PROTECTION OF LANDSCAPE CONNECTIVITY FOR LARGE MAMMALS

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Table of Contents

Acronyms:

AADT – Annual average daily traffic
AOPK ČR – Agency for Nature Conservation and Landscape Protection of the Czech Republic
EEA – European Environment Agency
EIA – Environmental Impact Assessment
GIS – Geographical Information System
GPS – Global Positioning System
HSI – Habitat Suitability Index
HSR – High-speed rails
LDMC – Long-Distance Migration Corridor
MT – Migration Route
NDOP – Records of Species of the Agency for Nature Conservation and Landscape Protection of the Czech Republic
NP – National Park
PLA – Protected Landscape Area
SCI – Site of Community Importance (Natura 2000 network)
SLC – Significant Landscape Components
SMA – Significant Migration Area
SPA – Special Protection Area (Natura 2000 network)
SSPA – Small-scale Specially Protected Areas
TSES – Territorial System of Ecological Stability

Participation of a wide range of workers was required for the purposes of this Project. Our thanks go to all who conducted literature and field research, processed data, wrote the text, created maps, supplied photographs, elaborated the graphical and text appearance of the publication, and to all the others who contributed with a number of comments and ideas.

1.

Protection of Landscape Connectivity for Large Mammals and Methodology of the Research Project

Petr Anděl

1.1. LANDSCAPE FRAGMENTATION AND MIGRATION OF LARGE MAMMALS

Transport, industrial, and urban infrastructures represent barriers that significantly limit free movement of animals in the landscape. Habitats offering favourable conditions for large mammals are each day more fragmented, creating isolated areas with insufficient connection to the surrounding environment. This process, called landscape fragmentation and fragmentation of populations, is one of the most significant negative impacts of human activities on the living nature (Miko & Hošek, 2009). Due to diverse ecological requirements of many species affected by landscape fragmentation and due to variable natural and social conditions in particular areas, finding solutions or proposing certain protection measures has become a very complex challenge.

The number of anthropogenic barriers has been increasing extremely fast over the past few decades. As a result, fragmentation of the landscape is perceived today as one of the hot issues. The open landscape composing of natural and semi-natural habitats, supposed to act as a connecting element between various populations, is now losing its capacities. In many cases, this is an irreversible process making the protection of the existing linear connections a key task within nature conservation. Ecological networks are hence coming to the fore with their basic attribute of suitable habitats and desired continuity.

Among these networks, there is one designed to preserve the connectivity of populations of large mammals in the Czech Republic. The main purpose of this publication is to present the process of preparation, delimitation, and proposal for the actual design of such an ecological network.

The present study delivers outputs of a research project conducted by the Ministry of the Environment of the Czech Republic. As mentioned above, it concerns one of the issues relating to landscape fragmentation, namely evaluation of the landscape permeability for migration of large mammals, and introduces proposals for protection and optimising measures. For the purposes of this project, the following focal species are understood under the term "large mammals": Eurasian Lynx (*Lynx lynx*), Grey Wolf (*Canis lupus*), Brown Bear (*Ursus arctos*), Eurasian Elk (*Alces alces*), and Red Deer (*Cervus elaphus*). A question may arise why to address such a relatively narrow group of species. Two fundamental reasons should be emphasised.

First, it is the species protection as such. All the species, with the exception of the Red Deer, are "specially protected species" under the act on the conservation of nature and the landscape. The lynx and the bear are also protected as animal species of Community interest under the Natura 2000 network. The species show considerable demands on free movement in the landscape and only functional interconnection of individual populations can secure their long-term sustainable existence.

Second and equally important, these large mammals should be regarded as representatives of forest ecosystems. Considering their high ecological requirements, we may presume that when securing permeability of the landscape for them, we also guarantee sufficient capacity for other forest animals. Forest ecosystems represent an essential part of Czech nature as they cover approximately 30% of the country area. By protecting the connectivity of the landscape for large mammals, we preserve the connectivity of forest ecosystems as a whole.

For the purposes of the present publication, we consider appropriate to comment on terminology. Animals move through the landscape in different ways and with different motives. In addition to long-distance migration, they disperse in order to spread their populations; the intensity of their movement varies depending on seasons and daily search for food, water, hiding places, etc. With respect to the landscape connectivity and mainly to practical protection measures, these forms of movement can hardly be separated. An ecoduct crossing a motorway will serve both an elk migrating a long distance from Poland to South Bohemia and for daily movement of animals living in the surroundings. With the view of simplifying the language, the term "migration" should be understood herein as any of the mentioned types of movement of animals in the landscape, despite the fact that this will not always conform to the terminology applied in zoology.

1.2. CONCEPT OF THE PROTECTION OF LANDSCAPE CONNECTIVITY

Only a systemic concept can ensure efficient protection of the permeability of the landscape for migration. The current proposal for such a concept originates from a study conducted by Anděl & Gorčicová (2007) and presupposes delimitation and protection of the following three hierarchically structured units: (i) Significant Migration Areas (SMA), (ii) Long-Distance Migration Corridors (LDMC), and (iii) Migration Routes (MR). This structure should establish sufficient grounds for a more precise amendment of measures reflecting newly acquired knowledge. These measures should further be linked to spatial planning.

1) Significant Migration Areas

Significant Migration Areas (SMA) represent the highest level of territorial delimitation and are based on a fundamental concept aimed at retaining the permeability of the landscape in the context of larger landscape units (e.g., connectivity of the Carpathians and the Bohemian Massif). These are wide areas both providing space for the permanent occurrence of species and securing permeability for migration. Landscape fragmentation should be understood here as one of the obligatory aspects for decision-making processes in spatial planning and investment. The maps of SMAs offer a basic working scale of 1: 500 000. The first map was published by the Agency for Nature Conservation and Landscape Protection of the Czech Republic (AOPK ČR) in 2008 as a so-called territorial analytic data source. SMAs covered approximately 67% of the country area and the map was supposed to be further elaborated, which was one of the objectives set by the project.

2) Long-Distance Migration Corridors

Long-Distance Migration Corridors (LDMC) are the basic units ensuring conservation of sustainable permeability of the landscape for large mammals. They are linear structures tens of kilometres long and on average 500 m wide, and connect areas significant for the permanent and temporary occurrence of large mammals. Their main purpose is to provide the necessary minimum of sustainable connectivity of the landscape for large mammals. They represent an instrument serving for coordination of interests in nature conservation and spatial development. In case of insufficient delimitation and protection of LDMCs, significant corridors can be easily disturbed by other barriers. The financial means and efforts invested in securing their permeability (e.g., by constructing ecoducts over motorways) may thus come to nothing. The basic working scale of these maps is 1: 50 000. LDMCs have not been delimited yet, raising conflicts within the processes of spatial planning. For these reasons, the presented project proposes LDMCs as its basic output.

3) Migration Routes

Migration Routes (MR) are the smallest units in the hierarchy of the present methodology. Hundreds of metres wide, they represent a detailed solution to critical sites within a migration corridor. The technical optimising measures are specified in detail: e.g., measures to secure permeability of migration barriers, adjustments of migration objects, planting tree species, etc. The maps are designed at the scale of 1: 5 000. The level of migration routes should be applied only in cases when the permeability of corridors is at stake and when technical measures are required to retain the migration potential. Migration Routes should be mainly considered within the processes of spatial planning and environmental impact assessment and thus are not subject to the present project.

To recapitulate, the concept of the protection of landscape connectivity involves three levels of practical measures. Significant Migration Areas are the signal level. Any disturbance representing a potential risk to their permeability has to be identified in time, thoroughly assessed, and subsequent preventive measures have to be adopted. The level of Long-Distance Migration Corridors is understood in the sense of conservation. No constructions or changes in habitats that would deteriorate their permeability are allowed. The actual investment or spatial measures are implemented at the level of Migration Routes. These are supposed to enhance connectivity in the given area, mainly where migration is obstructed by already existing significant barriers.

The outputs of the present research project fundamentally complement the concept of the protection of landscape connectivity for large mammals. They provide more details on Significant Migration Areas and determine Long-Distance Migration Corridors.

1.3. PROJECT METHODOLOGY

Achieving the above-mentioned objectives is a very demanding multidisciplinary task that encompasses elements of ecology, biogeography, spatial planning, GIS, technical and other sectors. A comprehensive methodology was applied to acquire the input data and for their further processing. Hence, the final outputs were obtained based on the current professional knowledge. The following overview shows the essential stages in the methodology of the present project.

Essential Stages of the Project

1) Background Research on Ecological and Behavioural Requirements of Large Mammals Subject to the Study

The primary data indispensable for further work provide information on biology of individual species subject to the project, their ecological requirements regarding permanent or temporary occurrence, behaviour when on the move through the landscape, and on how they overcome migration barriers. A detailed background research was carried out to obtain such data both from literature and from specific outcomes of modern monitoring of certain animals using GPS telemetry.

2) Review of Data on Focal Species

The data on the occurrence of the given species in the Czech Republic are fundamental for the determination of their permanent and temporary occurrence, and of the main migration corridors. Unfortunately, these data show significant heterogeneity and discrepancies in location; they were acquired in various periods and descriptions of individual areas lack uniformity. Their credibility also varies. For these reasons, all the available data were collected and reviewed. The present study may be considered as the most comprehensive source currently available in the Czech Republic.

3) Assessment of Principal Migration Barriers

Various types of technical and natural barriers (such as settlements, transport structures, watercourses, fenced areas, etc.) limit the free movement of animals in the landscape. According to their characteristics, they produce various levels of resistance. The basic step to determine the permeability and thus the perspective of a migration corridor is to define this resistance. Therefore, these barriers were assessed, categorised, and localised. The assessment involved individual types of barriers as well as their cumulative effects.

4) Implementing Mathematical Models of the Landscape Potential

Ecological requirements of animal species differ. That is why each place in the landscape shows different probability of the given species occurrence, depending on the diversity of natural and anthropogenic conditions. This probability of the species occurrence is called the landscape potential and may be estimated through mathematical models. Among a number of methods, we may mention the following two approaches:

a) Methods of Statistical Analysis – are based on an analysis of selected factors of the environment where the occurrence of the given species has been proven, on statistical evaluation of relationships between variables, and on application of the resulting relationships for other areas under review using GIS tools. The results may be expressed as categories of the given area from the point of view of the habitat potential for the species occurrence. This type of models is known as the habitat model.

b) Methods of Multicriteria Analysis – stem from methods of multicriteria evaluation and are equally based on an analysis of selected factors of the environment in relation to the given species ecology. A team of experts carries out a formalised assessment to determine the importance and preferences of individual variables. Using GIS tools, the outputs are further utilised to categorise the given area taking into consideration the suitable landscape potential. Each approach has its pros and cons and their combination is desired. Nevertheless, it should be noted that all models solely approximate the reality and their outputs should be viewed with a critical eye. They still certainly serve as a suitable instrument while solving landscape connectivity issues.

5) Extensive Field Research

The permeability of a migration corridor may be threatened even by a several meters wide barrier (e.g., roads with noise barriers, terraced houses or a line of recreational weekend houses with fenced gardens, etc.). A detailed field research was conducted to define such places and to determine the actual permeability of routes proposed as Long-Distance Migration Corridors. Impermeable critical sites within corridors can be identified neither in maps nor through mathematical models, but only based on a detailed local field research, which is thus a fundamental methodological step. The outputs of such research served as a ground for the delimitation of LDMCs.

6) Further Elaboration of the Map of Significant Migration Areas

The previously acquired data, particularly the comprehensive evaluation of the findings regarding migration barriers in the landscape and of the results based on mathematical models, were used to delimit more precisely the extent and localisation of SMAs.

7) Delineation of Long-Distance Migration Corridors

Long-Distance Migration Corridors were delineated on the basis of a comprehensive evaluation of records of the given species, their ecology and behaviour, existence and categories of migration barriers, mathematical models, and, above all, an extensive field research verifying their actual permeability. The relation of the corridors to ecological networks in neighbouring countries was taken into consideration within the process of their delineation.

8) Proposal for Measures to Secure the Landscape Permeability

Based on the outcomes of the entire project, principal measures were proposed to secure migration permeability of the landscape for large mammals. These encompass both general and specific measures, e.g., aimed at protecting Significant Migration Areas and Long-Distance Migration Corridors.

The respective chapters of the present document address methodologies of individual approaches in detail.

Structure of the Report

The structure of the present report reflects the applied methodology mentioned above. The introduction is followed by Chapter 2 dealing with a background research on the ecological and behavioural requirements of focal large mammals and presenting data on their permanent and temporary occurrence. Chapter 3 analyses and classifies migration barriers, whereas Chapters 4 and 5 concern applications of individual mathematical models in the evaluation of landscape connectivity. Two models were applied to provide a more comprehensive view, i.e. the habitat model (Chapter 4), and the model of the landscape potential (Chapter 5). While Chapters 2-5 aim at acquiring the input data, Chapters 6-9 address the actual results. Chapter 6 introduces Significant Migration Areas and their relation to the administrative structure of the Czech Republic and categories in nature conservation. Chapter 7 is devoted to Long-Distance Migration Corridors with their relations to the neighbouring countries described in Chapter 8. Chapter 9 proposes protection measures. The final chapter brings conclusions.

The present document is an outcome of Project SP/2D4/36/08 “Evaluation of Migration Permeability of the Landscape for Large Mammals and Proposal of Protection and Optimisation Measures”, launched by the Ministry of the Environment.

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2.

Biology and Ecology of Focal Species

Tereza Mináriková, Martin Strnad, Václav Hlaváč, Anna Bláhová, Dušan Romportl, Pavel Šustr, Luděk Bufka & Michal Andreas

2.1. INTRODUCTION

The originally continuous distribution ranges of many animal species are being disintegrated by rapid landscape fragmentation. The most affected are groups restricted to the well-preserved natural environment, those with great requirements on the size of their home range, or regularly or occasionally migrating species. The impacts of ongoing fragmentation in the conditions of the Czech Republic are most severe on all three species of large carnivores – the Grey Wolf, the Eurasian Lynx, and the Brown Bear. They all have very similar environmental requirements, i.e. they are restricted to vast forested areas with minimum human disturbances. Long-distance migration is inseparable part of their biology. In many cases, this migration may involve dispersing subadults that are being pushed away from their parent's home ranges, but we may also record vagrancy of adult animals. Animals can migrate tens or even hundreds of kilometres. Long-distance migration is also typical for large ungulates, i.e. mainly the Eurasian Elk in our conditions. The Red Deer rather migrates medium distances reaching tens of kilometres. The Eurasian Elk is a typical species of forested marshes of northern countries. The current population of maximum twenty animals living in South Bohemia fully depends on at least occasional migration of individuals from populations in the northeast of Poland. During their outstanding journey, the animals will conquer distances of more than 800 km, crossing densely populated landscapes, overcoming a number of barriers, such as motorways, railways, and fenced areas. Despite the still unclear motives for such migration, it is obvious that our population will disappear very fast if migration opportunities for these animals are not preserved. The Red Deer typically moves between its summer and winter grounds, but it also irregularly travels longer distances. At present, its distribution is much regulated through game management activities. This species shows requirements on the environment similar to large carnivores. It may thus be considered as a reliable indicator when determining the state of the environment in areas where large carnivores do not occur.

Considering the above-mentioned facts, large carnivores, the Eurasian Elk and the Red Deer, serve as ideal species for the project focused on preservation and restoration of the landscape connectivity. Except the Red Deer, these species are rare and strictly protected. The high requirements of all the mentioned species as to the size and quality of their habitat and their biology relate to long-distance migration. Their high requirements on the quality and structure of the habitat cover the requirements of a number of other species restricted to a well-preserved forest environment. Securing the protection and connectivity of their habitats will bring solutions to problems in the conservation of entire forest ecosystems and many other endangered species.

The need to enhance the connectivity of significant remote forest habitats is currently gaining another dimension. The expected climate change will undoubtedly have considerable impacts on the structure of forest communities, i.e. also on the conditions suitable for the existence of many animal species. Opportunities for free movement to a new and more favourable environment will certainly increase the chance of the species to survive. However, only sufficient connectivity of individual habitats can provide suitable conditions for such movement. Respecting the requirements of the species covered in the project will significantly contribute to enhancing the adaptation of forest ecosystems to climate change.

This chapter will further describe the particular focal species (large carnivores and ungulates) in the following order: Brown Bear (*Ursus arctos*), Grey Wolf (*Canis lupus*), Eurasian Lynx (*Lynx lynx*), Red Deer (*Cervus elaphus*), and Eurasian Elk (*Alces alces*).

2.2. BROWN BEAR

Ursus arctos Linnaeus, 1758

2.2.1. Conservation Status

International Conservation Status

The IUCN Red List of Mammals (IUCN 2010e) records the Brown Bear among the least concern species and considers its population trend as stable.

The Brown Bear is protected within the EU under Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, listed in Annex II and IV. It is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Further protection applies under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), where the species is recorded in Appendix II (Strictly Protected Fauna Species), and the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).

National Conservation Status

The Red List of Vertebrates in the Czech Republic lists the Brown Bear as a critically threatened species (Anděra & Červený 2003).

Pursuant to Act No. 114/1992 Coll., on the conservation of nature and the landscape, and related Decree No. 395/1992 Coll., the Brown Bear is defined as a specially protected species and classified as critically threatened. Under Act No. 449/2001 Coll., on game management, the species is understood as game that may not be hunted.

2.2.2. Distribution Range

Distribution Range in Europe

With an exception of the adjacent islands – Iceland, Ireland, Corsica, and Sardinia, the Brown Bear could originally be found on the entire European mainland. Its populations suffered substantial reduction in the course of the 19th and 20th centuries, particularly as a result of deforestation, intensification of agriculture, and intensive hunting by man.

Southeast of Europe, namely the Iberian Peninsula, is currently home to two populations of the Brown Bear (Fig. 2.1.). The tiny Pyrenean population amounts to 15–21 animals, whereas the Cantabrian population in the northwest of Spain is estimated to 130 bears. The species is further distributed in central Italy, the Apennines, with an isolated population of 40–50 animals living in the National Park Abruzzo and in the adjacent surroundings. Three core areas of the bear distribution are identified in the Alps, namely the Southern Alps on the border between Austria and Slovenia, the Central Italian Alps, and the Central Austrian Alps. Reintroductions of the species between 1989 and 1993 actually gave rise to the population in the Central Austrian Alps, supported by reintroduction of individual animals from the Italian Alps in 1999–2003. The population in Southern Europe, spreading from central Slovenia and Croatia over Albania to northern Greece, is dependent on the Dinaric massif and the Pindos Mountains, and the estimates count with 2 100–2 500 animals.

The second largest in Europe is the Carpathian population with 8 100 animals distributed over the east of the Czech Republic, in Slovakia, southeast of Poland, Ukraine, Romania, and Serbia. A vast majority of this population, estimated to 6 000 animals, is concentrated in Romania. Northeast of Europe is home to the largest population of the Brown Bear, which is supposed to comprise 11 100 animals and involves several subpopulations. The Karelian subpopulation amounts to 4 300 animals and includes Norway, Finland, and the Murmansk and Karelian Regions in Russia. The Baltic subpopulation of approximately 6 800 animals is distributed in Baltic countries (Lithuania, Latvia, Estonia), Belarus, and western Russia. There is also a population of 2 600 bears living in Northern Europe, which is restricted to the border area between Sweden and Norway (Linnell et al. 2007).

Estimated numbers of the Brown Bear in countries neighbouring with the Czech Republic are as follows: Slovakia 700, Poland 100, and Austria 23–28 animals (Swenson et al. 2000).

Distribution Range in the Czech Republic

In the Middle Ages, the Brown Bear was widely distributed over the territory of the current Czech Republic. The

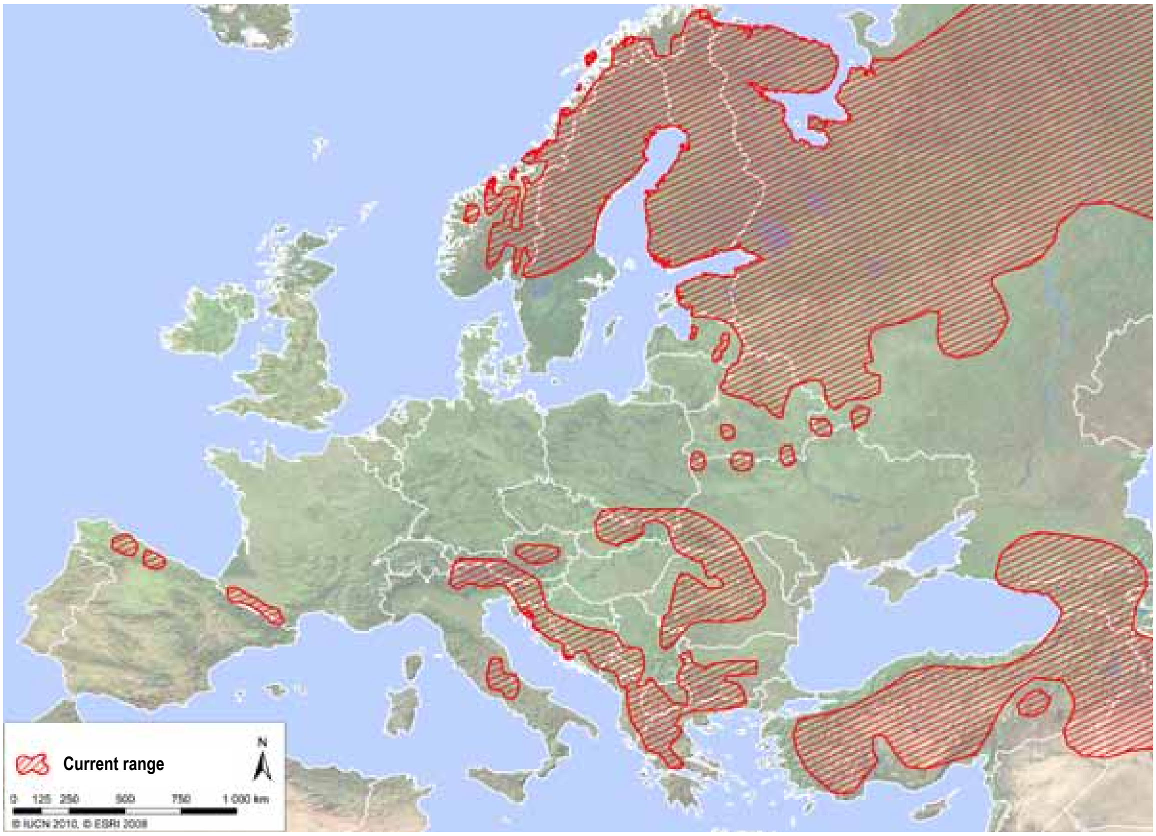

Fig. 2.1. Map of distribution of the Brown Bear (*Ursus arctos*) in Europe (after IUCN 2010e).

last animals were surviving in the Šumava Mts., but bears were finally hunted to extermination in the mid 19th century (Kokeš 1961).

Several bears occurred in the Beskydy Mts. in Moravia until the end of the 19th century. In the past, all border mountains and many other places in the country were home to this species, e.g., Křivoklátsko, the Brdy Mts., the Českomoravská vrchovina Highlands (Červený et al. 2006a).

The Brown Bear began to reoccur more frequently during the 70s of the 20th century, namely in the Moravskoslezské Beskydy Mts. along the border with Slovakia. The number even increased in the course of the 80s. Bears were seen in 41 map squares, e.g., in the Jeseníky Mts., the Drahanská vrchovina Highlands, the Moravský kras (Moravian Karst), and the Bílé Karpaty Mts. In the 90s, bears were also recorded in the Oderské vrchy Hills and the Jeseníky Mts. Migrating animals even appeared in the region of Broumov (Červený et al., 2004).

At present, the Brown Bear permanently occurs purely in the core area of the highest and most remote peaks of the Beskydy Protected Landscape Area – e.g., Mionší and Smrk (Fig. 2.2.). The total number of bears living in the mountain border area with Slovakia is estimated to maximum five animals, while potentially up to 23 animals could live there in the future (Bartošová 2004).

Other potential areas offering favourable conditions for long-term occurrence of bears are supposed to be the Vsetínské vrchy Hills, the Javorníky Mts., and the Bílé karpaty Mts. The Jeseníky and the Orlické hory Mts. have also been proven as suitable habitats.

The Brown Bear is currently a considerably threatened species in the Czech Republic. Its permanent occurrence is recorded merely in the regions of the Moravskoslezské

Beskydy Mts., the Javorníky, and the Vsetínské vrchy Hills, which is the westernmost edge of its range. This population fully depends on animals migrating from the neighbouring source populations in Slovakia and Poland, i.e. from the large population of the Carpathians.

2.2.3. Ecology and Behaviour of the Brown Bear

Reproduction and Social Behaviour

The Brown Bear leads rather a solitary life. Males are larger than females. They only meet during the breeding season, i.e. from May to the beginning of August. A strong dominating male is capable of travelling to several ranges of females in order to mate. In case a resident male encounters a female with cubs of other male, he frequently kills them. As a result of this infanticide, the oestrous cycle will start in the female that lost its cubs sooner and the male thus secures successful mating. The oestrus cycle in female bears lasts for approximately a month and occurs exclusively during the period when the mother does not care for her cubs. After mating, the fertilised egg ceases to develop until autumn (this process is called delayed implantation). The embryo develops in 8–10 weeks. Females will give birth in their den between the end of December and the beginning of February, i.e. in the period of false winter hibernation. The animal's respiratory and pulse rate decreases but the body temperature remains stable. Sows usually have 1–3 cubs of maximum 25 cm, which are not fully developed – blind and practically hairless. The sow will take care of her offspring for two or three years. By their fourth summer, the young bears become sexually mature, set off in search for a favourable home range, and begin to wander for longer distances. They will mark their vast territory by depositing urine or visually by peeling or browsing bark particularly on conifers.

Mating period, i.e. from the end of May to July, is the time when bears may be more active and penetrate the wider surroundings of their range. Bears can normally live up to more than 30 years of age (Nowak 1999).

