by wide intermediate greenery (which in settlements and in the case of roads connecting municipalities can be partially driveable for e. g. ambulances or as escape or emergency routes)
- Optimal design of the vegetated strips (nutrient-poor substrate, seeding of native, insect-flowering plants, if necessary zoned from meagre and short grassland to tall herbs and copse; introduction of additional structures, e. g., reptile hiding places outside unsealed hard shoulders or emergency escape routes) for the development of a traffic related habitat corridor (visually appealing greenery as habitat).
- Limiting vehicle speeds as far as possible, not only to promote passability for wildlife and pedestrians but also to minimise noise and pollutant emissions, accidents and animal losses (also with regard to the strict ban on killing strictly protected species), and
- Animal-friendly lighting (long-wave, focused; see Schroer et al. 2019).

Figure 85: Example of a so-called "landscape road"

(here: N 200 motorway in the Dune National Park near Amsterdam)
Habitats between roadways are ideally designed in such a way that the roads are only perceivable to a limited extent from the pedestrian perspective and, above all, in such a way that habitats such as heaths or flower meadows dominate the perception, at least for participants in slow-moving traffic, and in such a way that conflicts between different road users are reduced and the habitat function and traversability for animals is greatly improved.

As soon as the green spaces are developed as habitats (especially as flowering areas), they should also be properly maintained (approaches to this: Rosell et al. 2020). Particularly effective for biodiversity would be maintenance parallel to strips or in sections (alternating for e. g. 50 m length per process; exception: intensive maintenance strips for traffic safety).

Figure 86: The minimum requirement for ecological functioning verges is the establishment of suitable maintenance regimes

Species-rich vegetation on nutrient-poor substrates that is not uniformly maintained over large areas can make a significant contribution to habitat connectivity. Mowing in sections or strip mowing (photo: B30n, 2020) prevents the extinction of small animal populations.

3.6.3 r+d needs concerning landscape roads

See chapters

"Better impact assessment 2: The neglected role of TIH as habitat corridor" and "Curbs, protection walls, fences & Co. as barriers and r+d-needs to overcome its adverse effects on biodiversity". Further r+d needs concern:

- Tipping points or optimization functions for the width of vegetated side or median strips (width versus biodiversity gain)
- The role of verges as supra-local corridors (because until now – studies, assessing the corridor effect of verges are missing for distances larger than ca. 1 km (Ouédraogo et al. 2020, Villemey et al. 2018) while local effects are evident (Vermeulen 1994, Rietze & Reck, Bockwoldt 2022)
- Tipping points or optimization functions for the transportation functions regarding pedestrians, cyclists and local, regional and supra regional motorized traffic, (width versus well-being, stress and transportation costs) = Cost-benefit analyses of the social, economic and ecological qualities of typical design and maintenance alternatives
- Applicability and application of the Czech concept (Mladek & Sikula 2016), and/or the respective principles for biodiversity-friendly greening of TI-side corridors or butterfly highways

(Zimmerbeutel et al. 2022) or of other opportunities to create species-rich verges for the different eco-regions of Europe

- Planning approaches for sustainable safeguarding of green side infrastructure against use as reserve for upgrading (widening) TI and/or intensive use (compare chapter “The critical role of bundling”

- Transferability to rail and bundled lines

- Efficiency (cost-effect balances) of wildlife warning systems at roads in comparison with prefabricated overpasses and/or wildlife friendly designed roads and side areas (width/velocity, placement of shrubs and trees or tall herb vegetation)

Figure 87: Especially the Herpetofauna suffers a high number of unnecessary roadkill
Scheltopusik or European legless lizard on a rural road, photo taken on the occasion of local roadkill monitoring by L. Georgiadis (Greece)

4 R+D: D5.3 LIST OF RESEARCH AND DEVELOPMENT NEEDS

Heinrich Reck, Marita Böttcher & Cindy Baierl

Table 30: Compilation of research and development needs

Improvement of the EDM	**→(see chapter 2.6.1)**
For an optimised **presentation** of the EDM data (including analyses results) in the future it is recommended to - elaborate an (ArcGIS) dashboard showing all relevant information on a single screen, here intuitive and interactive data and information presentation/visualization based on spatial analytics (and/or) - to build an immersive web app (e. g., with the ArcGIS Experience Builder), where web maps, apps, pages, interconnected widgets, and both 2D and 3D data are combined through a flexible drag-and-drop interface. Such an application allows the audience a better interaction with data and contents and even an interaction with each other To supplement the **content** of the EDM we recommend: - the complementation of the missing ecological networks in eastern and northern Europe for states by funding state-wide planning and/or modelling a consistent corridor framework across Europe - The Improvement of the existing networks (e. g. implementation of missing habitat types/ networks/Ecosystems, Migration corridors …) - the establishment of a meta-information system of all major defragmentation measures in Europe - the identification and compilation of data on transport infrastructure at the EU and national levels needed for a more accurate and complete assessment of the specific barrier effects of each mode and type of transport - the overlay with a European artificial lighting map (to identify "dark areas" worthy of protection and the extent of light pollution of protected areas)	
Use of Remote sensing data	**→(see chapter 2.6.2)**
- e. g., Copernicus Land Monitoring Service (CLMS) for an automatic identification of habitat topology as a prerequisite for the construction of ecosystem-specific habitat networks and subsequently for the reduction of disturbances - combination of remote sensing data evaluation, airborne laser scanning and artificial intelligence technologies for qualification and improvement of an automatised identification of habitat topology	
Use (Geospatial) Artificial intelligence	**→(see chapter 2.6.3)**
- Geospatial Artificial intelligence (GeoAI) could be used e. g. for an automatic identification of habitat topology; first approaches of habitat classification using the combination of AI and Deep Learning have been developed and published recently	
Fill data gaps regarding Indicators	**→(see chapter 2.6.4)**
… for assessing the need for defragmentation: - Comprehensive integration/consideration of wilderness areas - Usage of remote sensing data (and GeoAI) for identification of endangered habitats - Creation of a suitable data background of high-quality habitats (e. g. with remote sensing data) - Definition of threshold minimum habitat size on European level - Definition of applicable ecosystem-/habitat types	

- Building a database with a selection of representative species for biographical regions (Natura 2000 database is insufficient)
- Designation of indicator/target species for the biotope network (with occurrence and distribution)
- Selection of relevant species
- Identification and designation of transnational migration routes
- Identification and designation of migration routes

… for assessing the barrier effect of transport infrastructures:

- Roads: specificized data e. g., on width, traffic volume, protection devices (e. g., fences, kind of guard rails) for a correct assessment of the barrier effect
- Rails: specificized data e. g., on number of tracks/the width, train frequency and the level of expansion (conventional or highspeed (and here also the type: gravelled or ballastless/slab track)) are needed to a precise estimation of the barrier effects.
- Inland waterways: information on level of expansion and the width are essential for the different consideration and treatment of artificial canals or natural/seminatural rivers.
- Bundling: Research of their barrier effects including the critical distances between the different transport routes. Closing data lacks for the consideration of bundling effects with other transport and energy infrastructures (powerlines, photovoltaic installations)

Proposal for a Regulation of the European Parliament and the Council on Union guidelines for the development of the Trans-European Transport Network amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) No 1315/2013[123]

→ (see chapter 2.6.5)

In principle:

- The costs for environmental measures arising from the implementation of the TEN-T projects, in this case the avoidance of fragmentation, but also measures for the avoidance of noise, green house gas emissions or also wildlife accidents (fencing) are project costs. They are not external costs, as proposed in the law so far, since they only arise from the implementation of the respective project (polluter pays principle) and therefore remain in the competences and responsibilities - in whatever form - of the respective departments.

According to the current state of discussion, at least the following paragraphs should be added to the proposal with regard to fragmentation.

- Art. 3: (ak) adequate consideration of the fragmentation of corridors and protected areas in the legal text; in addition, the fragmentation of corridors should be designated, as these have not been sufficiently considered in the designated environmental directives to date,
- Art. 4: addition of the term "fragmentation of corridors".
- Art. 5: besides the degradation of ecosystems, fragmentation must be added as a significant impairment factor.
- Art 51: integration of an analysis of possible fragmentation impacts caused by infrastructure and necessary measures, in addition to measures to avoid greenhouse gas emissions, noise and other negative impacts on the environment
- Art 53: Designation of the costs of reconnection aids in the National Report of the countries.

[123] Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU Text with EEA relevance. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R1315

COMPILATION FROM D5.3/2

r+d = research and development; r = mainly research; d = mainly development;
the references to the explanatory report pages (p) are approximate

MIGRATION CORRIDORS

d: Compilation of a up-to date European long-distance migration network (p38)

Drawing up a European long-distance migration network to be integrated in (a) land use planning (from state development plans to local zoning plans or from TEN-T to local traffic networks) and in (b) landscape planning (from environmental development plans on state level to the local level) by e. g. compilation of remaining supralocal drift paths of domestic ungulates and known existing (and lost) long distance migration corridors of wild ungulates on European and national scales (p146)

r+d: Identification of migration corridors (p37)

Migration corridors of animals must be identified and kept free from barriers and traps or restored.
As migration corridors are not sufficiently deducible by landscape features but often known by animal observers, information on important European or supra-regional corridors must be compiled for TI-planning (see above) and, on regional and local level, project-specific detected for assessment of TI-impacts and for defragmentation. Methods for detection must encompass more than habitat suitability and habitat topology and therefore the **development/improvement of methods for scale-adequate delineating of existing or recoverable migration routes and/or main deer paths is necessary (improvement of models for small-scale/large area application and methods for efficient mapping from local to regional scale) p146**

PROVIDING AND MODELLING HABITAT CORRIDOR NETWORKS

d: Regulary updated indicative corridor and fauna passage maps (p131)

Indicative maps on Euopean and national level should be regularly updated on the basis of habitat topology, migration corridors and landuse as well as on passage-construction monitoring at European-wide and national critical fragmentation sctions.

r: Further identification and monitoring of supra-regional eco-corridors by (1) using remote sensing data on habitat topology (automatic classification using artificial intelligence) and analysis of habitat distance, e. g. CarHAB in France or Habitat-Net in Germany, by (2) compiling expert information on large-distance migration corridors and transhumance corridors plus further identification by individual tracking using methods as developed e. g. in the ICARUS-project (International Cooperation for Animal Research Using Space) plus (3) developing guidelines to classify and identify main deer paths on local level (p175).

r: Quatifying the effects of habitat mirror fronts on connectivity (p 44-45)

d: European-wide monitoring of WVC-hotspots or compilation from national projects respectively (p175, cf. *Figure 14: Traffic kill and Habitat Net in Plön county*)

Because WVC-hotspots can give an important indication of migration corridors (and because they need to be mitigated) a coordinated collection and analysis of accident data is helpful.

SCOPING (in the broadest sense) and ASSESSMENT BASIS
Effect areas and impact factors
r+d: Identifcation of typical, impact factor-specific effect areas for all different types of transport infrastructure. Especially the impact areas of barrier effects are underestimated in assessment procedures and respective survey areas are wrongly chosen (p43)
d: Compilation of a complete list of relevant impact factors for the respective TI-types, regulations about ways for their treatment in EIA and IR (p143)
d: Development of conventions on minimum scoping or survey ranges regarding fragmentation effects with respect to (1) traffic modes and planning type (e. g. new construction or upgrading or bundling) and to (2) the different indicators (see Table 23, Table 25) to prevent assessment errors which will lead to biodiversity loss as well as to planning and project delays (p132, p133, p138)
r: Pars pro toto research on the effects of relevant impact factors on representative sensitive taxa/guilds as a (imoroved) comparative base for a more exact impact prognosis and for more exact reasoning on the width of severly affected impact areas (p133)
r: Coordinated studies for the better understanding of the barrier strength for different indicative species types, regarding the impact factors (1) TI-width, (2) protection walls, (3) curb stones, (4) density and height of verge vegetation, (5) traffic velocity and (6) traffic density (p236)
r: Long-term effects of ports on the occurrence and survival of representative target species (indicator species) of riparian and coastal ecosystems by both, population vulnerability models and by interpreting comparative inventories (p240)
Effects of design speeds, bundling and fencing/walling and better alternatives
r: Questioning the alleged, unproven (or imbalanced) economical or ecological or safety benefits of (a) high traffic velocity, (b) bundling and (c) safety fences or safety walls (p133), especially: Quantifying the relation between environmental and social costs and economic or time-saving (often only pretend) benefits of high traffic velocity must be scientifically examined. Best tipping points for cost-benefit balances must be found for decision-making (p200). Especially quantifying and balancing negative and positive economic and ecological effects of different traffic velocities on different TI types with regard to the total ecological footprint and especially WVC or the avoidability of fences or protection walls or curbs (p208)
Speed
r: Possibilities to enhance travel **speed** by optimizing traffic flow instead of high vehicle speeds - or enhancing travel speed by optimizing boarding and disembarkation times (p201)
Bundling
r: Survey of the ecological function of buffer areas or the minimum required distance between bundled transport infrastructure and/or technical facilities accompanying transport infrastructure (p198)
r: General assessment of bundling effects: Representative case studies to get comprehensive ecological and economic assessments for typical bundling projects in comparison to typical alternatives as an orientation for strategic environmental assessment (p198)

d: Guidelines for conducting individual life cycle assessments of bundling projects (relevant factors include land use, energy and material demand, total costs including planning and administrative efforts, barrier effects and possibilities for ensuring sufficient ecological connectivity) (p198)
r: Survey on the ecological function of wildlife passages through technical areas, as PV-GMS related to TI. What is the optimal or most efficient length and width ratio of such passage corridors? (p198)
Curbs, protection walls, gullies
d: Implementation of a general rule that curbs & co. are forbidden in TI construction or TI renovation if not individual case-specific justified (case-specific assessment has to be obligatory) (p208)
d: Guidelines (standards, construction models) for easily surmountable curbs or for curbs placing on gaps and thus be climbable that are useful as rainwater barrier (as alternative for precipitation water steering by curbs) / development of curb designs that guarantee directed rainwater drainage that is no barrier for the small fauna (e. g., specially designed grating stones) (p208)
d: Guidelines (standards) for gully design which ensures the escape of small animals like ground beetles, amphibians, reptiles, shrews etc. (p208)
Fencing, verges and WVC
d: Implementation of standards for mortality safe wildlife fences (p208)
r: Quantifying negative and positive effects of wildlife fences related to typical environmental situations and to traffic characteristics (rules for application or avoidance, tipping points for decision-making) (p208)
r: Quantifying the impact of different distances of woody plantations along traffic routes on WVC (p208)
r: Quantifying the impact of different densities of fauna passages on WVC (p208)
r: Survey of the effects of more or less ungulate-nourishing roadside or rail side vegetation and related WVC (p208)
r: Survey of the effects of herb and grass density in verges (a) on the migration of the small fauna, (b) on the habitat quality for the small fauna and (c) on the traffic mortality of birds of prey (p208)
Transportation design
r: Tipping points or optimization functions for the transportation and corridor functions comparatively regarding pedestrians, cyclists and local, regional and supra regional motorized traffic (width versus well-being, stress and transportation costs) = Cost-benefit analyses of the social, economic and ecological qualities of typical design and maintenance alternatives (p244)
INDICATORS
d: Compilation of mandatory scale-related indicator sets (standard indicator systems) (p132, 175)
Convention on a representative and eco-regional stratified list of indicators and indicator taxa (regarding the ecological guild principle) for which surveys (adapted to different scales) should be obligatory (p160). As WVC-hotspots can be used as an indicator the necessity to standardize traffic-kill monitoring is high (p45, p160)
d: European target species for defragmentation (132)
European list of target species for defragmentation (and barrier impact assessment) should be compiled because the species listed in the annexes of the Habitat Directive fail to be representative for ecosystem connectivity and spatial functions of ecosystem (p175)

r: Testing of the representativeness of EU Natura 2000 target and indicator species for functioning eco-corridor netwoks and testing the Natura 2000 species and biotopes for the representation of biodiversity at all for the different eco-regions in the EU (p175)
r Testing of the representativeness of the future Eruopean target species lists (p175)
MITIGATION AND COMPENSATION
d: Guidance/Manual for of cross-sectional parity green infra structure concepts and its obligatory implementation (p133, p175, p210, p212)
r: Assessment (balance regarding ecological effects as well as planningacceleration effects) of light house projects reon parity connection (p212)
d: European standard rules for the implementation of large fauna passages across Transport Infrastructure, (p215)
r+d: Identification and implementation of standards for watercourse underpass design that securely saves any migration needs for limnic and bank species (p175)
r: Assessment of the maximum length of amphibian culverts narrower than 2 m or (see below) defining the correlation between underpass use and openness index (p232)
r: Finding the interrelationship between openness index (w*h/l) and the (eco-regional different) use of underpasses a) by insects (especially diurnal species or species of warm or dry habitats) and b) by amphibians and reptiles.
Especially dimension thresholds for the usability of underpasses by flightless insects of dry open habitats (e. g. flightless grasshoppers and crickets) and for reptiles (especially lizards) are nearly not calculable and the possible eco-regional differences of underpass use are not known (p232)
r: Finding dimension thresholds (openness index: width x height / length) for the usability of underpasses by ungulate species, esp. red deer, chamois, reindeer as probably most demanding and sensitive mammal species (p232) – at watercourse underpasses with regard of the height above mean water level and the preconditions for use of the water bodies / bottom of the water body by land mammals.
r: Is there an improvement of underpass use below four- or six lane TI by tight light gaps (width < 3 m) between traffic lines (p232)
r: What are the quantitative effects of green strip fp on species representative for the different relevant guilds (p233)
d: Conventions on thresholds for rating passage effectiveness (p234)
d: Low-cost construction types for overpasses and underpasses with prefabricated elements should be developed (p234) as well as rules for their use
r: Efficiency (cost-effect balances) of wildlife warning systems at roads in comparison with prefabricated overpasses and/or wildlife friendly designed roads and side areas (width, velocity limits, placement of shrubs and trees or tall herb vegetation)
r: Balancing fauna passage effects against habitat development effects with regard to the dependent role of passage densities (p236)
d: Survey of existing TI where curbs & co. should be deconstructed or de-fencing should be applied (primarily along defragmentation areas due to the EDM or regional eco-corridor or defragmentation concepts if no or too few fauna passages are realized) (p208)

r: Modelling the effects of the fp target densities proposed by BISON D5.3 and comparison to the respectively current densities of national and/or state corridor systems (p175)
Prognostic success controls of different implementation variants for eco-corridors (inter alia looking for tipping points of effectiveness regarding corridor densities) by using the example of the effects on representative target species (population viability analyses, examination of the influence on the distribution or recolonisation of abandoned areas under different land use or climate scenarios) (p175)
r: What is the minimum density (dependent on habitat size, quality and mirror front situations and also dependent on matrix qualities) for sufficient step stone bank/coast elements within ports (p240)
VERGES AND OTHER TIH
r: Assessment of eco-regional specific effects of soil management in TIH (p139)
d: Guidance for eco-region-specific design and substrate management of verges and other TI- side areas as habitat and corridor (p133, p184)
r+d: Methods to change species-poor verges to species rich habitats (e. g. by 1. sowing selected herbs or woody species – if appropriate in combination with hemiparasites like yellow rattle for reducing biomass and overgrow and/or 2. by soil treatment and/or 3. harrowing etc.) should be developed as well as appropriate applications and design (e. g. Unterseher 2015, Reck & Müller 2018, Rosell et al. 2020, Zmmerbeutel et al. 2022). Thereby special solutions for dry and warm areas in e. g., the pannonic or Mediterranean regions in Europe are probably needed (p184)
Testing the applicability and application of the Czech concept (Mladek & Sikula 2016) and/or the respective principles for biodiversity-friendly greening of TI-side corridors or butterfly highways (Zimmerbeutel et al. 2022) or of other opportunities to create species-rich verges for the different eco-regions of Europe (p244)
r: Survey of the corridor effect of verges for different guilds (because supralocal or cross-sectional effects are not calculable yet) (p133); especially the role of verges as supra-local corridors should be quantified (p244)
Survey of (positive and negative) verge impacts on representative guilds or taxa or representative target-species respectively is necessary to permit appropriate impact balances. Especially the role as feeding corridors to fp and as supra-local habitat corridors and the supporting TI and TIH features have to be closely examined (dispersal distances of representative target species from different small-animal guilds, influence of vegetation density (p184)
r: Quantifying the mortality risk or, more probably, the opportunities for risk-avoiding by insect-friendly verge design and maintenance (p184)
r: Finding appropriate distances for shrubbery to TI edges
Different distances of shrubbery should be examined to define minimum distances of shrubs to reduce bird and game kill and methods for compensation for the therewith connected increased barrier effect for woodland species should be developed (p184)
r: Quantifying the resistance of dense herb and grass strips on small animal movement and thresholds for verge vegetation or green strip vegetation densities (p198)

5 REFERENCES

Aigner, H., Becher, R. et al. (o. D.): Leitfaden zur Zulassung von Photovoltaik-Freiflächen-Anlagen, Anregungen für Gemeinden (Beispiel: Landkreis Freising). Arbeitsgemeinschaft Bayerischer Solar-Initiativen, Solarfreunde Moosburg e.V., Sonnenkraft Freising e.V., ZIEL 21 Fürstenfeldbruck e.V.

Anstoetz, K. (2018): Amphibien nutzen eine Grünbrücke über die A33 in Bielefeld. Feldherpetologisches Magazin (9).

Arnold, E. / KNE (2021): Kriterien für eine naturverträgliche Gestaltung von Solar-Freiflächenanlagen, Übersicht und Hinweise zur Gestaltung, 6 S.