Diet

Bears are typical omnivores. They mainly eat plants, their roots, leaves and buds, bilberries or raspberries. They

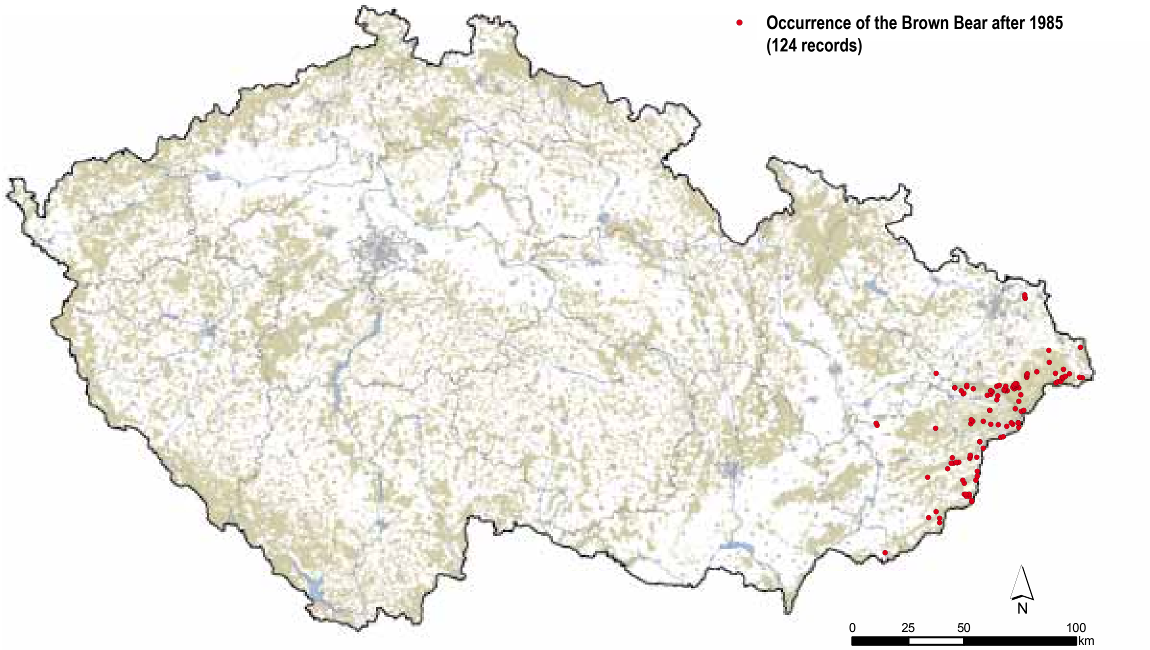

Fig. 2.2. *Occurrence of the Brown Bear (Ursus arctos) in the Czech Republic (source: records of species – AOPK database 2009)*

also search for insects, especially ants, and like to destroy bee nests for honey. They will neither refuse to feed on carrion. Their diet varies upon availability throughout the season (Nowak 1999).

It has been found in some parts of Northern Europe that bears rather behave as carnivores in spring, feeding on the wild boar, red deer, and their carrions (Sidorovich 2006). By contrast, findings in Slovakia prove consumption of almost pure plant food with prevailing beech masts, maize, and wheat. They often eat merely grass or ants and larvae of xylophagous insects. The highest share (35%) of flesh in food was determined during August and September. From October until the end of the year, their diet mainly consists of berries, such as bilberries, blackberries, raspberries, rowanberries, and other fruit rich in energy (Štofík, not published).

Role in the Ecosystem

Prevailingly behaving as a herbivore, the Brown Bear will hunt a relatively lower share of wild hoofed game compared to the wolf or lynx. Using its highly sensitive nose, it is capable of finding carrions to feed on. Its principal role in the ecosystem is hence that of an opportunistic scavenger, reducing dead animals to simpler constituents and preventing a potential spread of diseases.

Habitat

Within its vast range, the Brown Bear occupies various environments from tundra and alpine meadows to continuous forest areas. In the conditions of the Czech Republic, its home are typically mountain coniferous and mixed forests and primeval forests rich in undergrowth and old trees, where it seeks shelter in remote and quite places (Anděra & Horáček 2005). Slovakia has recently documented migration of bears to lower altitudes where they occupy beech and oak forests as these provide sufficient food supply during the season (Finďo et al. 2007).

The decisive factors for a bear to choose a suitable place for reproduction are availability of food, sufficient remoteness, and a certain level of impermeability of the given area that minimises potential human disturbance. Migrating young bears then significantly reduce their requirements on the environment and become more willing to overcome barriers, such as agricultural landscape, roads, or railways.

The habitat model implemented in the area of the Swiss Alps documents that bears should tend to prefer areas with a high terrain gradient and distant from towns. They are also supposed to seek habitats at higher altitudes and free of dense road networks. A higher share of forested areas and shrub covers in the landscape enhances the potential of the species occurrence. Pastures and other agricultural landscape seem to be less favourable, although they often represent a convenient food base, which the animals particularly use during the night time (Zajec et al. 2005).

The data collected in Sweden support the mentioned presumption. It has been verified that both males and females prefer a broken terrain distant more than 10 km from towns and recreational resorts, and always seek forested areas with minimum human interference. The records show that animals approaching urban areas are rather young males with a higher migration potential (Nellemann et al. 2007).

2.2.4. Analysis of Critical Ecological and Behavioural Parameters Related to Migration

Behaviour in the Brown Bear varies significantly depending on geographical areas and individual animals show great differences. Despite the fact that the bear is primarily dependent on a calm forest environment with sufficient hiding places, it is largely tolerant to an open landscape during migration. Under certain circumstances, the animals can overcome anthropogenic barriers, such as motorways or railways. Findings in Southern Europe indicate that their relationship to transport infrastructure is not purely negative. Seventeen animals were monitored using GPS telemetry in the vicinity of a motorway between the towns of Vrhnika and Postojna in Slovenia. Four of them crossed the motorway, three of which even repeatedly. These were mostly subadults (two males and a female) searching for a favourable territory. The death rate on both the motorway and an adjacent railway was high though. From 1992 to 1999, twenty bears (only four females) were found dead after being hit by vehicles. Eleven cases were recorded on the motorway, nine on the railway. The vast majority were subadults seeking a new territory. Two animals were directly hit by a train when moving on the railway in an area with no surrounding vegetation. Considering the locations where the dead bears attempting to cross the motorway were found, it is presumable that they had no specific requirements on a place (or habitat) where to cross (Kaczensky et al. 2003). In Slovakia, the death rate of bears was higher on roads (10) compared to railways (6), all the animals being killed during the night. As most of them were found on roads with a lower traffic flow, it may be concluded that they rather intended to avoid motorways (Finďo et al. 2007).

The requirements on space vary greatly in bears. Their home ranges in the Carpathians in Poland reach from 50 to 270 km^2 (Finďo et al. 2007). In Slovenia, the size of the home range of 5 female adults, 3 yearling male cubs and 2 yearling female cubs, was surprisingly consistent, ranging from 21 to 63 km^2. The greatest variance in the size of a home range was recorded in male subadults (n = 5), i.e. 53–516 km^2 (Kaczensky et al. 2003). Differences were also determined between sexes, where males generally occupied larger areas than females. The size of a home

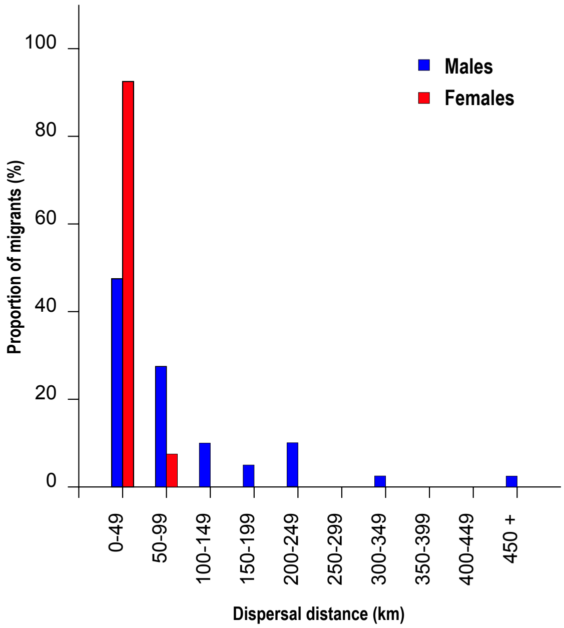

Fig. 2.3. *Proportion of dispersing bears in a population and distances they cover (after Andersen et al. 2003). The data represent the Scandinavian population.*

range diminished along with an increasing density of the population, while larger bears were capable of defending a larger territory, regardless their age (Dahle et al. 2006).

Records from Sweden document a higher potential for long-distance migration in males. This potential decreases in older and larger females, which, however, does not apply to males (Zedrosser et al. 2007). Males of four years of age settled on average 119 km from their place of birth, while this distance in young females was significantly shorter – on average 28 km. Females thus show more philopatry searching their territory closer to their mother, which is, in fact, true of most mammals (Støen et al. 2006).

Bears in Sweden, for instance, migrate longer distances than bears in British Columbia, which is probably given by a long distance between the neighbouring territories of females and by the fact that not all favourable habitats are occupied. The longest distance of dispersal was recorded to reach 467 km in males and 90 km in females, as Fig. 2.3. depicts (Andersen et al. 2003).

Bears living in Banff National Park in Canada were proven to prefer areas with a lower traffic flow and crossed such roads more frequently. Moreover, they were documented to cross roads with a higher traffic flow more frequently in locations where favourable habitat occurred on both sides (Chruszcz et al. 2003).

Kunc and Bartošová (2005) describe that, in the area of the Beskydy Mts., bears even use for their night travels forest roads, which are much frequented during the day.

Fragmentation of habitats related to urban sprawl may lead to altered behaviour in bears. They are capable of adapting to modified conditions and thus may clash with man, as stated by Linnell et al. (2007) from Romania. Bears descending to valleys in the Tatra Mountains are probably driven by a lack of autumn food, i.e. berries, which is caused by excessive harvest by man. The animals search for food in the vicinity of human settlements and are forced to cross roads and railways (Finďo et al. 2007). In another case, it was discovered that the River Danube represents an impassable natural obstacle for bear populations living in the north of Bulgaria and south-east of Serbia (Linnell et al. 2007).

RECORDS OF BEAR MIGRATION IN THE CZECH REPUBLIC

The records in the Czech Republic prove that several bears have certainly moved through the open field landscape, outside larger forest areas. A bear migrating from the Beskydy that was monitored in 1989 managed to reach as far as the Drahanská vrchovina Highlands and another animal appeared in the region of Náchod in 1994 (Červený et al. 2004). In 2002, a bear was known to occupy, for a longer period, abandoned orchards in the precincts of a mine near Orlová, Ostrava region, where it fed on apples (Kunc & Bartošová 2005).

Recent observations also bring interesting data. On 14 May 2009, a bear appeared in the region of Přerov, between the villages of Nová Ves and Kostelec u Holešova. It was observed by several persons at around 4 o'clock in the morning by the main road and disappeared in a rape field. Most probably, the animal was migrating from the Beskydy, heading westwards.

Fig. 2.4. *Virtual migration route of the Brown Bear in Moravia between 14 March and 22 April 1989 (after Šimek 1989).*

That would mean crossing the entire highlands of the Hostýnské vrchy. The animal was observed at the edge of the large forest complex, which presumably served for its movement. Following the mentioned route, the bear would have to overcome several main roads and a railway. However, there is no direct evidence that would support this hypothesis through further observations or findings documenting its presence in the given areas.

Behavioural plasticity associated with migration of the Brown Bear related to barriers and permeability of the landscape in the Czech Republic was best documented by monitoring of a young male that traversed a great part of northern and central Moravia (Fig. 2.4.). The bear was seen near the village of Těšíkov in the Nízký Jeseník on 14 March 1989. He continued heading north-westwards through the Hrubý Jeseník to the area of Králický Sněžník. Travelling further south-westwards, he was observed south of Ústí nad Orlicí. As he followed the same route, he reached the Žďárské vrchy Hills near Žďár nad Sázavou. Turning southeast, he travelled close to the city of Brno, crossed central Moravia heading eastwards, and finally, on 22 April 1989, was captured with the use of a tranquiliser gun south of Prostějov. Unfortunately, the animal died after transport to the zoo in Olomouc, where it was finally discovered that the lethal injury had been caused by a fragment of the tranquiliser dart. The male moved on total 4 000 km^2 and covered a distance of nearly 350 km (Šimek 1989). On his way, he passed close to towns and was forced to surmount several rivers, and a great number of roads and railways.

2.3. GREY WOLF

Canis lupus Linnaeus, 1785

2.3.1. Conservation Status

International Conservation Status

The Grey Wolf is listed in the IUCN Red List of Mammals (IUCN 2010c) as a species of least concern and its population trend is defined as stable.

Within the European Union, the species is protected under Directive No. 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, listed in Annex II and IV. It is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Further protection applies under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), where the species is recorded in Appendix II (Strictly Protected Fauna Species), and the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).

National Conservation Status

The Red List of Vertebrates in the Czech Republic lists the Grey Wolf as a critically threatened species (Anděra & Červený 2003).

Pursuant to Act No. 114/1992 Coll., on the conservation of nature and the landscape, and related Decree No. 395/1992 Coll., the Grey Wolf is defined as a specially protected species and classified as critically threatened. Under Act No. 449/2001 Coll., on game management, the species is understood as game that may not be hunted.

2.3.2. Distribution Range

Distribution Range in Europe

The Grey Wolf, with its originally Holarctic distribution, inhabited continuously the entire Eurasia and North America. Its populations dropped sharply in Europe during the 60s and 70s of the 20th century. Nevertheless, the numbers appear to be rising again.

We may distinguish several subpopulations in Europe (Fig. 2.5.), which are isolated from each other to a various extent. In Western and Southern Europe, wolves predominantly inhabit the northwest of the Iberian Peninsula (approx. 2 500 animals), the Western and Central Alps (130–160 animals originating from the Apennines), and the Italian Peninsula itself (500–800 animals). More to the east, there is Dinaric-Balkan population (approx. 5 000 animals), which is in contact with the most stable Carpathian population (over 5 000 animals) mostly occupying the territories of Romania and Ukraine. The numbers of the Grey Wolf in Slovakia and east of Poland are estimated to 250–300 and 180–220 respectively. In the mid 1990s, a tiny population appeared in Germany, namely in Saxony and Upper Lusatia, which, together with individuals from the western part of Poland, amounts to fewer than 50 animals. The Baltic population comprises north of Poland, Belarus, and other Baltic countries, including the adjacent parts of Russia, and counts with approximately 3 600 animals. In Northern Europe, there is a population of estimated 750 wolves living in Karelia, 200 of these in Finland. Other Scandinavian countries estimate their wolf population to 130–150 animals. Norway is home to 20% of them. Migrants from Finland gave rise to this population, which still depends on them (Linnell et al. 2007).

The estimated numbers of wolves living in the countries neighbouring with the Czech Republic are the following: Slovakia 250–300 animals (Finďo et al. 2007), Poland 600–700 animals, and Germany 5 animals (Boitani 2000).

Distribution Range in the Czech Republic

Wolf was not an abundant species in Bohemia and Moravia already in the early Middle Ages. The range of its distribution and its numbers oscillated greatly and only fragments of records have been preserved. Presumably, the largest population of wolves was in the territory of the current Czech Republic in the 17th century, which may be deduced from the fact that 400 animals were killed only within the demesne of the Rosenberg family in the surroundings of Český Krumlov between 1621 and 1650 (Kokeš 1961). At that time, the species was abundant in other places as well, e.g., in the region of Aš, the Krušné hory Mts., or Podbořansko. The last wolves are documented to have been shot near Doupov in 1825 (Kothera 1995) and in the Šumava Mts. in 1874. However, the species remained in the Beskydy almost continuously until 1914.

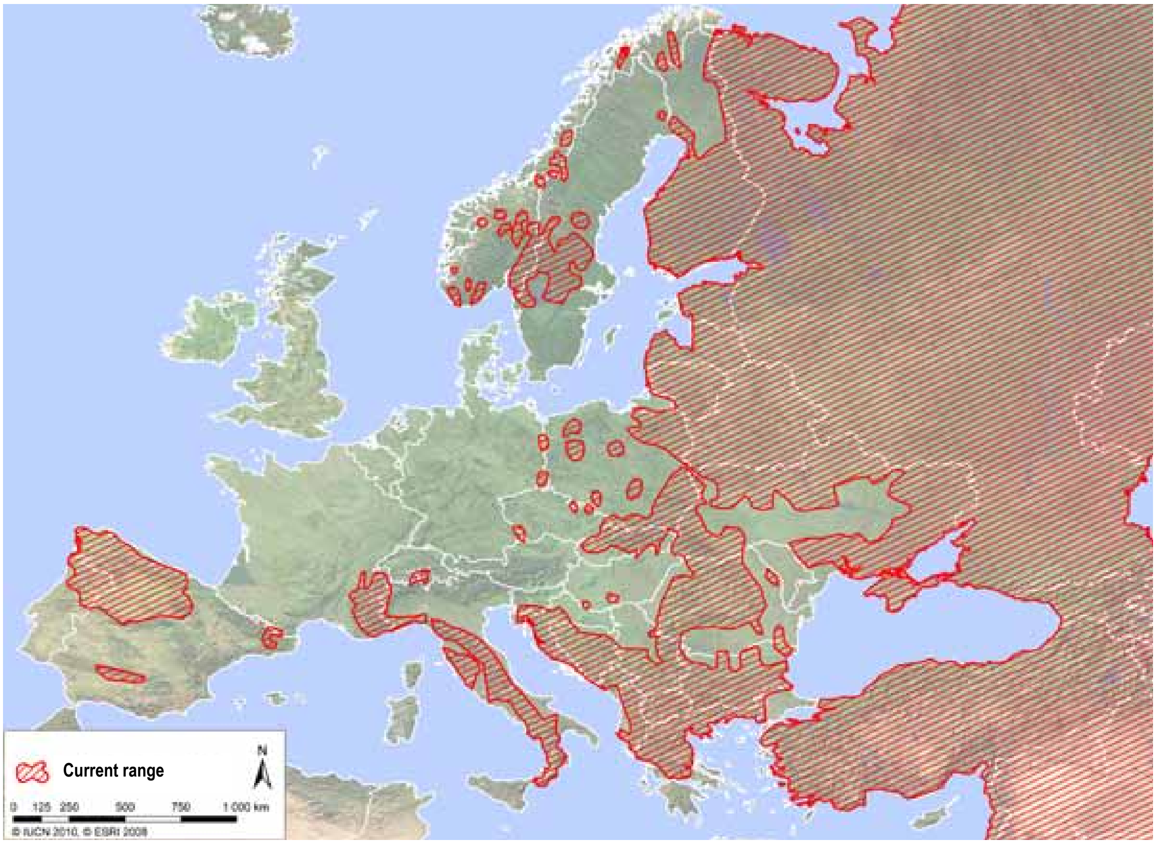

Fig. 2.5. *Distribution of the Grey Wolf (Canis lupus) in Europe (after IUCN 2010c).*

Wolves did not reappear in our country until 1947. The evidence of their occurrence before 1969, only in form of tracks, also comes from the regions of Králický Sněžník, Opava, and the Český les. In the 1970s, wolves were known to occur only in the region of the Šumava Mts. and the Český les. These, however, were merely individuals that had escaped from captivity (Bufka et al. 2005).

Occasional occurrence of 23 animals was recorded during the period 1990–1999 mostly in the Šumava Mts., the Jeseníky, and the Beskydy Mts. (Anděra et al. 2004). Total 124 records come from the region of the Šumava Mts. and the Bayerischer Wald Mts. between 1990 and 2004, 66 of which were documented in the Czech territory. Most records mention occurrence of individual animals. The origin of these wolves is generally unknown. Migration from the Western Carpathians or Saxony may be considered. Approximately five animals have been regularly recorded to occur in the area of the Moravskoslezské Beskydy Mts. Wolf pups were even observed there in 1996 (Bartošová 1998). The mentioned increase in the records of the species occurrence reflects the growth of the population in neighbouring Slovakia.

The Grey wolf is currently restricted in the Czech Republic to the central area of the Moravskoslezské Beskydy (Fig. 2.6.). Migrants subsequently appear in the Javorníky Mts., the Vsetínské vrchy Hills, and the Vizovické vrchy Hills. Occasional presence of wolves is also documented in the Jeseníky. A pack of six animals with pups was observed in the area of the Hostýnské vrchy Hills in 2004 (Bartošová 2005). The current population of the Grey Wolf in the Czech Republic is estimated to 5–15 animals and their occurrence has been recorded in 30 squares on a grid map with a resolution 11.2 x 12 km (Anděra & Hanzal 1996, Anděra et al. 2004).

However, the size of the wolf population in the Czech Republic still depends on animals migrating from Slovakia and Poland. Protected Landscape Area Kysuce in Slova-

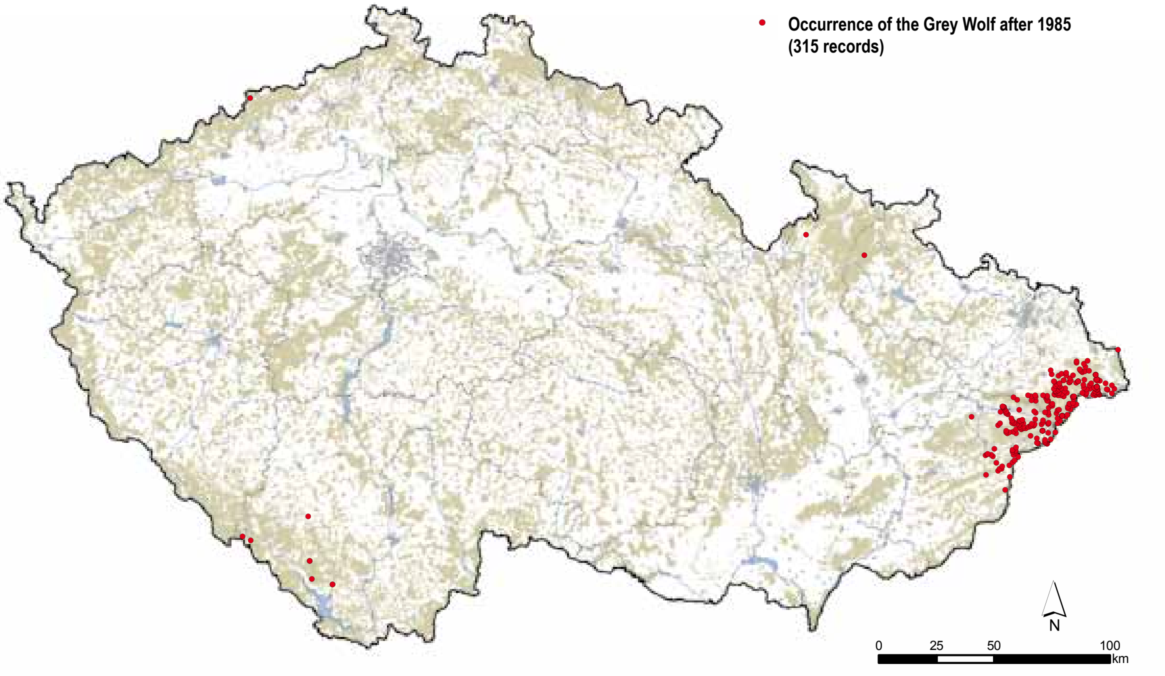

Fig. 2.6. *Occurrence of the Grey Wolf (Canis lupus) in the Czech Republic (source: records of species – AOPK database 2009).*

kia appears to play a key role as it adjoins the area of the Beskydy on the Czech side and provides favourable conditions for the species migration. Two or three packs regularly occupy this area (Bartošová 2005).

2.3.3. Ecology and Behaviour of the Grey Wolf

Reproduction and Social Behaviour

The Grey Wolf is a canine carnivore living a family life in packs during its entire year. The alpha male and alpha female form a dominating couple and most often enjoy the exclusive right to reproduction. The phase of oestrus in females lasts for 5–7 days once in a year, between January and March. After 60–62 days of pregnancy, the future mother gives birth to 1–11 whelps in a well-hidden den under a fallen tree or among the roots. In the temperate climate, wolves usually abandon their den and do not use it in the following year. They rather establish a new one in the same part of their territory. The pack prevailingly consists of young wolves of 1–2 years of age that take their part in the common feeding and protection of newborn pups. The position of each wolf in the pack is determined by its dominance. This hierarchy, however, may alter several times throughout the year. Most of the aggression between individual animals in the packs comes in the period of reproduction. An average pack in the Central European conditions amounts to 4–5 animals (Nowak et al. 2008). The total number of animals in a pack reduces towards the end of winter (Finďo & Chovancová 2004). The family occupies a large territory and jointly protects it against invading individuals from the neighbouring pack. They mark the borders of their territory by depositing urine and feces. The Grey Wolf lives on average up to 10 years in the wild (Gipson et al. 2000) and even longer in captivity; there is a record that mentions an animal of 16 years of age.

Young wolves become mature at the age of two, which is the time when they begin to leave their parent territory and migrate to new areas searching for sufficient food supply and a favourable habitat. Both males and females dispose of very similar capacities to migrate long distances and the actual distances they travel during migration do not differ much (Fig. 2.8.). Wolves disperse throughout the year with notable accentuation in spring and autumn (Linnell et al. 2005). The intensity of migration is influenced by an increased social pressure caused by competition for food and by territoriality. Supply of food certainly has an impact on the size of a pack. Lack of food forces the wolves to leave the pack and seek conditions that are more favourable.

The distance that a wolf will travel during a day varies significantly, depending on its geographical range, availability of food, and the season. For instance, Jędrzejewski et al. (2001) state that the average distance that a wolf travels during a day in Białowieża National Park is 21.1 km in females and 27.6 km in males. Males reach the most remote places in February, i.e. during the mating period. By contrast, wolves typically move the shortest distances at the end of spring and the beginning of summer when they feed their pups and remain close to the den.

In autumn and winter, wolves always use only a part of their territory and regularly change places to hunt for their prey. The density of available prey is a significant factor regulating the size of the wolf population and directly affects the distance the animals travel each day (Jędrzejewski et al. 2001).

Diet

As to food, the Grey Wolf is an opportunist. It hunts the most abundant prey in its territory and can easily adapt to a wide range of food. Hoofed game falls prey most often, namely the Red Deer (*Cervus elaphus*), Roe Deer (*Capreolus capreolus*), and the Wild Boar (*Sus scrofa*). Occasionally, wolves will feed on smaller vertebrates or carrion as well (Anděra & Horáček 2005). They prefer to hunt out of the weak, sometimes also young or female (Nowak et al. 2008). In Northern Europe and America, wolf packs principally specialise in hunting elks or reindeer. In summer and during periods of insufficient food supply, they may attack livestock, such as goats, sheep, or cows. Nevertheless, domestic animals represent a negligible share of their total consumption (approximately 1%). Wolves also occasionally eat plant food, such as blackberries or bilberries.

Role in the Ecosystem

As a top predator, the wolf plays an irreplaceable part in the ecosystem. To save energy while hunting, it primarily focuses on weak, old, or ill animals, which makes it a natural agent enhancing regulation and regeneration of hoofed game populations in the forest environment.

Habitat

The Grey Wolf may be considered a generalist that is capable of adapting to a wide range of habitats. However, its requirements on the environment vary substantially in the period of reproduction and during migration, as is the case of other species.

During the reproduction period, wolves seek areas with a high forest cover (maximum approx. 70%), and sufficient food and water supply. The mentioned factors, along with intensive hunting by man, play the most significant role within the search for a suitable territory. The European population is currently highly fragmented and is restricted mainly to mountains and their feet characteristic with a high forest cover and remoteness. Wolves' adaptability allows them to use areas with a lower forest cover as well if these are covered with more wetlands, meadows, and pastures. During their reproduction, they tend to avoid human settlements and prefer territories with a minimum number of roads with dense traffic (Jędrzejewski et al. 2008).

The tolerance of the species with regard to an anthropogenic environment varies largely though. In populations particularly in Southern Europe, Romania, and Italy, wolves may commonly be observed in suburban areas. They manage to creep unobserved to towns and feed on dumping grounds. They will mainly set off during the night. If not disturbed by humans, or in winter periods, they are also more active during the day.

The wolf's behaviour changes radically when it roams short distances and when it migrates to places that are more distant. During these periods, the animal becomes more tolerant to barriers and manages to overcome even busy roads and motorways and traverse an open landscape close to villages, although only at night or in the early morning hours.

MIGRATION OF THE GRAY WOLF IN THE BORDER AREA BETWEEN THE CZECH REPUBLIC, POLAND, AND SLOVAKIA

The current records show that the Grey Wolf most frequently occurs in the Czech Republic in the area of the Moravskoslezské Beskydy Mts. (PLA Beskydy). Wolves regularly migrate to our country from populations inhabiting the Western Carpathians, i.e. Poland and Slovakia. The nearest territory of the species in Poland can be found east of the town of Wisła, not far from the Czech border (Fig. 2.7.). The animals migrating westwards have to cross the Jablunkovská brázda (the Jablunkov Furrow), which divides two mountain ranges, i.e. the Moravské Beskydy and the Slezské Beskydy Mts. Here, the evidence of the species occurrence most often comes in form of tracks from areas close to the border crossing Bukovec, cadastral area of the village of Jablunkov, and from the territory between the village of Zašová and Rožnov pod Radhoštěm (Bartošová pers. comm.). The precincts of the former customs houses in Mosty u Jablunkova are one of the few places where the connectivity of the forest remains uninterrupted by urban areas. They serve as another key point enabling migration of wolves and other species. In other words, this area provides the nearest natural connection of the above-mentioned mountain complexes.

Wolves also keep migrating to the Czech Republic from Slovakia, where their natural range is in the Kysuce Protected Landscape Area. These animals are often documented to occur in Velký Polom and Malý Polom, and also coming from Bílý Kříž, over Visalaje, towards Hill Travný. They frequently occur in the surroundings of the Makovský průsmyk mountain pass.

Fig. 2.7. *Home ranges of the Grey Wolf between 1996 and 2003 in Polish national parks of the Slezské Beskydy and the Żiwiecké Beskydy Mts. (Nowak et al. 2008).*

2.3.4. Analysis of Critical Ecological and Behavioural Parameters Related to Migration

In the Czech Republic, the Grey Wolf predominantly inhabits remote mountain areas with a high forest cover and limited accessibility. Wolves are prevailingly active during the night (Kusak et al. 2005) or at dusk (Theuerkauf et al. 2003). It may hence be presumed that they will always prefer to migrate during the night hours and in less disturbed places. However, as they lead this type of a hidden life, there is only limited information available regarding migration of individual animals.

The extent of the stable territory depends, in particular, upon the food supply, season, the type of environment, and the number of animals in the pack. There is usually no overlap with the neighbouring home ranges (Okarma et al. 1998). The borders of the defended territory may change throughout the year in accordance with the reproduction cycle. An adult female in Białowieża National Park used merely the immediate surroundings of 73 km^2 when taking care of her pups. In the winter period, she enlarged her home range more than 2.5 times though, reaching 191 km^2. Other data support the fact that equal behaviour concerning the use of territory applies to males (Jędrzejewski et al. 2007). The range of wolves in the Italian Apennines varies between 120–200 km^2 (Ciucci & Boitani 1998), two packs in Croatia inhabited 160 km^2 and 140 km^2 respectively (Kusak et al. 2005), while in Scandinavia the territory can reach up to 1 000 km^2 (Håkan et al. 2000). In Slovakia, the home range of a male monitored by GPS telemetry in the Tatras National Park was to 146 km^2; a female monitored in the Low Tatras defended the territory of 191 km^2 (Finďo et al. 2007). An average size of a wolf territory in Poland is 158 km^2, which is well comparable to the data from Slovakia. The size of an inhabited territory generally increases along with the increasing geographical latitude, as this increase in latitude represents a decline in the density of prey.

Young wolves leaving their pack in search of a new territory will travel significantly longer distances than usual. Fig. 2.8. shows differences in the distances that wolves migrating from North America travel. It implies that both males and females have approximately an equal potential

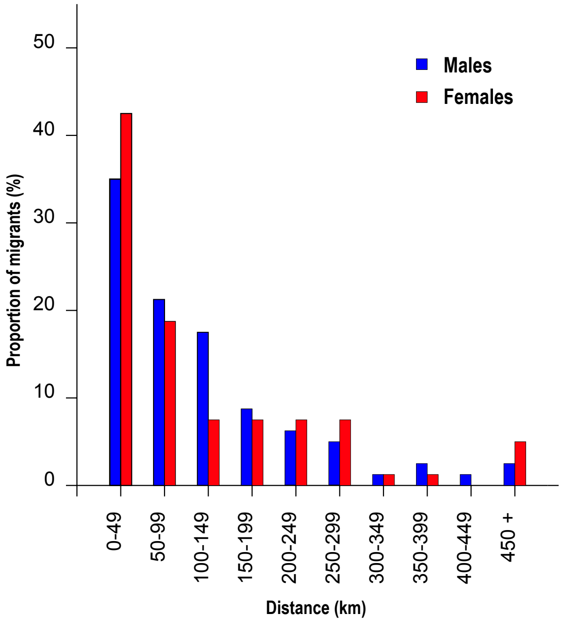

Fig. 2.8. *Proportion of migrating wolves and migration distances (after Andersen et al 2003).*

for long-distance migration; similar data are recorded in Scandinavia (Andersen et al. 2003).

There are records documenting that a wolf managed to travel 206 km in two months (Mech 1974 ex Nowak 1999) and another animal even 670 km in 81 days (van Camp & Gluckie 1979 ex Nowak 1999). A female originating from the south of Norway and later hunted in the north of Finland travelled probably the longest way ever recorded, i.e. 1 100 km (Finďo et al. 2007).

There are great differences in individual animals and populations with regard to their capacity to overcome migration barriers. The River Mackenzie, flowing from the south northwards to the Amundsen Gulf, represents an insurmountable migration barrier in the Northwest Territory in Canada. Wolves inhabiting one bank of the river showed closer genetic relations among themselves than with those living on the other side. The authors explain this phenomenon by the fact that wolves follow their principal prey, i.e. reindeer, which migrate along the river (Carmichael et al. 2001). A contradictory case was documented on the western coast of Canada, where a wolf crossed the 13 km wide sea to reach an adjacent island (Paquet et al.

2005 ex Finďo et al. 2007). In northern Minnesota, wolves did not occur so frequently in areas with the road density higher than 0.59 km/km^2. The species can also occupy areas with a higher road density provided that there are sufficiently large areas with no or very limited infrastructure. In Alaska, wolves are known to avoid tourist trails and to prefer less disturbed areas (Mech et al. 1998).

North to the Lake Superior, wolves are supposed to be using roads, railways, and open areas under power lines as migration corridors. They did not reflect on the type of roads and rather used them proportionally according to their density. Presumably, for the lack of food, seven out of ten marked wolves abandoned the monitored area and crossed a motorway during their migration. The death rate was extremely high though and road kills represent the second most frequent cause of death just after shot wounds (Krizan 1997). Wolves in western Montana preferred a plainer terrain and minimum elevation differences for migration. During migration, they remained more frequently close to water resources and roads, which is in contrast to how they used their new territory during the subsequent periods (Boyd 1997 ex Singleton et al. 2002). In Croatia, wolves also used areas in the vicinity of water resources and roads for their night moves within their territories (Kusak et al. 2005). In winter, wolves in the Beskydy Mts. commonly use counter hunting trails, forest roads, and ski trails for their night moves. To ease their journeys, they use mountain ridges, for instance, from Jablunkov over Velký Polom and Malý Polom to Vsacký Cáb, or valleys along streams. Wolf tracks have been found 80–100 m far from lonely houses and once even 10 m from a secluded hunting lodge hidden in a dense forest cover (Kunc 1998). A fence of 120–150 cm is no barrier for a wolf in search of food (Jirát 2003, Kunc 1998). Another interesting observation depicts how wolves moved through an open field landscape in the morning hours in the area of the Slovak Karst near the village of Hrhov and crossing the local road caused them no difficulties (Finďo et al. 2007).

In Southern Europe (Italy and Romania), the variation in the species behaviour is even more pronounced. Wolves live here also in densely populated areas surrounding towns and dumping grounds. Crossing railways and various types of roads, including fenced motorways, is their common activity (Mech & Boitani 2003 ex Finďo et al. 2007). Wolves are tolerant to the presence of man in Minnesota, too (Thiel et al. 1998 ex Kusak et al. 2005), and do not avoid human settlements as is the case, for example, in Poland (Theuerkauf et al. 2003). Such tolerant behaviour both towards settlements and to the actual presence of man is probably largely influenced by their higher population density and perhaps by a lower hunting pressure from the side of man. The acquired data imply that the approach of wolves to the presence of roads is not purely negative. To a certain extent, the species is so adaptable that it does not avoid even motorways or railways and crosses an open agricultural landscape. However, abovementioned behaviour is conditioned by a possibility to avoid the direct contact with man during their active time (i.e. especially during the night hours).

A YOUNG MALE WOLF MIGRATING IN THE APENNINES

An interesting case from Italy documents the ability of wolves to migrate long distances and inhabit new territories (Fig. 2.9.). A 10 months old wolf originating from the Apennines was monitored for the period of 10 months and 11 days with the use of a GPS collar. He had been found knocked down by a car near the town of Parma and released soon after a quick recovery.

For the first two months, he remained in the wide surroundings of the site of release. After this period, he began to migrate north-westwards along the Apennines until he reached the French border. During the following 7 months of travelling, he crossed four fenced four-lane motorways, several railways, a great number of local roads, and an open agricultural landscape. He often made use of frequent ecoducts to overcome motorways in mountain areas or moved along the riparian vegetation of the river below the motorway. The most distant place he reached was in the French Alps, 187 km far from the site of his release. He finally settled in the Italian Alps, where he was tracked and found in the presence of a young female coming from one of the neighbouring populations. As his body was finally found longer after the actual death, the cause of death could not be established (Ciucci et al. 2009).

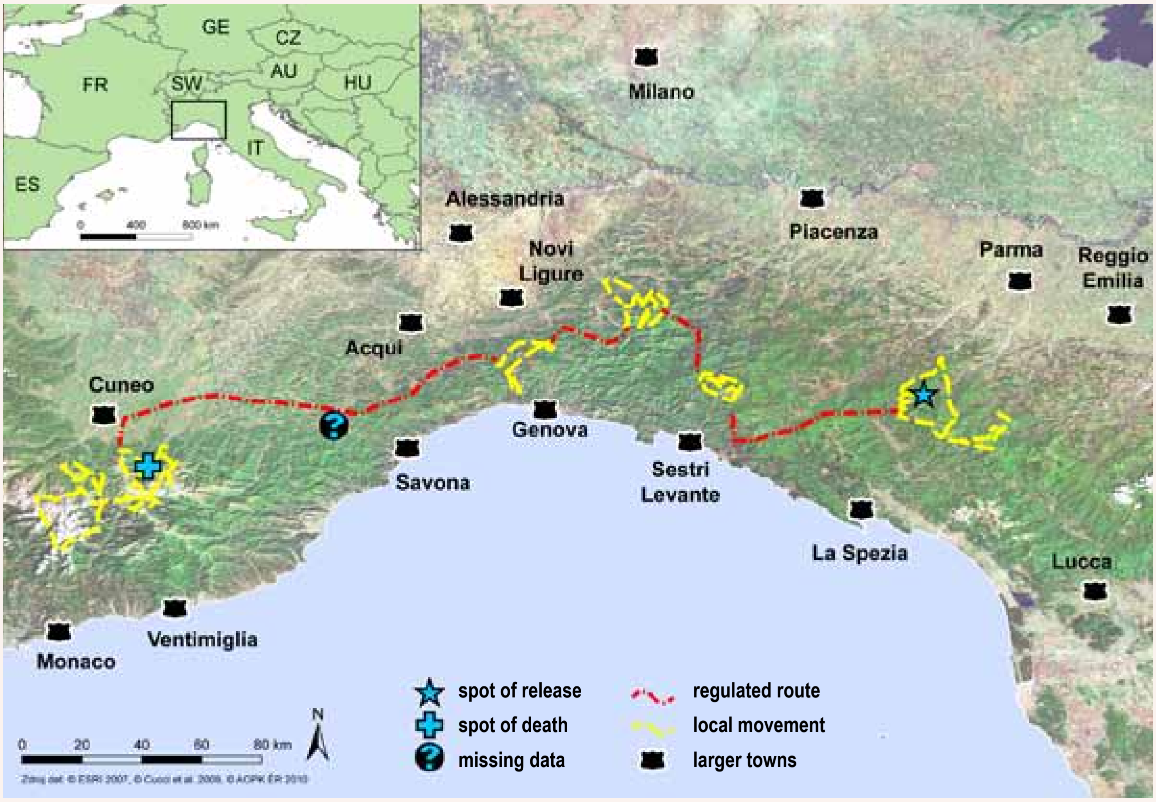

Fig. 2.9. *Migration of a ten-month-old wolf documented by telemetry. The animal was monitored moving from the north-west of Italy to the French Alps (after Ciucci et al. 2009).*

2.4. EURASIAN LYNX

Lynx lynx (Linnaeus, 1758)

2.4.1. Conservation Status

International Conservation Status

The Eurasian Lynx is listed in the IUCN Red List of Mammals (IUCN 2010c) as a species of least concern and its population trend is defined as stable.

Within the European Union, the species is protected under Directive No. 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, listed in Annex II and IV. It is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Further protection applies under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), where the species is recorded in Appendix III (Protected Fauna Species), and the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).

National Conservation Status

The Red List of Vertebrates in the Czech Republic lists the Eurasian Lynx as a threatened species (Anděra & Červený 2003).

Pursuant to Act No. 114/1992 Coll., on the conservation of nature and the landscape, and related Decree No. 395/1992 Coll., the Eurasian Lynx is defined as a specially protected species and classified as strongly threatened. Under Act No. 449/2001 Coll., on game management, the species is understood as game that may not be hunted.

2.4.2. Distribution Range

Distribution Range in Europe

The Eurasian Lynx became locally extinct in most of Western and Central Europe in the course of the 19th and mid 20th century. Its denser population remained solely in the Carpathians. Only thanks to aimed protection measures and particularly reintroduction programmes in some countries (France, Switzerland, Slovenia, Germany, Austria, and the Czech Republic), the species reappeared in several places of Western and Central Europe. Its population is currently concentrated into several secluded and highly fragmented areas. A few more or less separated subpopulations may be identified in the European part of its range (see Fig. 2.10).

The core area of its distribution in Western Europe lies in the region of the Jura Mountains, at the border between France and the west of Switzerland, where the population, currently estimated to 80 animals, was reintroduced in 1974–1975. The Vosges Mountains in France are home to two perhaps largely separated subpopulations that count with approximately 30–40 animals. A population of an equal size, i.e. 30–40 animals, is also estimated in the Eastern Alps. Most animals of this population inhabit the area of the Alps in Slovenia and further penetrate the adjacent parts of Italy and Austria. This population was also established thanks to reintroduction of individual animals of the Carpathian origin in the area of the Slovenian and Austrian Alps during the same period.

The Dinaric population in Southern Europe was estimated to 130 animals occurring from southeast of Slovenia, over Croatia, to Bosnia and Herzegovina. The Balkan population of estimated 100 animals is mostly scattered along the borders of Albania, Macedonia, and Serbia, with a potential occurrence in Greece.

Another population of approximately 75 lynxes lives in the area of the Šumava Mts., the Bayerischer Wald Mts., and in the surroundings. The Carpathian population encompasses eastern Moravia, southeast of Poland, larger parts of Slovakia, west of Ukraine, east of Serbia, and Romania. Its total size is estimated to 2 500 animals, a half of which occupy the territory of Romania. Slovakia is also one of the countries sheltering a numerous population, namely estimated to 500 lynxes (Finďo et al. 2007).

The Baltic population of the lynx is supposed to comprise 3 400 animals and covers northeast of Poland, Estonia, Lithuania, Latvia, Belarus, and Russia from the Leningrad Oblast to Smolensk. Northern Europe distinguishes two other populations –Karelian and Scandinavian. Approximately 1 500 animals occupy the south of Finland, and Murmansk and Karelian Regions. These lynxes are genetically related to the Baltic population. Approximately

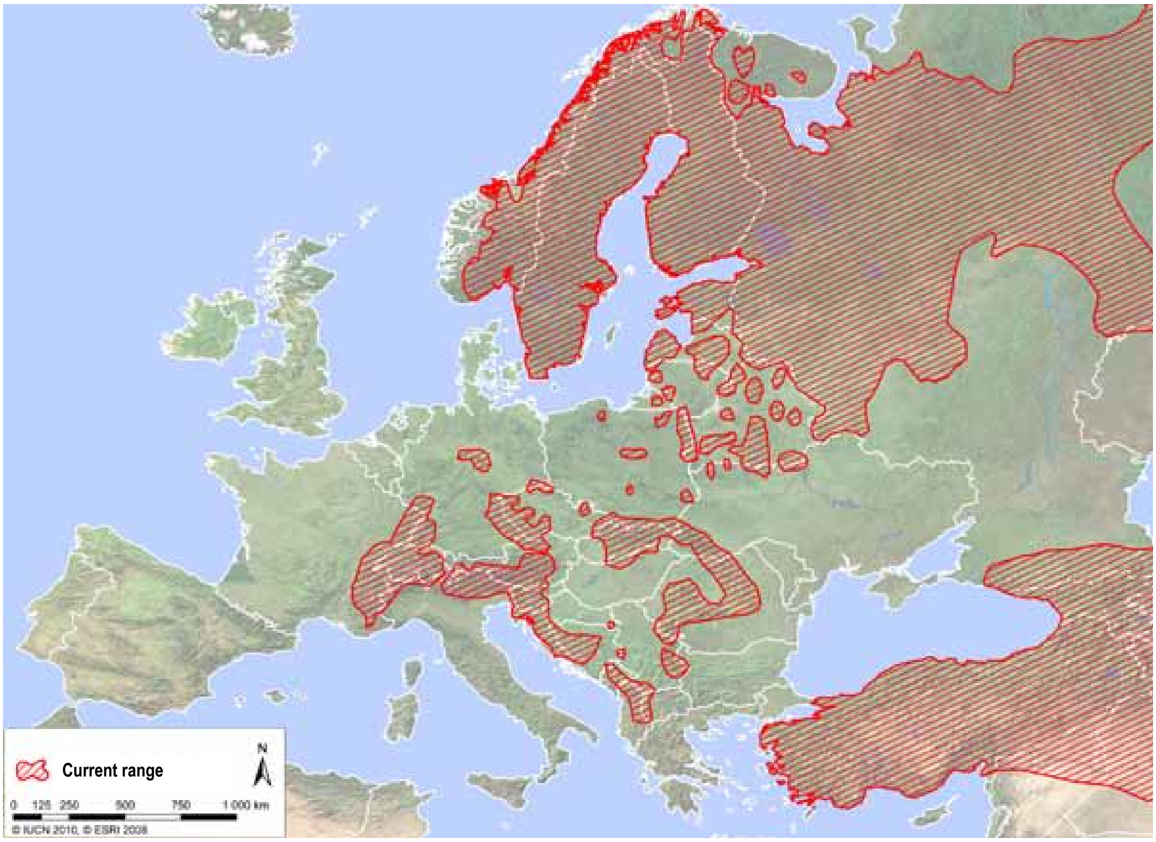

Fig. 2.10. *Distribution of the Eurasian Lynx (Lynx lynx) in Europe (after IUCN 2010d).*

2 000 animals of the species live in Norway and Sweden. The total population of the Eurasian Lynx in Europe is thus estimated to approximately 10 400 animals. (Linnell et al. 2007).

The following estimates show numbers of the Eurasian Lynx in countries neighbouring with the Czech Republic: Slovakia 400–500, Poland 185, Germany 18–26, and Austria 3–5 animals (Červený et al. 2006b).

Distribution Range in the Czech Republic

In the Middle Ages, the lynx was distributed in most forested areas, including at lower altitudes. Intensification of agriculture, augmenting fragmentation of forests, and more pronounced persecution by man during the 18th century gradually forced the species to retreat to higher mountain and submountain areas. At the end of the 18th century, the lynx could be found nearly restricted to the Czech border mountains. In Bohemia, these were namely the Šumava Mts., the Český les, the Krušné hory Mts., and certain patches in the area spreading from the Labské pískovce Sandstone Mountains to the Orlické hory Mts. and the Českomoravská vysočina Uplands. The last lynx shot in Bohemia was recorded in the region near Tábor in 1835 (Červený et al. 2006c). The population in Moravia survived much longer supported by migrants from the Slovak Carpathians. Individual animals appeared until the beginning of the 20th century in the regions of the Moravský kras (Moravian Karst), the Drahanská vrchovina Highlands, and especially in the Moravskoslezské Beskydy Mts. (Červený et al. 1996c).

The lynx reappears in our country along with wolves and bears after 1945, first in the region of the Moravskoslezské Beskydy and the Jeseníky Mts. Scarce observations are reported from the 1950s–60s in the Šumava, the Český les, and the Labské pískovce Sandstone Mountains.

Thanks to the release of 5–9 animals in the Bayerischer Wald Mts. at the beginning of the 70s, supported by subsequent reintroduction of 17–18 animals in the course of the 80s, the population of the Eurasian Lynx on the Czech side of the Šumava Mts. increased and gradually became stable (Koubek & Červený 1996). However, the relatively stable populations in the Beskydy and the Jeseníky were severely suppressed by illegal hunting in the 1970s. The grid map from the 1980s shows occurrence of the species in 97 squares, compared to 29 in the preceding years. This may be interpreted as a result of the expanding population supported by reintroduction in the Šumava, but also as a result of natural migration of individual animals from Slovakia to the Moravskoslezské Beskydy. This fact reflected in the size of the Šumava population, which was estimated to 70–100 animals at the end of the 90s (total estimate for the Czech Republic was 100–150 lynxes) (Červený et al. 2006b). At that time, migrating lynxes were observed also, for instance, in the Žďárské vrchy Hills, the Jihlavské vrchy Hills, the Křemešnická vrchovina Highlands, the Javornická vrchovina Highlands, the Brdy Mts., and the region of Třeboň. Between 1996 and 1998, the species temporarily appeared even in Central Bohemia, namely in the regions of Příbram, Votice, and Benešov, the total records rising to 256 squares (Červený et al. 1996). The lynx also successfully dispersed in the area of the Labské pískovce and successively in its wider surroundings on the right bank of the River Elbe. The number of lynxes was determined to six animals in the mid 90s (Benda 1994, 1996). Individual animals were illegally released in NP Podyjí and PLA Moravský kras (Moravian Karst). Their occurrence was not recorded though (Červený et al. 2005). In 2002–2003, the distribution of the lynx was limited again to 185 squares (Červený et al. 1996), which was probably caused by illegal hunting. The population of the Eurasian Lynx in the Czech Republic is currently restricted to two core areas of distribution (see Fig. 2.11.):

1) south and west of Bohemia – the Český les, the Šumava Mts., the Novohradské hory Mts., and Blanský les, including its temporary occurrence in the area of the Plánický hřeben Ridge and the Brdy Mts. (60–75 animals),
2) the Beskydy Mts. – the Moravskoslezské Beskydy (11 animals), the Javorníky Mts. (3 animals), the Vsetínské vrchy Hills (3 animals, including temporary occurrence in the Bílé Karpaty; Bartošová 2005).