Attermeyer, S., Herzberg, H., Engels, M., Bauckloh, M., Bömer, A., Böttcher, M., Geiger, A., Hänel, K., Heil, A., Henneberg, M., Herrmann, M., Kaledin, M., Meinig, H., Podloucky, R., Reck, H., Sauer, J., Schneider, H., Strein, M., Tegethof. U.: Merkblatt zur Anlage von Querungshilfen für Tiere und zur Vernetzung von Lebensräumen an Straßen, Ausgabe 2022. Forschungsgesellschaft für Straßen- und Verkehrswesen 89 S. + 55 S. Anhang, FGSV Verlag GmbH, Köln.

Babinska-Werka, J., Krauze-Gryyz, D., Wasilewski, M., Jasinska, K. (2015): Effectiveness of an acoustic wildlife warning device using natural calls to reduce the risk of train collisions with ani-mals. - Transportation Research Part D: Transport and Environment, 38, S. 6-14.

Backs, J., Nychka, J., St.Claeir, C. (2017): Warning systems triggered by trains could reduce collisions with wildlife. – In: Ecological Engineering 106, S. 563–569.

Baierl, C., Schröder-Rühmkorf, H., Hänel, K., Reck, H., Nissen, H. (im Druck, 2023): Wiedervernetzung von Lebensraumkorridoren über bestehende Bahntrassen (ICE, IC, Güterverkehr). Naturschutz und Biologische Vielfalt 1XX.

Barrientos R, Bolonio L. The presence of rabbits adjacent to roads increases polecat road mortality. Biodivers Conserv. 2009; 18: 405–18.

Billon, L., Sordello, R. (2017): Réalisation d'une carte nationale de la Trame verte et bleue. Note méthodologique.

BMVI (2020): Leitfaden zur Berücksichtigung des Artenschutzes bei Aus- und Neubau von Bundeswasserstraßen. Bundesministerium für Verkehr und digitale Infrastruktur: 66 S.

BNetzA (2019): Bündelung von Stromleitungen mit linienhaften Infrastrukturen. Bericht der Bundesnetzagentur. Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen, Bonn.

Boitani, L., Falcucci, A., Maiorano, L., Rondinini, C. (2007): Ecological Networks as Conceptual Frameworks or Operational Tools in Conservation. Conservation Biology Volume 21, No.6, pp1414-1422.

Bolger DT, Scott TA, Rotenberry JT. Use of corridor-like landscape structures by bird and small mammal species. Biol Conserv. 2001; 102:213–24.

Burkhardt, R., Baier, H., Bendzko, U., Bierhaqls, U., Finck, P., Liegl, A., Mast, R., Mirbach, E., Nagler, A., Pardey, A., Riecken, U., Sachteleben, J., Schneider, A., Szekeley, S., Ullrich, K., van Hengel, U., Zeltner, U., Zimmermann, F. (2004): Empfehlungen zur Umsetzung des § 3 BNatSchG „Biotopverbund“. Ergebnisse des Arbeitskreises „Länderübergreifender Biotopverbund“ der Länderfachbehörden mit dem BfN. Naturschutz und Biologische Vielfalt, Heft 2.

Burkhardt, R., Finck, P., Liegl, A., Riecken, U., Sachteleben, J., Steiof, K., Ullrich, K. (2010): Bundesweit bedeutsame Zielarten für den Biotopverbund – Zweite, fortgeschriebene Fassung. Natur und Landschaft 85 (11): 460-469.

Chetkiewicz, C.-L.B., St. Clair, C.C., Boyce, M.S. (2006): Corridors for Conservation: Integrating Pat-tern and Process. Annual Review of Ecology, Evolution, and Systematics 37, 317–342.

COST OFFICE (2006): COST 350 Integrated Assessment of Environmental Impact of Traffic and Transport Infrastructure – A Strategic Approach. – Part C Chapter 4 WG3 Environmental Indicators.

Dániel-Ferreira, J., Berggren, Å., Wissman, J., Öckinger, E. (2022): Road verges are corridors and roads barriers for the movement of flower-visiting insects. Ecography e05847, doi: 10.1111/ecog., 13 p.

Drobnik, J., Finck, P., Riecken, U. (2013): Die Bedeutung von Korridoren im Hinblick auf die Umset-zung des länderübergreifenden Biotopverbundes in Deutschland. BfN-Skripten 346. BfN Bundesamt für Naturschutz, Bonn.

Dudley, N. (Editor) (2008): Guidelines for Applying Protected Area Management Categories. Gland, Switzerland. IUCN. x + 86pp. WITH Stolton, S., P. Shadie and N. Dudley (2013). IUCN WCPA Best Practice Guidance on Recognising Protected Areas and Assigning Management Categories and Governance Types, Best Practice Protected Area Guideline.

EC - European Commission (2021): EU Biodiversity Strategy for 2030. Bringing nature back into our lives. 1st edition. doi:10.10.2779/677548.

ECMT – European Conference of Ministers of Transport (1992): Resolution 92/2 on New Classification of Inland Waterways [CEMT/CM(92)6/FINAL]. https://www.itf-oecd.org/sites/default/files/docs/-wat19922e.pdf [21.11.2022].

Edge, C. B., Fortin, M.-J. (2020): Habitat network topology influences the importance of ecological traps inmetapopulations. Ecosphere 11(5): e03146. 10.1002/ecs2.3146.

EEA – European Environmental Agency (2020): Building a coherent Trans-EuropeanNature Network. https://www.eea.europa.eu/publications/building-a-coherent-trans-european [23.03.2022].

Eilertsen S., Almas, P., Naestad, F., Winsvold, A., Mathisen, K. (2021): Scary sounds as a tool to prevent moose – train collisions in Norway and Sweden. – In IENE 2020, International Conference - LIFE LINES – Linear Infrastructure Networks with Ecological Solutions. Abstract Book, S. 88.

EU-Kommission, Richtlinienvorschlag COM (2020), 0380: EU-Biodiversitätsstrategie für 2030 – Mehr Raum für die Natur in unserem Leben, Mitteilung der Kommission vom 20.

European Court of auditors (2018): Europäisches Hochgeschwindigkeitsschienennetz: keine Realität, sondern ein unwirksamer Flickenteppich. Sonderbericht Nr. 19 DE., 120 S.

Eurostat, UNECE & ITF (2019): Glossary for transport statistics — 5th edition — 2019. https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/ks-gq-19-004.

Fehlberg U., Pohlmeyer K. (1994): Ökologische Barrierewirkung von Straßen auf wildlebende Säugetiere. Dtsch. Tierärztl. Wochenschr. 101, 125ff.

Finke, D., Werner, M. (2020): Artenreiche Grünflächen, Handreichung zur Anlage und Pflege artenreicher Grünflächen an Straßen, Wegen und Plätzen. Broschüre, Ministerium für Energiewende, Landwirtschaft, Umwelt, Natur und Digitalisierung des Landes Schleswig-Holstein: 58 S.

Friebe, K., Steffens, T., Schulz, B., Valqui, J., Reck, H., Hartl, G. (2018): The significance of major roads as barriers and their roadside habitats as potential corridors for hazel dormouse migration - a population genetic study. Folia Zoologica (Brno) 67, 98–109.

Fuchs, D., Hänel, K., Lipski, A., Reich, M., Finck, P., Riecken, U. (2011): Länderübergreifender Biotopverbund in Deutschland, Grundlagen und Fachkonzept. - Schriftenreihe Naturschutz und Biologische Vielfalt 96, 192 S.

Fuhrmann, M., Tauchert, J. (2010): Annahme von Kleintierdurchlässen – Einfluss der Laufsohlenbeschaffenheit und des Kleinklimas auf die erfolgreiche Durchquerung. Forschungsbericht BASt-Forschungsprogramm Straßenwesen, F+E 02.263/2005/LRB, 149 S.

Guinard, E. (2022). Report on identification of Gaps and Barriers to expand replicability and application of good practice to mainstream biodiversity and transport. Tec. report on Deliverable D3.2,43 p.

Guinard, E., Billonc, L., Bretaud, J., Sordelloc, R., Chevalliera, L., Wittéc, I. (n.p., under review): Comparative study of two animal carcass survey methods on roads.

Günnewig, D., Johannwerner, E., Kelm, T., Metzger, J., Wegner, N. (2022): Anpassung der Flächenkulisse für PV-Freiflächenanlagen im EEG vor dem Hintergrund erhöhter Zubauziele – Notwendigkeit und mögliche Umsetzungsoptionen. Umweltbundesamt. 76/2022

Hakansson, E. (2020): Effectivity of road and railway crossing structuresfor wild animals. Master degree project, University of Gothenburg, 31 p.

Hänel, K, Reck, H. (2011). Bundesweite Prioritäten zur Wiedervernetzung von Ökosystemen: Die Überwindung straßenbedingter Barrieren. BfN, Naturschutz und Biologische Vielfalt, 108.

Hänel, K. (2007): Methodische Grundlagen zur Bewahrung und Wiederherstellung großräumig funktionsfähiger ökologischer Beziehungen in der räumlichen Umweltplanung - Lebensraumnetzwerke für Deutschland. Dissertation, Universität Kassel, Fachbereich 06 - Architektur, Stadtplanung, Landschaftsplanung, URN: http://nbn-resolving.org/urn/resolver.pl?urn=urn:nbn:de:hebis:34-2007121319883.

Hänel, K., Baierl, C., Ulrich, P. (2015): Lebensraumverbund und Siedlungsentwicklung in Deutschland – Identifikation von Engstellen und Planungsempfehlungen. Naturschutz und Biologische Vielfalt 144, 241 S.

Helldin, J.O. (2022): Are several small wildlife crossing structures better than a single large? Arguments from the perspective of large wildlife conservation. Nature Conservation 47: 197-213.

Herrmann, M. Jennewein, J. (2019): Von Insellösungen zum Vernetzungskonzept - Beispielhafte Lösungen beim Straßenausbau in Brandenburg. Beitrag zur Landschaftstagung 2019, 15 S. FGSV 002/125, Köln; ISBN 978-3-86446-247-4.

Hietel, E., Reichling, T., Lenz, C. (2021): Leitfaden für naturverträgliche und biodiversitätsfreundliche Solarparks – Maßnahmensteckbriefe und Checklisten. 58 S. PDF-Datei verfügbar über die Hochschule Bingen.

Hlaváč, V. (2022 in lit.): Verification of migration corridors and defragmentation in the Czech Republic. Presentation, 26 slides.

Hlaváč, V., Andel, P., Matousova, J., Dostal, I., Strnad, M., Immerova, B., Kadlecik, J., Meyer, H., Mot, R., Pavelko, A., Hahn, E., Georgiadis, L. (2019): Wildlife and Traffic in the Carpathians. Guidelines how to minimize impact of transport infrastructure development on nature in the Carpathian countries. Danube Transnational Programme TRANSGREEN Project. The State Nature Conservancy of the Slovak Republic, Banská Bystrica, 2019, 228 p.

Hlaváč, V., Andel, P., Pesout, P., Libosar, T., Šikula, T., Bartonicka, T., Dostal, I., Strnad, M., Uhlikova, J. (2020): Doprava a ochrana fauny v České republice - 1. vydání. - Praha: Agentura ochrany přírody a krajiny České republiky (Metodika AOPK ČR) ISBN 978-80-7620-070-8.

IENE (2022) Transport Ecology Guidelines Portal - https://handbookwildlifetraffic.info/transport-ecology-guidelines-portal/?fwp_category=publications; retrieved 15 December 2022.

Iuell, B., Bekker, G.J., Cuperus, R., Dufek, J., Fry, G., Hicks, C., Hlavác, V., Keller, V., Rosell, C., Sangwine, T., Tørsløv, N., Wandall, B. le Maire, (Eds.) (2003): Wildlife and Traffic: A European Handbook for Identifying Conflicts and Designing Solutions, 172 p.

Jaeger, J. (2002): Landschaftszerschneidung. Eine transdisziplinäre Studie gemäß dem Konzept der Umweltgefährdung. Verlag Eugen Ulmer, Stuttgart. 447 S.

Janke, F., Maaß, K. (2018): Solarenergie und Naturschutz - Naturverträgliche Freiflächen-Photovoltaikanlagen. Dialogforum Erneuerbare Energien und Naturschutz von BUND und NABU Baden-Württemberg, 6 S.

Jones ME. Road upgrade, road mortality and remedial measures: impacts on a population of eastern quolls and Tasmanian devils. Wildl Res. 2000; 27:289–96.

Kauffman, Matthew J. et al. 2021: Mapping out a future for ungulate migrations. In: Science, Vol. 372, Issue 6542, 566-569.

KNE (2021, 3. Fassung): Auswahlbibliografie „Photovoltaik-Freiflächenanlagen und Naturschutz“, 6 S.

Koch, M., Reck, H., Scholles, F. (2011): Thesenpapier Biologische Vielfalt in Umweltplanungen. UVP-report 25 (2+3): 112-121.

Kramer, H., Mücher, S., Knapen, R., Franke, J., Hennekens, S., Ilhame Janssen (2022): Habitat classification using AI and Deep Learning. Workshop Biodiversity monitoring through RS & AI techniques. https://edepot.wur.nl/588099.

Kruidering, A., Veenbaas. G., Kleijberg, R. Koot, G., Rosloot, Y., vanJaarsfeld, E. (2005): Leidraad faunaverzieningenbij wegen. Delft, Rijkswarerstaat, Dienst Weg- en Waterbouwkunde, 215 p.

LFU 2014: Praxis-Leitfaden für die ökologische Gestaltung von Photovoltaik-Freiflächenanlagen. Umwelt Spezial, 70 S. Augsburg.

Marti, F., Stutz, H-P. (1993): Zur Erfolgskontrolle im Naturschutz. Literaturgrundlagen und Vorschläge für ein Rahmenkonzept. Ber. Eidgenöss. Forsch.anst.Wald Schnee Landsch. 336.

MI/MELUND (2021): Grundsätze zur Planung von großflächigen Solar-Freiflächenanlagen im Außenbereich: Gemeinsamer Beratungserlass des Ministeriums für Inneres, ländliche Räume, Integration und Gleichstellung und des Ministeriums für Energie, Landwirtschaft, Umwelt, Natur und Digitalisierung vom 1. September 2021, 17 S.

Mladek, J., Sikula, T. (2016): Greening highway corridors to support butterfly metapopulations in protected areas. In: Guinard, E. (ed.): IENE 2016 – Integrating transport infrastructure with living landscapes. Lyon 303 p.

MLUK/Ministerium für Landwirtschaft, Umwelt und Klimaschutz des Landes Brandenburg (2021): Vorläufige Handlungsempfehlung des MLUK zur Unterstützung kommunaler Entscheidungen für großflächige Photovoltaik-Freiflächensolaranlagen (PV-GMS), 14 S.

Müller, K., Tetzlaff, A., Reck, H. (2016): The importance of roadside vegetation on plant diversity in Northern Germany. In Guinard, E. (Ed.): IENE 2016 - Integrating Transport In-frastructure with Living Landscapes; p. 223, DOI: 10.13140/RG.2.2.30321.25442.

Niemann, K., Rüter, S. et al. (2017): Photovoltaik-Freiflächenanlagen an Verkehrswegen in Deutsch-land. Natur und Landschaft 92 (3), 119-128.

Noordijk, J., Schaffers, AP., Heijerman, T., Sýkora, KV. (2011): Using movement and habitat corridors to improve the connectivity for heathland carabid beetles. J Nat Conserv. 19: 276–84.

Okániková, Z., Romportl, D., Kluchová, A., Hlaváč, V., Strnad, M., Vlková, K., Janák, M., Kadlečík, J. & Papp, C.R. (2021). Methodology for Identiἀcation of Ecological Corridors in the Carpathian Countries by Using Large Carnivores as Umbrella Species. Danube Transnational Programme ConnectGREEN Project "Restoring and managing ecological corridors in mountains as the green infrastructure in the Danube basin". State Nature Conservancy of the Slovak Republic, Banská Bystrica, 82 p.

Orlowski G. Roadside hedgerows and trees as factors increasing road mortality of birds: implications for management of roadside vegetation in rural landscapes. Landsc Urban Plan. 2008; 86:153–61.

Ouédraogo, DY., Villemey, A., Vanpeene, S.,Coulon, A., Azambourg, V., Hulard, M., Guinard, E., Bertheau, Y., De Lachapelle, F., Rauel, V., Mitouard, E., Jeusset, A., Vargac, M., Witté, I., Jactel H., Touroult, J., Reyjol, Y., Sordello, R. (2020): Can linear transportation infrastructure verges constitute a habitat and/or a corridor for vertebrates in temperate ecosystems? A systematic review. Environ Evid 9, 13; doi.org/10.1186/s13750-020-00196-7.

Papp, C. R., Berchi, M. G. et al., (2019): State of the Art Report and Gap Analysis in the field of environmentally-friendly transport infrastructure development, Danube Transnational Programme TRANSGREEN Project, WWF Romania, Bucharest, Romani, 142 p.

Patterson, C., Torres, A., Coroi, M., Cumming, K., Hanson, M., Noble, B.,Tabor, G., Treweek, J., Jaeger, J. (2022): Treatment of ecological connectivity in environmental assessment: A global survey of current practices and common issues, Impact Assessment and Project Appraisal, 40:6, 460-474, DOI: 10.1080/14615517.2022.2099728.

Peix, M., Semke, L. (n.p.): Totraum oder Lebensraum? – Biologische Vielfalt in Autobahnknotenpunkten. BfN-Skripten XXX

Perez Carabaza, S., Boydell, O. (2021): Habitat classification using convolutional neural networks and multitemporal multispectral aerial imagery. Journal of Applied Remote Sensing July 2021. DOI: 10.1117/1.JRS.15.042406.

Peter, F., Reck, H., Trautner, J., Böttcher, M., Strein, M., Herrmann, M., Meinig, H., Nissen, H., Weidler, M. (2023, submitted): Lebensraumverbund und Wildtierwege - Standards bei der Bündelung von Verkehrswegen und Photovoltaik-Freiflächenanlagen, Manuskript, 30 S., Natur und Landschaft.

Reck, H. (2022): Tiere am Straßenrand. Natur und Landschaft 97 (9/10): 443-454.

Reck H. (2013): Klimawandel, Biodiversität und Kompensation - Maßnahmen für die Zukunft. Natur und Landschaft 88 (11): 447 - 452.

Reck, H., Böttcher, M. (n.p.; Stand 11/2022): Lebensnetze und die Vermeidung von Lebensraumzerschneidung: Anforderungen an die Eingriffsplanung (SUP, UVP, Eingriffsbewältigung). BfN-Skripten XXX

Reck, H., Schmüser, H. (2022): Wolves_die_on_motorways_in_Germany. English translation of the improved version from December 2022, based on Reck, H., Schmüser, H. (2022): Natur und Landschaft 97 (9/10). Textbox 1, p 424-425; DOI 10.19217/NuL2022-09-02.

Reck, H., Nissen, H., Holst, U.,Heiler, C., Konn Vetterlein, D., Lamp, F. (2020): The barrier effect of railwaysand other linear grey and green infrastructure on the small fauna - What can we learn from flightless, stenotopic woodland ground beetles? Presentation at IENE International Conference Evora. DOI: 10.13140/RG.2.2.28643.53285.

Reck, H., Hänel, K., Strein, M., Georgii, B., Henneberg, M., Peters-Ostenberg, E., Böttcher, M. (2019): Green Bridges, Wildlife Tunnels and Fauna Culverts: The Biodiversity Approach. BfN-Skripten 522, 97 p.

Reck, H., Müller, K. (2018): Straßenbegleitgrün und biologische Vielfalt: Potenziale und Realität. Straßenverkehrstechnik 62 (7), 469-480.

Reck, H., van der Ree, R. (2015): Insects, snails and spiders: The role of invertebrates in road ecology. In van der Ree, R., Smith, D. J., and Grilo, C. (eds), Handbook of Road Ecology. John Wiley & Sons, Oxford, 247-257.

Reck, H., Hänel, K., Böttcher, M., Walter, A. (2011): Die Überwindung von Barrieren: Wiedervernetzung für Deutschland. – Jahrbuch für Naturschutz und Landschaftspflege 58 (1): 26–42.

Reck, H., Hänel, K., Huckauf, A. (2010): Nationwide Priorities for Re-Linking Ecosystems: Overcoming Road-Related Barriers. https://www.bfn.de/sites/default/files/BfN/planung/eingriffsregelung/-Dokumente/nationwide_priorities_for_re-linking.pdf.

Reck, H., Sachteleben, J., Hänel, K., Hermann, M. (2008): Checkliste zur Auswahl von Zielarten des überörtlichen Biotopverbundes (= Zeigerarten zur Analyse großräumiger Lebens-raumfragmentierung. - http://www.jagdnetz.de/Aktuelles/Naturschutz/index.cfm, 7 S.

van der Ree, R., Smith, D. J., and Grilo, C. (2015) (eds), Handbook of Road Ecology. John Wiley & Sons, Oxford.

Regionale Planungsgemeinschaft Oderland-Spree (2020): Planungshilfe Freiflächen-Photo-voltaikanlange, 30 S.,

Richter, K., Zinner, F., Böckelmann, R., Dörks, S., Durka, W., Fritzsch, S. (2013): Barrierewirkung von Straßen auf bodengebundene Kleintierpopuationen. Forschung Straßenbau und Straßenverkehrstechnik, 108, 199S.