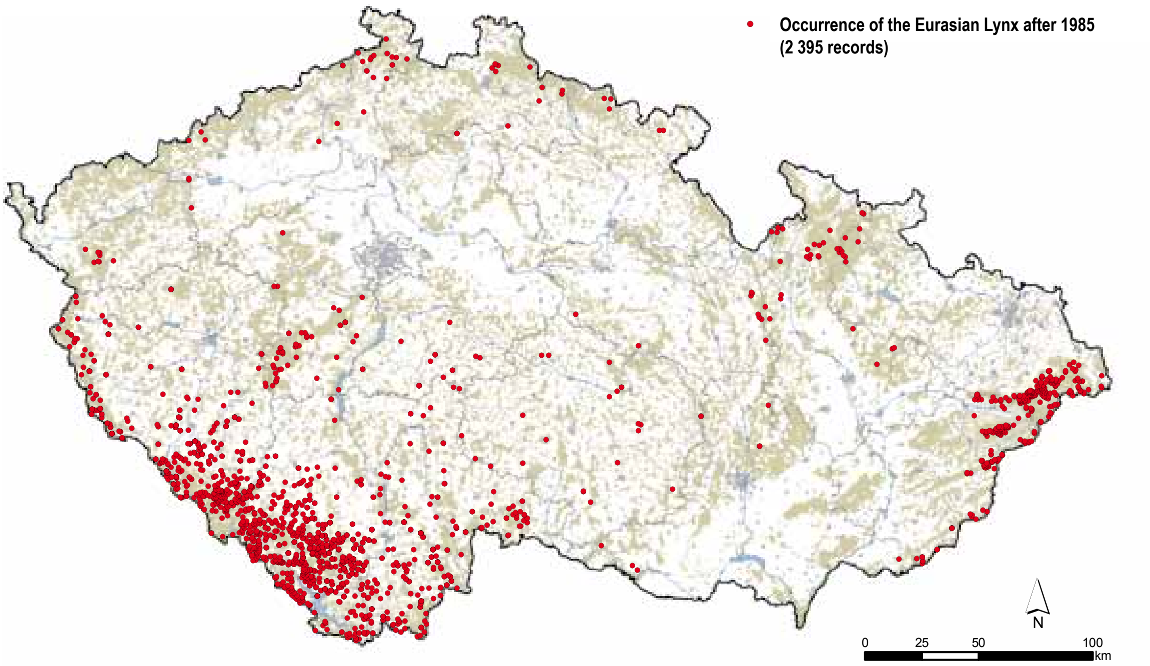

Fig. 2.11. *Occurrence of the Eurasian Lynx (Lynx lynx) in the Czech Republic (source: records of species – AOPK database 2009).*

The population of the Eurasian Lynx in the Labské pískovce Sandstone Mountains is presumed to have died out.

2.4.3. Ecology and Behaviour of the Eurasian Lynx

Reproduction and Social Behaviour

The Eurasian Lynx is the largest Europe's wild felid species. The male and the female spend most of the year separated and meet only during a short mating period, i.e. from January to March. This is the time when males fight for access to females. In the rest of the year, both males and females strictly defend their own territories against individuals of equal sex, while there may be a slight overlap of territories, particularly in males. A territory of a male may cover home ranges of several females. Territories of females do not usually overlap. Oestrus in a female lynx lasts for 1–3 days and ovulation comes after several mating acts (induced ovulation). In May to June, after 70–75 days of pregnancy, the female gives birth to 2–3 cubs in a perfectly hidden place. They will nurse on their mother's milk for 2–3 months. The death rate in lynx cubs is high and reaches up to 50% (von Arx et al. 2001, Červený et al. 2005).

Young lynxes begin to disperse at the age of 8–10 months. No differences between sexes have been recorded in this respect. Until the mentioned moment, they follow their mother, who educates them in hunting techniques. The kittens may leave their mother's territory as early as in January, but most frequently during April (Zimmermann et al. 2005). Males become adult at the age of 33 months, females at the age of 21 months.

Migration for long distances and search for favourable territories are predominantly a task for the young that are forced to leave their parent's home range in spring. The distance they will reach during migration varies in individual cases. Nevertheless, females obviously seek their new territory closer to their mother, while males migrate longer distances (Fig. 2.12.).

Diet

The Eurasian Lynx feeds mainly on hoofed animals. Its most frequent prey is the Roe Deer (*Capreolus capreolus*).

Other animals falling prey to the lynx are the Red Deer (*Cervus elaphus*), the European Hare (*Lepus europaeus*), and the Wild Boar (*Sus scrofa*). It occasionally hunts other smaller vertebrates; foxes, cats, and birds are known to form a significant share of its diet (Fejková et al. 2003, Anděra & Horáček 2005).

Role in the Ecosystem

As a top predator, the Eurasian Lynx naturally regulates the populations of hoofed game and enhances their balanced numbers required for successful forest regeneration.

Habitat

The distribution of the Eurasian Lynx is highly restricted to large forest complexes at mountain and submountain altitudes. To rest, it searches quiet and remote places with a heterogeneous terrain, especially areas covered with rocks or boulders and that provide a number of natural refuges. The habitat of the species alters greatly during the hunt though. Animals from the primeval forest of Białowieża had no strict requirements on the type of the forest for hunting. They selected particular terrains with uneasy orientation and movement, such as fallen trees and branches, uprooted trees, or dense shrub covers, where they could comfortably watch their prey. In summer, they often came out to hunt at the edges of clearings (Podgórski et al. 2008).

A study by Maye et al. (2008) addresses modelling habitat requirements using telemetric data on monitored species of carnivores – the lynx, wolf, and the bear – in the southeast of Norway. It proves that the habitats of all three primarily forest species overlap to a great extent. Although they hunt for their prey in distant places, the lynx and the wolf show many common habitat requirements. The lynx most frequently preferred the highest forest cover and hunted in the most heterogeneous terrain. The forests in its home range in the Jura Mountains represented on average up to 60% of the total area (Zimmermann 2004).

Despite the fact that its requirements concerning the forest cover are reduced during the migration period, the lynx remains a species that is most restricted to these conditions of the tree mentioned carnivores.

2.2.4. Analysis of Critical Ecological and Behavioural Parameters Related to Migration

When migrating, lynxes undoubtedly prefer forest or scrub habitats. It is supposed that they consider a distance between two covers shorter than 1 km as surmountable and perceive fragments of forests of 1 km^2 as acceptable for their migration activities (Haller & Breitenmoser 1986 ex Kramer-Schadt et al. 2005). This is also supported by Zimmermann & Breitenmoser (2007).

However, young subadult lynxes in the primeval forest of Białowieża had serious difficulties to cross the field landscape and usually tended to avoid it, which could be caused, however, by the high forest cover in the region, where the animals are not forced to leave their ideal habitats (Schidt 1998 ex Hetherington et al. 2008).

Individual animals monitored by telemetry in the area of the Jura Mountains were recorded in 75% in a forest habitat and only in 25% appeared in an open landscape, such as pastures or other agricultural land (Hetherington et al. 2008).

Telemetric monitoring of four subadult males in the northwest of the Swiss Alps clearly depicts that the motorway and railway infrastructure represents a serious problem in lynx migration. A single lynx managed to overcome a fenced motorway and reached the neighbouring area to establish his new territory. Having crossed an open landscape and having spent a week in the vicinity of the motorway, two other animals returned to their original place. On his way back, one of these traversed 650 m of an agricultural land and continued migrating along the riverbank. The last lynx was localised 50 m from an unlit bridge, which he did not manage to surpass, and finally, after several days, returned to his original territory as well (Zimmermann 2004). Other monitoring involved an adult male in the same region. He successfully traversed the valley of the Aare River, where he had to face, in addition to the 30–40 m wide watercourse, barriers in form of a railway and a fenced motorway. He managed to overcome these barriers in a 1 km wide open landscape four times. There is a record documenting a lynx that even crossed a 200 m wide lake (Zimmerman & Breitenmoser 2007).

A Canadian Lynx (*Lynx canadensis*) monitored through telemetry in Yellowstone National Park, Wyoming, also succeeded in crossing several two-lane motorways during its roaming (always returning to is territory). During three years, it had to cross the road minimum four times and always used approximately the same place, following the main migration corridor (Squires & Oakleaf 2005).

In the core area of the Swiss Alps, lynxes occurred several times close to human settlements, mountain lodges, ski lifts, or even near main roads if these places provided a suitable environment for their rest (Zimmermann & Breitenmoser 2007). Settlements larger than 50 ha become unfavourable for the species migration (Hetherington et al. 2008).

Herfindal et al. (2005) describe factors influencing the size of home ranges inhabited by the lynx in various places in Europe. The main factor was determined to be the population density of its principal prey (hoofed game). Males reacted to changes in the density of prey with higher plasticity. The size of an occupied area increased along with a reduced prey density. The extent of the home range inhabited by a resident male amounted to 100–400 km^2 (115 km^2 on average). The size of a home range thus varies significantly and is also influenced, to a certain extent, by the habitat type. The home ranges of males and females in the Swiss Jura Mountains were specified to reach 364 and 216 km^2 respectively. In the primeval forest of the Białowieża National Park, males occupied an area of 248 km^2 and females 133 km^2, whereas in the south of Poland, close to the Slovak border, males used only 120 km^2 and females 80 km^2 (Finďo et al. 2007). The size of the lynx range in the Czech Republic was deduced based on telemetric data from the Šumava Mts. and determined to 386 km^2 (105–635 km^2) in males and 278 km^2 (180–369 km^2) in females, which roughly corresponds with the data from Switzerland. The extent of the utilised range varies even throughout the year. Nursing periods bring the most evident difference in females. With her kittens at the age of a month, the mother remained in an area of 10.7 km^2 (Bufka in litt.).

Young migrants in the Swiss Alps travelled an average distance of 42 km (Kramer-Schadt et al. 2004). The differences in the migration distance were caused by population density of the lynx in the area and predominantly by substantial habitat and barrier limitations that inhibit migration between individual subpopulations (Zimmermann et al. 2005). Figure 2.12. describes the migration potential of lynxes in Scandinavia. The proportion of individual animals migrating more than 150 km is significantly higher in males, which supports the findings from other parts of Europe (Anderson et al. 2003).

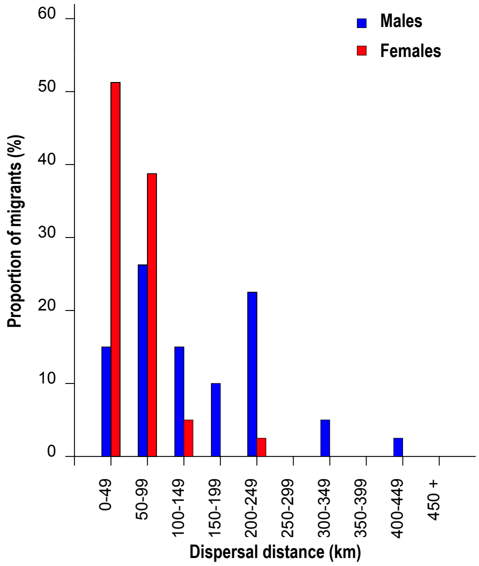

Fig. 2.12. *Proportion of migrating lynxes and their migration distance (after Andersen et al. 2003).*

Lynx males are mainly active at night or at dusk and may become more active during the day when not disturbed. By contrast, females are active during both the day and the night. Their activity during the day even increases in the time when they take care of their kittens. The lynx begins to be active at 15 o'clock and retreats at 7 o'clock in the morning, reaching the peak around midnight. A successful hunt significantly reduces the animal's activity, including the travel distances (Schmidt 1999). At dusk, the lynx returns to its prey and usually remains on the site over the night. During the day, it rests within 5 km of the place (Kocurová et al. 2003). On average, males travel 7.2 km and females 6.8 km a day. This distance increases during the mating period, particularly in males, who will travel on average 1.5 km an hour. Females manage a bit less, i.e. approximately 1 km (Jędrzejewski et al. 2002). In the wild nature, the lynx can live up to 17 years of age (Breitenmoser et al. 2000).

MIGRATION ROUTE OF LYNX BENJAMIN FROM THE ŠUMAVA MTS. TO THE BRDY MTS.

Thanks to a long-term project focused on telemetric monitoring of the Eurasian Lynx in the Šumava Mts., there are records documenting movement of a migrating young lynx named Benjamin (Fig. 2.13.).

The animal was captured in the Šumava National Park, where it partly occurred in the home range of a resident male called James. From February to June 1997, Benjamin defended his territory of 332 km^2 in the area of Křemelná. In June, he began to migrate through the highest parts of the mountain range heading northwards along the border with Germany. The migration as such lasted until July 1997 and, on his move, Benjamin used strictly the forest environment or migration corridors with a high share of scrubs or other scattered vegetation. Finally, he settled in the forests of the Brdy Mts. where he enjoyed a large territory of 394 km^2.

Based on the data describing the migration behaviour of the mentioned lynx, a natural migration corridor was identified. It almost exclusively involves forest units and connects the two vast forest complexes. The corridor leads from PLA Šumava northwards to the area between the towns of Klatovy and Plánice, where it continues through the Plánický hřeben Ridge and further to the east from Nepomuk towards the Třemšínské Brdy. The young male had to travel approximately 432 km and overcome several frequented roads and railways.

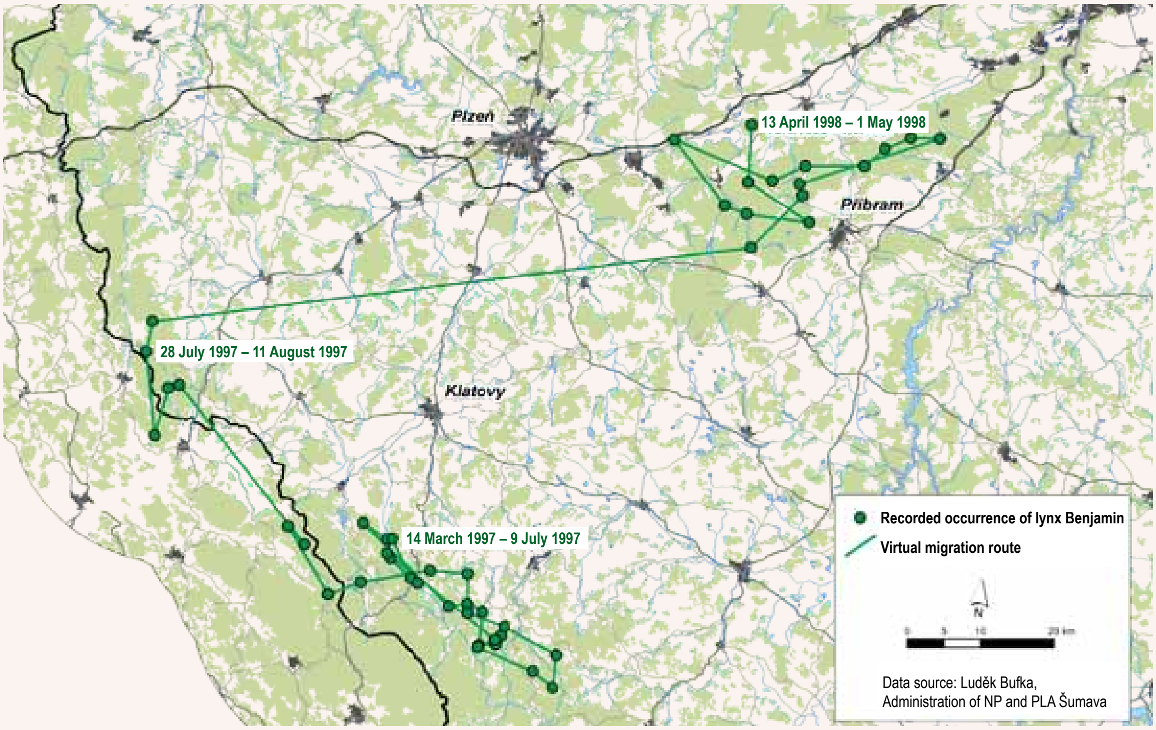

Fig. 2.13. *Migration route of the young male lynx leading from the Šumava to the Brdy Mts. (Bufka et al. 2000).*

2.5. THE RED DEER

Cervus elaphus Linnaeus, 1785

2.5.1. Conservation Status

International Conservation Status

The IUCN Red List of Mammals (IUCN 2010b) records the Red Deer as a species of least concern and considers its population trend as stable.

The only international convention that applies to the species is the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), where it is recorded in Appendix III (Protected Fauna Species).

National Conservation Status

The Red Deer is not stated in the Red List of Vertebrates in the Czech Republic (Anděra & Červený 2003). It is neither protected under any legal regulations concerning nature conservation in the Czech Republic. Pursuant to Act No. 512/1992 Coll., the Red Deer is game that may be hunted during the period from 1 July to 15 January.

2.5.2. Distribution Range

Distribution Range in Europe

The distribution of the Red Deer is rather patchy. It can be found in a great part of Eurasia – from Ireland to the Himalayas, in southeast of Asia, and in northern Africa (Anděra & Horáček 2005). It is distributed in most of the Continental Europe but Scandinavia and the major part of European Russia. The species occurs on many islands, including the British islands and Sardinia. It was driven to extinction in Albania. Several tiny and introduced subpopulations of unknown origin live in Russia; a small subpopulation inhabits the region of Kaliningrad. A tiny secluded

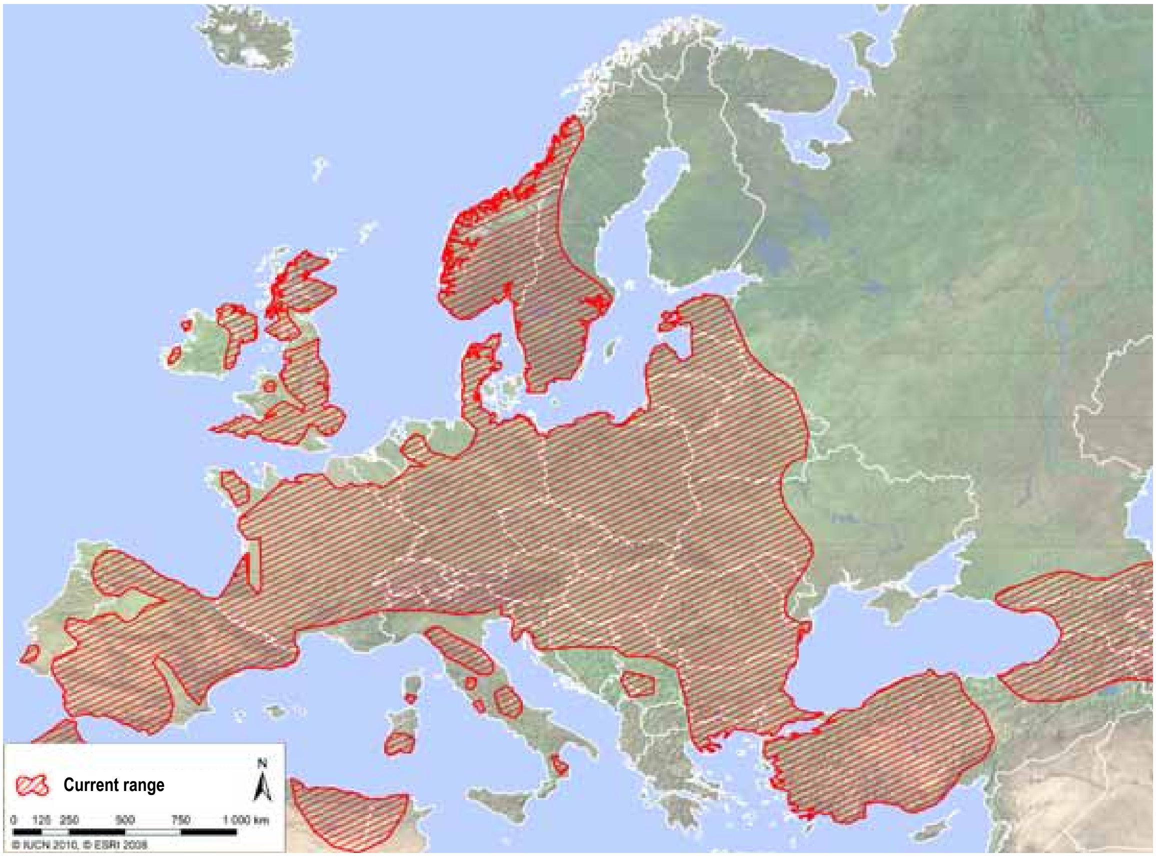

Fig. 2.14. *Distribution of the Red Deer (Cervus elaphus) in Europe (after IUCN 2010b).*

population was reintroduced in Greece, in the area of its historical distribution range.

The Portuguese population of the Red Deer originates from reintroduction and the naturally dispersing Spanish populations, which also were reintroduced in their historic range.

Distribution Range in the Czech Republic

In the current territory of the Czech Republic, the Red Deer predominantly inhabits larger forest complexes in mountains and highlands of border areas. Lowland floodplain forests are also its home in Moravia. Most of its population is subject to game management practices, which have an effect on its distribution and numbers. According to the most recent data, the Red Deer is distributed in approximately two thirds of the Czech Republic and permanently occupies a half of the country area (see Fig. 2.15.) (Anděra & Červený 2009). Inland, permanent populations can be found in the Brdská vrchovina Highlands, Křivoklátsko, the Žďárské vrchy Hills, and the Drahanská vrchovina Highlands (Hlaváč & Anděl 2001). According to the game management data published by the Czech Statistical Office as at 31 March 2010, the minimum viable population of the Red Deer is 29 895 animals.

2.5.3 Ecology and Behaviour of the Red Deer

Reproduction and Survival Strategy

Both sexes of the Red Deer live apart and hidden for most of the year. Males live a solitary life or form smaller groups. Females gather in herds of up to 40 animals, including the young. The characteristic population density in the Red Deer is 2–10 animals per km^2 (exceptionally up to 25 animals per km^2) (Koubek & Zima 1999, Wilson & Ruff 1999, IUCN 2010).

Old and ill deer live a lonely life. They will seek refuge during the day in remote places, where they hide lying in a dense cover or high grass. Early in the evening, in winter even before noon, they set off in search of their pasture. They slowly travel several kilometres a night (Anděra & Horáček 2005). Depending on their activities during the

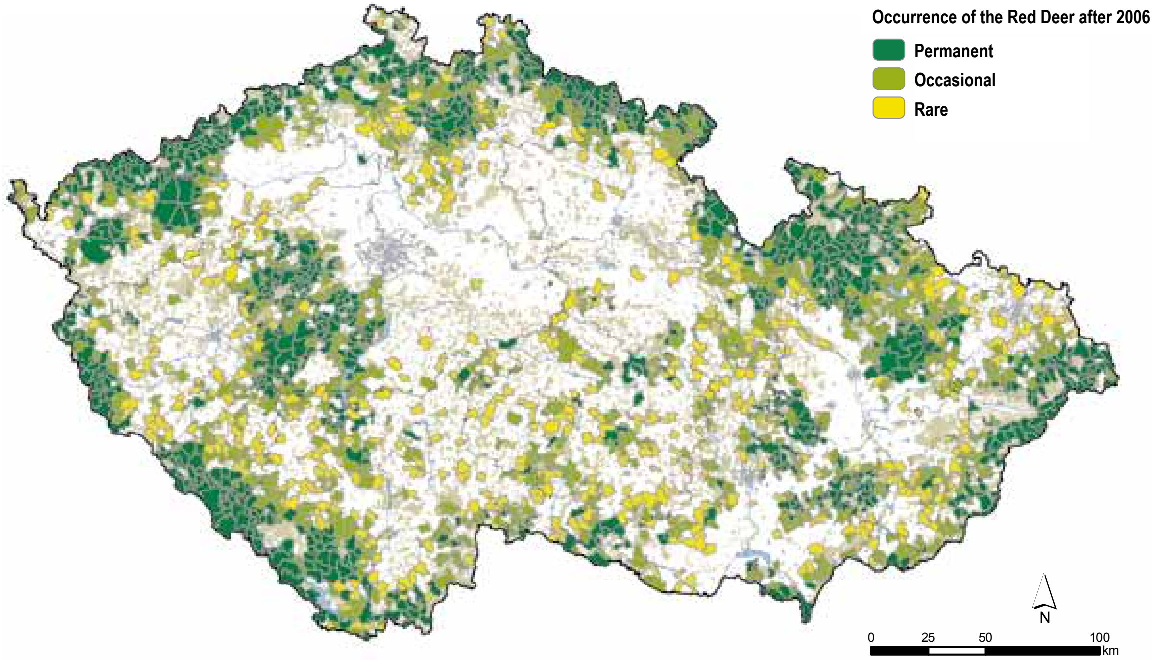

Fig. 2.15. *Distribution of the Red Deer (Cervus elaphus) in the Czech Republic.*

day, Finďo (2002) distinguishes two types of the Red Deer. The first type spends all the year in a forest environment and its pasture is evenly distributed throughout the day. By contrast, the second type, living at the lower edges of forests, uplands, and lowlands, has an opportunity to search for food in agrocenoses and open habitats. As it may be disturbed by human activities during the day, it gives preference to pasture during the night hours.

The second half of September sees the start of the rutting period for the Red Deer. This is the time when males challenge their rivals by issuing deep guttural sounds. As they do not feed at this time, they significantly lose weight. The strongest male, supported by several females, temporarily herds a larger group of females. These groups, however, split during winter (Anděra & Horáček 2005). Females become available for mating in the half of September. The fertilized embryo remains latent throughout the winter period (Reichholf 1996) and the actual pregnancy lasts for approximately 8 months. The mother usually gives birth to a single offspring, exceptionally to twins, most often at the end of May and at the beginning of June. A newborn deer weighs 3–10 kg and 7–10 days after the birth returns with its mother to the herd. The offspring will nurse on its mother's milk for four months and, except the rutting period, will remain by her side until spring of the following year. Females become adult at the age of two or three. The maximum life expectancy of the Red Deer is estimated to 20 years (Anděra & Horáček 2005).

Diet

The Red Deer mainly feed on grass, leaves, and branches of woody species, forest fruits, dicotyledonous plants, and ferns. They often browse newly planted seedlings and, in winter, peel the bark of conifers up to the height of 2 metres. In autumn, they look for acorns and beech mast to accumulate sufficient reserves of fat for winter. Grass forms 90% of their diet in summer and only 40% in winter as they consume other 50% of fir sprouts (Koubek & Homolka 1995, Šustr et al. 2006).