Rietze, J., Reck, H. (1998): Das Einzugsgebiet von Grünbrücken und der Einfluss von Lebens-raumkorridoren, untersucht am Beispiel von Heuschrecken. Forschung Straßenbau und Straßenverkehrstechnik 756: 493-513.

Rosell et al. (2022): Handbook wildlife & traffic - update of Iuell et al. 2002 - online version accessible at: https://www.iene.info/projects/iene-handbook/

Rosell, C., Torrellas, M., Colomer, J., Reck, H., Navàs, F., Bíl, M., O'malley, V., Hahn, E., Hofland, A., Sangwine, T., Sjölund, A (2020): Maintenance of ecological assets on transport linear infrastructure Wildlife & Traffic A European Handbook for Identifying Conflicts and Designing Solutions CEDR.

Santos SM, Mira A, Salgueiro PA, Costa P, Medinas D, Beja P. Avian trait-mediated vulnerability to road traffic collisions. Biol Conserv. 2016;200: 122–30.

Schmüser, H., Broszio, F., Fehlberg, U., Reck, H., Graumann, S. (2014): Das Wildunfall und Totfund-Kataster Schleswig-Holstein – ein Modell. Jagd- und Artenschutz Jahresbericht 2014, Ministerium für Energiewende, Landwirtschaft und ländliche Räume Schleswig-Holstein (Hrsg): 24-28.

Schöps, K., Reck, H. mit Beiträgen von M. Wallaschek & D. Lorenzen (2003): Praxistest FFH-Verträglichkeitsprüfung und Landschaftspflegerischer Begleitplan A 143, Westumfahrung Halle: Modellhafte Populationsanalysen zur Quantifizierung der Auswirkung straßenbedingter

Lebensraumzerschneidung; Population viability analysis and the assessment of habitat defragmentation; – Schr. R. Angewandte Landschaftsökologie, 51: A1-A71.

Schroer, S., Huggins, B., Böttcher, M., Hölker, F. (2019): Leitfaden zur Neugestaltung und Umrüstung von Außenbeleuchtungsanlagen – Anforderungen an eine nachhaltige Außenbeleuchtung. – BfN-Skripten 543, 97 S., Bonn-Bad Godesberg.

Seiler, A., Olsson, M. (2017): Wildlife Deterrent Methods for Railways-An Experimental Study. In Borda-de-Água, L., Barrientos, R., Beja, P., Ppereira, H. (Eds.): Railway Ecology. - Springer International Publishing, S. 277–291.

Shimura, M., Ushiogi, T., Ikehata, M. (2021): Prevention of Deer-train collisions by a deterrent sound – In IENE 2020, International Conference - LIFE LINES – Linear Infrastructure Networks with Ecological Solutions. Abstract Book, S. 253.

Sinsch, U., Stamann, T. (2023): Automatisierte Amphibienerfassung in Kleintierdurchlässen unter Straßen: Ein Lichtschranken-basiertes Kamerasystem. Zeitschrift für Feldherpetologie 30: 108–121.

Steiof, K. (1996): Verkehrsbegleitendes Grün als Todesfalle für Vögel. Natur und Landschaft 71 (12), 527-532.

Strein, M. Hänel, K., Reck, H. (2018 n.p.): Wirksamkeitskontrollen an Querungshilfen - Untersuchungen zur Ableitung von Gestaltungsempfehlungen und Prüfkriterien für eine verbesserte und nachhaltige Funktionsfähigkeit. Abschlussbericht FKZ 3509 82 2100. Forstliche Versuchsanstalt Freiburg. 272 S.

Strnad, M., Mináriková, T., Dostálová, A., Plesnik, J., Vrba, J., Hošek, M. and Condé, S., 2013. Report on methodological evaluation of approaches to migration corridors. ETC/BD report to the EEA.

Struijk, R., Jansen, S., Van de Veer, O. (2014): Herpetoduct Elspeetsche Heide: The new standard for Herpetofauna? Zeitschrift für Feldherpetologie 21: 207-218.

Tesch et al. 2020: Pflege- und Entwicklungsplan für den Biotopkorridor Alte Süderelbe – Moorgürtel, 253 S. See daten.transparenz.hamburg.de.

Trautner, J., Reck, H., Mayer, J., Müller-Pfannenstiel, K. (2021): Tierarten und Artengruppen von allgemeiner und von besonderer Planungsrelevanz - Empfehlungen für eine sachgerechte und rechtskonforme Definition zur Anwendung bei der Bewertung und Bewältigung von Eingriffen in Natur und Landschaft. Artenschutz und Biodiversität 2 (4), 1-19. DOI: 10.55957/OZIT2246.

U.S.DT / U.S. Department of Transportation, Federal Highway Administration (download 2022): Wildlife crossing structure handbook Design and Evaluation in North America; https://www.fhwa.dot.gov/clas/ctip/wildlife_crossing_structures/ch_4.aspx.

Unterseher B. (2015): Straßenbegleitgrün. Hinweise zur ökologisch orientierten Pflege von Gras- und Gehölzflächen an Straßen. Ministerium für Verkehr und Infrastruktur Baden-Württemberg: 61 S.

Vagolins, J. (2019,n.p.): Rail Baltica network integration in landscape of Latvia. Research report, DBU short-term fellowship.

Vermeulen, H.J.W., 1994. Corridor function of a road verge for dispersal of stenotopic heathland ground beetles carabidae. Biological Conservation 69, 339–349.

Verstrael T, van den Hengel B, Keizer PJ, van Schaik T, de Vries H, van der Berg S, 2000. National highway verges ... national treasures. Drukkerij Ronaveld, Den Haag.

Villemey, A., Jeusset, A., Vargac, M., Bertheau, Y., Coulon, A., Touroult, J., ... & Sordello, R. (2018). Can linear transportation infrastructure verges constitute a habitat and/or a corridor for insects in temperate landscapes? A systematic review. Environmental Evidence, 7(1), 1-33.

Vliegenthart, A., Zollinger, R. (2012): Manual for the booklet Provisions for Small Wildlife at Infrastructural Works. Compiled by: Albert Vliegenthart (VOFF/Dutch Butterfly Conservation) and Ronald Zollinger (VOFF/ Foundation Reptile, Amphibian and Fish Conservation Netherlands, RAVON) 2012.

Vlkova, K., Zyka, V., Romportl, D. (eds) (2021): Map of core areas and ecological corridors for large carnivores in the Carpathian Mountains. Online map, output of the ConnectGREEN project, suported by Interreg Danube Transnational Programme, 2021. Road management measures in West Macedonia, Greece.

Voumvoulaki, N. (2022, in lit): Human-beat coexistence and road management measures in West Macedonia, Greece in the frame of LIFE SAFE CROSSING PROJECT. Presentation, 17 slides.

Weber, M. (2011): Potential kleinerer Autobahnunterführungen als Querungsmöglichkeit für Wildtiere. - Masterarbeit an der Universität für Bodenkultur Wien, 51 S. + Anhang.

Werner M. (2014): Leitfaden für die fachgerechte Unterhaltungspflege von Gehölzflächen an Straßen. Landesbetrieb Straßenbau und Verkehr Schleswig-Holstein: 11 S. + Anhang.

Xu, W., Dejid, N., Herrmann, V., Sawyer, H., Middleton, A.D. (2020). Barrier behaviour analysis (BAB) reveals extensive effects of fencing on wide-ranging ungulates. Journal of Applied Ecology, 58: 690-698.

Yanes, M., Velasco, J., Suárez, F. (1995): Permeability of roads and railways to vertebrates: The importance of culverts. Biological Conservation, 71(3), 217–222.

Zinner, F., Fritzsch, S., Richter, K. (im Druck): Faunistische Untersuchungen zur Bedeutung des Straßenbegleitgrüns in der Bördelandschaft Sachsen-Anhalts - Straßenbegleitgrün als Habitat der Zauneidechse. BfN-Skripten XXX.

Zinner, F., Reck, H., Richter, K. (Bearb.) (2018): Wirksamkeit von Querungshilfen für Kleintiere. Forschung Straßenbau und Straßenverkehrstechnik 1131: 199 S. + Beiheft.

Żylkowska, J., Stolarski, M., Bartoszek-Majewska, D. (2021): Acoustic Animal Deterring Device as a mitigation measure to limit collisions of rail vehicles with wild animals. – In IENE 2020, International Conference - LIFE LINES – Linear Infrastructure Networks with Ecological Solutions. Abstract Book, S. 44.

6 SUPPORT AND THANKS

Funding and thanks

We would like to express our thanks to the funding organizations. The BISON project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement no. 101006661. The workshop on bundling, held at the International Academy for Nature Conservation Isle of Vilm in November 2022 was initiated and sponsored by the German Federal Agency for Nature Conservation (BfN).

We also want to thank the BISON project partners and the many partnerts of the practical and scientific projects on which the recommendations are based, the co-authors of special chapters, Mathias Herr-mann, Vaclav Hlavac, Anne Hopf, Holger Meinig, Henning Nissen, Franziska Peter, Martin Strein, Jürgen Trautner & Manuel Weidler and Pierre-Yves Belan who helped with the port chapter.

Last but not least we would like to express our special thanks to participants of the 2022 March / May BISON D5.3-workshops: H. Chalkia, L. Fernández, L. Georgiadis, E. Guinard, Vaclav Hlavac, R. Mot, C. Rosell, N. Voumvoulaki and A. Seiler for discussion and many helpful proposals and E. Guinard and R. Mot for reviewing BISON Delivery 5.3.

7 ABOUT THE AUTHORS

Marita Böttcher

Cindy Baierl

Heinrich Reck

Marita Böttcher

Since 1993, Marita Böttcher is a staff member of the Federal Agency for Nature Conservation (BfN) in the field of transport route planning and impact regulation. She is also a member of the governance board of IENE (Infra Eco Network Europe) and of national conservation foundations and expert groups. Main objectives of her current work are:

1. Fragmentation of habitats due to linear transport infrastructure and its impact on biodiversity, main contributions thereby:

   - Review of concrete projects (road) with regard to the consideration of fragmentation and the derivation of adequate defragmentation measures within the framework of the National Road Construction Plan ragmentation of habitats due to linear trasnport infrastructure and its impact on biodiversity,
   - Commissioning and managing research projects to assess the impact of fragmentation on biodiversity, developing defragmentation guidelines for habitat reconnection, developing strategies for habitat reconnection over and along linear transport infrastructure at project and national level,
   - Development of sublegal and legal requirements for the consideration of fragmentation and compensation in infrastructure planning.

2. Light pollution and its impacts on biodiversity with special regard to nocturnal and twilight insects:

   - commissioning and managing research projects to assess the impact of lightpollution on biodiversity, developing of guidelines to avoid severe impacts on biodiversity with regard on artificial light, main contributions thereby:
   - Participation in the development and implementation of legislation to avoid the effects of artificial light on biodiversity.

Cindy Baierl

Landscape ecologist and researcher Cindy Baierl is working on several research projects at Kassel University, department landscape and vegetation ecology. She is dealing with fragmentation/defragmentation and nature conservation aspects and issues at all planning levels, from local, via supra-regional to transnational. Her interests and expertise also comprise nature conservation management. Beside the work in the BISON-project she manages a research project regarding indicators for climate change adaption management and works on an update of the German woodland habitat network currently.

Heinrich Reck

Associate professor, Dr.-Ing. Heinrich Reck is agricultural biologist and habilitated landscape ecologist. He works part-time as a researcher and lecturer in the field of landscape ecology at the Institute for Nature and Resource Conservation at Kiel University on the topics of "Spatial Environmental Planning" and "Applied Animal Ecology". Through private activities in cooperation with various companies and expert groups since 1982, H. Reck is also familiar with freelance planning and nature conservation practice.

Current foci of his research group are:

- the importance of mobility for the survival of species ("reconnection of ecosystems / green infrastructure"),
- the effects of transport infrastructure (effects of habitat fragmentation / habitat qualities of side areas),
- the monitoring and analysis of biodiversity dynamics and the importance of biogenic heterogeneity in the cultural landscape and in special nature conservation areas ("ild ungulates and biodiversity / spatial distribution patterns of indicator species / wildlife register Schleswig-Holstein) and
- the development of planning guidelines for the protection of biodiversity (regional planning, landscape planning, impact assessment and impact regulation).

H. Reck has been a member of various natural science societies and environmental associations for many years, and he is a member of the State Planning Council of Schleswig-Holstein.

8 ANNEX

8.1 Guidelines for contents and use of national and international ecological networks

Table of Contents

Alpine Carpathian Corridor

Alpine Carpathian Corridor	
Original title	Alpen-Karpaten-Korridor Alpine Carpathian Corridor (ACC Corridor)
Network description (content and main criteria)	The corridor between the Alps and the Carpathians is a traditional migration route for wildlife. This corridor does not only connect the Eastern border of the Alps with the Little Carpathians in Slovakia but also crosses a highly dynamic European region located between the cities of Bratislava, Sopron and Vienna. As part of the EU Strategy for the Danube Region (EUSDR), the corridor is being restored to reconnect the eastern foothills of the Alps with the Western Carpathians and promote ecological connectivity and sustainable development throughout the region. This was initiated and started by the "Alpine-Carpathian Corridor" project and with EU funds for the program period 2007 to 2013
Important websites	https://www.wwf.at/artikel/alpen-karpaten-korridor/ http://www.alpenkarpatenkorridor.at/
Data form, state and source	Shapefile (ACC_ALL_Detailed_Corridor) created by BOKU Wien (franz.suppan@boku.ac.at) (state: 21/01/2013), Data download: https://lebensraumvernetzung.at/de/projects/5 (29/10/2021)
Relevance for spatial planning	
Planning level	
Planning instruments and implementation level	Within the framework of the "Alpine-Carpathian Corridor" project, numerous institutions, NGOs, universities as well as road construction companies and regional and national authorities of Austria and Slovakia have joined forces to establish a joint cross-border platform that will enable the migration and genetic exchange of wildlife populations. The outcome of this project is a joint Austrian-Slovak action plan for the corridor covering land use, communication, scientific basis, protection and spatial planning. Upon project completion, this plan will be complemented with an implementation manual that will serve as reference material for similar future projects. Furthermore, a comprehensive manual on spatial planning will be written, translating spatial planning objectives into planning tools for all regional authorities. A system of "green bridges" is currently under construction to allow wildlife to cross easily. The first bridge of this type is being built in Austria over the A4 Vienna-Budapest highway. A similar crossing aid for wildlife, designed to improve ecological connectivity, is being built in Slovakia over the D2 freeway from Bratislava to Brno. The structure of the corridor led to the establishment of a forum for representatives of these regions to exchange ideas and develop solutions

	that can be applied not only in individual protected areas, but throughout the region. To ensure long-term continuity, the main stakeholders signed a memorandum of understanding that can contribute to sustainability in their area of responsibility. In addition, the relevant spatial development plans will take into account the results and recommendations of this project at the regional and national levels.
Contacts	BOKU, Vienna

Literature:

EUROPEAN COMMISSION (2019): Guidance on a strategic framework for further supporting the deployment of EU-level green and blue infrastructure. Commission Staff Working Document. Brussels, 101p.

Austria

Habitat network Austria	
Original title	Lebensraumvernetzung Österreich Current version of the habitat corridors Austria (LRVA-2022, State 16/10/2022)
Network description (content and main criteria)	Since 2018 there is nationwide Austrian concept for supra-regional ecological networks. It was developed within the framework of the project "Habitat-Network as a contribution to securing biodiversity in Austria", which was carried out as part of the Austrian Rural Development Programm 2014-2020. Optimal habitat corridors were GIS based calculated on a landscape and a permeability/resistance model. After the calculation of the habitat corridors, corridor sections were analyzed. As a result, the most important regional and national habitat corridors in Austria were mapped as an essential basis for the conservation of networked habitats. In several workshops the habitat corridors in Austria were examined by specialist departments of the state government and their comments were considered in a revised version of the concept. Not all supra-regional habitat corridors but only the ones important für Austria were included in the network. The network focusses on large species of forest habitats (but also migration corridors for amphibians are considered). Wetland or dryland habitats are not considered. The current version of the integral dataset for habitat connectivity in Austria takes into account all datasets and designations of habitat corridors from scientific projects and projects of the public sector (federal provinces). The dataset was evaluated by the experts of the coordination platform "Habitat Connectivity Austria" and updated as soon as new findings and designations from projects are available.
Important websites	http://www.lebensraumvernetzung.at/ (accessed 15/11/2022) http://www.umweltbundesamt.at/umweltsituation/naturschutz/lr_schutz/vernetzung/ (accessed 20/11/2019) https://lebensraumvernetzung.at/publikationen/LRV%20Technischer%20Bericht_MST_2020_05_16.pdf
Data form, state and source	Shape files for habitat network Austria, 2022: http://www.lebensraumvernetzung.at/de/geodata (state: 16/10/22) accessed 15/11/2022)
Relevance for spatial planning	The Biodiversity Strategy of Austria formulates specific targets for integrating biodiversity and ecosystem services in spatial planning with measures such as incorporating ecological infrastructure, consideration of functional connectivity and the habitat network when establishing compensation areas and the preservation of unfragmented areas and migration corridors (BMLFUW, 2014).

Planning level	In Austria, the implementation of ecological networks is currently at provincial level at different stages of development. In Styria and in the district Pinzgau in Salzburg for example, green zones and green corridors are protected by decree. In several other Austrian federal provinces, the theoretical and technical bases for ecological networks have already been established, however these are not legally binding. Since 2018 a nationwide Austrian concept for supra-regional ecological networks is existing.
Planning instruments and implementation level	Secured according to federal provinces in different plans: e. g. Styria: Green zones by ordinances; Salzburg/Pinzgau Green Corridors in the regional programs
Contacts	Roland Grillmayer +43676 9410850 Roland.grillmayer@umweltbundesamt.at

Defragmentation measures	
Description of the defragmentation measures	ASFINAG will build a total of 18-20 green bridges on existing line sections by 2027. 4 have been constructed so far. One of them, the Green Bridge on the A1 West motorway near Ybbs, was completed in 2015. With this 60-metre-wide bridge, ASFINAG is reopening the main Kalkalpen-Czech Republic corridor for wildlife migration.
Important Websites, Data form and source	https://www.asfinag.at/media/ssupru2t/2020_gr%C3%BCnquerungen_monitoring-endbericht_asfinag.pdf (accessed 20/01/2023) https://www.asfinag.at/media/5xgicclz/2020_gr%C3%BCnquerungen_kurzleitfaden-zur-gestaltung-und-pflege_asfinag.pdf (accessed 20/01/2023)
Relevant habitats/species	Terrestrial species of forests (mainly large mammals such as bear, lynx, deer, badger, fox)
Legal instruments (HABITATS Directive II and IV, national conservation acts)	
Contacts	ASFINAG (Autobahnen- und Schnellstraßen Finanzierungs-Aktiengesellschaft) Ulli Vielhaber, Mobile: +43 664 6010810014; Ulli.vielhaber@asfinag.at

Literature:

ASFINAG (2011): Natura 2000 und Artenschutz – Empfehlung für die Planungspraxis beim Bau von Verkehrsinfrastruktur

Bieringer, G., Kollar H. P., Strohmayer, G. (2007): Auswirkungen von Straßenlärm auf Vögel in Österreich, UVP-Report 21, Ausgabe 3

Oberösterreicher Umweltanwaltschaft (ed.) (2012): Wildtierkorridore in Oberösterreich – Wildtierkorridorstudie für Oberösterreich, erstellt in Zusammenarbeit von den Abteilungen Naturschutz, Raumordnung sowie Land- und Forstwirtschaft bei Amt der Oö. Landesregierung, dem Oö. Landesjagdverband und der Oö Umweltanwaltschaft

BMLFUW (2014): Biodiversitätsstrategie Österreich 2020+. https://www.bmlfuw.gv.at/dam/jcr:7dd9ff6f-1a39-4f77-8c51-6dceaf6b195f/Biodiversit%C3%A4tsstrategie2020_dt.pdf

Dienstanweisung – Lebensraumvernetzung Wildtiere (2006), Bundesministerium für Verkehr, Innovation und Technologie, Sektion II – Gruppe Straße

Eidgenössische Finanzkontrolle (2007): Normen und Standards betreffend Wildtierpassagen in Österreich, Separates Dokument im Rahmen des Berichts „Protection de l'environment et routes nationales: Evaluation des normes et standards pour les passages a faune

Enzinger, K., Gross, M., Berg H.-M., Werdenic, D. (2010): Aktionsplan Feldhamsters (Cricetus cricetus) in Österreich unter besonderer Berücksichtigung von Niederösterreich, Naturschutzbund NÖ

Glitzner, I. (1999): Literaturstudie zu anlage- und betriebsbedingten Auswirkungen von Straßen auf die Tierwelt – Endbericht, erstellt im Auftrag der Magistratsabteilung 22 – Umweltschutz Magistrat der Stadt Wien (MA22-6888/98, Auftrag vom 21.12.1998)

Hinterstoisser, H., Heiselmayer, P., Grabner, S. (2007): Biotopverbund – Lebensraumvernetzung, Land Salzburg - Tagungsband, Naturschutzbeiträge 34/07, Universität Salzburg, FB Organismische Biologie, AG Ökologie und Diversität der Pflanzen & Amt der Salzburger Landesregierung, Naturschutzabteilung, ISBN 3-901848-36-3

Lachner, O. (2008): Biotopverbund – Situationsanalyse, Elemente und Handlungsansätze unter Berücksichtigung von Erfahrungen aus der angewandten Landschaftsplanung, Dissertation, Universität der Universität für Bodenkultur Wien, Department für Raum, Landschaft und Infrastruktur, Institut für Landschaftsentwicklung, Erholung und Naturschutzplanung

Leitner, H., Grillmayer, R., Leissing, D., Lackner, S., Banko, G., Stejskal-Tiefenbach, M. (2018): Lebensraumvernetzung zur Sicherung der Biodiversität in Österreich. Technischer Bericht, erstellt im Auftrag des Bundesministeriums für Nachhaltigkeit und Tourismus (BMNT) aus Mitteln des Österreichischen Programms für die Ländliche Entwicklung, Wien. 134 S.

RVS 04.03.11 – Umweltschutz – Amphibienschutz an Straßen – (2003), Österreichische Forschungsgemeinschaft Straße und Verkehr (FSV), AA Verkehr und Umwelt, AA – Amphibienschutz an Straßen

RVS 04.03.12 – Umweltschutz – Flora und Fauna an Verkehrswegen – Wildschutz (2007), AG Verkehr und Umwelt, AA Fauna und Flora an Verkehrswegen, Österreichische Forschungsgesellschaft Straße – Schiene – Verkehr

RVS 04.03.13 – Umweltschutz – Flora und Fauna an Verkehrswegen – Vogelschutz an Verkehrswegen (2007), AG Verkehr und Umwelt, AA Fauna und Flora an Verkehrswegen, Österreichische Forschungsgesellschaft Straße – Schiene – Verkehr

RVS 04.03.14 – Umweltschutz – Flora und Fauna an Verkehrswegen – Schutz wildlebender Säugetiere (ausgenommen Fledermäuse an Verkehrswegen (2009): AG Verkehr und Umwelt, AA Fauna und Flora an Verkehrswegen, Österreichische Forschungsgesellschaft Straße – Schiene – Verkehr

Schacht, H., Grillmayer, R., Wöss, M. (?): Entwicklung von fernerkundungsgestützen Methoden zur Erfassung und Bewertung von wildökologischen Korridoren als Grundlage landschaftspflegerisch-naturschutzfachlichen Planungen

Reiss-Enz, V., Spindler, E. (2007): Faunistische Richtlinien für die Straßenplanung in Österreich, UVP-Report 21, Ausgabe 2

Völk, F., Glitzner, I., Wöss, M. (2001): Kostenreduktion bei Grünbrücken durch deren rationellen Einsatz, Kriterien – Indikatoren – Mindeststandards, Bundesministerium für Verkehr, Innovation und Technologie, Straßenforschung, Heft 513

Völk, F., Reiss, V., Walcher, A., Schacht, H., Ellmauer, T., Reimoser, F. (Punktation 2006): Überregional bedeutsame Wildtierkorridore für Säugetierarten – Erfordernisse für eine erfolgreiche planerische Absicherung

Lacon Landschaftsplanung Consulting (2014): Fledermäuse und Straße – Ausnahmewahrscheinlichkeit von Querungshilfen für Fledermäuse – Endbericht: im Auftrag des Bundesministeriums für Verkehr, Innovation und Technologie (bmvit)

Pfeifer, M., Leitner, H. (2010): Entwicklung methodischer Standards für die Erfolgskontrolle von Wildquerungshilfen, Projektbericht im Auftrag des Bundesministeriums für Verkehr, Innovation und Technologie (bmvit)

Leitner H., Grillmayer R., Leissing D., Banko G., Brandl K., Stejskal-Tiefenbach M., Zulka, K. P. (2016): LEBENSRAUMVERNETZUNG ÖSTERREICH: Grundlagen – Aktionsfelder – Zusammenarbeit (Umweltbundesamt)

Belarus

National Ecological Network Scheme of the Republic of Belarus	
Original title	Нацыянальная схема экалагічнай сеткі Беларусі
Network description (content and main criteria)	The National Ecological Network of Belarus includes 93 sites with the total area of 3.37 million ha (16.2% of the country's territory). The National Ecological Network represents a system of natural and territorial complexes where the management of natural resources is governed by special rules in order to ensure the natural movement of living organisms. The network plays an important role in maintaining ecological equilibrium and ensuring the sustainable development of territories (the region, the country, and the continent), in preserving natural ecological systems, the biological and landscape diversity. The national ecological network comprises nucleus zones (core areas), ecological corridors and protected areas. The nucleus zones of the national ecological network are specially protected natural areas (their parts) and natural areas (their parts), which are subject to special protection. Nucleus zones are designed to preserve the entire diversity of landscapes and ecological systems, habitats for plants and animals. The ecological corridors of the national ecological network are meant to ensure communication between nucleus zones. They allow wild plants and wild animals to spread and migrate. The protected areas include natural territories, which are subject to special protection and lie outside the nucleus zones and ecological corridors. The protected areas safeguard vital ecological systems against potential risks. They prevent or reduce the harmful impact that natural complexes and sites inside the nucleus zones and ecological corridors may suffer from.
Important websites	http://www.minpriroda.gov.by/en/news-en/view/scheme-of-national-ecological-network-adopted-2373/ (accessed 06/03/2020) https://zviazda.by/ru/news/20180328/1522243055-v-belarusi-utverzhdena-shema-nacionalnoy-ekologicheskoy-seti (accessed 14/11/2022)
Data form, state and source	http://www.mappery.com/Belarus-National-Ecological-Network-Map (accessed 06/03/2020); here download of raster data (picture) Remark: GIS-Data request from 11/5/2020; yurgenson@biobel.bas-net.by, minproos@mail.belpak.by without success
Relevance for spatial planning	

Planning level	
Planning instruments and implementation level	The scheme of the national ecological network was adopted by Belarus president decree No.108 on 13 March 2018.
Contacts	Natalia Yurgenson E-Mail: yurgenson@biobel.bas-net.by

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø
Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

Belgium

Flemish Ecological Network (VEN)	
Original title	**Vlaams Ecologisch Netwerk (VEN),** Integraal Verwevings- en Ondersteunend Netwerk (IVON) La Structure Écologique Principale de la Wallonie (SEP)
Network description (content and main criteria)	The **Flemish Ecological Network (VEN)** comprises 125,000 ha of "large units of nature" and "large units of nature in development", in which the function of nature conservation prevails. Additionally, 150,000 ha of nature reserves (NVWG) are to be defined, in which the natural function is to be coordinated with the functions of agriculture, forestry and recreation in a sustainable way. These areas are linked to each other via "Nature Linking Areas" (NVBG). The NVBG and NVWG together form the **IVON or Integral Intervention and Support Network.** There are additional maps with search zones for planning and effective forest expansion. Priority areas in the function of the construction of 125,000 ha of VEN cover approximately 140,000 ha. The Delimitation was based mainly on ecological criteria. A map with focus areas for the realization of 150,000 ha NVWG covers approximately 180,000 ha. The GNBS directive status is a working map in the field of nature and forest policy. The **main ecological structure (SEP) of Wallonia** aims to bring together in a coherent outline all the areas of the territory having a current or potential biological interest. It materializes the theoretical concepts of the ecological network, it helps to identify areas with biological challenges for the implementation of several commitments of international conventions or agreements as well as the areas of green infrastructure necessary for the production of a wide range of ecosystem services. The SEP embodies the theoretical concepts of the ecological network of central zones, development zones, zones to be restored, buffer zones and connecting zones or corridors as defined by the Pan-European Ecological Network. The SEP currently covers around 300,000 ha (18% of Walloon territory) including 46,500 ha in agricultural areas (6.1% of the UAA = 15.5% of the SEP). 3/4 of the current SEP are Natura2000 sites for which detailed mapping has been launched. In the same spirit, it is planned in the long term to obtain a detailed cartography for the sites of great biological interest and to recover the information produced by the works of cartography of the natural inheritance in the PCDN.
Important websites	https://www.inbo.be/nl/vlaams-ecologisch-netwerk-ven-en-integraal-verwevings-en-ondersteunend-netwerk-ivon (accessed 18/12/2019) https://download.agiv.be/Producten/Detail?id=3966&title=Groenkaart_Vlaanderen_2012 (accessed 18/12/2019)

	https://download.agiv.be/Producten/Detail?id=1567&title=Gebieden_met_recht_van_voorkoop_VEN_en_IVON_21_juni_2016 (accessed 18/12/2019) http://passthrough.fw-notify.net/download/889115/http://etat.environnement.wallonie.be/files/Publications/TBE_2014_UK.pdf (accessed 18/12/2019) http://biodiversite.wallonie.be/fr/structure-ecologique-principale.html?IDC=2997 (accessed 18/12/2019) https://www.ecopedia.be/encyclopedie/vlaams-ecologisch-netwerk (accessed 23/03/2022)
Data form, state and source	https://pureportal.inbo.be/portal/nl/datasets/search.html (accessed 18/12/2019) GIS data of the Vlaams Ecologisch Netwerk (VEN) are integrated in the EDM
Relevance for spatial planning	The new policy concept (so called 'white book') for 'Spatial planning of Flanders' mentions that regional spatial planning has an important task to implement green infrastructure (GI). The multiple benefits, e. g. for climate adaptation, biodiversity and recreation, are recognised. Operational goals should include norms for including GI (Ruimte Vlaanderen, 2016). On 1 April 2017, the Department of Environment, Nature and Energy and the Department of Spatial Planning merged under the name of the Department of Environment (Omgeving) in order to better integrate spatial planning and environmental policy (Departement Omgeving, 2017). Wallonia: the new spatial planning tool, the code for territorial development (Art. R.II.21-6) includes ecological liaison areas to ensure the circulation of species between their biotopes. In addition, for most licences or authorisations about spatial and urban planning, mitigation and/or offset measures are imposed within the permits. In some cases, spatial planning can lead to an improvement of the ecological network (extension of economic activities with green areas, trees, ponds etc. instead of intensive chemical agricultural land).
Planning level	The Spatial Plan for Flanders of 23 September 1997 (RSV) provides for the delimitation of a natural structure. The Aim of the main ecological structure (SEP) is bringing together all area of current or potential biological interest in a coherent manner: -> materializes the theoretical concepts of the ecological network, -> it helps to identify the areas of biological importance for the implementation of several obligations of international conventions or agreements as well as the green infrastructure zones necessary for the production of a wide variety of ecosystem services The preliminary area SEP (Sepp) currently includes: 220.944 ha Natura 2000 network and other areas
Planning instruments and implementation level	The delineation of VEN and NVWG is linked to specific planning objectives in the Land Use Plans (RUP) and regional plans. The RSV indicates that 38,000 hectares of natural and reserve land are planned for the realization of the natural structure in addition to the 10,000 hectares of forest

	extension. This distinction is made in regional RUPs. The demarcation of the VEN takes place in two phases (Decree of the Flemish Government on 07.12.2001). In the first phase (2002-2003), consensus areas were identified based on GNBS and the desired agricultural structure. This resulted in the design delineation of approximately 86,900 ha of VEN in the Nature Decree (first track) and 8,000 ha of design green RUPs in the RSV version (second track). After processing public research, which in the period from 23 / 09-21 / 11/2002 to the draft demarcation of about 86,900 hectares of VEN finally the VEN was kept at a level of about 85,000 ha definitively fixed at 18.07.2003 was by the Flemish government. In a second phase (2003-2007), at the end of the demarcation of 125,000 ha of VENs, a decision was taken on the areas where consensus is more difficult, and at the same time the definition of agricultural structure was managed. 20/02/2004 saw the establishment of a first series of 15 RUPs by the Flemish government with a size of about 830 ha of the additional VEN area. On 04/02/2005 a second tranche of 6 RUPs for about 1,010 ha of an additional VEN area was established by the Flemish Government. All this means that the area of VEN has grown to 86,800 ha in practice. The SEP also implements the commitments of the European Union which are defined in the European Biodiversity 2020 Strategy to go beyond the challenges of the "Habitats" and "Birds" Directives and of the Natura 2000 network (objective 1) to take into account restoration ecosystem services (objective 2) and to strengthen the contribution of agriculture and forestry to maintaining and improving biodiversity (objective 3).
Contacts	

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø
Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

Poleman, E. (2014) (student Nr.: 3169529): Crossing possibilities for wildcats at a highway in Belgium, Environmental Biology, Universität Utrecht

Carpathian Corridors

Carpathian Corridors	
Original title	**Map of core areas and ecological corridors for large carnivores in the Carpathian**
Network description (content and main criteria)	The Carpathian Corridors are an Ecological Network for large carnivores in the Carpathians. It is a connectivity model presenting coherent network of core areas, stepping-stones and corridors. The Ecological Network is consisting of three categories: favorable and suitable habitats (Core areas), movement / migration zones (Ecological corridors) and critical connectivity zones. The identification of the ecological network was based on the habitat suitability models using the actual occurrence data of large carnivores (wolf, lynx and bear) and a set of environmental variables including abiotic, habitat and anthropogenic factors (in ESRI grid 100x100 m). According to the habitat suitability models core areas and stepping stones were identified and their function in the Carpathians was discussed. The output was edited and classified by experts in order to produce the final version of the ecological Network. The ecological network in the Carpathians has an area of 114,045 km2 (49.1% of the Carpathians). In the whole layer dominate favorable and suitable habitats (95.9% of the total area), followed by movement/migration zones (3.5%) and critical zones (0.6%). The ecological network is located in the territory of seven states. Slovakia (44.5%) and Romania (25.2%) show the largest share of the ecological network in the area of the state. In total, there are 484 critical zones in the ecological network: Slovakia 188, Romania 165, Poland 43, Ukraine 42, Czechia 31, Hungary 27, and Serbia 12 (border zones are counted twice). The as favorable and suitable habitats described Core areas are represented by large continuous favorable area that fulfil requirements for the permanent occurrence of the selected species. It mainly concerns forests with natural / semi-natural conditions and environment that enables natural growth of populations. The core areas are interconnected by movement / migration zones respectively Ecological corridors. They include linkage areas, corridors and stepping-stones that fulfil the migration requirements of species in a sufficient way. Corridors usually lead through the suitable habitats with sufficient refugee possibilities. Critical connectivity zones represent localities with significant limitations of the land permeability due to the difficult passable migration barriers.
Important websites	https://www.interreg-danube.eu/uploads/media/approved_project_output/0001/46/b06b6e925fd510bee8d1ca23fff5b03424c513fa.pdf (accessed 21/07/2021)
Data form, state and source	**Source:** Vlkova, K., Zyka, V., Romportl, D. (eds) (2021): Map of core areas and ecological corridors for large carnivores in the Carpathian Mountains. Online map, output of the ConnectGREEN project, suported by Interreg

	Danube Transnational Programme. https://ccibis.org/thematic-map-01-3/ **Meta data:** https://ccibis.org/thematic-map-01-2-2-2/ **Publication year:** 2020 **Download date:** 21/07/21
Relevance for spatial planning	Variable data can be used in the decision making processes in both spatial planning and management of protected areas at different levels of decision making (local, regional, national, transboundary, Carpathian).
Planning level	
Planning instruments and implementation level	The Methodology is embedded as part of the International Action Plan on Conservation of Large Carnivores and Ensuring Ecological Connectivity in the Carpathians into the frame of the Carpathian Convention through its parties.The modelled ecological network of the Carpathians was a basis for further use at the level of pilot areas within the ConnectGREEN project (2018-2021; https://www.interreg-danube.eu/approved-projects/connectgreen) as well as beyond the project's implementation.
Contacts	Dusan Rompotl, Dusan.Romportl@vukoz.cz

Literature:

Okániková, Z., Romportl, D., Kluchová, A., Hlaváč, V., Strnad, M., Vlková, K., Janák, M., Kadlečík, J., Papp, C.R. (2021). Methodology for Identification of Ecological Corridors in the Carpathian Countries by Using Large Carnivores as Umbrella Species. Danube Transnational Programme ConnectGREEN Project "Restoring and managing ecological corridors in mountains as the green infrastructure in the Danube basin". State Nature Conservancy of the Slovak Republic, Banská Bystrica, 82 pg.

Czech Republic

Biotope of selected specially protected species of large mammals of national importance	
Original title	Biotope of selected specially protected species of large mammals of national importance
Network description (content and main criteria)	Network comprises national biotopes/cores for large mammals, areal ecological corridors for connecting these cores and critical barrier sites within the corridor areas. Cores: distinction of national core areas and biotopes/cores for large mammals Corridors: areal corridors for large mammals; designation of critical zones Large mammal (carnivores (lynx, bear, wolf) and ungulates (moose and red deer)) migration corridors allowing dispersal through the landscape; migration corridors were modelled using GIS software (anthropogenic as well as environmental characteristics were included such as barriers - roads, railways, settlement, and large water bodies, as well as species occurrence data, slope, vertical heterogeneity etc.). Consequently, the migration corridors were checked in the field, especially in critical barrier sites for migration (where the corridor was in conflict with some impermeable or hardly passable barrier). Eventually, corridors were proposed in a different and more suitable direction without any barriers. This resulted in GIS layers of significant migration areas, migration corridors and their critical barrier sites, which are provided as non-obligatory information material for spatial planning purposes (source: https://biodiversity.europa.eu/countries/czechia/green-infrastructure) Resulting GIS layer of biotope of specially protected large mammals was elaborated during the project: Complex Approach to the Protection of Fauna of Terrestrial Ecosystems from Landscape Fragmentation in the Czech Republic, which was realized during years 2015-2017. We used the results from previous project and updated the approach for core area and especially migration corridor´s delineation. Resulting output consists of the synthesis of inputs such as data on the occurrence of focal species (lynx, bear, wolf moose), habitat suitability models, barrier permeability assessment and landscape connectivity analyses. The most apparent difference is that migration corridors were designated not only as an axis (with 250 m buffer) but as a surface of suitable biotopes interlinking core areas (see fig. 1). The migration corridors were checked in the field. Problematic sites with identified barriers for migration (highway, high speed railway, 1. class road, settlement, fences, water bodies, build up area, forest free area) were visited and possible solutions to allow the migration permeability were described. The core areas were designated as a compact territory, which hosts or have high probability to allow long-term occurrence of large mammal´s population (large carnivores – lynx, wolf, bear, moose) in the future. The area must provide enough food, shelter and undisturbed space for reproduction. Those areas are covered by vast

	forests and other suitable biotopes such as meadows, shrubs or extensively used fields. In the project individual spots of currently existing impermeable barriers were identified during an intensive field survey. These spots are viewed as "critical sites" where mitigation measures and solutions to acquire permeability were proposed (28 identified sites). In the future, the critical sites have to be addressed in detail, i.e. by delimiting precisely the migration routes. Spots with multiple migration barriers (128 identified sites) or with an otherwise significantly reduced or complicated permeability are viewed as "limited barrier sites". From beginning of the year 2012, all shapefile outputs of the project are provided through the web database and serve as a recommendation material which can be used during spatial planning process. Another Territorial System of Ecological Stability Ecological Stability exists in CZ called "Územní systém ekologické stability (dále ÚSES)". It is not integrated in the EDM! The Territorial System of Ecological Stability (TSES), as defined in Czech act No. 114/1992 Gazette, section 3, article a), is a mutually interconnected complex of both natural and near-natural, altered ecosystems that maintain natural balance. Its main purpose is to reinforce ecological stability of the landscape by conservation or restoration of ecosystems and their mutual interconnection. The TSES consists of biocentres, ecological corridors and interaction elements and has been enshrined in law since 1992 There are three TSES categories (ordered according to significance: - Supraregional TSES: These are vast (at least 1000 ha) landscape units and areas of ecological significance, forming a network providing conditions for the existence of characteristic coenosis together with complete biota biodiversity in the context of a certain biogeographical region. - Regional TSES: These are landscape units and areas of ecological significance (minimum area of 10 - 50 ha). A network of these units must represent a diversity of biochore types in the context of a certain biogeographical region. - Local TSES: These are small landscape units of ecological significance (area about 5 - 10 ha). A network of these represents biogeocoenosis type groups in the context of a certain biochore. The TSES comprises migration and dispersal corridors for bigger woodland mammals.
Important websites	http://www.ochranaprirody.cz/en/what-we-do/territorial-system-of-ecological-stability/ (accessed 18/12/2019) http://ec.europa.eu/environment/nature/ecosystems/docs/5_JPVH_GI_191110.pdf (accessed 18/12/2019)
Data form, state and source	**Source:** https://data.nature.cz/ds/53 - press green button on the bottom of the page with STÁHNOUT DATA (S-JTSK) **Meta data:** https://metadata.nature.cz/record/basic/4f6892ad-5810-49a4-a2db-44650a02080a **Publication date:** 23/04/2021

	Download date: 07/07/2022
Relevance for spatial planning	The TSES plan serves as documentation for TSES projects, land consolidations and land replotting, processing of territorial planning documentation, forest management plans, water management documents and other documents regarding protection and restoration of the landscape.
Planning level	TSES are established by plans that should include in particular the following: a) a draft map of existing and proposed biocentres and ecological corridors with marked protected areas to a minimum scale of 1:50 000 (supraregional and regional TSES) or 1:10 000 (local TSES). b) a table and a theoretical section describing functional and spatial factors c) detailed rationale including outline measures for its conservation or regeneration.
Planning instruments and implementation level	TSES is used as an instrument for establishing and managing new corridors: Its implementation into land-use/territorial plans as well as subvention programmes/subsidiary schemes (EU or national funds) allows to build new segments of „green infrastructure“.
Contacts	Václav Hlaváč; vaclav.hlavac@nature.cz Jan Plesník; jan.plesnik@nature.cz

Defragmentation measures	
Description of the defragmentation measures	List of all existing green bridges for CZ (with additional information on existing structures in Slovakia and Romania; state 25/05/2021). The locations of planned green bridges are not included.
Important Websites, Data form and source	GIS point-layer with 21 items Date: 25/05/2021 Source: Ivo Dostal
Relevant habitats/species	
Legal instruments (Habitats Directive II and IV, national conservation acts)	
Contacts	Ivo Dostal, ivo.dostal@cdv.cz

Literature:

Andel, P. et al. (2006): Assessment of Landscape Fragementation caused by Traffic, ANCLP CR.: 1 – 99 p, ISBN 80-86064-98-0

Andel, P., Gorcicova, I., Petrizilka, L. (2008): Impact of the road traffic on biodiversity atlas, 62 p, ISBN 978-80-903787-1-1

Andel, P. et al. (2010): Migracni Koridory Pro Velke savce V Ceske Republice, ISBN 978-80-903787-6-6

Andel, P., Minarikova T., Andreas, M. (eds.) (2010): Protection of Landscape Connectivity for Large Mammals. Evernia, Liberec, pp. 134

Andel,P., Belkova,H., Gorcicova,I. Hlavac, V., Libosvar, T., Rozinek, R., Sikula, T. et Vorjar, J. (2011): Pruchodnost silnic a dalnic pro volne zijici zivocichy.- Evernia, Liberec, pp. 154

Dufek, J. (without year): Transport 'Research Centre, Brno, Czech Republic, Vladimir Adamec, PhD., Department of Environmental Chemistry and Ecotoxikology, Faculty of Schience, Masaryk University, Brno, Czech Republic: The State of Habitat Fragmentation Caused by Transport Infrastructure in the Czech Republic (www.dot.state.fl.us/emo/sched/dufek.pdf)

Hlavac, V., Andel, P. (2002): On the Permeability of Roads for Wildlife, 52 p.