Role in the Ecosystem

In the territory of the Czech Republic, the species is subject to intensive game management practices. It may occasionally fall prey to large carnivores if it lives in their

range. The deer often represents significant impacts on forest regeneration, particularly in monocultures, where it lacks supply of suitable food and causes damage by browsing new shoots and peeling bark. Due to the effects of intensive browsing in certain areas, it may become a substantial element affecting the tree species composition (Anděra & Červený 2009, Reichholf & Steinbach 2002).

Habitat

Broadleaf and mixed forests with open meadows represent a native environment for the Red Deer, which is distributed from lowlands to mountain areas (Festa-Bianchet & Apollonio 2003). Floodplain forests with a high carrying capacity have always provided the most favourable conditions for this game. Nevertheless, it later dispersed to coniferous mountain forests, which are currently considered the centre of its range. As the food supply in the conditions of mountain forests lacking meadows is not sufficient for the species, additional feeding by man is unavoidable (Reichholf & Steinbach 2002).

According to Kamler (2008), we may see the animal most frequently in coniferous forests (mainly spruce), but it also occurs on meadows, wetlands, or heaths. Borkowski and Ukalska (2008) state that the most preferred habitat in the southwest of Poland is a mature pine forest with dense undergrowth. In Čejka's (2001) opinion, the deer in the Šumava Mts. generally prefer young growth stands and pastures, and avoid clear-cuts (in spring and summer, they even avoid mature forest cover; in summer, they will prefer areas abundant with raspberries, blackberries, bilberries, cowberries, and broadleaf trees). They keep away from ranges of lynx and areas of frequent human activities (e.g., tourist trails), where they become more wary and often herd (Čejka 2001, Jayakody 2008).

2.5.4. Analysis of Critical Ecological and Behavioural Parameters Related to Migration

In general, the Red Deer is not considered a migrating species. In his study, Finďo (2002) distinguishes two types of deer – the sedentary deer remains in a single area throughout the year and the migrating deer sets off regularly in search of food. Globally, we may say that there are two types of migration in deer, i.e. seasonal migration for food and migration during the rutting period. In both cases, the animals travel several kilometres, although some cases talk about distances of 50–60 km, exceptionally even over 100 km. The recorded maximum distance of migration reached 120 km (Bruiderink et al. 2003).

The home range of the Red Deer in the Šumava extends over 20–50 km^2 in sedentary animals and 60–120 km^2 in migrants (Šustr 2008). This is remarkably more then the figures for the Roe Deer (30 km^2).

A research relating to migration and barrier effects of motorways on the population of the Red Deer conducted in Austria came with a conclusion that the species is generally unwilling to use small motorway underpasses (15–30 m wide). The only exception is an underpass in an area abundant with vegetation. The animals use underpasses that are located directly on their migration routes (Völk & Glitzner 1999, Woess et al. 2001) but will practically never use those, even large ones (wider than 100 m), that are located out of these routes.

MIGRATION OF THE RED DEER IN THE CZECH REPUBLIC

In contrast to other species under review, long-distance migrations in the Red Deer are rather an exception. A systemic research of hoofed mammals of the family Cervidae provides detailed information on spatial requirements and habitat preferences of the species within National Park and Protected Landscape Area Šumava, but also in the territory of the Krkonoše National Park. Unfortunately, more specific data on the occurrence and local migration of the species in other areas of its distribution are not available.

Red deer moving seasonally for short distances were documented in both mentioned parks, whereas long-distance migration was rarely recorded.

Evidence of exceptional migration comes from the Šumava Mts. A male deer marked with an ear tag travelled minimum 90 km straight line and had to cross several roads and densely inhabited areas to be finally found near Regensburg (Šustr pers. comm. 2010.).

Two hinds were monitored using GPS telemetry at the borders of the Krkonoše National Park to determine their behaviour related to roads and railways. During a period longer than a year and a half, the monitored hinds never crossed the nearby first class road leading from Harrachov to Szklarska Poręba in Poland, although the environment on both sides of the road is very similar and the animals were frequently observed in its immediate vicinity. The road does not suffer from an extreme traffic flow but is still frequently used for international freight transport. The sporadic records of occurrence on the east side of the road may be a result of imprecise detection caused by a low GPS signal in dense undergrowth or by worse weather conditions (Fig. 2.16.). The same animals were equally detected close to the settlements of Harrachov and the area of former customs houses called Nový svět.

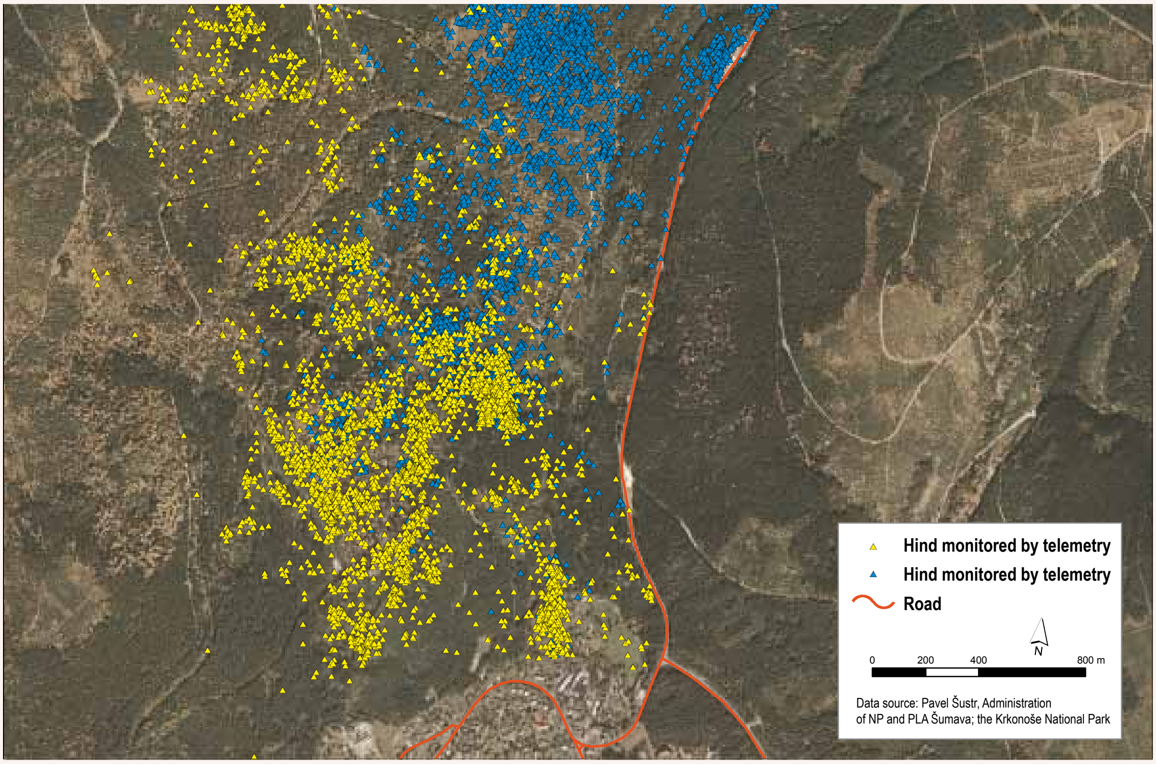

Fig. 2.16. *Occurrence of two hinds monitored by GPS telemetry in the area of the Krkonoše Mts. between 2006 and 2008.*

2.6. EURASIAN ELK

Alces alces (Linnaeus, 1758)

2.6.1. Conservation Status

International Conservation Status

The IUCN Red List of Mammals (IUCN 2010a) records the Eurasian Elk as a species of least concern and considers its population trend as increasing.

Further protection applies under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), where the species is listed in Appendix III (Protected Fauna Species).

National Conservation Status

The Red List of Vertebrates in the Czech Republic lists the Eurasian Elk as a strongly threatened species (Anděra & Červený 2003).

Pursuant to Act No. 114/1992 Coll., on the conservation of nature and the landscape, and related Decree No. 395/1992 Coll., the Eurasian Elk is defined as a specially protected species and classified as strongly threatened. Under Act No. 449/2001 Coll., on game management, the species is understood as game that may not be hunted.

2.6.2. Distribution Range

Distribution Range in Europe

The Eurasian Elk is dispersed over the Eurasian forest zone from Scandinavia and Poland, north of Austria and

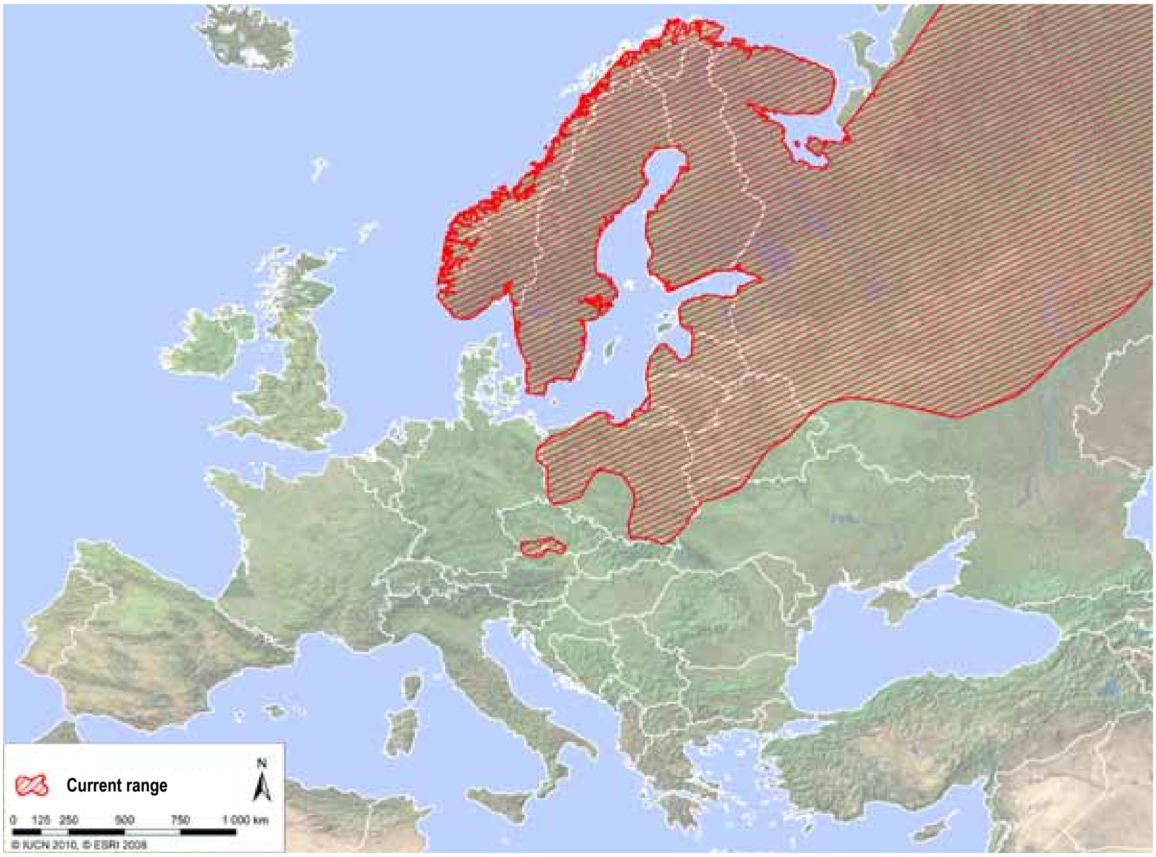

Fig. 2.17. *Distribution of the Eurasian Lynx (Alces alces) in Europe (after IUCN 2010a).*

south of the Czech Republic, over Northern Asia, to the River Yenisei. Its continuous range in Europe involves Norway, Sweden, Finland, Russia, Estonia, Lithuania, Latvia, Belarus, Poland, and Ukraine (Fig. 2.17.).

Occurrence of elks in northern Austria depended on tiny Czech populations and, inconceivably, was subject to hunting (Ševčík 1994). Due to that hunting and a drop in the Czech populations, the local population of elk in Austria has very probably become extinct. Three secluded subpopulations inhabited southern Bohemia and individuals were occasionally observed in Germany, Croatia, Austria, and Romania. The species dispersed broadening its range along rivers reaching North Caucasus. In Europe, elks occur at altitudes of up to 1 500 m a.s.l. Their range extends to Siberia in the east, to Ukraine in the south, and further to northern Kazakhstan, Mongolia, and northern China. However, the animal was driven to local extinction in Western and most of Central Europe (Cobert 1978, Bauer & Nygrén 1999, Wilson & Ruff 1999).

The European population of the Eurasian Elk is estimated to 500 000 animals. Estimated maximum 50 animals live in the Czech Republic, 2 800 in Poland, 10 000 in Estonia, minimum 110 000 in Finland (60–80 000 hunted animals each year), and 340 000 animals are supposed to occur in Sweden. (Bauer & Nygrén 1999, IUCN 2010a).

Distribution Range in the Czech Republic

The Eurasian Elk has never been abundant in the Czech Republic. The last records of its presence before its local extinction come from the 16th century. Archaeological findings document remains of elk from the Early Middle Ages (approx. until 1200) mainly in lowlands of the Elbe River basin, the Ohře River basin, and southern Moravia. These findings do not report any later occurrence of the species (Peške 1995, Kyselý 2005), which implies that, starting from the Late Middle Ages, its presence was relatively rare. The elk reappeared in our territory in 1957. The observed animals were migrants coming from preserves in northern and central Poland (e.g., the Kampinoski National Park near Warsaw), where they had been reintroduced, and their populations thrived. Until the end of the 1960s, prevailingly young males could be observed in the territory of the Czech Republic, but only sporadically and for short periods. The numbers of migrating elks began to rise at the turn of the 1960s, along with the time of their presence and a more balanced ratio of males and females (Anděra & Kokeš 1978). The first calf was recorded to be born in the region of Jindřichův Hradec in 1974, which may be considered as the first record of the species' permanent occurrence in the territory of the Czech Republic. Migrating elks may be observed in any area with a higher share of forests. They have been recorded on approximately 40% of the country area (Anděra & Horáček 2005).

A study conducted by Homolka (2000) mentions that the Eurasian Elk has been permanently present in our country since the 1980s and that 120–150 calves have been born in the Czech Republic since then. In 2000, the species population density in the region of Třeboň was estimated to 3–4 animals per 100 km^2 of forest. Compared to 800–1 200 elks per 100 km^2 in Sweden in 1992 (Hörnberg 2001), the species appears to be at the edge of its subsistence level in our country (Homolka 2000). Hunting in neighbouring Austria also probably affects the species numbers in the Czech Republic (Ševčík 1994). No reliable data are available in this respect though. Homolka & Heroldová (1997) assess the population of the Eurasian Elk in the Czech Republic as critically threatened. The authors explain that southern Bohemia forms an enclave, where the elk is present secluded several hundreds of kilometres from its continuous range. The mentioned distance is likely to increase in the future due to envisaged extension of human-affected areas and fluctuation of the size of the continuous range in Poland. The study concludes that the conditions in the Czech Republic are not sufficiently favourable to support a larger stable population.

Despite the above-mentioned facts, the permanent population of the Eurasian Elk in the country has been approximately 40 animals since the 1990s. In addition, 10–20 migrants are estimated to occur in the territory of the Czech Republic; limited data are available though (Homolka 2000, Mrlík 1998, Hutr 2004, Märtl 2009).

In 1995, three areas were recorded as permanently sheltering the population of elks: PLA Třeboňsko in the region of Jindřichův Hradec, surroundings of the right bank of the Lipno Reservoir, and the region of Nymburk.

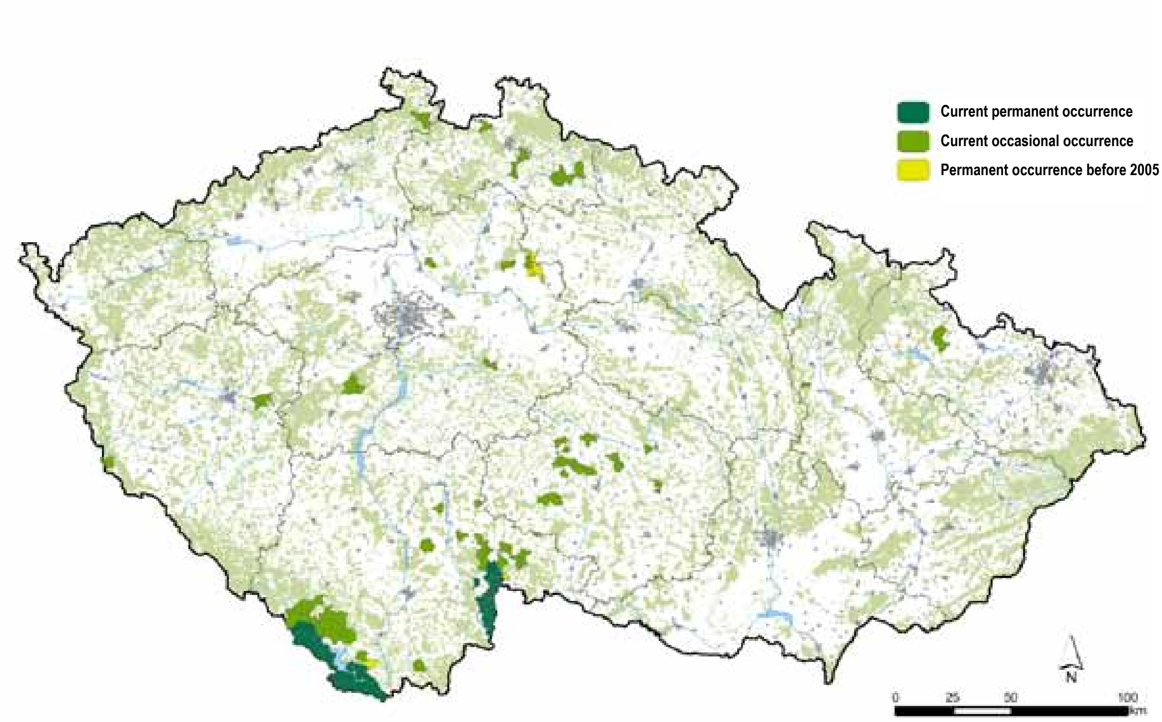

Fig. 2.18. *Distribution of the Eurasian Elk (Alces alces) in the Czech Republic.*

The Region of Třeboň

The area is formed by a 20 km wide belt running from the Novohradské hory Mts. to the Středočeská vrchovina Highlands (i.e. approx. 1 500 km^2). In winter periods, elks occur here quite regularly in pine forests of the region of Bechyně, in the surroundings of the Borkovická blata Moors, in the region of Jindřichův Hradec, and between Příbraz and Mirochov. In summer, they migrate to PLA Třeboňsko and can also be observed in the landscape combining forests with agricultural land and ponds, e.g., in the region of Jistebnice.

The relatively small refugia do not provide ideal environment during the entire year. Despite being subject to intensive management and tourism, these areas offer relatively favourable conditions as opposed to the rest of the country – forest cover 50–60%, a low human population density (approx. 40/km^2), a large number of ponds and wetlands (Homolka 2000). The estimates from 1990s mention about 15 animals inhabiting the mentioned area (Homolka 1998).

Right Bank of the Lipno Reservoir

The elk distribution is delimited by the Austrian border in the south, by the right bank of the Lipno Reservoir in the north, by the village of Studánky in the east, and by the village of Stožec in the west. Elks find suitable conditions on 100 km^2 throughout the year. Located at 600–1000 m a.s.l., the area is laced with streams and covered with a number of heathlands, waterlogged meadows, and vast stands of the Goat Willow. Forest clearings are covered with European Rowans, birch trees, and Alder Buckthorns. The most recent numbers of the population are estimated to 10–15 animals (Šustr 2010).

Region of Nymburk

The third and more stable population of the Eurasian Elk began to form in Central Bohemia, northeast of the Nymburk District in the early 1990s. Migrating animals were regularly seen here and, since 1991, several females with calves were recorded in the area of Forest District Dymokury. Nevertheless, the most recent research indicates that the population has died out (Anděra & Červený 2009).

2.6.3. Ecology and Behaviour of the Eurasian Elk

Reproduction and Social Behaviour

Elks live a solitary life, including females that, in contrast to their relatives, do not herd. Elks rarely form herds. If so, it is mainly during the rutting period or in winter. As the rut is not fixed in time and cows do not synchronise in this respect, the mating period may last from August to November. During this period, females form mating arenas of 0.5–0.75 km^2, where they leave their marks and signal their physiological state. The males roaming around are in active search of females and bugle to attract them. Going through the fight for females, the winning male does not form a harem but rather temporarily joins the herd of females in the mating arena. These temporary groups are typically composed of a single male and one or two females; herds of nine males and twelve females have also been recorded (Zheleznov & Fox 2001, Rolandsen et al. 2010). After copulation, the male leaves the female in search of a new partner (Mrlík 1998, Zheleznov & Fox 2001).

The cow will commonly give birth to one or two offspring. The period of gestation lasts for approximately 8 months and calves are born between the end of April and the beginning of May (14 May – 30 August as described in Norway; Rolandsen et al. 2010). During this period, cows seek a quiet place near forest borders and in non-forest areas, e.g., forest edges, large escape covers in fields, and reed and scrub along ponds, where they take care of their offspring. Frequently, males can be seen moving close to these places (Andreska 1998). Mothers nurse their kids for 3–4 months and keep en eye on them until new calves are born.

According to the data from Norway, 40% of males and 60% of females disperse (mostly at the age of 2.5 years) 10–175 km far from their mother's home range. Elks become adult in their second year, but particularly males become sexually active later (at the age of 4–5). The death rate in the first year after birth approximates 45% and the life expectancy reaches 20–25 years (Mrlík 1998).

Diet

The species feeds on easily digestible plants rich in nutrients, annual shoots of broadleaves, or dicotyledonous plants and water plants. Their diet is predominantly composed of leaves and tree shoots in summer, and buds in winter. As a food complement, elks will consume water plants rooted in the bottom, such as pondweed (Potamogeton spp.) or the Canadian Pondweed (*Elodea canadensis*). The most significant plants forming the food structure of the elk in summer in the conditions of the Czech Republic are the Goat Willow (*Salix caprea*), Alder Buckthorn (*Frangula alnus*), European Rowan (*Sorbus aucuparia*), but also the White Birch (*Betula pubescens*). Elks have not been observed yet grazing off water plants on Czech ponds. However, records show grazing on unripe wheat (*Tricitum spp.*), maize (*Zea mays*), Brassica spp., and oats (*Avena sativa*) (Andreska 1998, Homolka & Heroldová 1997). In winter, elks will also eat needles of the Scots Pine (*Pinus sylvestris*), Silver Fir and Grand Fir (*Abies alba* and *A. grandis*), and branches and bark of species offering softer wood, such as the Goat Willow (*Salix caprea*), birch (*Betula spp.*), alder (*Alnus spp.*) or aspen (*Populus tremula*). Its short neck forces the elk to stand with its legs wide open in order to reach the ground. This indicates that the species is naturally adapted to feed on leaves of scrub rather than on grass. The overhanging upper lip eases the mentioned manner of feeding. An elk will consume 10–30 kg of food daily. Despite this necessity, elks have never been observed eating from a feeder stand (Andreska 1988, Reichholf 1996, Anděra & Horáček 2005).

Role in the Ecosystem

The Eurasian Elk adapted its food requirements to the forest with undergrowth, where it browses branches and eats leaves from trees and scrubs. In areas with its permanent distribution, the species may represent significant damage caused to forest stands, which is not the case of the Czech Republic, as its numbers in the country are negligible compared to other ungulates (Homolka & Heroldová 1997). The Grey Wolf is a natural predator to the elk. With respect to its low numbers and a limited range in the territory of the Czech Republic, the elk has no natural predator in areas of its permanent distribution.

Habitat

Elks enjoy wet marshy forests of lowlands and uplands but avoid steep slopes. During the vegetation period, they remain in waterlogged habitats with scrub covers and abundant wetland vegetation. Frost makes them leave towards drier forest complexes where they seek clearings with naturally seeded vegetation and young growth of pine (Homolka 2000). They make use of alder and birch forests with marshes and fens; their wide hooves allow them to access bogs, mires, and heaths. In search of their food, they wade through shallow waters of forest wetlands. Elks are excellent swimmers and thus can be observed on large islands where they avoid their predators – in particular wolves.

Based on data from Norway, the local elks give strong preference to forest habitats; 90% of telemetric records come from various types of forests. In the daylight, Norwegian elks prefer dark forests with prevailing high conifers, whereas in the dark, they use open habitats, such as mires, meadows, and fields. Field cultures are most attractive for the species during summer and autumn evenings and night hours. In contrast to elks inhabiting coniferous forests, animals living in areas with a higher share of mires and other non-productive habitats generally have larger home ranges (Rolandsen et al. 2010).

In winter periods, elks seek food in forests that provide a sufficient potential in this respect, i.e. forests affected by fires, pest outbreaks, other disasters, or harvest (Courtois et al. 2002).

In Canada, elks mostly give preference to mature mixed forests, then mature coniferous forests, and young coniferous forests (Courtois et al. 2002). They will favour habitats with a sufficient food supply and a lower risk of predation. It seems though that availability of suitable refuges does not represent a limiting factor as to whether they actually use the land (Dussault et al. 2005).

Among other fundamental conditions influencing the presence of the Eurasian Elk in the Czech Republic, there is a quality food base and a low disturbance by man. The carrying capacity of land is one of the limiting factors for the species. Other members of the family *Cervidae* represent competition for the elk in food supply and their occurrence appears to be another limiting aspect. Felling of the Goat Willow on waterlogged meadows and increased effects of human disturbance through management and tourism may very fast lead to a complete destruction of the Eurasian Elk population in the Czech Republic (Homolka 2000).