Hlavac, V., Plesnik, J. (2010): Experience in Landscape connectivity Management in the Czech Republic. Green Infrastructure Implementation, EC Conference, Brussels

Ministerstvo Dopravy Odbor Pozemnich Komunikaci (2006): Migracni objecty pro Zajisteni Pruchodnostig, pp. 180

Strnad, M., Mináriková, T., Dostálová, A., Plesnik, J., Vrba, J., Hošek, M., Condé, S. (2013): Report on methodological evaluation of approaches to migration corridors. ETC/BD report to the EEA, pp. 145.

Pomportl, D. et al. (2013): Designing Migration Corridors for Large Mammals in the Czech Republic, Journal of Landscape Ecology, Vol.6/No. 1

Denmark

Green Map of Denmark	
Original title	Grønt Danmarkskort (Green Map of Denmark)
Network description (content and main criteria)	The Green Map of Denmark provides information about the distribution of threatened and vulnerable species and an overview of high value natural areas. It shows both existing natural areas and the locations where the municipalities have planned new nature areas to connect existing areas. The Natura 2000 sites are used as the backbone, as well as other existing valuable natural areas, such as conservation areas, nature and wildlife reserves, sand dune conservation areas, large forests nature protection areas and national parks.
Important websites	http://naturstyrelsen.dk/media/137410/danish-nature-policy.pdf (accessed 31/01/2020) https://biodiversity.europa.eu/countries/gi/denmark (accessed 31/01/2020) http://www.tekno.dk/wp-content/uploads/2017/04/Areal-afslutningsrapport.pdf (accessed 31/01/2020) https://mst.dk/natur-vand/natur/national-naturbeskyttelse/groent-danmarkskort/ (accessed 11/07/2022) https://miljoegis.mim.dk/cbkort?profile=miljoegis-plangroendk (accessed 16/11/2022)
Data form, state and source	Data download: https://geoserver.plandata.dk/geoserver/wfs?servicename%3Dwfs&request%3Dgetcapabilities&service=wfs (Style name: oekologiske_forbindelser_vedtaget) State: https://geodata-info.dk/srv/dan/catalog.search#/metadata/48ad0732-e3ca-4481-aba4-b71b0351aeed
Relevance for spatial planning	Danish municipalities are to include their contribution to the Green Map of Denmark into municipal plans from 2017 onwards. Before this date, the municipalities had to plan for national nature priorities by designating and formulating guidelines for the administration of valuable nature areas and ecological corridors including both existing nature areas and corridors and potential nature areas and potential corridors forming green networks (“økologiske forbindelser”, “grønne korridorer” or “grønne strukturer”) (IEEP, 2010). The Green Map of Denmark is giving further guidelines to the planning of a green network.
Planning level	In the Danish Spatial Planning Act in 2015 the idea of a Green Map of Denmark (“Grønt Danmarkskort”) was introduced with the aim to ensure that the most valuable Danish nature is sufficiently interconnected to allow species to spread and thrive. Although the term “green infrastructure” is

	not explicit in the document, "more and better interconnected nature" is the main objective of the Green Map of Denmark. The Green Map is to provide the strategic framework for Danish nature policy by ensuring that existing and new measures and new natural areas are located where they will have the largest effect. The Map is also intended to function as a concrete map of existing natural areas in order to support land use planning processes and the location of new GI. To support the municipalities' development of the Green Map and improve land use planning, a digital mapping service of biodiversity in Denmark ("biodiversitetskort") was developed.
Planning instruments and implementation level	A strategic framework for nature and countryside (a master plan) and actual map: As a map, the Green Map of Denmark will show where existing valuable nature is located and where new natural areas that could create an interconnection between existing natural areas could be located – in the same way as we have a map of the rail network and the roads between our towns. Evaluation of municipal planning: The municipalities' designations on the Green Map of Denmark will be based on a common base map and common criteria. Areas on the Green Map of Denmark will be included for the first time in municipal plans in 2017. Thereafter the Map will be gradually refined and implemented up until 2050
Contacts	

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø
Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

Torslov, N. (without year): Fauna- og menneskepassager, envejledning, Vejdirektoratet

Madsen, A. B. (1998): Faunapassager I forbindelse med mindre vejanlaeg – en vejledning, Danmarks Naturfredningsforening, Danmarks Miljoundersogelser

Madsen, A. B., Fyhn, H. W., OPrang, A. (1998): Trafikdraebte dyr i landskabsokologisk planlaegning og forskning, Faglig rapport fra DMU, Nr. 228, miljo- og Energieministeriet, Danmarks Miljoundersogelser

Jeppesen, J.L., Madsen, A. B., Mathiasen R., Gaardmand, B. (1998): Faunapassager i forbindelse med storre vejanlaeg, III, Faglig rapport fra DMU, Nr. 250, Rapporten er udarbejdet i samarbejde med Skov- og Naturstyrelsen of Vejdirektoratet

Hammershoj, M., Madsen, A.B. (1998): Fragmentering of korridorer i landskabet – en litteraturudredning, Faglig rapport fra DMU, Nr. 232, miljo- og Energieministeriet, Danmarks Miljoundersogelser

Madsen, A. B. (2002): TEMA-rapport fra DMU, 40/2002: Barrierer I landskabet – betyder de noget for de vilde dyr?, 58 p., ISBN 87-7772-662-6; internetversion: http://www.dmu.dk/Pub/FR626.pdf

Andersen, P. N., Madsen A. B. (2007): Faglig rapport fra DMU Nr. 626, 2007: Trafikdraebte storre dyr i Danmark – kartlaegning og analyse of pakorselsforhold, ISBN 978-87-7772-995-9

Christensen, E. et al. (2007): A biological assessment and investigation of the use of fauna passages at the motorway system in Denmark, NERI Technical Report No. 631, 172 p.

Danish Ministry of the Enviroment, Danish Nature Agency (2014): Danish Nature Policy – our shared Nature (available at nst.dk/naturplandk)

England

National Habitat Network	
Original title	Habitat Networks (Combined Habitats) (England)
Network description (content and main criteria)	Habitat Networks (England) is a spatial dataset that describes the geographic extent and location of Habitat Networks for 18 priority habitats based primarily, but not exclusively, on the priority habitat inventory with additional data added in relation to habitat restoration-creation, restorable habitat, plus fragmentation action, and network enhancement and expansion zones. The maps are created following a standardised process that incorporates a range of data layers and identifies specific locations for a range of actions to help improve the ecological resilience for each of the habitats/habitat networks. This is the combined habitat network map. The habitat network maps are developed around 4 distinct habitat components sets and include 4 distinct network zones where action may be undertaken to build greater ecological resilience. The **different elements** of the maps are: **Habitat Components (Cores)**: The location of existing patches of a specific habitat for which the network is developed. This is termed the 'Primary habitat' e. g. lowland heathland. The main baseline data used for this is the Priority Habitat Inventories (PHI). The location of additional habitat that naturally form mosaics with the primary habitat e. g. habitats that are most likely to form ecological mosaics possibly used by species associated with the primary habitat. This is termed the 'Associated habitat'. The main baseline data used for this is the PHI. The locations where habitat creation or restoration is known to occur, this is primarily sites under relevant agri-environment options. This is termed the 'Habitat creation'. Sites where data suggests small fragments of the primary habitat or degraded habitat exists and where restoration may be possible, this is primarily developed from information held within the current PHI. This is termed the 'Restorable habitat'. **Network Zones (Corridors):** Land within close proximity to the existing habitat components that are more likely to be suitable for habitat re-creation for the particular habitat. These areas are primarily based on soils but in many cases has been refined by also using other data such as hydrology, altitude and proximity to the coast. This is termed the **'Network Enhancement Zone 1'**. Land within close proximity to the existing habitat components that are unlikely to be suitable for habitat re-creation but where other types of habitat may be created or land management may be enhanced including delivery of suitable Green Infrastructure. This is termed the **'Network Enhancement Zone 2'**. Land immediately adjoining existing habitat patches that are small or have excessive edge to area ratio where habitat creation is likely to help reduce the effects of habitat fragmentation. This is termed the **'Fragmentation Action Zone'**. Land within relatively close proximity to the Network Enhancement Zones 1 & 2 that are more likely to

	be suitable for habitat creation for the particular habitat and identifying possible locations for connecting and linking up networks across a landscape. This is termed the **'Network Expansion Zone'** Further details are outlined in the Habitat Network Mapping Guidance document (Edwards et al. 2020): The Network boundary is drawn around the 4 habitat components using a variable buffering process with a generalised distance of 500m although 1km was used for Blanket Bog. As the boundary for each habitat network is tightly drawn around the existing patches of habitat this means that at a national scale the habitat network is composed of a series of smaller 'networks' that encapsulates one or more clusters of existing habitat patches. These may be considered as 'network segments'. The Network Expansion Zone has been drawn around these segments to identify areas where additional action may be undertaken to build greater ecological resilience across the wider landscape.
Important websites	https://naturalengland-defra.opendata.arcgis.com/search?collection=Dataset&q=habitats (accessed 19/01/2022) https://naturalengland-defra.opendata.arcgis.com/datasets/Defra::habitat-networks-combined-habitats-england/about (accessed 19/01/2022)
Data form, state and source	Open Data (via link https://naturalengland-defra.opendata.arcgis.com/search?collection=Dataset&q=habitats): e. g. as ESRI-Shapefile: Habitat_Networks__Combined_Habitats___England____Natural_England.shp (creation: 21/11/2018; last update: 14/08/2021, publication: 16/08/2021) or File-Geodatabase: Habitat_Networks_(Combined_Habitats)_(England).gdb (creation: 21/11/2018; last update: 14/08/2021, publication: 16/08/2021) There are no public access constraints to this data. Use of this data is subject to the Open Government Licence. - http://www.nationalarchives.gov.uk/doc/open-government-licence/version.
Relevance for spatial planning	The Government's 25 Year Environment Plan (HM Government 2018) includes provision for a Nature Recovery Network (NRN) and states that it will deliver on the recommendations of the Lawton Report and that recovering wildlife will require more habitat; in better condition; in bigger patches that are more closely connected. As well as helping wildlife thrive, the NRN could be designed to bring a wide range of additional benefits: greater public enjoyment; pollination; carbon capture; water quality improvements and flood management. Nature Recovery Network is required within the 25 Year Environment Plan and Local Nature Recovery Strategies as proposed within the Environment Bill.
Planning level	

Planning instruments and implementation level	The Habitat Network Maps provide spatial guidance to plan and develop local ecological networks and may be used to help target action to build greater ecological resilience for habitats across England. The habitat network maps are intended to be used to help identify areas for future habitat creation and restoration at a landscape scale but need to be considered alongside other local datasets and knowledge.
Contacts	Natural England County Hall Spetchley Road Worcester WR5 2NP United Kingdom Email: enquiries@naturalengland.org.uk data.services@naturalengland.org.uk Telephone: 0300 060 3900

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø
Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

Crick, H. Q. P., Crosher, I. E., Mainstone, C. P., Taylor S. D., Wharton, A., Langford, P., Larwood, J., Lusardi, J., Appleton, D., Brotherton, P. N. M., Duffield, S. J., Macgregor N. A. (2020): Nature Networks Evidence Handbook. Natural England Research Report NERR081. Natural England, York. (download: http://publications.naturalengland.org.uk/publication/6105140258144256, (accessed January 18, 2022))

Edwards, J., Knight, M., Taylor, S., Crosher, I. E (2020): Habitat Networks Maps, User Guidance v.2', Natural England.

HM Government (2018): A Green Future: Our 25 Year Plan to Improve the Environment. London, 151 p..(download: https://www.gov.uk/government/publications/25-year-environment-plan, (accessed January 18, 2022))

Lawton, J.H., Brotherton, P.N.M., Brown, V.K., Elphick, C., Fitter, A.H., Forshaw, J., Haddow, R.W., Hilborne, S., Leafe, R.N., Mace, G.M., Southgate, M.P., Sutherland, W.A., Tew, T.E., Varley, J., Wynne, G.R. (2010): Making Space for Nature: a review of England's wildlife sites and ecological network. Report to Defra. (download: https://webarchive.nationalarchives.gov.uk/ukgwa/20130402170324/http:/archive.defra.gov.uk/environment/biodiversity/documents/201009space-for-nature.pdf, (accessed January 18, 2022))

Estonia

Estonian green network	
Original title	Eesti Roheline Võrgustik
Network description (content and main criteria)	Due to the abundance of natural landscapes and landscapes in close to natural condition, the green network in Estonia does not have to be constructed but rather „developed” from reality and perception. As a result, the network is quite large in area, covering more than 50% of the territory. For identification of core areas two criteria were used in this work – the size of the area in natural condition and its conservation value. Core areas of international importance are com-pact natural areas with a territory of at least 100 km^2. In Estonia these form12 major core areas (predominantly forests and swamps). Core areas of national importance are natural areas with a territory of at least 15 km^2. Major „green corridors” between international core areas traverse the core areas of national importance. Core areas of international importance are so large, guarded by protective measures and in the main located beyond the predictable concentration of economic interests, that there will be few problems with their survival. At a more detailed planning level, attention should be paid to the preservation of core areas of national importance and green corridors useable by wild animals.
Important websites	https://www.eea.europa.eu/data-and-maps/figures/map-of-the-estonian-green-network (accessed 12/03/2020) http://www.ceeweb.org/wp-content/uploads/2014/06/03-Mart-Kylvik.pdf (accessed 12/03/2020) https://planeerimine.ee/juhendid-ja-uuringud/rohevorgustiku-juhend/ (accessed 12/03/2020) https://portals.iucn.org/library/efiles/documents/eep-032.pdf (accessed 12/03/2020) https://biodiversity.europa.eu/countries/gi/Estonia (accessed 12/03/2020)
Data form, state and source	
Relevance for spatial planning	The hierarchy of the spatial planning system is organised mainly around basic administrative units in Estonia (i.e. country, county and municipality). The Green Network is addressed at all three levels of planning.
Planning level	In 1999, the phase of county planning was initiated including the design of the Green Network. By 2002, each of the 15 counties of Estonia had to prepare a map of ecological networks on a scale of 1:50,000. However, it took until the end of 2007 for all 15 counties to finish the preparation of these plans.

Planning instruments and implementation level	The nationwide spatial plan "Estonia 2030+" aims to achieve a rational use of space in Estonia. The main principles include "preserving the qualities of settlement pattern and landscape" and "preserving the good condition of the natural environment". The plan emphasises the importance of green infrastructure in the preparation of spatial measures (European Commission, 2017). The basic legislation for this network is the Planning Act that defines the green network and its elements. The establishment of the green network at national level was launched in 1995 (National Plan Estonia, 2010) and approved in 2000. At county level, a thematic spatial plan was launched in 1999. County thematic plans were approved during the period 2003-2007. According to the Planning Act, the Green Network needs to be addressed in each municipality's comprehensive plan (specify the boundaries and environmental conditions/restrictions). The Estonian Environmental Action Plan for 2007-2013 sets a target to determine and implement measures for the Green Network within all municipalities by 2013. A Green Network Planning Guide, completed in June 2018, aims at providing substantive and technical recommendations for green network planning based on real examples, especially when preparing local government master plans so as to ensure spatial preconditions for maintaining or improving the quality of biodiversity and ecosystem services. The most important goals of the preservation and planning of the green network are the protection and preservation of biodiversity, the mitigation and adaptation to climate change, and the promotion of a green economy, including recreation.
Contacts	

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø
Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

Sepp, K., Kaasik, A. (eds.) (2002): Development of National Ecological Networks in the Baltic Countries in the framework of the Pan-European Ecological Network. IUCN Office for Central Europe, Warsaw, Poland. International Union for Conservation of Nature (IUCN), Gland, Switzerland. 183 pp.

Külvik, M., Sepp, K. Jagomägi, J., Mander, Ü. (2003): Ecological networks in Estonia - from classical roots to current applications. In: Mander, Ü. and M. Antrop Eds., Multifunctional Landscapes, Vol. III, Continuity and change. Series: Advances in Ecological Sciences, Vol 16. WIT Press: Southampton, Boston, pp 263-298.

France

The Green and Blue Network (TVB)	
Original title	Trame verte et bleue (TVB)
Network description (content and main criteria)	The green and blue framework aims to halt the loss of biodiversity, by preserving and restoring networks of natural environments that allow species to circulate and interact. These exchange networks, called ecological continuities, are made up of biodiversity reservoirs linked to each other by ecological corridors. The green and blue frame includes a green component which refers to terrestrial natural and semi-natural environments and a blue component which refers to aquatic and wet networks (rivers, rivers, canals, ponds, wetlands, etc.). These two components are superimposed in interface zones (wetlands and vegetation along riversides in particular) and form an entity intended to ensure the good ecological state of the territory. Preserving and restoring ecological continuity means taking action wherever possible: in rural areas, on the scale of rivers and in urban areas. The green and blue network fights against the fragmentation of natural environments and contributes to the preservation of biodiversity.
Important websites	https://www.ecologique-solidaire.gouv.fr/trame-verte-et-bleue (accessed 10/11/2021) Framework Document: National guidelines for the preservation and restoration of ecological continuity (pdf - 7.64 MB): https://www.ecologique-solidaire.gouv.fr/sites/default/files/Document-cadre%20Orientations%20nationales%20pour%20la%20pr%C3%A9servation%20et%20la%20remise%20en%20bon%20%C3%A9tat%20des%20continuit%C3%A9s%20%C3%A9cologiques.pdf (accessed 10/11/2021) http://www.trameverteetbleue.fr/ (accessed 10/11/2021) http://www.trameverteetbleue.fr/sites/default/files/references_bibliographiques/plaquette_tvb_english-june2010.pdf (accessed November 10, 2021)
Data form, state and source	Data of the Trame verte et bleue can be downloaded as shape files for the different departments of France from: https://www.data.gouv.fr (accessed 10/11/2021)
Relevance for spatial planning	Law n ° 2010-788 of July 12, 2010 relating to a national commitment to the environment, known as the Grenelle 2 law, proposes and specifies the Green and Blue Network among a set of measures intended to preserve the diversity of organisms. In particular, it provides for the development of national guidelines for the preservation and restoration of ecological continuity, which must be taken into account by regional schemes of ecological coherence co-developed by the regions and the State. Planning documents and projects at national level, in particular the large linear infrastructures of the State and its public establishments, must be compatible with these guidelines. The planning documents and projects of

	the territorial collectivities and the State will have to take into account the regional diagrams
Planning level	The green and blue fabric policy is based on three levels: 1. National guidelines 2. The regional ecological coherence scheme (SRCE) at the regional level. The SRCE is a strategic document for sustainable spatial planning. By identifying the green and blue fabric at the regional level, the SRCE allows better consideration of biodiversity in development projects and urban planning documents. In the light of this diagram, the communities can decline and specify the green and blue fabric on their territory, by associating all the actors concerned. As a pilot of the territorial biodiversity policy, the region is a major player in the green and blue fabric policy. The region animates the other territorial levels. 3. Planning documents and projects from the State and local authorities, particularly in terms of spatial planning and town planning (local town planning plan - PLU, local intercommunal town planning plan - PLUI, coherence scheme territorial - SCOT, municipal map), which take into account SRCE at local level.
Planning instruments and implementation level	The State sets the working framework and ensures its consistency across the entire territory. The State and the regions have jointly developed planning documents, called regional ecological coherence schemes, in consultation with all of the local stakeholders. These plans, which are subject to public inquiry, respect national guidelines and identify the green and blue fabric on a regional scale. They will be integrated into new schemes, SRADDETs, with other policies. The departments steer the policy of sensitive natural areas which contributes to the green and blue fabric. They can also carry out projects to restore ecological continuity. Local authorities and their groups take ecological continuities into account in urban planning documents and their territorial projects, which in particular frame the development of urbanization. Companies can act by developing their site to preserve ecological continuity, but also take care to reduce their impact on the environment. Farmers and foresters play a positive role in maintaining ecological continuity. Citizens have the means to act at their level, in their garden (openings in fences, etc.), individually or collectively in the context of an association, for example. National guidelines for the preservation and restoration of ecological continuity: The framework document "National guidelines for the preservation and restoration of ecological continuity" has been developed as the national level of texts framing the green and blue frame policy, in addition to the laws and regulations. It contains two parts: • a section on strategic choices outlining the definitions, objectives and broad guidelines for the implementation of the green and blue grid;

	• a part constituting the methodological guide specifying the national and cross-border issues for the ecological coherence of the green and blue grid at the national scale, the methodological elements to ensure the coherence of the regional schemes in terms of objectives and content, and a last part relating to the preparation of regional plans for the overseas departments. Financing the green and blue frame The Ministry of the Environment financially supports the development, monitoring, updating and implementation of regional ecological coherence schemes and network animation at the national level, as well as research and technical work on the green network and blue (including the national green and blue frame committee and the green and blue frame resource center), for example through calls for projects to financially support concrete actions to implement the green and blue framework. The challenge today is the development of actions to achieve the goals of preserving and restoring ecological continuity in regional ecological coherence schemes and other planning documents. The achievement of these objectives must be reflected in urban planning operations, the implementation of development or transport projects, the management of natural, agricultural and forest areas, as well as the conduct of ecological continuity restoration operations. The mobilization of European funds and communities, but also the State in the framework of State-Region plan contracts, will have to accompany these achievements.
Contacts	

Defragmentation measures	
Description of the defragmentation measures	Linear transport infrastructure (roads, highways, railways, canals) and that of energy transport (high-voltage power lines, gas pipelines) are a major cause of the fragmentation of natural environments. New projects, which are less frequent now, must be designed in such a way as to avoid breaks in ecological continuity. If necessary, they must be reduced and compensated. The existing infrastructures constitute the major challenge: as part of their renovation, they can benefit from improvements (vegetated bridge, tunnel, etc.) for the restoration of continuities identified by the regional ecological coherence scheme or by a development document for the territory on another scale. The crossing devices can be supplemented by surrounding elements. Various actions can be undertaken for the management of roadsides combining road safety and preservation of biodiversity. For example, reasoned mowing consists in putting an end to systematic mowing close to the ground, three times a year, to favor late or less level mowing, except in areas at risk for road traffic. These green outbuildings become ecological corridors that allow species to migrate between biodiversity reservoirs. Recent experimentation has also shown that late mowing is favorable to the return of pollinating insects, attracted by the increase in food resources.