2.6.4. Analysis of Critical Ecological and Behavioural Parameters Related to Migration

Both migrants and resident individuals may be found in the population of the Eurasian Elk. In Scandinavia, most migrants fall into populations occupying high elevations (i.e. colder climate), whereas populations along the coast enjoying more favourable climate have sufficient supply of food throughout the year and, in some cases, do not include a single migrant (Rolandsen et al. 2010). Migrating elks will move to lower elevations in winter and to higher elevations in summer. The distance of their migration reflects the actual elevation of their habitat – the higher their current habitat, the longer they migrate to reach favourable wintering grounds at lower elevations. The longest migration distances documented in Norway are approximately 180 km (Rolandsen et al. 2010). Migration routes of elks follow significant topographic elements, such as valleys, rivers, and fiords (Andersen 1991, Ball et al. 2001, Rolandsen et al. 2010). Elks inherit their migration behaviour from their parents, which is notably resistant to any changes in availability of food or migration barriers (Sweanor & Sandegren 1989, Andersen 1991, Ball et al. 2001). In autumn, elks in Norway usually begin to migrate at the turn of November, driven by the first significant snowfall. Spring migration can be seen at the turn of April and is influenced by the snow cover in the given area and presumably also by the availability and quality of food (Rolandsen et al. 2010). Males will generally travel at a pace of 40–300 m/hour and females 30–100 m/hour, while both sexes are most active in summer and during the mating period. Activity in females substantially drops when offspring are born (at the turn of May). Both Norwegian males and females are equally active during the wintertime, males occurring more often at higher elevations if the snow cover is poor (Rolandsen et al. 2010). Elks reach the peak of their activity at the sunrise and before sun-

set, or during the night in more densely inhabited areas (Anděra & Horáček 2005).

The home range of Norwegian elks oscillated between 10 and 5 268 km^2, with merely a few individuals exceeding 1 000 km^2. The home range of males (on average 384 km^2) was larger than of females (on average 178 km^2). Home ranges of migrants were 5–10 times the size of those of resident individuals of equal sex (Rolandsen et al. 2010).

Homolka (2000) states that, based on various data from the Czech Republic, Slovakia, and Austria, road kills (38%) and hunting (36%) were the most frequent cause of death in the species, while 92% of animals hit by a car die (Seiler 2004). Road kills and hunting also represented the most common cause of death in Norway (Rolandsen et al. 2010). The death rate in winter was, among other factors, positively influenced by low temperatures and a high snow cover (Rolandsen et al. 2010).

Seiler et al. (2003) studied the effects of the newly constructed motorway (E4) on the migration of elks in Sweden and discovered that the animals are highly sensitive to the mentioned type of barriers. Fencing of the motorway helped reduce the road kills by 90% but minimised the species migration across the motorway. Observations have shown that elks rarely use special underpasses (seemingly due to their insufficient dimensions: height 4 m, width 5 m, length 26 m) and finally draw back or decide to overcome the fence barrier to cross the motorway in their own way. Monitoring of the mentioned underpasses did not show any seasonal, direction or continual annual variations in their use that would have supported their significance in migration periods. With time, the barrier effect of the road becomes probably even more deterring. As the animals adapt to its existence, they cease attempting to overcome it and gradually perceive it as a natural and insuperable border of their home range (Seiler et al. 2003).

In Norway, the monitored animals avoided roads more often than railways. More attempts to cross roads were recorded during migration, particularly in males. No sex difference was noted in this respect as to railways. It may be concluded that roads represent a more significant migration barrier than railways (Rolandsen et al. 2010).

Animals migrating to the territory of the Czech Republic are predominantly of Polish origin. At the time when first migrants appeared in our country, the continuous range of distribution was 400–500 km distant (Hlaváč & Anděl 2001). The principal migration corridors used by elks penetrating the territory of the Czech Republic are the area between Frýdlant and Náchod, and nearly the entire Czech-Polish border in Moravia, i.e. from Vidnava to Jablunkov.

The majority of migration activities of our permanent elk population relate to the mating period and occur from mid August to October. Based on specific monitoring in the region of Jindřichův Hradec, Mrlík (1998) delineated certain corridors where individual animals migrated and presumably may migrate in the future between mating arenas or areas of regular or more frequent occurrence. In the region under review, the mentioned migration was observed south of Veselí nad Lužnicí, east of Třeboň, or possibly in the area between Nové Hrady and České Velenice (Mrlík 1998).

MIGRATION OF THE EURASIAN ELK IN THE CZECH REPUBLIC

A route of a migrating young male elk was recorded in more detail in the Czech Republic in June 2001. According to observations reported by various persons, the animal was seen near Choceň (4 June), then roaming around the Hamry Reservoir (8 June), near Vysoká (9 June, in the morning), near Štoky (9 June, in the afternoon). He was later seen from motorway D1 near Humpolec (10 June) and attempted to cross it between the villages of Plačkov and Kamenice, close to “Myší díra” (12–14 June), where he was actually shot with a tranquiliser and transported to the southern side of the road to be released near the village of Bystrá (14 June). On 15 June, he was observed approaching human settlements.

The male’s migration continued around the village of Dudín (16 June). He attempted to overcome a busy road leading from Jindřichův Hradec to Prague (20 June) near Kardašova Řečice and finally disappeared in the reeds of the Velký Pond. He was last recorded on 21 June between the villages of Novosedly nad Nežárkou, Ječmina, and Kolence, where he headed southwest towards the Rožmberk Pond. The elk thus travelled over 150 km straight line in less than three weeks.

The migration route of the mentioned young male appears not to be accidental. Several other observations were recorded from the same area (e.g., near the village of Dudín in November 2006 and an elk attempting to cross motorway D1 close to “Myší díra” on 12 December 2006). Another animal was seen crossing the same motorway on the 72nd km near Loket (22 October 2002) and practically on the same site on 3 January 2003 (Hlaváč pers. comm. 2010).

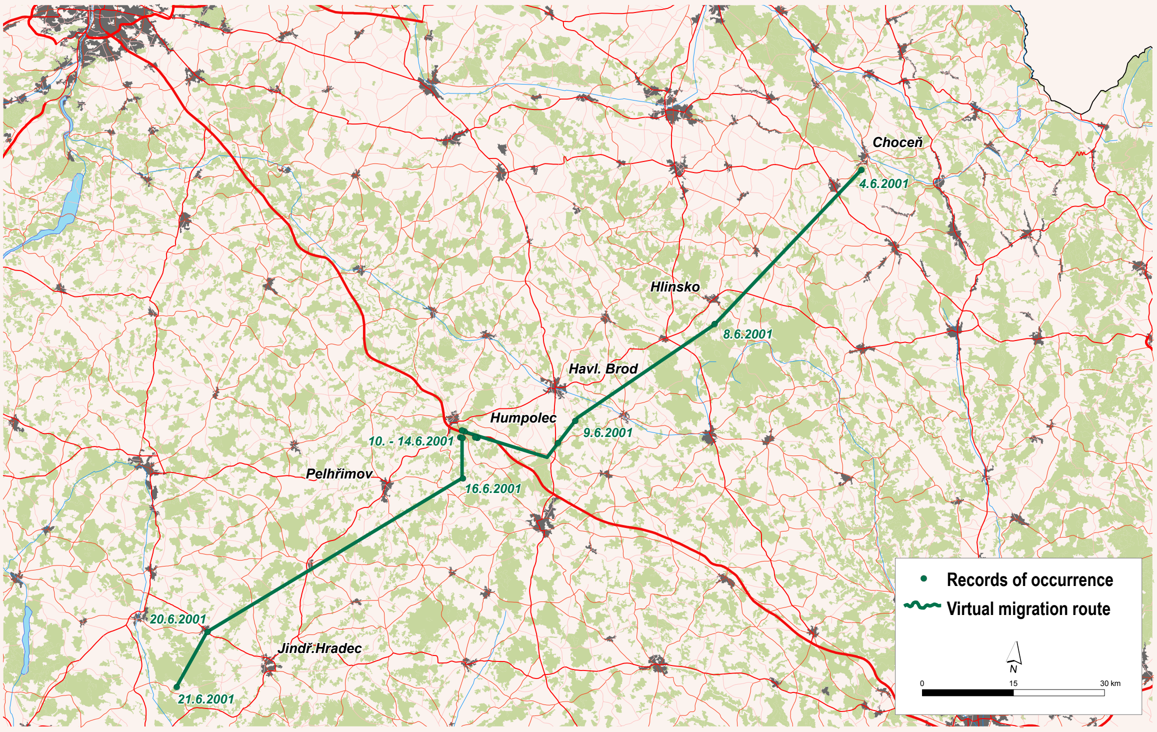

Fig. 2.19. *Migration route of a young male elk travelling from Poland to southern Bohemia (Hlaváč pers. comm. 2010).*

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3.

Migration Barriers in the Landscape

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3.1. BARRIERS AS PRINCIPAL STRUCTURES IN THE LANDSCAPE AFFECTING MIGRATION OF FAUNA SPECIES

Definition

Natural and anthropogenic structures in the landscape that inhibit free movement of fauna species are understood as migration barriers. Barriers created by man are crucial from the practical point of view. These are subject to the subsequent analysis.

Classification of Barriers

Migration barriers may be classified with respect to a number of mutually related aspects. The substantial factors to be considered are (i) barrier strength, (ii) duration of barrier effect, and (iii) type of barrier in the landscape.

(i) Barrier Strength

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

The following scale was applied to depict generally the level of permeability in individual parts of migration corridors. Each type of barrier shows specific parameters.

Chart 3.1. *General classification of areas and critical locations with respect to their permeability.*

Part of a migration corridor	Symbol	Level of permeability
Existing barriers	K1	Entirely impermeable barrier (critical site)
	K2	Significant barrier (limited site)
	K3	Medium level barrier
Permeable area	P	Permeable (low disturbance)
	PZ	Entirely permeable (no barriers)

(ii) Duration of Barrier Effect

The duration of the barrier effect, i.e. permanent or temporary, plays a decisive role as to the risk it poses. Permanent barriers, such as settlements or transport infrastructure, represent the most severe threat. They alter the given environment for the period of 50–100 years and, from our point of view, may be perceived as definite. By contrast, certain fences constitute a temporary obstacle.

(iii) Type of Barrier in the Landscape

The main objects causing a barrier effect that are subject to further evaluation are the following: (A) roads and motorways, (B) railways, (C) watercourses and other water bodies, (D) fences, (E) settlements, (F) non-forest areas.

Principles of Practical Assessment of Barriers

Practical assessment of barriers should be grounded on the following principles:

Each barrier shall be assessed individually

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

Considering the Cumulative Effect of Barriers

Individual barriers may finally have a cumulative effect. A high density of even partially permeable barriers can result in an overall impermeability of the landscape. The proposal of migration corridors has to consider this fact. For this reason, migration barriers were incorporated in mathematical models of the landscape potential (see Chapter 5.).

The present chapter is structured according to the abovementioned facts. Chapter 3.2. analyses individual types of barriers; Chapter 3.3 evaluates their spatial density and an overall resistance of the given area based on a mathematical model.

3.2. MAIN TYPES OF MIGRATION BARRIERS

The following overview enumerates the basic types of landscape barriers that limit migration of large mammals:

- roads and motorways
- railways
- watercourses and other water bodies
- fences
- settlements
- non-forest areas

Each type of barrier has its characteristic effect. The present classification was applied within the field evaluation of Long-Distance Migration Corridors. The cartograms introduced below are rather supposed to illustrate the density of individual types of barriers in the Czech Republic. The photographs show typical examples of the given type of barrier.

3.2.1. Roads and Motorways

A) Barrier Characteristics

The barrier effect of roads and motorways is determined by a combination of the following three factors: (i) selected route of the future road, (ii) technical solutions to the construction, and (iii) traffic parameters.

1) Route of the Future Road

The route of the future road and its incorporation in the landscape represent an essential and decisive step influencing its future impact on the environment. To a certain extent, this factor also predetermines the technical solution. Development of a new road is a complex process composed of various stages. The level of landscape fragmentation and permeability of the road for fauna should be one of the obligatory considerations within the decision-making process. Environmental Impact Assessment (EIA, pursuant to Act No. 100/2001 Coll., as amended) and spatial planning represent the legal instruments. Technical Conditions No. 180 set by the Ministry of Transport of the Czech Republic define so called "migration studies", which play a key role providing a professional groundwork (Anděl, Hlaváč, Lenner et al. 2006).

The most challenging topics are the following:

(i) Establishing new transport corridors in the landscape – construction of roads in currently undisturbed areas and introduction of all related negative effects (noise, emissions, visual disturbance). This leads to further fragmentation of the landscape.

(ii) Cumulative effect of partial barriers - potentially leading to a complete discontinuation of the corridor. In some cases, this point of view may be in conflict with the above-mentioned issue (i.e. establishing new corridors). Former transport corridors are commonly composed of a number of parallel barriers (an existing first class road, railway, dense settlement). Attaching a new expressway directly to the mentioned corridor leads to such a cumulative effect that the area becomes completely impermeable. To avoid this, it is more appropriate to build the new road in a new corridor. The situation always requires particular evaluation of the given conditions.

(iii) Direct and indirect disturbance of ecological network elements – i.e. direct destruction of habitats that are part of an ecological network. The space available for the existence of wild fauna has been constantly diminishing and free movement in the landscape becomes more complicated each day.

The methodology to be applied when deciding on the routes of new roads is laid down by Technical Conditions No. 181 set by the Ministry of Transport of the Czech Republic (Anděl et al. 2006).

2) Technical Solutions

The principal concept of technical solutions is based on the proposed classification of roads, geomorphology of the terrain, and choice of the route.

Essential aspects are predominantly the following:

(i) Road class – determines the basic width of the road and the technical solution. Most serious barrier effects are caused by motorways and expressways. Nevertheless, low class roads should also be addressed with respect to the death rate of animal species.

(ii) Objects increasing the barrier effect – retaining walls, noise walls, fencing, guardrails, and steep embankments and cuts (Fig. 3.1).

Fig. 3.1. *Fenced motorways form an insurmountable barrier in the landscape.*

Fig. 3.2. *A high bridge represents an object reducing the barrier effect of the road.*

(iii) Objects reducing the barrier effect – culverts, bridges, special migration objects (overpasses and underpasses) established or adjusted with the view to facilitating movement of animals (Fig. 3.2.).

The methodology to be applied when proposing migration objects and evaluating their permeability is determined by the previously mentioned Technical Conditions No. 180 set by the Ministry of Transport of the Czech Republic.

Practices to be applied in reconstruction of bridges over small watercourses are specified in the methodology guide called Mosty přes vodní toky (Bridges over Watercourses) (Hlaváč & Anděl 2008).

3) Traffic

Vehicle traffic on roads brings along direct kills of animals hit by cars and contributes to the barrier effect causing noise and visual disturbance (Iuell et al. 2003). Road kills constitute a substantial factor influencing road safety and threatening populations of certain fauna species. The role of the barrier effect caused by traffic is significant; the average daily density of traffic is a parameter used when evaluating fragmentation of the landscape by traffic (Gawlak 2001, Anděl et al. 2005). Among the number of parameters characterising the traffic, the annual average daily traffic (AADT) expressed in vehicles/day is the most important quantity. The method of its determination and the principles of interpretation with respect to conservation of the environment are stipulated by Technical Conditions No. 219 set by the Ministry of Transport (Martolos et al. 2009). The AADT value is an output of regular traffic count and determines the basic classification of roads by their potential impact. More detailed evaluation of the road permeability also requires data on the distribution of traffic throughout the day. This aspect is obvious when comparing night traffic on busy motorways and on first class roads where sufficient distances between individual vehicles increase the permeability of the barrier.

Overall Permeability

The resulting barrier effect is given by a combination of all the above-mentioned factors. Thus, these should always be considered individually for each focal species taking into account the specific conditions on site. The assessment of the existing transport network focuses narrowly on the technical parameters and traffic. Retrospectively, deficiencies of the given route may be determined and, if possible, minimised.

B) Network of Motorways and Roads in the Czech Republic

The Czech Republic has a high density of roads but still a low share of motorways and expressways. From the perspective of protection of the landscape from fragmentation, this is a positive fact. Adequate protection measures may be adopted when constructing new motorways. Figure 3.3. shows the network of roads and motorways in the Czech Republic. The map in Fig. 3.4. depicts the basic classification of Czech roads and motorways.

C) Classification of Permeability for Large Mammals

The chart below gives a framework classification of roads by their permeability for large mammals, which was used to evaluate locations where roads cross Long-Distance Migration Corridors. Two aspects are subject to evaluation – the technical solution and the traffic flow. The technical solution was assessed within a field survey on site with regard to the actual method of implementation and combination of the given elements. The data on traffic flow were acquired from the outputs of the national traffic count. In case the individual criteria determined different classification, the less permeable class applied.

When the permeability of roads for animals is assessed in more detail, for instance with the view to proposing migration objects, such assessment is grounded on the theory of migration potential (Hlaváč & Anděl 2001) and on Technical Conditions set by the Ministry of Transport.

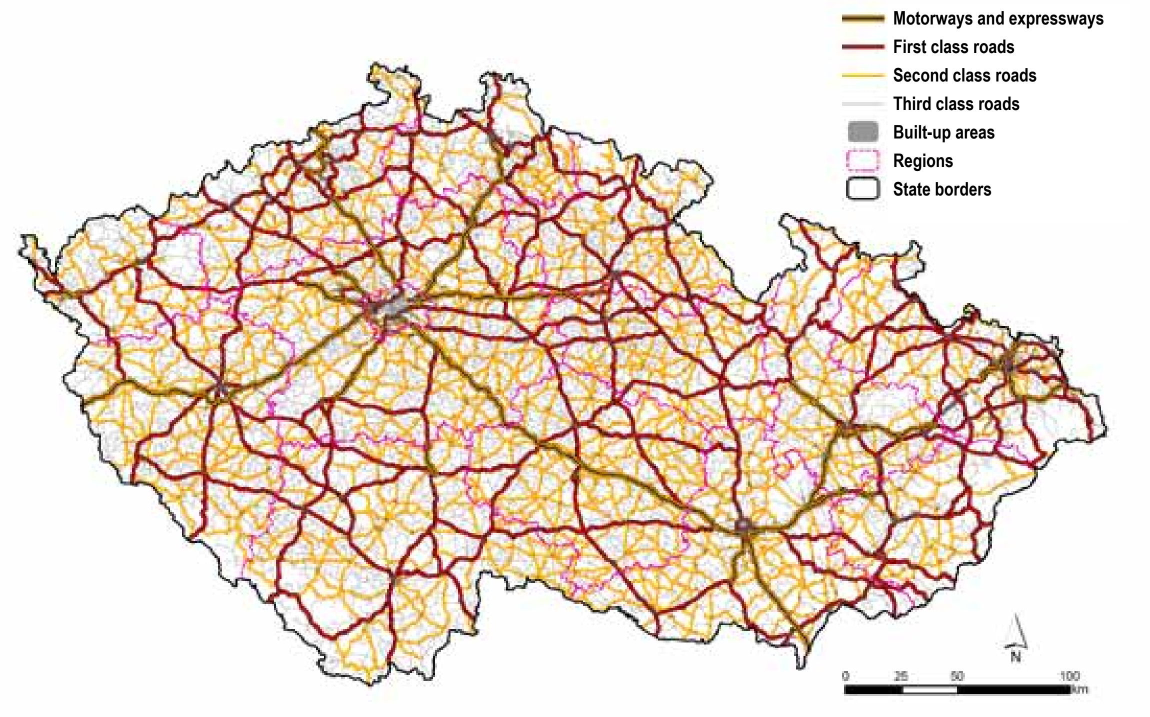

Fig. 3.3. *Road and motorway network in the Czech Republic.*

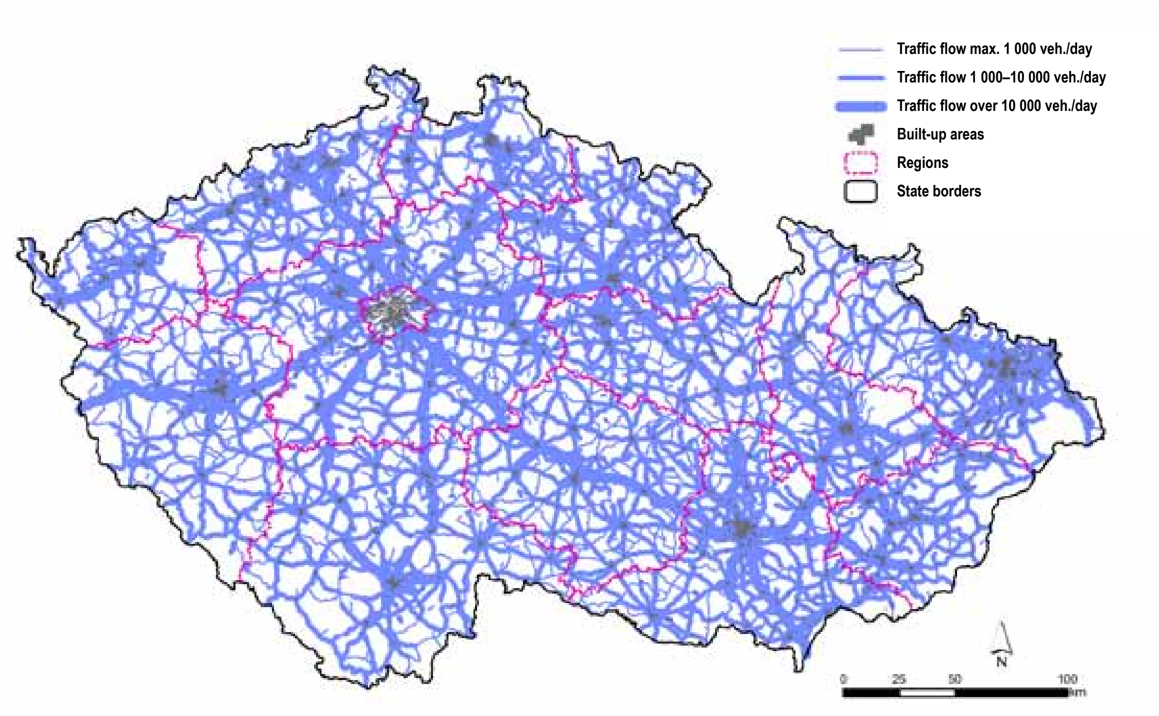

Fig. 3.4. *Traffic flow of the main transport network in the Czech Republic.*

Chart 3.2. *Classification of roads and motorways by their permeability for large mammals.*

Class	Specification	Technical solution	Traffic flow
K1	Motorways and expressways	Insurmountable physical obstacles (steep slopes and cuts, noise barriers, abutment, stone walls, etc.) lacking any migration objects	Over 30 thousand vehicles per day
K2	Other multi-lane roads	Significant technical obstacles, high banks and cuts which may be partly surmountable	10–30 thousand vehicles per day
K3	Other first class roads	Roads with surmountable physical obstacles (central or side guardrails)	5–10 thousand vehicles per day
P	Local roads	No technical barriers	Under 5 thousand vehicles per day
PZ	No roads		

3.2.2. Railways

A) Barrier Characteristics

The principles of the barrier effect in railways are analogically equal to those in roads and motorways.

1) Route of the Future Railway

Generally, no new railways are currently being constructed in the Czech Republic. Financial means are rather invested in the reconstruction of main rail corridors and shifting of certain parts of railway, particularly in towns. As these constructions are mostly built on existing lines, they cannot be understood as selections of new routes.

However, following the trends of other Western European countries, construction of high-speed rails (HSR) poses a serious challenge for the future. High-speed rails are designed in completely new corridors and accompanied with noise walls or fences along their entire length. The lack of any migration objects makes them completely impermeable. The desire to make use of the speed potential of trains sets very strict technical parameters and considerably limits possible modifications as to the direction or gradient of the routes in the landscape. Special attention will have to be paid to the selection of new routes and to their migration permeability.

2) Technical Solutions

Railways are generally narrower than roads and thus become easier to surmount. Construction of specific migration objects is hence required merely in high-speed corridors. In other cases, investment should mainly aim at reconstructing bridges over watercourses and securing dry paths for fauna under them. The methodology to be applied is determined by the publication Mosty přes vodní toky (Bridges over Watercourses) (Hlaváč & Anděl 2008). Individual spots on common railways may become impermeable for animals when laced with noise walls, abutments, or other technical objects.

3) Traffic

Traffic on railways is much distinct from that on roads. The time intervals between individual trains provide sufficient time for the animals to cross the rails. Even the main railway corridors are surmountable. Nevertheless, animals are still killed on railways. Railways were classified not according to the traffic flow but rather based on categories of their importance.