	Stopping phytosanitary treatments is another way of acting effectively in favor of biodiversity. These steps must be accompanied by programs to understand the challenges of the fragmentation caused by roads. The census of animals run over by road officials is a way to identify breaks in ecological continuity and to give ourselves the opportunity to act accordingly: construction of a passage for small fauna, fences to guide the animals. The blue grid is also affected by many fragmentation problems caused by hydraulic structures (thresholds, dams, diversion bays, etc.), by the alteration of the banks, by the installation of dikes, Such developments on watercourses are all attacks on the good ecological functioning of these natural environments and constitute obstacles for the circulation of aquatic species. The erasure of structures or their layout, in particular by installing fish passes, allows species to overcome these obstacles and ensure their life cycle. Similarly, the erasing of the dykes and the renaturation of the banks allow the natural functioning of watercourses to be restored and the interfaces between different subframes to be restored (watercourses, wetlands, wooded areas, etc.).
Important Websites, Data form and source	http://www.trameverteetbleue.fr/entree-thematique/infrastructures-lineaires-transport (accessed 12/03/2020) http://www.trameverteetbleue.fr/qui-sommes-nous/centre-ressources-trame-verte-bleue (accessed 12/03/2020) Data for fauna passages can be retrieved as shape files from: https://www.data.gouv.fr/fr/datasets/passages-pour-petite-faune-diro/ (accessed 12/03/2020)
Relevant habitats/species	The last generation of fauna passages in France shows more suitable characteristics, forms, and roadsides. New forms such as "parabolic shape" designed to minimise the tunnel effect for large fauna are favourable to a wide range of species. The small fauna is gradually take account since the 1980's. Pipes (Type I) designed for a large number of species show their effectiveness and are located every 300 metres (taking account of other structures usable by small fauna such as hydraulic widened passages, large fauna passages, agricultural or forestry passages). Specialized passages (Type II), are built for target species (otter, beaver) or a group of species (amphibian tunnels). These structures can be used by several species, providing diversified crossing conditions.
Legal instruments (Habitats Directive II and IV, national conservation acts)	In the law of August 3, 2009 concerning the implementation of the Grenelle Environment Forum, infrastructure projects must consider the impacts on biodiversity and ecological continuity from the start of project design and in all investigative procedures. The transport policy of France results from the Grenelle of the environment and should soon be translated into the national infrastructure plan transport (SNIT). This policy aims to combine the construction of an efficient society with social and economic plans with

	the essential objectives of combating climate change, reduction of energy dependence or preservation of biodiversity.
Contacts	

Literature:

Allag-Dhuisme, F. et al. (2010): Prise en compte des orientations nationales pour la préservation et la remise en bon état des continuités écologiques par les grandes infrastructures linéaires de l'État et de ses établissements publics – troisième document en appui à la mise en œuvre de la Trame verte et bleue en France. Proposition issue du comité opérationnel Trame verte et bleue. MEEDDM ed.

Bielsa, S., Pineau, C. (2007): Inventory and Typology of Fauna Passages on French Transport Infrastructures. In: Irwin, C. L., Nelson, D., McDermott, K.P. (eds.): Proceedings of the International Conference on Ecology and Transportation, Center for Transportation and the Environment, North Carolina St. Univ., p. 401–408.

Collectif (2017): Des outils pour la mise en oeuvre de la TVB. Montpellier, AFB, 70 p. Coll "Cahiers techniques", n. 91.

IUCN France and CILB (2015): Infrastructure Corridors, Ecological Corridors – Status report and recommendations

Ministere de l'Equipment, Ministere de L'Environment (1993): Passages pour la grande faune - Guide technique

Ministere des Transport de l'Equipment du Tourisme et de la Mer, Ministere de L'Environment (2005): Amengements et measures pour la petite faune: Guide technique - Setra (Service d'Etudes techniques des routes et autoroutes)

Ministere des Transport de l'Equipment du Tourisme et de la Mer (2006): Les mustelides semi-aquatiques et les infrastructures routieres er ferroviaires – Loutre et vision d'Europe, Setra (Service d'Etudes techniques des routes et autoroutes) – note d'information

Ministere des Transport de l'Equipment du Tourisme et de la Mer (2006): Routes et passages a faune – 40 ans d'evolution, Setra (Service d'Etudes techniques des routes et autoroutes)

Cete de L'Est Cete Nomandie-Centre (2009): Bats and road transport infrastructure – threats and preservation measures, Setra

Setra (Service d'Etudes techniques des routes et autoroutes (2004): La pollution des sols et des vegetaux a proximite des routes (Les elements traces metalliques (ETM) – note d'information

Cerema (2016): Rapport: Retour d'experience des amengements et des suivis faunistiques sur le reseau, VINCI Autoroutes, Restauration des Continuites ecologiques sur autoroutes

Cerema (2016): Sythese- Retour des amengements et des suivis faunistiques sur le reseau, VINCI Autoroutes, Restauration des Continuites ecologiques sur autoroutes

Infrastructures de transport terrestres, ecosystemes et paysages – des liasons dangereuses? Direction de l'information legale et administrative, Paris, 2013

Germany

Internationally significant biotope network axes	
Original title	Länderübergreifender Biotopverbund in Deutschland – international bedeutsame Achsen des Biotopverbunds
Network description (content and main criteria)	The dataset represents the internationally significant biotope network axes (focal lines) of Germany and takes into account the transitions/connections to neighbouring countries. The axes have been identified to connect the most important dry, wet and forest habitat complexes. The original data of internationally significant biotope network axes distinguish between biotope network axes for (connecting) woodlands, habitats for large mammals, watercourses and wetlands. The aim of the biotope network is - in addition to the sustainable protection of native species and species communities and their habitats - the preservation, restoration and development of functional, ecological interrelationships in the landscape. The focus is on the ecological and spatial-functional demands of the native species on their habitat. In this context, composite systems are intended to guarantee the genetic exchange between populations, animal migration and natural processes of spreading and resettling. Biotope network also means ensuring ecological interrelationships between different types of biotope, e. g. B. for species with changing habitat requirements or those that colonize habitat complexes. In 2004 the nationally important areas for the biotope network and the nationally and internationally important biotope network axes were located and displayed in a map for Germany. Biotope mapping from the federal states and occurrences of target species for the transnational biotope network formed an essential basis. The networks of functional spaces were determined for dry, wet and forest habitat complexes. The nationally and internationally significant biotope network axes were ultimately derived from these. The development of a transnational biotope network is an important contribution to the implementation of Article 10 of the Habitats Directive and in general to improving the coherence of the Natura 2000 network in Germany. In the context of climate change and the expected climatic shifts and changes in habitats, a functioning biotope network is a crucial prerequisite for many species to be able to react to the expected changes by resettling habitats.
Important websites	https://www.bfn.de/karten-und-daten/bundeskonzept-gruene-infrastruktur-biotopverbund-lebensraumnetze-und www.bund.net/handbuch-biotopverbund https://www.bfn.de/thema/karten-und-daten (accessed 10/11/2021)

Data form, state and source	Shapefiles (available on request at info@bfn.de), Publication year: 2006 Maps at: https://www.bfn.de/karten-und-daten/bundeskonzept-gruene-infrastruktur-biotopverbund-lebensraumnetze-und
Relevance for spatial planning	The biotope network has been anchored in the Federal Nature Conservation Act since 2002. In the last amendment from July 2009, the corresponding regulation can be found in sections 20 and 21. After that, a biotope network system is to be developed on at least 10% of the country's surface. It is also intended to improve the connection between the European Natura 2000 system of protected areas. Not all protected areas in the various categories listed in Section 21 (3) BNatSchG meet the criteria for biotope composite areas. To achieve the objectives of the biotope network, the securing and, if necessary, development of additional areas is necessary. From a technical point of view, the area to be considered for the implementation of the biotope network is far larger than the value enshrined in the law. The concept of the biotope network is also supported by the EU Water Framework Directive, which is intended to improve the status of waters, including dependent terrestrial ecosystems, and their networking.
Planning level	
Planning instruments and implementation level	Although the implementation of the biotope network has been prescribed by the Federal Nature Conservation Act since 2002 and since then has also been incorporated into the nature conservation laws of the federal states and supported by specific specialist plans at the federal and state levels, the practical implementation of the biotope network in the field has been slow. There is a considerable need to implement further collaborative projects. In order to support this, the BfN has promoted the development of a manual for the biotope network by the German Federal Agency for the Environment and Nature Conservation (BUND), which should serve regional planners, authorities and those interested in nature conservation as a guide for the implementation of their own biotope network projects: www.bund.net/handbuch-biotopverbund
Contacts	National level: Federal Agency for Nature Conservation (BfN) At Bundesländer level: The relevant agencies for nature conservation

Defragmentation measures	
Description of the defragmentation measures	The Federal Defragmentation Programme of Germany is a long-term programme. Its central component is an investment programme for constructing crossing aids for wildlife within the federal trunk road network. Implementation of the investment programme will commence on

	completion of the construction projects under economic stimulus package II. State of implementation of the Programme: 93 over- and underpasses (50 GB >= 50 m, 28 at motorways, 22 at national roads) 29 Greenbridges 15 at motorways, 14 at national roads (>= 25 m und < 50 m) 21 Greenbridges < 25 m 13 at motorways and 8 at national roads Since 2010 habitat networks are considered an important criterion for the planning and construction of defragmentation measures.
Important Websites, Data form and source	https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Naturschutz/bundesprogramm_wiedervernetzung_eng_bf.pdf (accessed 13/03/2020) https://www.bfn.de/themen/planung/eingriffe/wirkungsprognosen/zerschneidung-wiedervernetzung.html (accessed 13/03/2020)) Data for defragmentation measures can be ordered at: naturschutzinformation@bfn.de
Relevant habitats/species	For species of dry, woodland and wetland habitats Corridors for bigger woodland mammals
Legal instruments (HABITATS Directive II and IV, national conservation acts)	The Federal Nature Conservation Act (BNatSchG, §§ 1, §§ 13 f., §§ 20, 21) obliges the Länder to establish a network of connected biotopes covering at least 10% of the area of each Land (federal state). Habitat connectivity should be established at federal level, transcending Land borders. The Länder must consult with each other in this respect. The avoidance of fragmentation had to be considered when drawing up the Federal Transport Infrastructure Plan 2013
Contacts	Ministry of Transport in cooperation the transport agencies of the Bundesländer

Literature:

Heiland, S., Mengel, A., Hänel, K., Geiger, B., Arndt, P., Reppin, N., Werle, V., Hokema, D., Hehn, C., Mertelmeyer, L., Burghardt, R., Opitz, S. (2017): Bundeskonzept Grüne Infrastruktur Fachgutachten. BfN Skripten 457, 279 S.

Fuchs et al. (2010): Länderübergreifender Biotopverbund in Deutschland – Grundlagen und Fachkonzept, Naturschutz und biologische Vielfalt 96, incl. Karten

Hänel, K., Reck, H. (2011): Bundesweite Prioritäten zur Wiedervernetzung von Ökosystemen: Die Überwindung straßenbedingter Barrieren, Naturschutz und biologische Vielfalt 108, 352 S. incl. CD

Hänel, K., Baierl, C., Ulrich, P. (2016): Lebensraumverbund und Siedlungsentwicklung in Deutschland – Indentifikation von Engstellen und Planungsempfehlungen, Naturschutz und biologische Vielfalt 144, 240 S. incl. CD

Natur und Landschaft – Zeitschrift für Naturschutz und Landschaftspflege Nr. 12 (2013): Überwindung von Barrieren – Wiedervernetzung an Verkehrswegen

Reck, H. et al. (2005): Lebensraumkorridore für Mensch und Natur 17, 314 S.

Reck et al. (2017): Grünbrücken, Faunatunnel und Tierdurchlässe – Anforderungen an Querungshilfen, BfN-Skripten 465

Hungary

The National Ecological Network of Hungary	
Original title	Országos Ökológiai Hálózat
Network description (content and main criteria)	The National Ecological Network includes the national importance of natural and semi-natural areas and among those link-creating ecological corridors belong to a single, coherent system, and which is part of the core areas, ecological corridors and buffer areas. The network includes different type of areas of nature conservation importance, like nature protected areas, Natura 2000 areas, high nature value areas. This accounts for 36% of the total area of the country. The three zones of the Ecological Network (Core areas, Ecological corridors and Buffer zones) are defined in Act CXXXIX of 2018 on the Spatial Planning Plan of Hungary and Certain Priority Regions of Hungary. Core areas are established zones in the priority regional and county spatial planning plan of the Ecological Network, which includes natural or semi-natural habitats that are capable of ensuring the long-term survival and living conditions of the natural fauna typical of the area and are home to several protected species or species of Community importance. Ecological corridors are applied in priority regional and county spatial plans, which includes areas - mostly linear, continuous or discontinuous habitats, habitat bands, habitat mosaics, habitat fragments, habitat chains - which are predominantly of natural origin and which are suitable for providing biological connectivity between other habitats of the ecological network - core areas, buffer areas. Ecological network buffer zones are applied in priority regional and county spatial plans, which includes areas with a function that prevents or mitigates the negative impact of activities that could adversely affect the status of core areas and ecological corridors or that are contrary to their function.
Important websites	http://www.terport.hu/tematikus-terkepek/orszagos-okologiai-halozat (accessed /04/2020) https://biodiversity.europa.eu/countries/gi/hungary (accessed 20/04/2020) http://naturaterv.hu/terkep https://termeszetvedelem.hu/orszagos-okologiai-halozat/(accessed November 16/11/2022)
Data form, state and source	The National Ecological Network of Hungary can be accessed via WMS link from: https://www.teir.hu/wms/ (as "országos ökológiai halozat" accessed 20/04/2020) Data provision (GIS-shapefiles: 29/07/2022 by MATE (Kollányi László)
Relevance for spatial planning	The zone of the National Ecological Network is entrenched in the municipal planning of settlements. It was incorporated into the spatial planning regulation. Act No. XXVI. of 2003 on National Spatial Plan (which is the main regulation for land use planning in Hungary) defines the zones of the

	network (core area, ecological corridor, buffer zone). These zones were harmonized with the Pan-European ecological network-related category system in 2009. The major elements of spatial planning that are considered as part of green infrastructure or regulate green infrastructure are as follows: - forest management area, agricultural land, water management area; - zones of national ecological networks (core area, ecological corridor, buffer area), zones of excellent-quality and good-quality arable land, zones of excellent-quality forest area, zones of areas of special landscape protection, zones of areas for afforestation; - the Balaton Act expressly names and strictly protects municipal green spaces.
Planning level	The area of the National Ecological Network was updated in 2014 and the National Spatial Plan was amended accordingly, keeping the regulations of the zones of the ecological networks (EC, 2017). Lead by the Ministry of Environment and Water, two of the aims of the National Ecological Network focus on implementing GI and emphasizing connectivity for the conservation of nature. The network is said "to maintain, conserve, restore and manage connections between the areas of the ecological network in Hungary; to aid species conservation through improved connectivity and reduced fragmentation" (IEEP, 2010).
Planning instruments and implementation level	Act XXVI of 2003 on National Spatial Planning lays down the national regulations for land use and the spatial framework of spatial planning in order to harmonise land use in Hungary's settlements and regions of different features and to develop a uniform infrastructure network. It was updated in 2013. The spatial plan ensures the protection of natural, landscape and cultural heritage values, primarily through rules of zones. The zone of the national ecological network includes natural and semi-natural habitats of national importance and the unified and composite system of ecological corridors, which provide links between them. In the zone of core areas and ecological corridors, the rules restrict the designation of areas for development, the placement of transport infrastructure and new surface mines. These regulations indirectly contribute to the protection of biodiversity (CBD, 2014). In certain agro-environmental, physical planning, water management and environmental impact assessment legal instruments there are clear provisions concerning ecological networks. In addition, the ministerial decree on the protection of an ecological network introduces measures for ecological networks and emphasises not only the exact protection of habitats and ecosystems of the ecological networks, but also the establishment, rehabilitation, and improvement of biological connectivity between them. Beside legislation concerning nature conservation, there are other important laws in which there are direct or indirect links to the conservation of ecological networks by other sectors.
Contacts	László Kollányi, kollanyi.laszlo@uni-mate.hu

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø
Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	The Hungarian government accepted the National Transport Strategy (NTS) in August 2014. The social goal of the NTS is to decrease the harmful impacts on environment through the existing EU and Hungarian regulations (e. g.: measurement of environmental impacts, Natura2000 impact assessment in planning). The economic challenge of the development of green infrastructure is to be accepted by the sector.
Contacts	Ø

Literature:

Ministry of Environment (2002): Progress report on the establishment of the National Ecological Network in Hungary. National Ecological Network No. 2, KÖM, pp. 14.

Latvia

Ecological Network of Latvia	
Original title	The Latvia Ecological Network (ECONET)
Network description (content and main criteria)	A **Latvian Ecological Network** was set up in 1998 in order to serve as a frame for a network of green structures to ensure the preservation of biological and landscape diversity, promotion of improvement of urban micro-climates and creation of the visual impression of “green” cities. The spatial structure of the Ecological Network (ECONET) in Latvia is based on analysis of landscape structure, biological values of the given territory and the drainage basins of waterbodies and watercourses. Analysis of landscape structure was conducted with the aim of: - evaluating differences between landscapes and habitats at the regional and local scale and the factors that affect them; - identifying landscape structures (matrices, corridors and patches), which are the basis for preserving biological diversity in a given territory; - describing habitats and species within a given territory in order to identify ecosystems and habitats of national and international importance. The Ecological Network at international level occupies 25% of the total are of Latvia. The Network at national level occupies 18%. The international and national level together occupies 43% of the territory of the Latvia. The Latvian ecological network consists of international and national level core areas (biocenters), bufferzones, corridors, nature development areas and stepping stones. National and international biocenters (core areas) are located equally throughout the country. They represent almost all of the landscape types of Latvia, except intensively cultivated and urbanised landscapes. Buffer zones should ensure the protection of core areas and ecological corridors. They can increase the size of core areas, correct the form of core areas and ecological corridors. They can also serve as corridors. Corridors include linear corridors structures as well as structures of mosaic landscapes with "green islands". They provide possibilities for the seasonal movement and migration of species, the spread of populations and natural links between them within their natural area of distribution, as well as suitable feeding conditions to maintain population viability.
Important websites	https://biodiversity.europa.eu/countries/gi/latvia (assessed 28/04/2020) https://portals.iucn.org/library/efiles/documents/eep-032.pdf (assessed 28/04/2020) http://www.ceeweb.org/work-areas/priority-areas/green-infrastructure/maps/ (assessed 28/04/2020) https://www.bef.lv/wp-content/uploads/2019/02/Deliverable_T.1.2.1_Methodology_for_Regional_and_Local_landscape.pdf (assessed 28/04/2020)

Data form, state and source	Raster data of the Network taken from the report: https://portals.iucn.org/library/efiles/documents/eep-032.pdf (assessed 28/04/2020, p. 150)
Relevance for spatial planning	
Planning level	
Planning instruments and implementation level	The implementation of an ecological network in Latvia is linked to the preparation and approval of physical plans at various levels. The provision of physical plans in Latvia is envisaged by the Cabinet of Ministers Regulations No. 423. on Physical Plans (5.12.2000.). Article 2 of the Regulations states that 'the physical plan as approved and passed represents the legal basis for decision-making with regard to land use'. The preparation of physical plans in Latvia takes place at national, regional and local level. The regulations stipulate that the ecological network must be included in physical plans.
Contacts	

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø
Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

Sepp, K., Kaasik, A. (eds.) (2002): Development of National Ecological Networks in the Baltic Countries in the framework of the Pan-European Ecological Network. IUCN Office for Central Europe, Warsaw, Poland. International Union for Conservation of Nature (IUCN), Gland, Switzerland. 183 pp.

Ruskule, A., Veidemane, K., Pržavoite, D. (2018): Methodology for Regional and Local Landscape and Green Infrastructure Planning in Lowland Areas - Deliverable T1.2.1. Baltic Environmental Forum-Latvia, 33 pp.

Lithuania

Ecological Network of Lithuania	
Original title	Ekologinis tinklas Lietuvoje
Network description (content and main criteria)	The Lithuanian Ecological Network is the part of the natural framework that connects the habitats of the greatest bioecological importance, their environment and the migration corridors of animals and plants. It is based on the Council of Europe Emerald and European Union Natura 2000 networks, as well as the Pan-European Ecological Network (PEEN). The Lithuanian ECONET, as a part of PEEN, has the following functional and spatial structure: core areas, buffer zones, restoration areas, ecological corridors and stepping-stones. The Lithuanian ECONET has three levels: European, regional (national) and local. Designation of structural elements of Lithuanian ECONET was based on criteria of ecological network and application of indicator species, communities and habitats. The main task was to prepare a map at a scale of 1:200,000. It is a detailed scale, and the map covers the whole territory of the Republic of Lithuania. The map must also reflect guidelines for designing ECONET at a district (local level). For these reasons, the map at a scale 1:200,000 was limited to the structural elements of the European and regional (national) levels. Generalisations were also applied to the design of maps, in order to show geo-objects composing the core areas and the main axes, and directions of ecological corridors, as well as ideas for their designation on the local level. The Lithuanian national ecological network is composed of 82 core areas (29 core areas of European importance – 746266.03 hectares, and 53 core areas of national importance – 229753.39 hectares), 9 stepping stones core areas(6049.47 hectares), 7 re-naturalisation areas (9746.29 hectares) (Appendix 13).Other elements of the national ECONET include buffer zones (65280.75 hectares), ecological corridors (European ecological corridors – 100753.45 hectares, and national ecological corridors – 440349.80 hectares) and stepping stone eco-logical corridors (10797.90 hectares). The most valuable parts of the core areas were designated as biocentres (European biocentres occupy 32021.82 hectares and national biocentres – 137.48 hectares). Detailed descriptions, including geographical location, conservation status, physical-geographical features, ecological features, reasons for designation and indicator species communities and habitats found in the given area, were prepared for each element (core area, corridor etc) of ecological network
Important websites	http://vhost.asu.lt/nm/l-projektas/krastovaizdzioekologija/29.htm (accessed 13/05/2020) https://www.geoportal.lt/map/# (accessed 13/05/2020) http://www.glis.lt/?pid=48 (accessed 13/05/2020)

Data form, state and source	The map of the Ecological Network of Lithuania can be accessed via WMS from: https://www.geoportal.lt/map/# (accessed 13/05/2020)
Relevance for spatial planning	The natural framework is not a protected area, but some protection is provided at the design level by incorporating it into spatial planning documents. In this way, it is mandatory for land users to comply with certain activity restrictions. These operational constraints can contribute to the conservation of valuable elements of the ecological network, as well as to biodiversity.
Planning level	The map of the Lithuanian ECONET was made on the basis of concepts and principles for the development of Ecological Networks in Lithuania prepared during the phase 1 of this project. Principles and recommendations for developing Pan-European Ecological Network were taken into consideration as well. The example of the Polish ECONET was analysed in the course of this phase of the project.
Planning instruments and implementation level	In the 1980s the Nature Frame started as a simple zoning of green belts, recreation areas and protected areas. It has progressively been worked out (and formally developed in 1988-89) into hierarchical structure of geo-ecological divides, areas of inner stabilization compensating the influence of land use and urban development and migration corridors. It is usually characterized by the absence of urban and industrial activities. In 1993 the Landscape Management Group of Vilnius University worked out Nature Frame Schemes at regional levels covering all 44 administrative districts and currently it covers 61.4% of Lithuania, varying from 35% - 45% (North Lithuania Plain) to 75% - 80% (Eastern Lithuania), depending on natural conditions and land use. The LIFE + Nature project “Establishment of a pilot ecological network in the nature framework areas of Southern Lithuania” is an innovative project aimed at conserving endangered animal species by strengthening the links between protected areas in Southern Lithuania. Selected reptile and amphibian species - Included in the EU Habitats Directive because they are relatively immobile and threatened by habitat destruction and degradation.
Contacts	

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø

Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

LGF (without year): Tikslinių rūšių ekologinio tinklo gamtiniame karkase sukūrimo metodika. LIFE+ NATURE PROJEKTAS LIFE09NAT/LT/00581 "BANDOMOJO EKOLOGINIO TINKLO GAMTINIAME KARKASE SUKŪRIMAS PIETŲ LIETUVOJE", 16 p.

Mierauskas, P., Palaima, A. (2012): Ekologinis tinklas Lietuvoje: kūrimo principai gamtinio karkaso pagrindu. Darnaus vystymosi strategija ir praktika. pp 58-77.

Sepp, K., Kaasik, A. (eds.) (2002): Development of National Ecological Networks in the Baltic Countries in the framework of the Pan-European Ecological Network. IUCN Office for Central Europe, Warsaw, Poland. International Union for Conservation of Nature (IUCN), Gland, Switzerland. 183 p.

The Netherlands

Nature Network of The Netherlands	
Original title	Natuurnetwerk Nederland (NNN), previously Ecologische Hoofdstructuur (EHS)
Network description (content and main criteria)	The Nature Network of the Netherlands (NNN) is the most important basis for nature policy, which contributes to the conservation and development of international natural values. The government is responsible for the NNN in the large waters. The provinces are responsible for the delimitation and development of the NNN; in the Nature Pact the provinces have agreed with the state government to create 80,000 ha of nature by 2027. The NNN contains: - existing nature reserves, areas in which nature is to be developed, agricultural, organic areas, - more than 6 million hectares of water: lakes, rivers, the Dutch part of the North Sea and the Wadden Sea and - all Natura 2000 sites
Important websites	https://www.rijksoverheid.nl/onderwerpen/natuur-en-biodiversiteit/natuurnetwerk-nederland (accessed 18/12/2019) https://www.rijksoverheid.nl/onderwerpen/natuur-en-biodiversiteit/documenten/brieven/2014/05/22/voortgang-begrenzing-nationaal-natuurnetwerk (accessed 18/12/2019) https://web.archive.org/web/20130820065057/http://www.natuurmonumenten.nl/dossier/ecologische-hoofdstructuur (accessed 18/12/2019) http://nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/map (accessed 18/12/2019) https://www.atlasleefomgeving.nl/kaarten (accessed 18/12/2019)
Data form, state and source	The NNN can be downloaded in gml-format for some of the provinces: The NNN can be downloaded in gml-format: https://service.pdok.nl/provincies/natuurnetwerk-nederland/atom/ps-nnn.xml (accessed 14/11/2022) A collection of geodata-viewers and download links for NNN sorted by provinces is here available: https://habitus.nl/NuttigeLinks (accessed 14/11/2022)
Relevance for spatial planning	The provinces have linked the determinations for the NNN to the provincial spatial structure, which allows for regulation of the planning of nature conservation.
Planning level	Until 2014 the provinces revised the National Ecological Network (EHS) and shifted the focus to international nature obligations -> should lead to a stronger and more effective natural network in which natural areas are interconnected: The functional spaces were determined for dry, wet and forest habitat complexes; forest habitat complexes integrate habitats for large mammals

Planning instruments and implementation level	The NNN is a Dutch network of existing and new nature areas where nature has priority. The network helps to prevent the extinction of plants and animals in remote areas and to prevent nature conservation areas from losing value. It can be regarded as the backbone of Dutch nature. Until 2014 the size of the NNN in all provinces was smaller than the size of the originally planned EHS, but larger than the adapted EHS of the Kabinet-Rutte I.
Contacts:	Ministerie van Landbouw, Natuur en Voedselkwaliteit

Defragmentation measures	
Description of the defragmentation measures	At the beginning of the multi-year defragmentation program ("Meerjarenprogramma Ontsnippering" (MJPO)) in 2005, the locations that had to be "defragmented" were recorded. Of the 178 bottlenecks in total by far the largest part has been solved in recent years by the construction of all kinds of faunal facilities. Many of these facilities are intensively used by the animals for which they are intended. The programme was completed in 2018, but when new infrastructure is built, fragmentation will always be on the agenda, guaranteed by the Nature Conservation Act. The knowledge acquired by the MJPO is passed on to provinces, other management organisations and abroad.
Important websites	https://www.mjpo.nl/ (accessed 18/12/2019)
Data form, state and source	https://geoservices.rijkswaterstaat.nl/geoweb53/index.html?viewer=Kernregistraties_Areaal.Webviewer (accessed 18/12/2019)
Relevant habitats/species	Terrestrial species of forests, wetlands and semi-open and dry habitats
Legal instruments (HABITATS Directive II and IV, national conservation acts)	
Contacts	Adam Hofland, Landelijk programmacoördinator Meerjarenprogramma Ontsnippering (MJPO), adam.hofland@rws.nl

Literature:

Bloemmen, M., von der Sluis, T. (eds.) (2004): Europwan corridors – example studies for the Pan-European Ecological Network. Wageningen, Alterra, Alterra-report 1087. 102p.; 16 figs.; 16 tables.; 148 refs; ISSN 1566-7197

Habitat Fragmentation & Infrastructure (1995): Proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering, Ministry of Transport, Public Works and Water Management, Editor: Kees Canters, ISBN 90-369-3727-2

Leidraad faunavoorzieningen bij wegen (2005): Dienst Wegen Waterbouwkunde, Ministerie von Verkeer en Waterstaat, Rijkswaterstaat

Alterra (2001): Handboek Robuste verbindingen, Ecologische randvoorwaarden, Wageningen, Alterra, Research Instituut vor de Groene Ruimte, ISBN 90 327 0314 5

Met vleermuizen overweg (2004): Ministerie von Verkeer en Waterstaat, Rijkswaters, ISBN 90-369-5562-9

Grift, E.A. van der, C.C. Vos, B.J.H. Koolstra, Kuipers, H. (2006): Meerjarenprogramm Ontsnippering en de Natte as; Quick-scan ontsnipperende maatregelen in robuuste verbindingen. Wageningen, Alterra, Alterra rapport 1309. 101 blz.; 15 fig.; 21 tab.; 17 ref.

Haasnoot, R. (2013): Faunavoorzieningen: Funktionaliteit, Effectiviteit en Toekomstig onderzoek. MSc. Stagerapport. Universiteit Utrecht, Ecologie en Biodiversiteit, Utrecht.

Poland

Ecological corridors of Poland	
Original title	Korytarzy ekologicznych w Polsce (Korytarze ekologiczne 2012)
Network description (content and main criteria)	The Ecological Corridors in Poland were developed by the Mammal Research Institute PAS in Białowieża under the guidance of Prof. Dr. hab. Włodzimierz Jędrzejewski and created in two stages: Stage I: In 2005, commissioned by the Ministry of the Environment, a map of the corridor network was developed for Natura 2000 areas, taking into account the need to protect key species of large mammals. Stage II: In 2011, in cooperation with the Laboratory for All Beings (under the EEA / EEA project), a complete map of corridors important for the population of large forest mammals and coherence of forest and wetlands. The basic goal of the map development was to create a practical tool for the protection of habitats and species threatened by fragmentation of the environment, used in spatial planning and linear investment design. The dataset of Ecological Corridors in Poland respresents multifunctional corridors which are designed for the largest possible number of species and to connecting various natural habitats, especially those protected under the Natura 2000 network. Beside the differentiated ecological corridors for woodlands and flowing water on national and international level core areas on national and international level are defined.
Important websites	https://korytarze.pl/ (accessed 13/03/2020) http://mapa.korytarze.pl/ (accessed 13/03/2020) https://biodiversity.europa.eu/countries/gi/poland (accessed 13/03/2020) https://korytarze.pl/upload/filemanager/Korytarze/Prezentacje%20pliki/2011-Gorny-Jedrzejewski-Korytarze-ekologiczne-w-Polsce.pdf (accessed 13/03/2020)
Data form, state and source	Different data types incl. metadata: https://gis.openforestdata.pl/layers/geonode:korytarze_ekologiczne_2012_wgs84 (accessed 13/03/2020)
Relevance for spatial planning	In Poland, regional and local authorities are responsible for spatial and land use planning. The three-tier spatial planning system in Poland is governed by the Land Use Planning and Development Act (DZ.U.2016.778). National and regional levels are strategic levels. The law requires that environmental requirements, including water management and protection of agricultural and forestry land and landscape requirements, are taken into account as a basis for spatial order and sustainable development. According to art. 72 of the Environmental Protection Act, the substantive basis of these actions are the relevant substantive laws and their implementing regulations – e.g the Nature Conservation Act, and at the level of local and regional planning eco-physiological development. The content of these publications is governed

	by the Ordinance of the Minister of the Environment (Dz.U.2002.155.1298). The boundaries of existing areas of nature conservation as defined in the Nature Conservation Act are the reference layer for land use planning. The national level (NSAC 2030) introduces general guidelines which are passed on to the regional level and government administration. The form of transferring content to the local level is addressed to the municipal boundaries, which are part of the spatial development plans of the voivodships. All voivodships have current spatial development plans that include green and blue infrastructure - both existing and planned. Likewise, the coverage of the conditions and directions of the spatial development of the municipality is presented.
Planning level	The ecological network consists of individual GI elements which are subject to national law. In addition to these regulations, there are diverse recommendations (including scientific maps and articles) which are also used for the spatial development strategy, e. g. regarding wolf and bear corridors. A network of ecological corridors was elaborated by the Ministry of Environment in 2005 mainly for large carnivores like wolf, lynx, bear and has to be taken into consideration under the Environmental Impact Assessment procedures in relation to planning transport infrastructure.
Planning instruments and implementation level	Within the framework of the Prioritized Action Framework for Natura 2000 for the EU Multiannual Financing Period 2014-2020 (PAF), the vast majority of activities are focused on Natura 2000, which is the backbone of green infrastructure. However, the document also proposes priority actions to ensure the benefits of Natura 2000's ecosystems, in particular mitigation and adaptation to climate change, for example, afforestation within ecological corridors (50,000 ha) and clearing ecological corridors and waterways corridors (29 animal passages and river clearing in the Odra and Vistula river basins) whose impact will extend beyond the Natura 2000 network. CBD NBSAP: The Programme of Conservation and Sustainable Use of Biodiversity and Action Plan for the 2015-2020 has seven specific objectives including: improving the level of knowledge and increasing the activity of society insofar as biodiversity actions are concerned; improving the nature protection system; preserving and restoring natural habitats and the populations of endangered species; maintaining and reconstructing ecosystem functions; increasing the integration of the operations of the economic sectors in biodiversity protection targets; limiting hazards resulting from climate changes and pressures from invasive species; and increasing Poland’s participation in international fora. The Programme gives consideration to the natural resources of the whole country however the majority of actions will be carried out in protected areas and through green infrastructure, including ecological corridors connecting the protected areas system.
Contacts	

Defragmentation measures	
Description of the defragmentation measures	In Poland, building a sufficient number of properly located and designed animal passages will be crucial for the maintenance and development of populations of large mammals with the highest habitat requirements, such as wolf, lynx, bear, bison and elk. In the case of most of these species, the transition will also decide on the development of their population on a continental scale, because the existence and construction of defragmentation measures in Poland ensures the connection to the best preserved habitats in Europe and cross the pan-European dispersion corridors of the species listed above.
Important Websites, Data form and source	https://korytarze.pl/przejscia-dla-zwierzat/znaczenie-przyrodnicze-i-funkcje-ekologiczne-przejsc-dla-zwierzat (accessed 13/03/2020) http://mapa.korytarze.pl/ (accessed 13/03/2020) https://biodiversity.europa.eu/countries/gi/poland (accessed 13/03/2020)
Relevant habitats/species	The focus of the defragmentation measures is on large mammals of the forest, such as wolf, lynx, bear, bison and elk.
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Transport policy in Poland for the years 2006-2025 requires environmental considerations, in particular nature protection, to be taken into account in the design and construction of transport infrastructure. The Transport Development Strategy by 2020 (with perspective by 2030) envisages a number of actions dedicated to enhancing transport's environmental performance. The measures include, amongst others, modernization and upgrading of transport infrastructure to meet EU and national environmental standards and requirements (including compliance with regulations on environmentally valuable areas, such as Nature 2000, marine and coastal environment protection), implementation of innovative construction technologies to minimize environmental pressures, development and common application of innovative solutions to protect wildlife against collisions with vehicles, maintenance of the existing wildlife passages and implementing best available practices while designing new wildlife passages.
Contacts	

Literature:

Gerlée, A. (2010): Landscape Representativeness within the Network of Ecological <<<<<<s linking Natura 2000 Areas in Poland. Miscellanea Geographica Vol. 14: 13-19.

Huck M., Jêdrzejewski W., Borowik T., Miosz-Cielma M., Schmidt K., Jêdrzejewska B., Nowak S. & Mysajek R. W. (2010): Habitat suitability, corridors and dispersal barriers for large carnivores in Poland. Acta Theriologica 55: 177–192.

Kurek, R.T. (2010): Poradnik projektowania przejść dla zwierząti działań ograniczających śmiertelność fauny przy drogach. Warszawa, pp. 252.

Portugal

National Ecological Network of Portugal	
Original title	Estructura Ecológica Nacional
Network description (content and main criteria)	The Fundamental Network for Nature Conservation (RFCN in Portuguese) consists of the core areas of nature conservation and biodiversity, an ecological reserve, an agriculture reserve, the Natura 2000 areas, other areas designated at international level and the areas of water in the public domain. The legislation also created the SIPNAT (Natural Heritage Information System) and the Cadastre of Designated Natural Values, as proposed in the Strategy for Nature Conservation and Biodiversity. Another important factor is a new economic and financial regime for nature conservation and biodiversity and the creation of the Fund for Nature Conservation and Biodiversity (EEA, 2015). The dataset in the EDM represents the 1st Level of the National Ecological Network with value or higher degree of ecological sensitivity were included in the 1st level and are as follows: water lines, marine and coastal waters, transitional waters(and river mouth), inland waters, Wet System, Soils with very high and high ecological value, Coastline, steep slopes, natural and semi-natural vegetation with very high and high conservation value, Nature conservation Areas that include: a) Natura 2000 b) IBAs c) Ramsar Sites; d) Biogenetic Reserves Network of the Council of Europe; e) UNESCO Biosphere Reserves; f) National Network of Protected Areas.
Important websites	https://biodiversity.europa.eu/countries/gi/portugal (accessed 20/04/2020) http://www.dgterritorio.pt/jiide2017/pdfs/Apresentacoes/JIIDE2017_EPIC_WebGIS_Manuela_R._Magalhaes.pdf (accessed 20/04/2020) http://epic-webgis-portugal.isa.ulisboa.pt/maps/epic_pt?startExtent=-1048380.0031735%2C4654647.5826316%2C-969649.86405071%2C4714421.3387422&maxExtent=-2226772%2C4257328%2C454026%2C5524348&visibleBackgroundLayer=Bing%20Aerial&visibleLayers=Continente%2CPermeabilidade%20Atual%2C&lang=pt_PT (accessed 20/04/2020)
Data form, state and source	The National Ecological Network of Portugal can be downloaded in shape or tiff format from http://epic-webgis-portugal.isa.ulisboa.pt/ (accessed 20/04/2020)
Relevance for spatial planning	Considering ecological systems in spatial and urban planning has been an accepted principle since the introduction of the REN (Decreto – Lei nº321/83 in 1983, Decreto – Lei nº 93/90 in 1990, latest update from 2008: Decreto – Lei nº 166/2008) (IEEP et al., 2011). The Portuguese land use planning policy is based on a hierarchical system of territorial management, which operates at three spatial levels: national, regional, and municipal. On the city level, Master Development Plans guide land use planning and includes the Municipal Ecological Structure as a key instrument for city planning, aiming at better coordination between green planning and 'grey'

	planning, improving connectivity, resilience and functioning of urban nature (often including climate adaptation and social cohesion) (Green Surge, 2015a). The spatial concept is enshrined in the Portuguese legislation (Decree-Law No. 380/99 of 22 September, asamended several times and whose latest version is given by Decree No. 80/2015 of 14 May) and is an indispensable tool for an ecologically based landscape planning.
Planning level	Green Infrastructure is primarily known in Portugal under the term "Ecological Network" or "Ecological Structure". An inter-ministerial coordination mechanism is in charge of promoting the integration of conservation and sustainable use of biodiversity into the various sectoral policies (Council of Ministers Resolution Nº 41/99 of 17 May), including considerations in ecological network planning.
Planning instruments and implementation level	The National Ecological Reserve (REN) Act is based on a hierarchical system of territorial management, which operates at the national, regional and municipal level and plans to incorporate green and blue infrastructure elements. As one of the components of the fundamental network for the conservation of nature, the REN supports the integration of the connection between the core areas of nature conservation and biodiversity into the National Classified Areas. In the REN, various green infrastructure elements are planned, including protected areas, sustainable use areas and natural connectivity features. At national level, the REN aims to: 1) protect water and soil resources and ensure ecosystem services, 2) protect groundwater levels, prevent and reduce the effects of maritime flood risk, drought, soil erosion and mass movements on slopes (as climate adaptation measures) and 3) contribute to the connectivity and ecological coherence of natural areas. The REN thereby relates to policies on water (including the EU Water Framework Directive), agriculture and adaptation to climate change (Trinomics et al. 2016). Land areas included under REN regulations must be identified in regional and local plans. Special committees, involving local authorities, central and regional public agencies, manage the application of this regulation and manage conflicts (IEEP et al. 2011).
Contacts	Manuela R. Magalhães, Landscape Architecture Research Centre "Prof. Caldeira Cabral", Instituto Superior de Agronomia, Technical University of Lisbon, mmagalha@isa.ulisboa.pt

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø

Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

Cunha, N.S.; Magalhaes, M.R. (2009): Methodology for mapping the national ecological network to mainland Portugal: A planning tool towards a green infrastructure. Ecol. Indic., 104, 802–818.