Overall Permeability

Railways represent a substantially lower risk to fauna migration than roads and motorways. Their final barrier effect is predetermined by a combination of all the above-mentioned factors, which have to be assessed for each

Fig. 3.5. *A multi-track railway with minor modifications of terrain.*

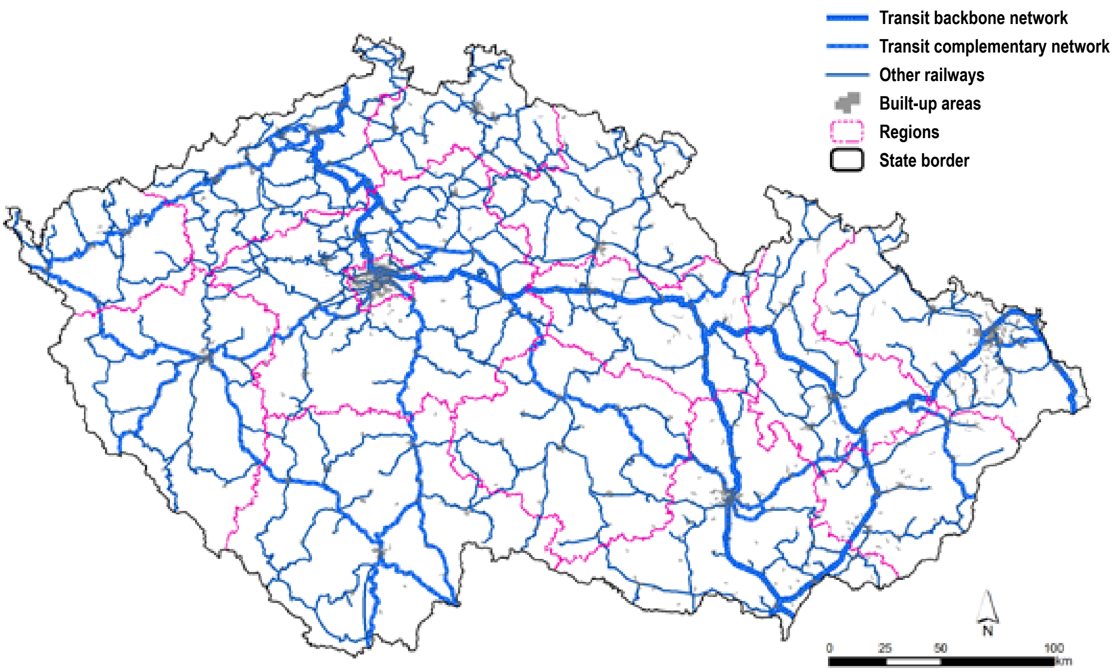

Fig. 3.6. *Map of railway network in the Czech Republic.*

species individually based on the actual conditions of the site under review. The negative impact may manifest itself above all in situations when the barrier effect is accumulated due to the presence of other barriers (roads, settlements).

B) Railway Network in the Czech Republic

Fig. 3.6. gives an overall view of the railway network in the Czech Republic, including classification according to its impact on fauna migration in the landscape. The data on the traffic flow of individual routes were provided by the Railway Infrastructure Administration.

C) Classification of Permeability for Large Mammals

The following chart establishes a framework classification of railways by their permeability for large mammals, which was used to evaluate the sites where railways cross Long-Distance Migration Corridors. Two aspects are subject to evaluation – technical solution and category of railway. The technical solution was assessed within a field survey on site with regard to the actual method of implementation and combination of the given elements. Categories of railways were provided by the Railway Infrastructure Administration. In case the individual criteria showed different potential classification, the less permeable class applied.

Chart 3.3. *Classification of railways by their permeability for large mammals.*

Class	Railway category	Technical solution
K1	High-speed rail (currently not existing in the Czech Republic)	Railways lined with steep slopes and cuts, other technical obstacles; physically insurmountable
K2	Transit corridors, backbone network	Railways with significant physical obstacles, which may be partly surmountable
K3	Transit corridors, complementary network	Railways with minor modifications of terrain
P	Other railways	Railways at the level of the surrounding terrain, no obstacles
PZ	No railways	

3.2.3. Watercourses and Other Water Bodies

A) Barrier Characteristics

Watercourses constitute an essential element that facilitates migration of animals in the landscape. Along with riparian vegetation, alluvial meadows, or floodplain forests, they originally formed one of the fundamental structures of the ecological network in the landscape. Regrettably, the extent of this network has been radically reduced in the past 200 years due to stream regulation, felling of floodplain forests, extending the proportion of arable land, and development in floodplain areas.

Watercourses and other water bodies may become, however, a barrier for migrating animals in the following situations:

1) Wide watercourses or other water bodies – there are a minimum number of such cases in the Czech Republic, in fact, being solely an issue of dams. As all large mammals are good swimmers, these reservoirs do not represent an insurmountable obstacle.

2) Unsuitable technical solution – constructions on the banks of water bodies do not permit free access (mainly concrete or stone walls). This is generally common in navigation channels (e.g., water canals in the Netherlands produce a notable barrier effect). This phenomenon does not signify any serious threat to migrating animals as the number of these sites is limited and mostly restricted to towns. Despite this, a field survey is necessary to determine the conditions of the banks on sites where watercourses cross migration corridors.

B) Network of Watercourses in the Czech Republic

The Czech Republic abounds with small watercourses, which rarely pose any threat to migrating animals. On the contrary, they may be valued for the connectivity function. The map in Fig. 3.8. incorporates data furnished by the Hydroecological Information System of the Czech Republic.

Fig. 3.7. *Technical stream regulation that transforms a positive landscape element into a migration barrier.*

C) Classification of Permeability for Large Mammals

The following chart shows a framework classification of watercourses and other water bodies by their permeability for large mammals, which was used to evaluate the sites where these cross Long-Distance Migration Corridors.

Two aspects are subject to evaluation – the size of the water body and the technical solutions. The technical solutions were assessed within a field survey on site with regard to the actual method of implementation and combination of the given elements. In case the individual criteria showed different potential classification, the less permeable class applied.

Chart 3.4. *Classification of watercourses and other water bodies by their permeability for large mammals.*

Class	Size of water body	Technical measures
K1	Width > 500 m	Watercourses with modified banks that entirely inhibit access
K2	Width 200–500 m	Watercourses with significant technical obstacles that may be partly surmountable
K3	Width 100–200 m	Watercourses and reservoirs with minor modifications of banks
P	Width < 100 m	Watercourses and reservoirs with natural banks
PZ	No water bodies	

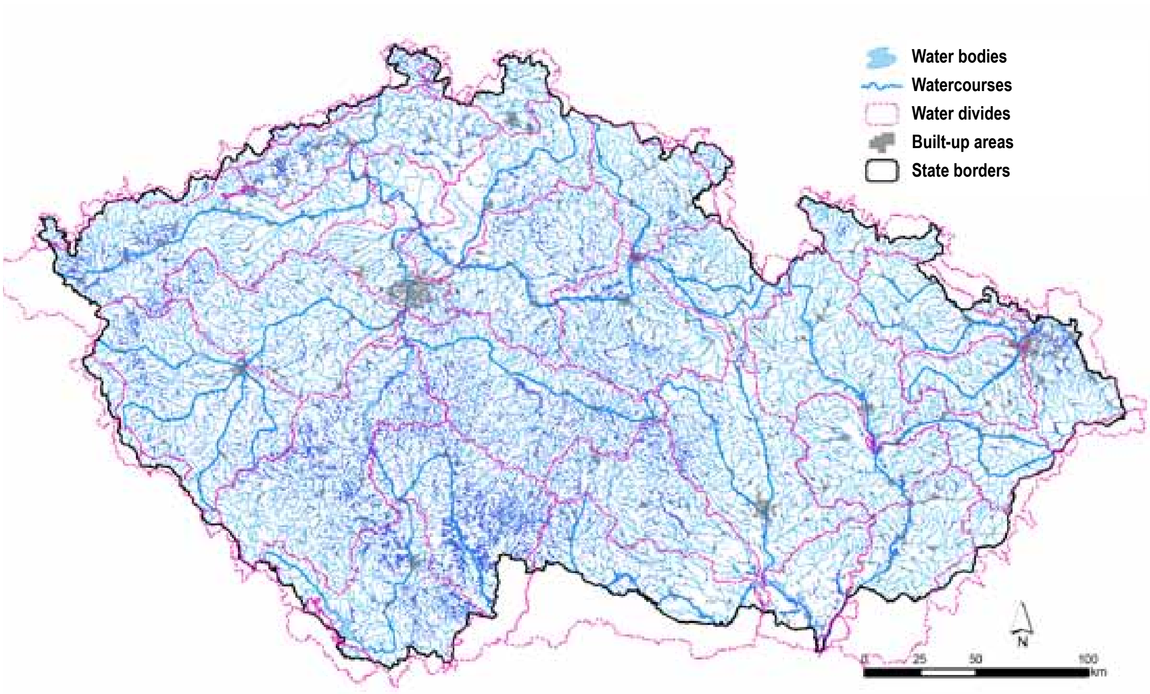

Fig. 3.8. *Watercourses and other water bodies in the Czech Republic.*

3.2.4. Fenced Areas

A) Barrier Characteristics

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

Various types of fences, enclosures, or electric fences, constitute a significant problem in the landscape. While fences permanently fixed to the ground are understood as construction and are subject to a building permit, other (particularly electric) fences are considered a common use of land and may be installed in the landscape without any limitations. Pasture areas consist of tens or even hundreds of hectares of land, i.e. kilometres or tens of kilometres of electric fencing. These constitute vast barriers inhibiting movement of mainly larger animals. The impact of such barriers varies depending on the type of fence and the fauna species. Individual types of fences may be classified in the following manner.

Wire fencing commonly represents a barrier for hoofed game. Its permeability depends on its height and strength (wild boars are capable of tearing low quality fencing). Some animals will skip over a lower fence. The Red Deer or the elk will generally overcome any fencing lower than 2 m. For large carnivores, wire fencing means rather a mental barrier. Undisturbed and well motivated, the animal usually has no problem to surmount (climb or skip over) the fence. This behaviour is known in bears, which get into gardens in search of food. A lynx will have no difficulties to overcome a fence of a game preserve.

Most game-proof fences used to protect newly established forest plantations against game damage may be categorised today as wire fencing. The previously common wooden fencing is being substituted by woven wire fence with large openings. The experience shows that mainly the Roe Deer can find a place to overcome the fence, but later face a problem how to get out of the enclosure. Animals wounded after hitting against the wire fencing are not an exception. Game-proof fencing designed to protect young plantations does not reduce the permeability of the landscape since the size of a regeneration unit is limited by law and does not encompass larger areas.

Wooden cattle pens constructed of two horizontal poles are easily surmountable by all wild animals. However, this type of fencing is currently nearly always accompanied by electric fencing to maximise the efficiency and minimise the risk of cattle escape.

Use of electric fencing is presently the most common way of enclosing pastures, which constitute the most frequent use of land in submountain areas. This implies the importance of this type of fencing. On the other hand, submountain areas are often home to species most threatened by landscape fragmentation. Enclosures of all pastures between individual forest complexes may bring severe problems for the local fauna. The difference between permanent and temporary installation of electric fences substantially influences the actual barrier effect. Temporary installation is such situation when the fence is removed after the period of pasture or at least the electricity is disconnected. The material used for fencing also plays the role. A simple rope is easier to surmount than a textile band, while a stiff wire constitutes the most complicated obstacle. The arrangement of live leads also makes the difference and is usually determined by the species of interest. Fencing for sheep is generally composed of two or three levels of stiff wire, while an enclosure for horses of cattle may be made of a single rope or textile band. Such fencing is easy to surmount for most wild fauna. The elk is presumably the only species that may have problems overcoming the barrier as its body proportions are comparable to those of the animals that are meant to remain within the enclosure. The intensity of the barrier effect also differs in individual species. Carnivores, including large ones (such as wolves or lynxes), are generally capable of interpreting the situation and will find an ideal place to surmount the obstacle. Other species are protected by their thick fur that substantially reduces the electric shock (unclipped sheep are able to overcome electric fencing with no difficulties; sheep pastures thus require fencing using a stiff wire installed at three levels). Thick fur will also help some potentially threatened species, such as the bear, to cross the electric barrier. The direct experience with how animals react to electric fencing shows that it is rather a mental issue than a question of physical abilities. The effect of electric fencing is based on a presumption that the animals will repeatedly experience a painful shock when in contact with the lead. They will gradually establish a mental barrier and will cease attempting to cross the fence. In general, hoofed game easily establishes the conditioned response of a mental barrier. Carnivores will analyse the situation faster and will find their way through the fence. It has also been proven that the actual response to the electric shock coming from the fence is highly individual. There are individual animals of the same species that will repeatedly surmount the barrier regardless their painful experience, whereas other individuals will never attempt to cross the fence or even approach it again. Electric fencing is thus not an absolute barrier as some individuals will always be capable of overcoming it. It is also easily removable with no investment required to enable permeability of the given area. Nevertheless, with respect to the extent of pastures present in submountain areas, this phenomenon deserves adequate attention in order to secure the permeability of the landscape.

B) Distribution of fencing in the Czech Republic

With regard to the above-stated circumstances, the present map only indicates areas with a potentially higher density of fencing. The source data represent vineyards, orchards, and pastures listed in the CORINE Land Cover 2006 database.

C) Classification of Permeability for Large Mammals

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

Chart 3.5. *Classification of fences by their permeability for large mammals.*

Class	Distance between fenced areas	Technical parameters of the fence
K1	< 10 m	Stable, tall fencing (over 2 m); wire, concrete, sheet metal; insurmountable for migrating animals
K2	10–30 m	Stable, hardly surmountable electric fencing
K3	30–100 m	Stable, non-electric fencing difficult to surmount
P	> 100 m	Surmountable fencing (e.g., wooden fence) and temporary fencing
PZ	No fence	No fence

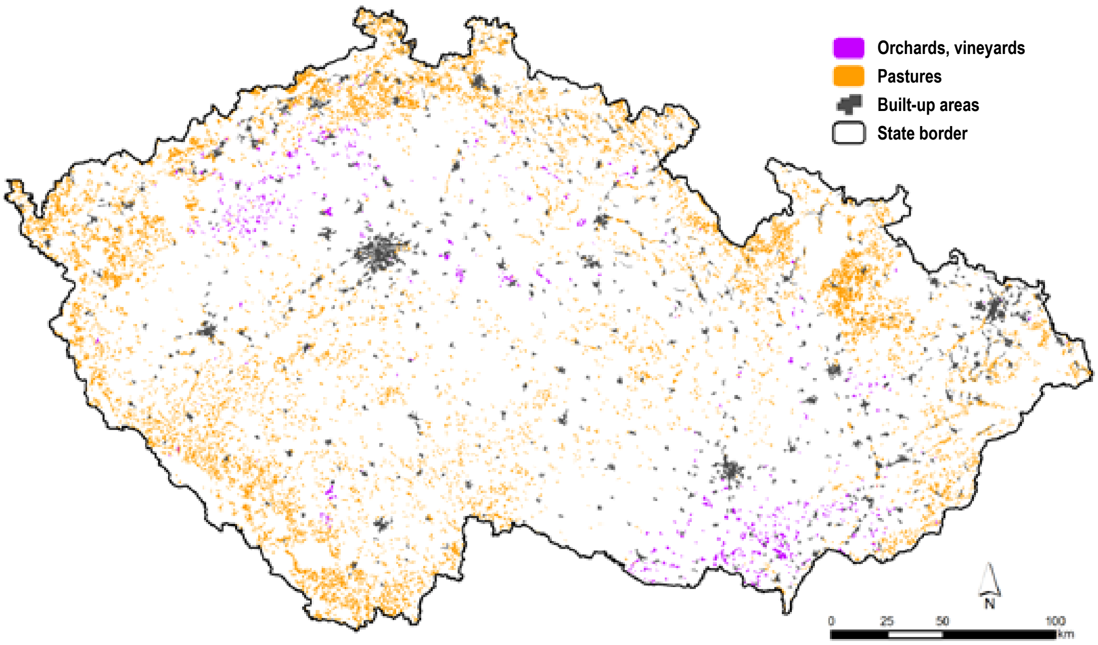

Fig. 3.9. *Areas with potentially higher density of fencing.*

Fig. 3.10. *An example of a vast fenced orchard.*

3.2.5. Settlements

A) Barrier Characteristics

Settlements represent key barriers determining opportunities for a free movement of fauna through the landscape. This category comprises residential areas, but also industrial, agricultural, mining, storage, and commercial precincts and other objects of anthropogenic infrastructure.

Although large mammals have been observed in urban areas, these should be understood as impermeable barriers for them. The level of permeability has to be assessed individually considering the character of the build-up area, its extent, the density, and the distribution of individual objects. Mainly the following situations result unfavourable for migrating fauna:

- Continuous built-up areas in valleys along rivers that form a long line barrier.
- Individual houses scattered over the hillsides – typical, for instance, for the Czech-Slovak border area. Combined with their complementary elements, such as fences and agricultural structures, they constitute vast areas with a barrier effect.

At present, both of the mentioned types of build-up areas manifest themselves to a large extent and result critical in order to secure the connectivity of the landscape. This particularly concerns industrial and commercial complexes established on a green field and settlements outside urban areas, both in large cities (urban sprawl) and practically in any municipality in the country. Not only that new areas are being built-up, but the existing settlements merge and create extensive lines or areas as continuous barriers. As the newly formed character of the landscape is more or less permanent and irreversible, no feasible measures can be adopted to re-establish its permeability. For these reasons, we are facing the most crucial negative impact both from the point of view of the landscape connectivity and nature conservation as such.

B) Distribution of Settlements in the Czech Republic

The map below illustrates the distribution of settlements in the Czech Republic. The barrier effect overlaps the borders of urban areas. Settlements are delimitated with buffer zones, with their extent depending on the size of the given settlement.

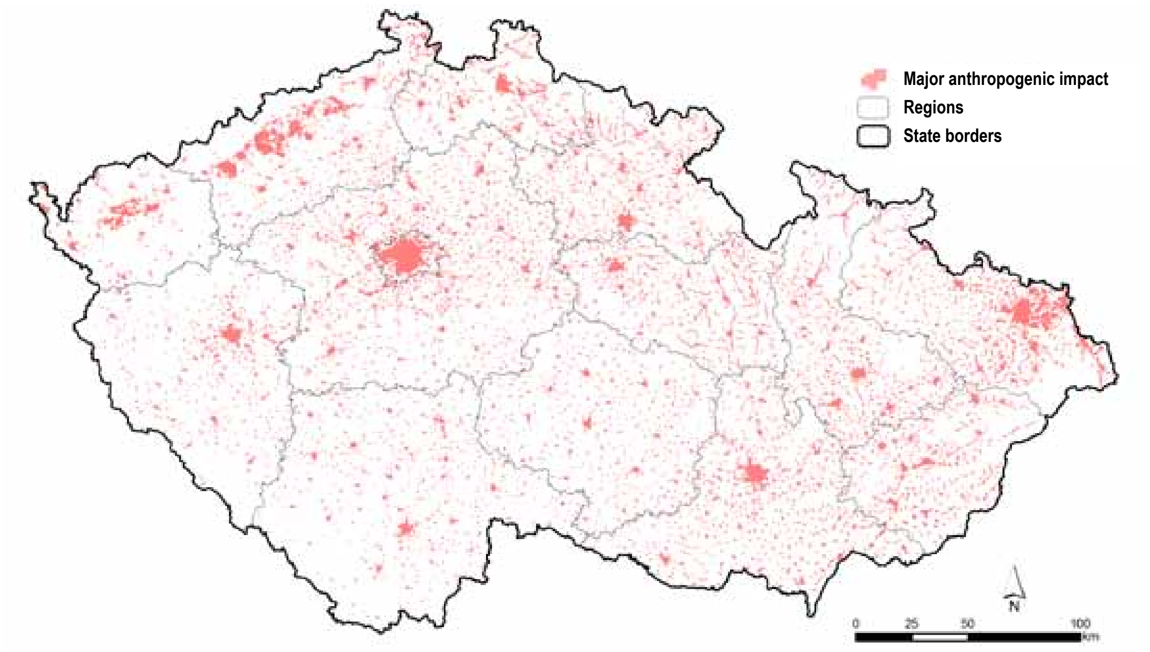

Fig. 3.11. *Areas with a major anthropogenic impact in the Czech Republic, i.e. urban areas, industrial zones, and opencast mines.*

Fig. 3.12. *Urban sprawl. Further land take for construction purposes in rural areas represents a serious fragmentation factor.*

The following data sources were utilised:

- residential areas and settlements – derived from topographic data and CORINE Land Cover 2006 database,
- planned industrial zones – data based on the Spatial Development Policy, Principles of Spatial Development in individual regions, and data delivered by the Centre for Regional Development of the Czech Republic, which list records on planned industrial zones in individual municipalities.

C) Classification of Permeability for Large Mammals

Urban areas and other infrastructure are generally considered as impermeable, i.e. class K1. The classification thus aims at areas between settlements, i.e. the extent of free zones permitting migration. We distinguish migration spaces between settlement complexes and among isolated structures scattered in the landscape. The open width of the given space is the main influencing factor. Nevertheless, the length of the passage also has to be considered in specific cases.

Chart 3.6. *Classification of settlements by their permeability for large mammals.*

Class	Free distance between villages, towns	Free space between scattered structures
K1	Continuous built-up area, less than 50 m	Scattered structures, less than 10 m
K2	50–100 m	10–30 m
K3	100–500	30–100 m
P	More than 500 m	More than 100 m
PZ	No settlement	No settlement

3.2.6. Unsuitable Habitats – Non-forest Area

A) Barrier Characteristics

Certain extensive habitats may also represent a barrier for migrating animals in the landscape. They do not match their ecological requirements and the animals tend to avoid them. These types of potential migration barriers have to be judged individually for each species. The demands of most species on their habitats vary throughout their life cycle (different requirements concerning the permanent range, mating areas, or migration), which makes the precise classification even more complicated. Other factors, such as climate, play a substantial role as well. Despite the methodology challenges, this type of barriers deserves adequate attention.

Considering the species of large mammals, whose primary habitat is the forest, non-forest areas constitute the most significant group of barrier habitats. When moving through the landscape, the animals are forced to overcome open spaces, i.e. areas that they usually instinctively avoid. The structure of the landscape – combination of forests and non-forest areas in a rougher or finer landscape mosaic, and presence of dispersed vegetation – essentially affects the potential to surmount the open space.

B) Distribution of Barriers in the Czech Republic

The graph in Fig. 3.13. and the map in Fig. 3.15. depict the distribution of non-forest areas in the Czech Republic while taking into consideration the distance to the nearest forest. The sizes of areas were derived from topographic data and the CORINE Land Cover 2006 database.

C) Classification of Non-forest Areas by Their Permeability for Large Mammals

The concept of classification is based on the assessment of a migration corridor that leads through a non-forested landscape, considering the distance between individual forest covers that the animal is forced to overcome. We distinguish a non-forested landscape lacking tree species and a landscape with dispersed vegetation.

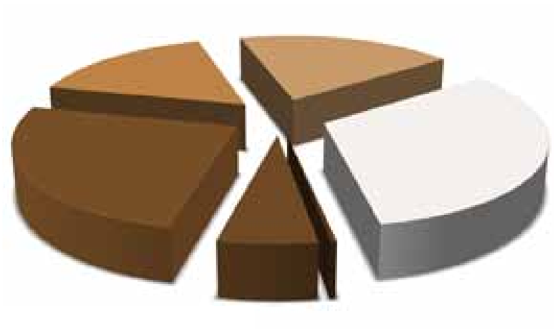

Fig. 3.13. *Share of individual classes of non-forest areas in the Czech Republic.*

Chart 3.7. *Classification of non-forest areas by their permeability for large mammals.*

Class	Landscape lacking tree species	Landscape with dispersed vegetation
K1	Over 5 km	Over 10 km
K2	2–5 km	5–10 km
K3	0.5–2 km	2–5km
P	Under 0.5 km	Under 2 km
PZ	Forest	Forest

Fig. 3.14. *Agricultural landscape with a minimum cover of dispersed vegetation constitutes a considerable migration barrier.*

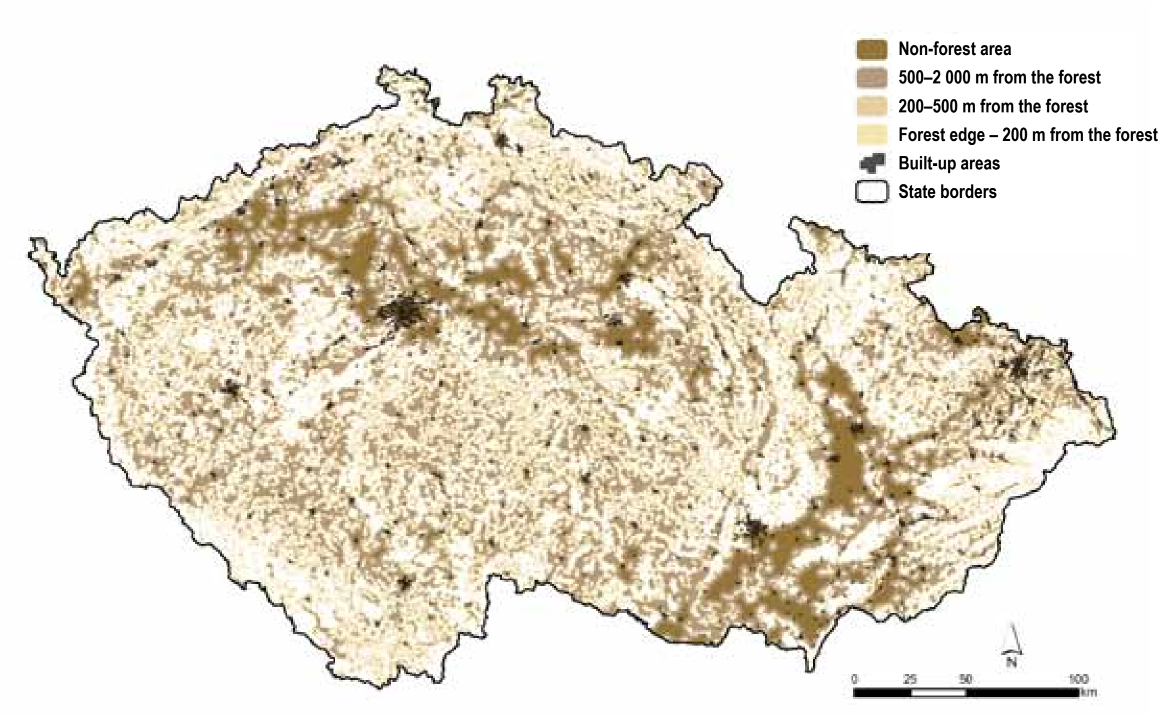

Fig. 3.15. *Distribution of non-forest areas in the Czech Republic.*

3.3. CUMULATIVE EFFECT OF BARRIERS AND OVERALL PERMEABILITY OF THE LANDSCAPE

As emphasised in Chapter 3.1., migration barriers should be viewed individually considering their direct effect on site, their potential accumulation, and the permeability of the landscape as a whole. A landscape composed of a dense network of migration barriers becomes hardly permeable even when individual barriers do not represent a significant limiting factor.