Cunha, N.S., Magalhães, M.R. (2013): The Portuguese National Ecological Network - A Mapping Proposal. Proceedings of the Fábos Conference on Landscape and Greenway Planning: Vol. 4: Iss. 1, Article 50. Available at: https://scholarworks.umass.edu/fabos/vol4/iss1/50

Gomes, A.L. (2011): CORREDORES PARA A VIDA SELVAGEM COM BASE NA MODELAÇÃO ESPACIAL DAS PERTURBAÇÕES AMBIENTAIS E A SUA UTILIDADE PARA A CONSERVAÇÃO DO LOBOIBÉRICO: PROCESSOS METODOLÓGICOS. 17. Congresso da APDR, Braganca – Zamora.

Scotland (Central part)

Network of Ecologically Important Areas	
Original title	Central Scotland Green Network (CSGN)
Network description (content and main criteria)	The Habitat Connectivity Map (CSGN 2021) identify areas of habitat (woodland, grassland, wetland and bog and heath) across central Scotland which should be protected and improved, as well as key sites for connecting these habitats so that species can move between them. The existing habitats shown on the Connectivity Map are limited to 'natural' or 'semi-natural' habitats. This means that they have not been significantly modified by humans; they have natural characteristics with a range of associated plant and animal species. Therefore, the existing habitats shown on the map do not include coniferous forest plantations or urban green spaces such as parkland. The map does not show acid or calcareous grassland habitats, nor does it show coastal, intertidal or marine habitats. Watercourses and open water are not included within the model, but can be identified from the base map or through other GIS layers used for analysis. Information on the current condition and future targets for rivers, lochs, coastal waters and groundwater can be found on the SEPA water environment hub. **Woodland**: woodland habitats (includes broadleaf, mixed and yew woodland heath habitats) alongside the dispersal distances (quarter distance and maximum distance) for woodland. **Grassland**: neutral grassland habitats (includes unimproved and species rich neutral grassland habitats) alongside the dispersal distances (half distance and maximum distance) for grasslands **Wetland**: wetland habitats (includes fen, marsh and swamp habitats) alongside the dispersal distances (half distance and maximum distance) for wetland. **Bog and heath**: bog & heath habitat (includes blanket, raised and modified bog and heath habitats) alongside the dispersal distances (quarter distance and maximum distance) for bog & heath. The dispersal distances for connecting habitats are differentiated: **primary** appear within the maximum dispersal distance where there is already some migration of species between habitat patches occurring; they connect habitat patches that are closer together so tend to be the quickest win for achieving connectivity; **secondary** opportunities connect the maximum dispersal distances for each patch. **Methodology**: The approach employs a detailed desk study using digital data within a geographic information system (GIS) to identify Integrates Habitat Networks (IHNs). The spatial position and extent of functional integrated habitat networks were determined through a landscape ecology model from the BEETLE (Biological and Environmental Evaluation Tools for Landscape Ecology) suite of tools.

Important websites	https://map.environment.gov.scot/sewebmap/
Data form, state and source	http://gateway.snh.gov.uk/natural-spaces/index.jsp (data download, accessed 16/11/2021) GIS-Dataset containing: GIS_AREA_OWNER.CSGN_HAB_NET_**WOODLAND** (creation: 31/12/2020; publication: 01/06/2021) GIS_AREA_OWNER.CSGN_HAB_NET_**GRASSLANDS** ((creation: 31/12/2020; publication: 01/06/2021 GIS_AREA_OWNER.CSGN_HAB_NET_**WETLANDS** (creation: 31/12/2020; publication: 01/06/2021 GIS_AREA_OWNER.CSGN_HAB_NET_(creation: 31/12/2020; publication: 01/06/2021
Relevance for spatial planning	Datas are intended to support planners, developers, land managers and communities identify areas to improve habitats (cores) and the dispersal zones (corridors) and opportunity areas will identify where there are areas to improve habitat connectivity (potential corridors). This data will also support the Scottish Government's commitments to protect and restore biodiversity and to develop nature-based solutions to the climate emergency. It is recommended that each habitat type is initially viewed alongside the other habitat layers, to ensure that the full range of habitats in an area are included in the decision-making process.
Planning level	
Planning instruments and implementation level	
Contacts	Responsible organisation: NatureScot Usage constraints/Limitations of use available under the Open Government Licence http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø

Important Websites, Data form and source	Ø
Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

Spain

Strategic Network of Ecological Corridors	
Original title	Red Estratégica de Corredores Ecológicos
Network description (content and main criteria)	In 2018 the WWF has identified a network of ecological corridors linking woodland, Natura 2000 sites on the Iberian Peninsula that would be essential to guarantee large scale movements of a representative group of forest mammals. It also accounts for transnational corridors though Portugal, France and Andorra. The study focuses on woodlands (forests and shrubs) both due to the wide representation of woodland habitat in Spain and to a larger availability of the necessary information for connectivity assessments. Apart from mapping priority ecological corridors, the study determines whether there is a need for conservation or restoration in each case and identifies bottlenecks (critical areas for connectivity) along the corridor pathways. In order to connect protected natural habitats with each other the WWF has created a map that identifies twelve great ecological corridors that animals use to move around the Iberian Peninsula. Additionally, 17 critical areas that are within these twelve corridors (called "bottlenecks") and that must urgently be restored have been identified.
Important websites	https://www.europapress.es/sociedad/medio-ambiente-00647/noticia-mapa-identifica-doce-grandes-corredores-emplean-animales-moverse-peninsula-iberica-20180309175506.html (accessed 20/04/2020) http://awsassets.wwf.es/downloads/AutopistasSalvajesInforme.pdf (accessed 20/04/2020)
Data form, state and source	The ecological corridors for Spain can be downloaded as shapefiles from: https://www.dropbox.com/sh/vr3l766kymf609a/AAD2sgPstVFjwFHDRecJvBv5a?dl=0 (accessed 20/04/2020)
Relevance for spatial planning	In their study the WWF provided key geographical information that should feed into national and international strategies and action planning. In other words, environmental policies as well as other sectorial policies such as agriculture, land use or transport infrastructure should be oriented towards the maintenance and restoration of these priority connectivity corridors. The information provided throughout this proposal is also very relevant for large-scale restoration and landscape connectivity objectives at the European level.
Planning level	The objective of the Strategic Network of Ecological Corridors is to set the guidelines to identify and preserve the elements that make up the green infrastructure of the terrestrial and marine territory in Spain, to be able to plan on a territorial and sectoral basis by public administrations, the actions that ensure connectivity and ecological and ecosystem functionality.

Planning instruments and implementation level	The priority corridors as well as a large part of the critical areas for connectivity are located in different autonomous communities. The WWF therefore proposes that a national and supra-autonomous approach should be adopted when maintaining and restoring connectivity in the territory, coordinating and jointly implementing all the necessary planning actions, field financing, restoration and conservation, without compromising the efforts made for the implementation at the regional or sub-regional level. In 2018 the WWF requested to include their analysis in the Green Infrastructure Strategy of Spain.
Contacts	

Defragmentation measures	
Description of the defragmentation measures	Since the 1990s, numerous transverse structures have been built in Spain with the objectives of facilitating the safe passage of fauna between both sides of roads and railway lines and, thereby, reducing both the effect of the fragmentation of habitats and of fauna populations. Each of the 1,358 cross-sectional structures considered has been incorporated into a database and part of its characteristics have been statistically analysed. The results of this study (MITECO 2018) report on the situation in which these structures are found and on their potential contribution to the permeabilization of roads to the passage of fauna.
Important Websites, Data form and source	https://www.miteco.gob.es/es/biodiversidad/temas/ecosistemas-y-conectividad/conectividad-fragmentacion-de-habitats-y-restauracion/fragm_habitats_causa_transp.aspx (accessed 20/04/2020) https://www.miteco.gob.es/es/biodiversidad/temas/ecosistemas-y-conectividad/estruct_poten_fauna_tcm30-485847.pdf (accessed 20/04/2020) Potential structures for fauna passages can be downloaded as kmz-file from: https://www.miteco.gob.es/es/biodiversidad/temas/ecosistemas-y-conectividad/conectividad-fragmentacion-de-habitats-y-restauracion/fragm_habitat_transp_estructuras.aspx
Relevant habitats/species	Medium sized and large mammals such as Iberian lynx, brown bear, wolf, deer; amphibians and reptiles, bats
Legal instruments (HABITATS Directive II and IV, national conservation acts)	The installation or adaptation of structures for defragmentation has been incorporated as corrective measures in the environmental impact statements of the construction projects of transport infrastructures.
Contacts	

Defragmentation measures - No Data	
Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø
Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

Caceres, G.R. et al. (2018): Autopistas salvajes - Propuesta de WWF España para una Red Estratégica de Corredores Ecológicos entre espacios Red Natura 2000. WWF/Adena, Madrid, pp. 40.

Martínez de Toda, S.S., Sánchez, M.C.M., de la Fuente Martín, B. & González, A.G. (2016): Estudio para la identificación de redes de conectividad entre espaciosforestales de la Red Natura 2000 en España. Fundación Conde del Valle de Salazar, Escuela Técnica Superior de Ingenieros de Montes Universidad Politécnica de Madrid, Estudio desarrollado para WWF-España, 56 pp.

Sunyer, C., Manteiga, L. (2008): Spatial planning and ecological networks in Spain. TERRA. La Navata (Madrid)

Switzerland

Wildtierkorridore Schweiz	
Original title	Wildtierkorridore Überregional
Network description (content and main criteria)	The Swizz Wildlife corridors (Wildtierkorridore Schweiz) are ecological corridors of supraregional/national importance (state 2021). In a first step, the known wildlife corridors were recorded canton by canton from existing data and potential corridors were identified using GIS and divided into wildlife corridors of supraregional, regional and local interest. Subsequently, the main features of the supraregional and regional connectivity system were visualized for the whole of Switzerland. The corridors were then classified as wildlife corridors of supraregional or regional interest according to the importance of the axis on which they lie. The data for the connecting axes and wildlife corridors were collected and processed in GIS by the Swiss Ornithological Institute Sempach. The supraregional corridors and the connecting axes were revised by the FOEN in 2012. In 2017 and 2021, the corridors were subject to a further revision. As of 2020 there are 304 wildlife corridors connecting fragmented ecosystems or suitable habitats and are vital for wildlife. An assessment of wildlife corridors concluded the following: 47 corridors (16%) are largely disrupted and can no longer be used by wildlife; over half (171 corridors, 56%) are appreciably to severely impaired; less than a third (86 corridors, 28%) can be classified as intact.
Important websites	https://www.bafu.admin.ch/bafu/de/home/themen/biodiversitaet/fachinformationen/oekologische-infrastruktur/wildtierpassagen.html (accessed 13/03/2020)
Data form, state and source	The supra-regional wild animal corridors are formed as focal lines and presented in as GIS polylines. Data download: https://www.geocat.ch/geonetwork/srv/ger/catalog.search#/metadata/6241112d-25c1-48bb-a6bf-c8b98805b5fc (accessed 20/03/2021) State: 31/12/2020
Relevance for spatial planning	Since 2003, the Federal Roads Office (FEDRO)FEDRO has been working together with the Federal Office for the Environment (FOEN) and the cantons on the rehabilitation of interrupted corridors - namely with the construction of wildlife passages along national roads. The status of the FEDRO subprogram Rehabilitation of Wildlife Corridors is updated and published annually. In spatial planning the Swizz Wildlife corridors have no legal obligation.
Planning level	

Planning instruments and implementation level	Within the framework of the Swiss Biodiversity Strategy Action Plan various projects, wildlife passages on roads and railroads are being improved, the basis for the rehabilitation of wildlife corridors is being revised, and the rehabilitations that the Federal Roads Office (FEDRO) carries out on national roads are being accelerated.
Contacts	BAFU AÖL Bundesamt für Umwelt / Abteilung Arten, Ökosysteme, Landschaften aoel@bafu.admin.ch

Defragmentation measures	
Description of the defragmentation measures	In collaboration with the FOEN and the cantons, FEDRO is working to redevelop them by planning and building wildlife passages. The results of the survey as of July 2021 (excluding NEB routes) can be commented as follows: - 39% of wildlife corridors are rehabilitated or under implementation; - 44% of wildlife corridors are in a project planning phase; - for 17% of wildlife corridors, project planning has not yet started. In the EDM a point feature dataset with 35 defragmentation measures (status 2016) is used. Information available about the type (overpass, underpass, tunnel), the barrier (street), purpose and origin.
Important Websites, Data form and source	https://www.bafu.admin.ch/bafu/de/home/themen/biodiversitaet/fachinformationen/oekologische-infrastruktur/wildtierpassagen.html#-698340157 (accessed 20/03/2021)
Relevant habitats/species	Medium-sized and large mammals, small mustelids, bats, amphibians and reptiles
Legal instruments (Habitats Directive II and IV, national conservation acts)	The Federal Department of the Environment, Transport, Energy and Communication (DETEC) has drawn up a directive on the construction of wildlife passages. DETEC's guidelines (Planning and construction of wild animal passages on traffic routes (PDF, 25 kB, 21/04/2010; https://www.bafu.admin.ch/dam/bafu/de/dokumente/biodiversitaet/fachinfo-daten/planung_und_bau_vonwildtierpassagenanverkehrswegen.pdf.download.pdf/planung_und_bau_vonwildtierpassagenanverkehrswegen.pdf)) show criteria on the basis of which the number of wild animal passages, their location, the type of building and the dimensions are determined. November 2001. The ASTRA Guideline " Crossing Aid for Wildlife " (Guideline 18008; https://www.astra.admin.ch/astra/de/home/fachleute/dokumente-nationalstrassen/standards/umwelt.html) specifies how the separation effect of national roads on the landscape can be minimized by optimally integrating crossings.

	In order to compare the success of the structures with each other, data are recorded according to a standardized procedure. Impact monitoring is a mandatory part of rehabilitation and restoration projects. https://www.bafu.admin.ch/dam/bafu/de/dokumente/biodiversitaet/fachinfo-daten/astrabafufunktionskontrollevonwildtierpassagen.pdf.download.pdf/astra_88012_funktionskontrolle_von_wildtierpassagen_2019_V1.00.pdf The Swiss Association of Road and Traffic Experts (VSS) standard for the design of water passages in traffic facilities (renovation and new construction) maintains or promotes the ecological networking of rivers. The standard shows how buildings can be planned, designed and maintained for the various groups of animals. Almost all amphibian species rely on the animals being able to safely move back and forth between different habitats several times a year. The standards for the construction of roads and rails have been updated accordingly.
Contacts	Adrien Zeender, adrien.zeender@bafu.admin.ch

Literature:

Dändliker, G., Durand, P. (2001): Grundlagenbericht für die Richtlinie „Planung und Bau von Wildtierpassagen an Verkehrswegen ". Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation, BUWAL, Genf.

Holzgang, O., Pfister, H.P., Heynen, D., Blant, M., Righetti, A., Berthoud, G., Marchesi, P., Maddalena, T., Müri, H., Wendelspiess, M., Dändliker, G., Mollet, P., Bornhauser-Sieber, U. (2001): Korridore für Wildtiere in der Schweiz. Schriftenreihe Umwelt Nr. 326, Bundesamt für Umwelt, Wald und Landschaft (BUWAL), Schweizerische Gesellschaft für Wildtierbiologie (SGW) & Schweizerische Vogelwarte Sempach, Bern, 118 p.

Oggier, P., Righetti, A., Bonnard, L. (eds.) (2001): Zerschneidung von Lebensräumen durch Verkehrs-infrastrukturen COST 341. Umwelt-Wissen Nr. 0714 (2. aktualisierte Auflage der BUWAL-Schriftenreihe Umwelt Nr. 332). Bundesamt für Umwelt; Bundesamt für Raumentwicklung; Bundesamt für Verkehr; Bundesamt für Strassen. Bern, 101 p.

Trocmé, M., Krause, K. (2019): Dokumentation Funktionskontrolle von Wildtierpassagen. Ausgabe V1.00, Bundesamt für Strassen ASTRA 88012, Bern, 42 p.

Hirschi, B. (2021): Nationalstrassen Teilprogramm Sanierung der Wildtierkorridore. Zwischenbilanz Juli 2021. ASTRA-D-50633401/1133, 7p.

Wales

Habitat Networks	
Original title	Habitat Networks for Welsh Woodlands, Grasslands, Heathlands, Bogs and Fens
Network description (content and main criteria)	This dataset provides an account of the work on connectivity and priority mapping in Wales and provides a basis for mapping connectivity. The output of the model is a series of mapping layers, known as **core, focal and local** networks. Together these provide a guide to overall habitat connectivity and can be interpreted in various ways to inform biodiversity action and environmental projects in general. This is a spatial dataset consisting of maps of habitat networks originally developed by Countryside Council for Wales (CCW) in collaboration with Forestry Commission Wales and Forest Research using a functional networks approach, and now managed and progressively developed by NRW. Patches of habitat and other intervening habitats through which many of their species are able to move are mapped as habitat networks. **Networks** have been mapped **for** habitats including **woodland, unimproved grassland, calcareous grassland, marshy grassland, heathland, fens and bogs**; in most cases these are divided into upland and lowland versions and in some cases networks that support the highest quality areas of habitat have been selected out as priority layers. Results are available for the whole of Wales as GIS layers and include **three levels of habitat networks**; **core networks** (areas within which species that require extensive habitat and disperse poorly are able to move), **focal networks** (areas within which species tolerant of smaller habitat patches and with greater dispersal ability are able to move), **and local networks** (areas within species that can persist within small habitat patches and have very limited dispersal abilities can move). Purpose of data capture was to allow the scope and range of potential networks to be rapidly explored. Layers are arranged in two folders: **Level 1, containing all outputs across Wales**, and Level 2 which are selected, priority networks, within which action may be targeted to enhance functional networks of the best habitat areas. Mapping is available for broadleaved woodland, heathland, unimproved grassland, fens and bogs, each (except woodland) in upland and lowland versions. **Methodology of Modelling the Habitat Networks:** 'Least-cost' modelling was carried out using Forest Research's BEETLE (Biological and Environmental Tools for Landscape Ecology) tools, coupled with Habitat Survey of Wales digital dataset (Phase 1). The model is based on species characteristics, taking into account a minimum habitat area and the relative ecological cost of different habitats- relates to ease of movement through different land cover types, expressed in terms of dispersal distance in metres over a 50 year timescale. In simple terms it

	draws a 'buffer' around habitat patches, the width of which depends upon the assumed permeability of the intervening habitats. When buffers around patches overlap the habitat patches are considered to be part of the same habitat network with many species potentially able to move between all habitat patches within it. This project uses data from Phase 1 Habitat Survey of welsh woodlands, grasslands, heathlands and bogs and fens, supplemented with National Forest Inventory data for woodland.
Important websites	
Data form, state and source	Data download: https://lle.gov.wales/catalogue/item/HabitatNetworks/?lang=en (accessed 25/01/2022) Metadata information: https://lle.gov.wales/catalogue/item/HabitatNetworks/?lang=en (accessed 25/01/2022) GIS-Dataset (Level 1) containing for each lowland and upland habitat: • Core Network → Core habitat network derived from Phase 1 Habitat Survey*, applying least-cost modelling • Focal Network → Focal habitat network derived from Phase 1 Habitat Survey*, applying least-cost modelling and • Local Network → Local habitat network derived from Phase 1 Habitat Survey*, applying least-cost modelling (Publication: 22/04/2013) There are no access restrictions on this data. NRW may release, publish or disseminate it freely.Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.
Relevance for spatial planning	Predicted habitat networks can be used to guide large-scale planning for nature conservation, provide insight into how the landscape is likely to be functioning and prioritise action to improve the connectivity and viability of protected sites.
Planning level	
Planning instruments and implementation level	
Contacts	

Defragmentation measures - No Data

Description of the defragmentation measures	Ø
Important Websites, Data form and source	Ø
Relevant habitats/species	Ø
Legal instruments (HABITATS Directive II and IV, national conservation acts)	Ø
Contacts	Ø

Literature:

Latham, J., Rothwell, J. (2016): Terrestrial Habitat Networks – Additional Information.

Latham, J., Sherry, J., Rothwell, J. (2013): Ecological Connectivity and Biodiversity Prioritisation in the Terrestrial Environment of Wales. CCW Staff Science Report No. 13/3/3