The cumulative effect of barriers should be assessed at two levels:

- Local level – the field survey and verification of permeability of the migration corridor on the given location should seek to assess the potential cumulative effect of all existing barriers. Most frequently, these include a combination of two road classes (e.g., a motorway and its supporting side road), roads and railways, a settlement and a road, a watercourse with managed banks and a parallel road, etc. Vast non-forest areas largely increment the cumulative effect of barriers. The final level of barrier accumulation and the permeability of the site have to be evaluated by experts within a field survey directly on the site.
- National level – based on the structure of settlements, the density of settlement and road network, and the distribution of non-forest areas, we may identify areas that pose a more potential threat as a whole. The output data from the model of the landscape potential described in Chapter 5 were used for identification. The map of areas with a higher cumulative effect of migration barriers presented in Fig. 3.16. illustrates that most affected are sites in lowlands, where the dense settlement and the road network are accompanied by farmland, i.e. non-forest land augmenting the barrier effect.

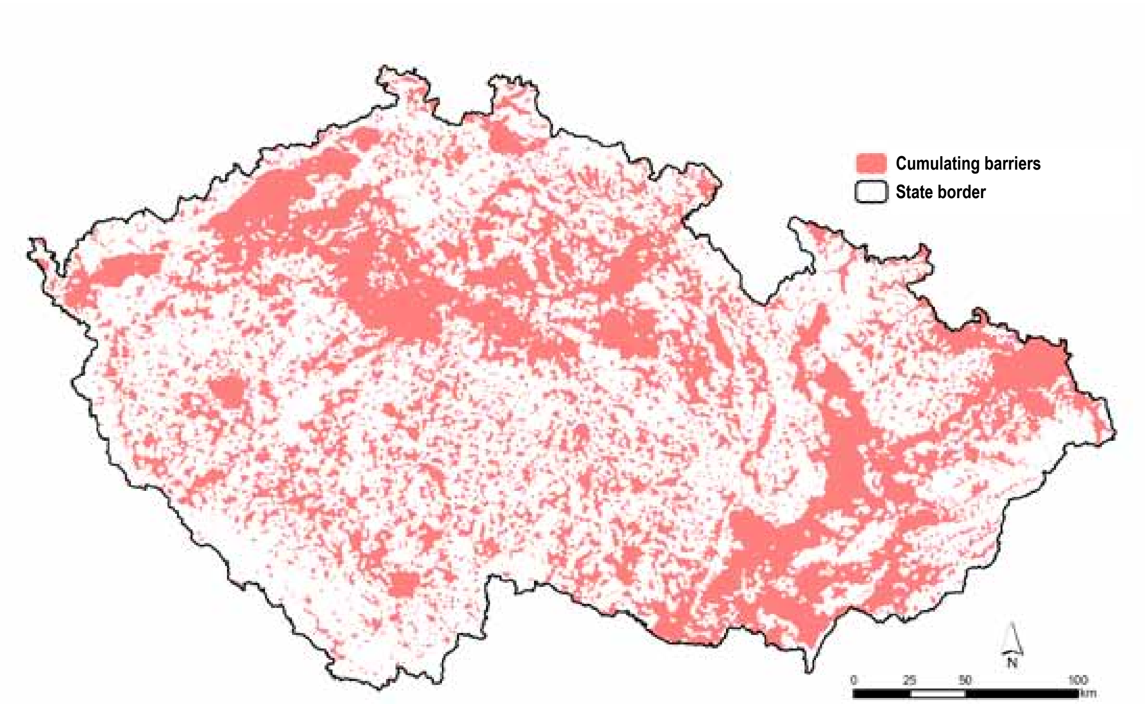

Fig. 3.16. *Areas characteristic with a high cumulative effect of migration barriers.*

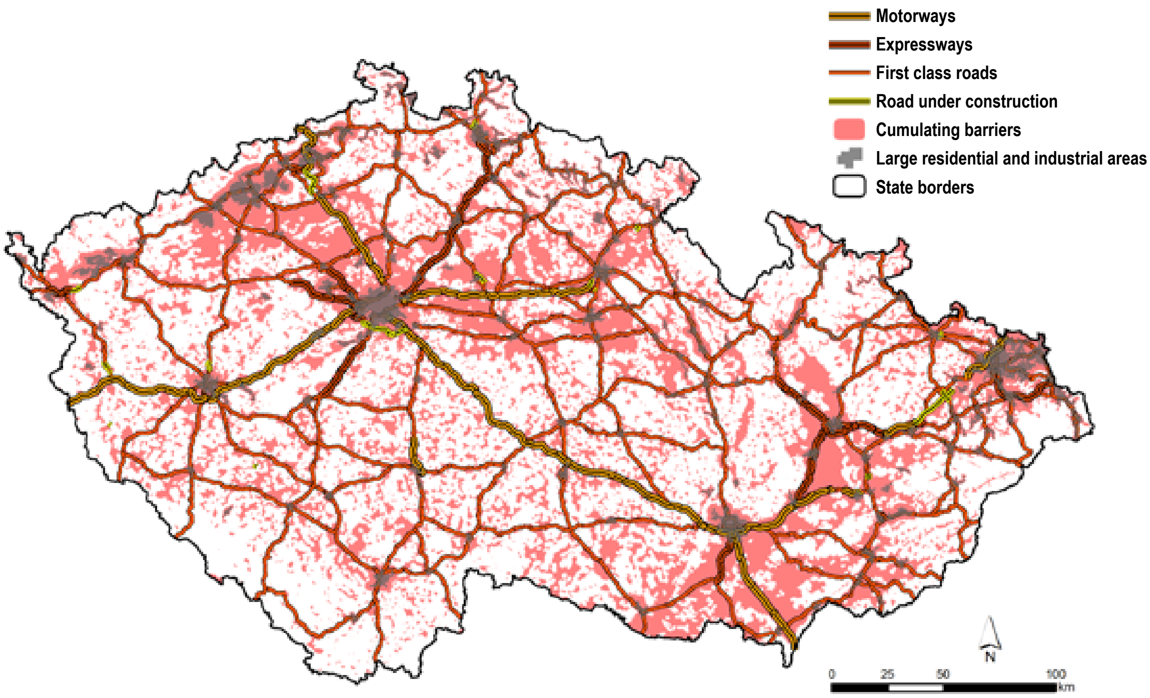

Fig. 3.17. *General map of main barriers in the Czech Republic.*

3.4. PARTIAL CONCLUSION ON MIGRATION BARRIERS

This report presents several output maps. One of them is the global map of migration barriers in the Czech Republic (see Fig. 3.17.). It determines the most significant types of individual barriers (roads, railways, settlements, locations with a potentially high density of fenced areas), and areas threatened by a potentially strong cumulative effect of migration barriers.

Migration barriers produce a varied and dynamic system and relate to various agricultural activities. It is important to note that, besides the two essential types of barriers (i.e. settlements and transport infrastructure), those involving agricultural practices also play their part.

All types of migration barriers are subject to development and create pressure on the landscape. Should we wish to avoid or minimise further fragmentation of the landscape in the Czech Republic, the sources of such fragmentation need to be regulated. Spatial planning represents the fundamental instrument to be applied to this end.

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4.

Habitat Models for Focal Species of Large Mammals

Dušan Romportl, Michal Andreas, Luděk Bufka, Eva Chumanová & Martin Strnad

4.1. INTRODUCTION

As a result of the historical development, the cultural landscape of the current Central Europe forms a diverse mosaic of habitats showing various levels of anthropogenic impact. The present trends in land use lead to its further fragmentation and to deterioration of the connectivity of habitats suitable for permanent occurrence of large mammals. Large carnivores (lynx, wolf, and bear) and herbivores (elk) with high territorial requirements inhabit today merely a few separated islands (patches) of suitable environment. However, the Czech Republic has a number of areas of various sizes that provide favourable conditions for the permanent or temporary occurrence of the mentioned species, whether for their populations or for individuals. Such places can be identified and delimited based on expert assessment or outputs of mathematical modelling of relationships of the given species to relative variables of the environment. The present chapter aims to introduce the method and outputs of models assessing habitat preferences in the given species and to propose practical applications for the process of delimiting the network of migration corridors for large mammals.

Habitat suitability modelling for the studied species is presently a widely applied approach in conservation biology (e.g., Hernandez et al. 2008, Hirzel et al. 2006, Václavík et al. 2009). The methods find their use in conservation of endangered species and in spatial protection of valuable habitats (e.g., Bassille et al. 2008, Braunisch & Suchant 2007, Rottenberry et al. 2006); similar methods are applied in modelling potential threats to ecosystems posed by invasive species (e.g., Ellis et al. 2010, Strubbe & Matthysen 2008). Their use is purposeful when evaluating environment preferences in specific species (e.g., Braunisch et al. 2008, Mertzanis 2008, Zimmermann et al. 2002) or when demarcating areas affected by a conflict between anthropogenic activities and nature conservation (e.g., Beier et al. 2008). To delimit coherent networks of migration corridors, modelling a potentially suitable habitat appears to be an appropriate instrument that enables determination of the potential of the landscape to host permanently or temporarily the populations of the focal species. The herein introduced approach was applied in the present research study to delimit the core areas of potential occurrence of the studied species and to classify the landscape by its importance for migration.

4.2. METHODS, DATA, AND TOOLS

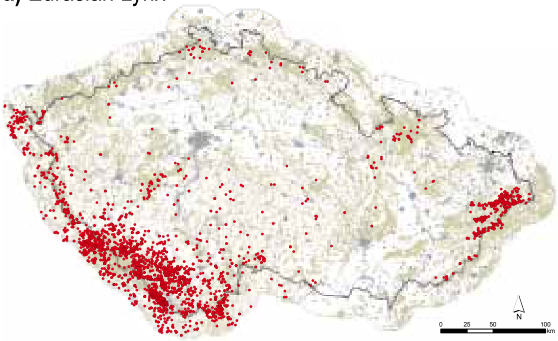
Modelling of the landscape potential to host the specified fauna species is grounded on a comprehensive evaluation of the relationship of the given species to the environmental variables. The methodology comprises several successive steps. First, the data on the species distribution are analysed. The second step involves preparation of background data characterising the environmental variables. The key phase is to establish a habitat model for the given species. The model outputs are applied in spatial analyses to determine the core areas of the potential occurrence of the species. Employing the method of least-cost path modelling, the core areas are further connected based on the outputs of habitat models.

4.2.1. Analysis of Data on the Occurrence of Focal Species

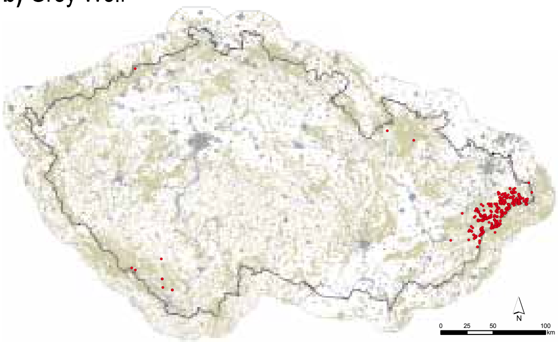
The quality of the input data on the distribution of the studied species is a crucial parameter and determines the method of the habitat analysis processing. The frequency, precision, and validity of the acquired records of large mammals substantially affect the quality of the final model. Adequate attention should be paid to the initial preparations of the records of species since their character is decisive as to which type of model will be applied.

The present project utilised data supplied from the database of central Records of Species of the Agency for Nature Conservation and Landscape Protection of the Czech Republic (NDOP AOPK), which covers all respective data for the country. In case of large carnivores (Eurasian Lynx, Grey Wolf, Brown Bear), the available data provide both point and polygonal layers of records, including the level of their reliability (Fig. 4.1.). However, the mentioned database does not contain sufficient data on the occurrence of the Eurasian Elk and the Red Deer. Other information sources (such as questionnaires to hunting organisations) provide incomplete data that are difficult to localise. For the above reasons, solely data on the occurrence of large carnivores were applied in habitat models. The database regarding the Eurasian Lynx was extended thanks to the data supplied by the Bavarian partner and the authorities of Upper Austria, which significantly increased the variability of the environment of the species occurrence. The geographical distribution of all the studied species is discussed in more detail in chapter Biology and Ecology of Focal Species. The present chapter deals purely with its relation to the model qualities.

a) Eurasian Lynx



b) Grey Wolf



c) Brown Bear

Fig. 4.1. *Occurrence of focal species after 1985 (source: Records of Species of the Agency for Nature Conservation and Landscape Protection of the Czech Republic ©, 2009, Hnutí Duha, CELTIC) – a) Eurasian Lynx (3 978 records), b) Grey Wolf (433 records), c) Brown Bear (154 records).*

The input data on the occurrence of focal species of interest were expressed in the point layer, ESRI shapefile format. They were subsequently covered with a 500 × 500 m grid covering the entire territory of the Czech Republic and the surroundings delimited by a buffer zone reaching 20 km beyond the state border to cover all suitable cross-border sites. Records were counted in each cell of the grid and the layer was transformed into a binary grid (1 – record, 0 – no record). All data on the occurrence of carnivores were processed in this manner.

4.2.2. Environment Data Processing

Processing of relevant data on the character of the environment is the next phase towards the creation of a habitat model. As is the case of the species occurrence, the selected way of expressing these data also influences the overall result of the analysis. The preparation of environment variables is, to a certain extent, limited by the availability of the required information. While some of the principal factors of the natural and anthropogenic impact can be expressed easily, a number of other environment variables can be neither conveyed as data nor visualised in the GIS environment (e.g., prey density, anthropogenic disturbance). The following environment parameters were set as input variables:

Abiotic Factors

- Elevation – expressed as a mean elevation above sea level in individual cells of a grid of 500 × 500 m, over a digital relief model SRTM 100 × 100 m, using Zonal Statistic Extension Spatial Analyst for ArcGIS.
- Vertical heterogeneity – expressed as a standard deviation in elevation within individual cells of a regular grid, also using the Zonal Statistic function (source data DEM SRTM 100 × 100 m).

Habitat Factors

- Type of habitat – expressed as a percentage of individual classes of the landscape cover based on the CORINE Land Cover 2006 database (EEA 2009) within individual cells of a grid of 500 × 500 m.
- Distance from the forest – expressed as a Euclid distance of cells of a regular grid from the nearest forest complex, derived from the CORINE Land Cover 2006 database.

Factors of Anthropogenic Disturbance

- Distance from settlements – expressed as a Euclid distance of individual cells of 500 × 500 m from the nearest settlement (CORINE Land Cover 2006 database).
- Road density – expressed as kernel density of roads and motorways weighted by traffic flow.

The presented data sets characterise the essential environmental conditions, i.e. factors enhancing occurrence and variables causing a reduced population density or non-occurrence of the species of interest. All data were transformed into a single format of an ESRI grid of 500 × 500 m and subsequently into the IDRISI RST format, which is available in both of the applied tools. The variables are depicted in Figures 4.2. to 4.7.

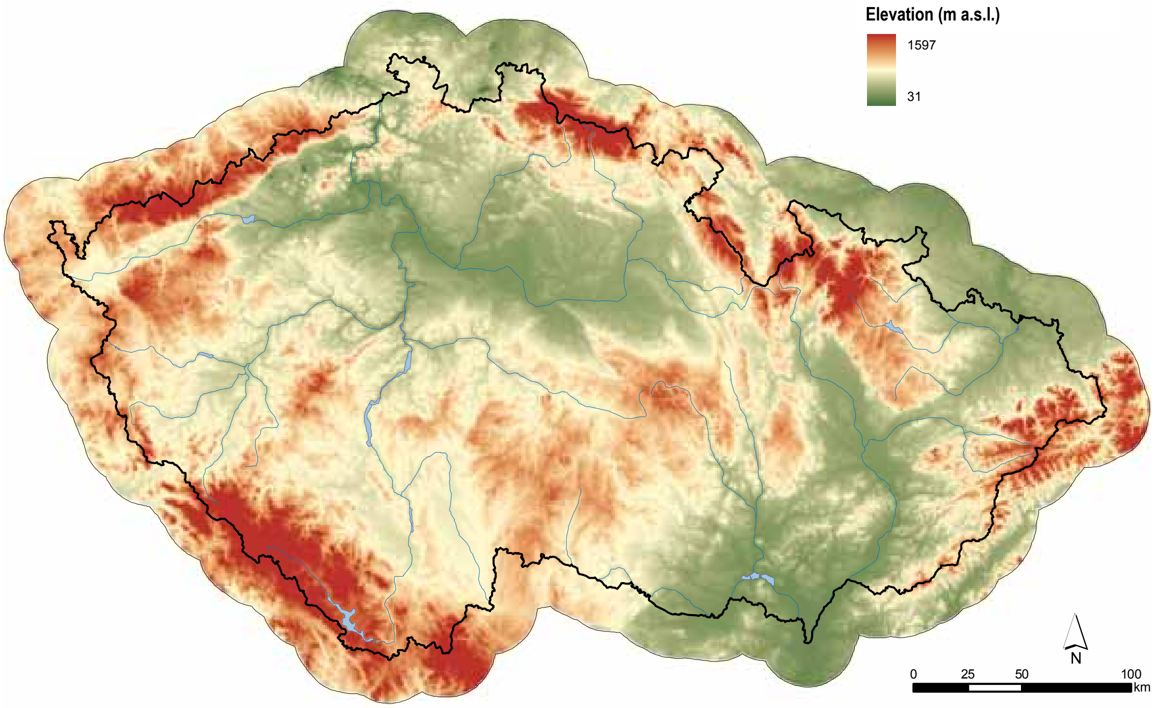


Fig. 4.2. *Elevation (source: DEM SRTM 100 × 100 m 2009).*

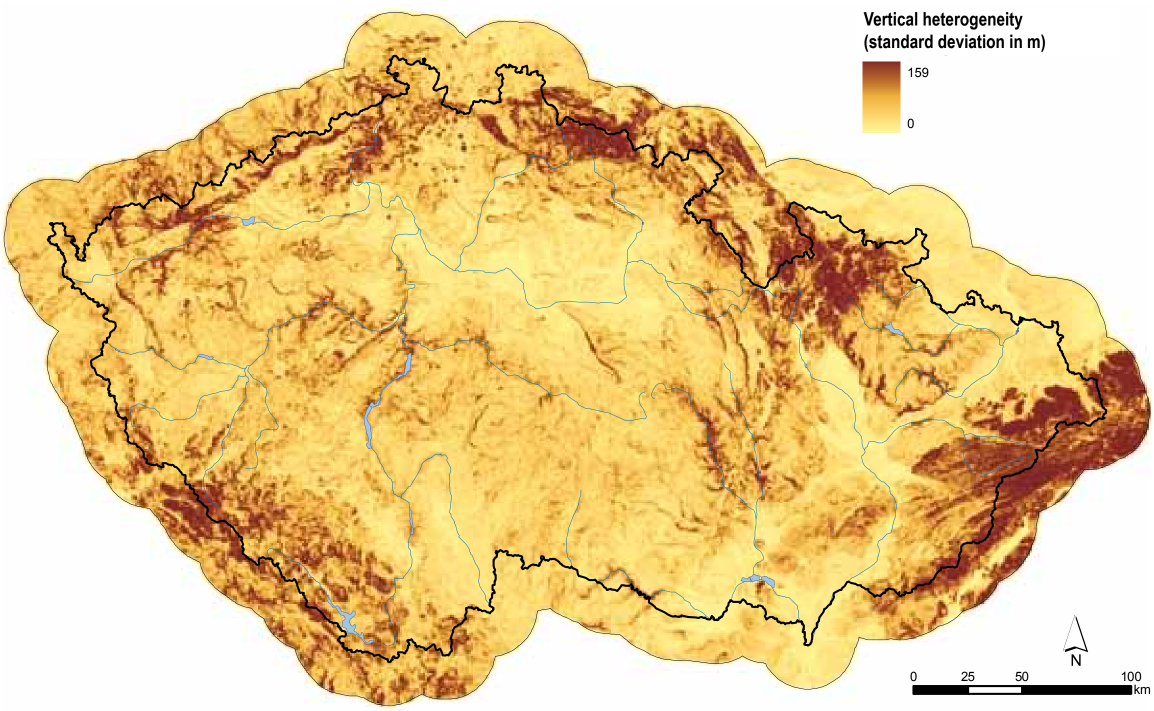


Fig. 4.3. *Vertical heterogeneity (source: DEM SRTM 100 × 100 m 2009).*

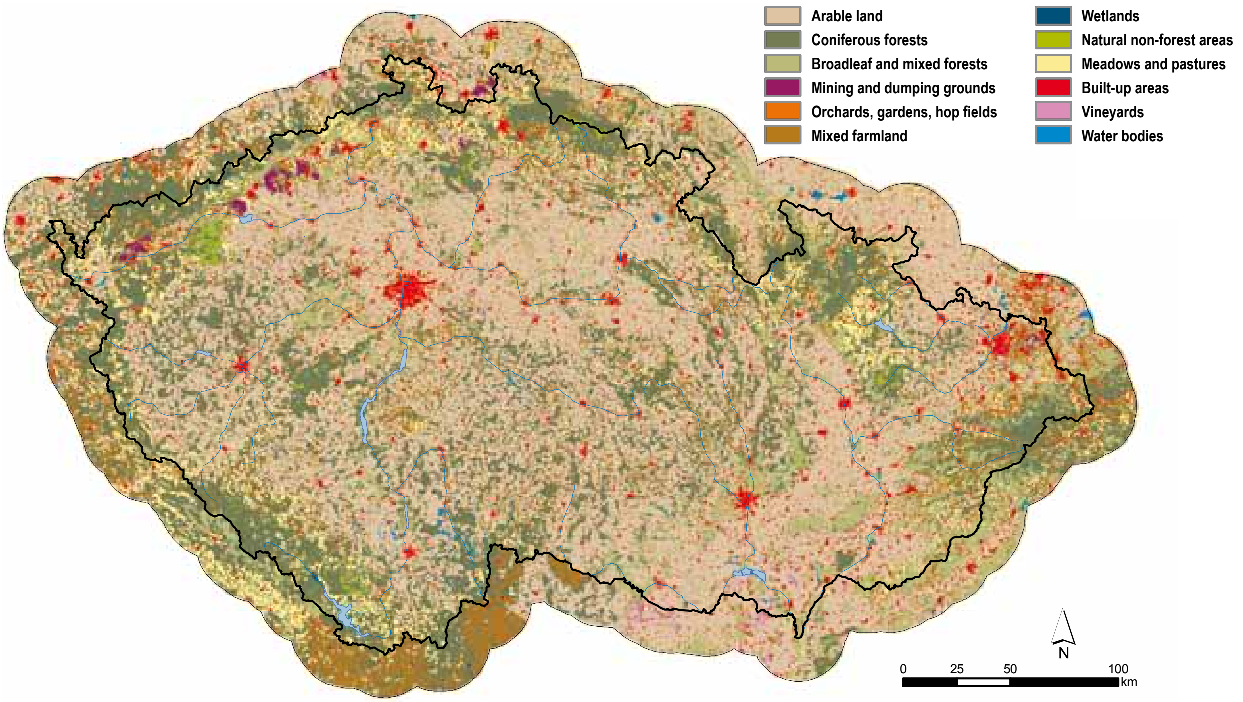


Fig. 4.4. *Land cover – generalised classes (source: CORINE Land Cover 2006, EEA 2009).*

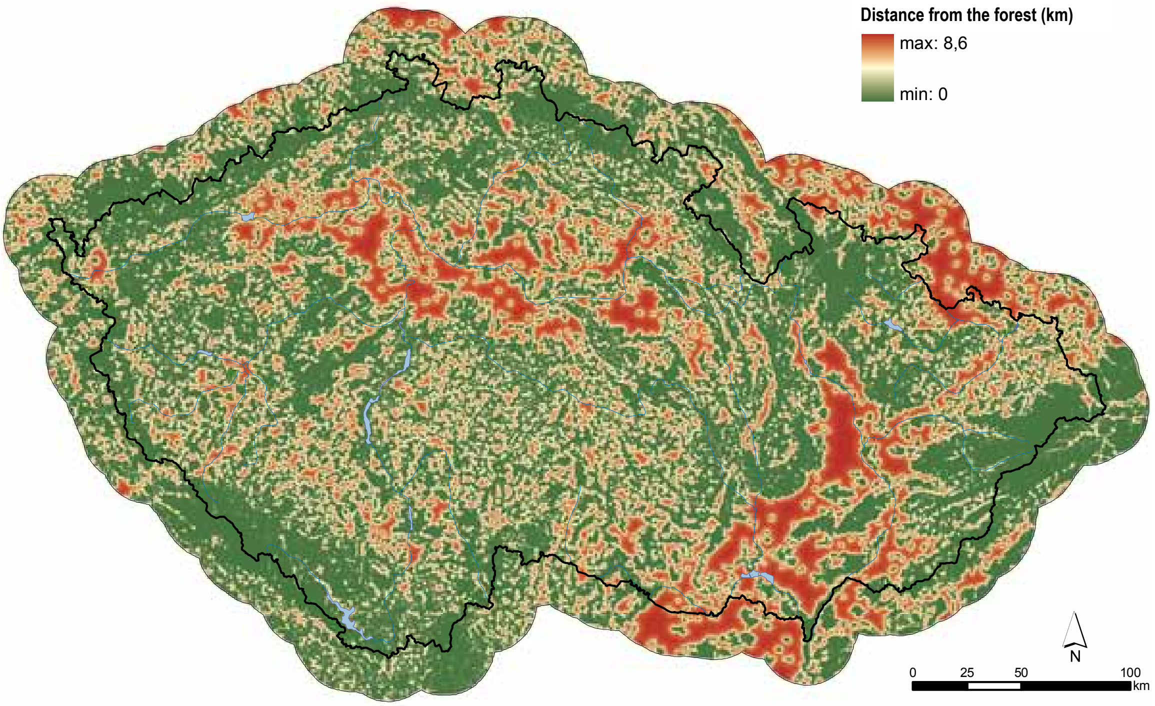


Fig. 4.5. *Distance from the nearest forest stand (source: CORINE Land Cover 2006, EEA 2009).*

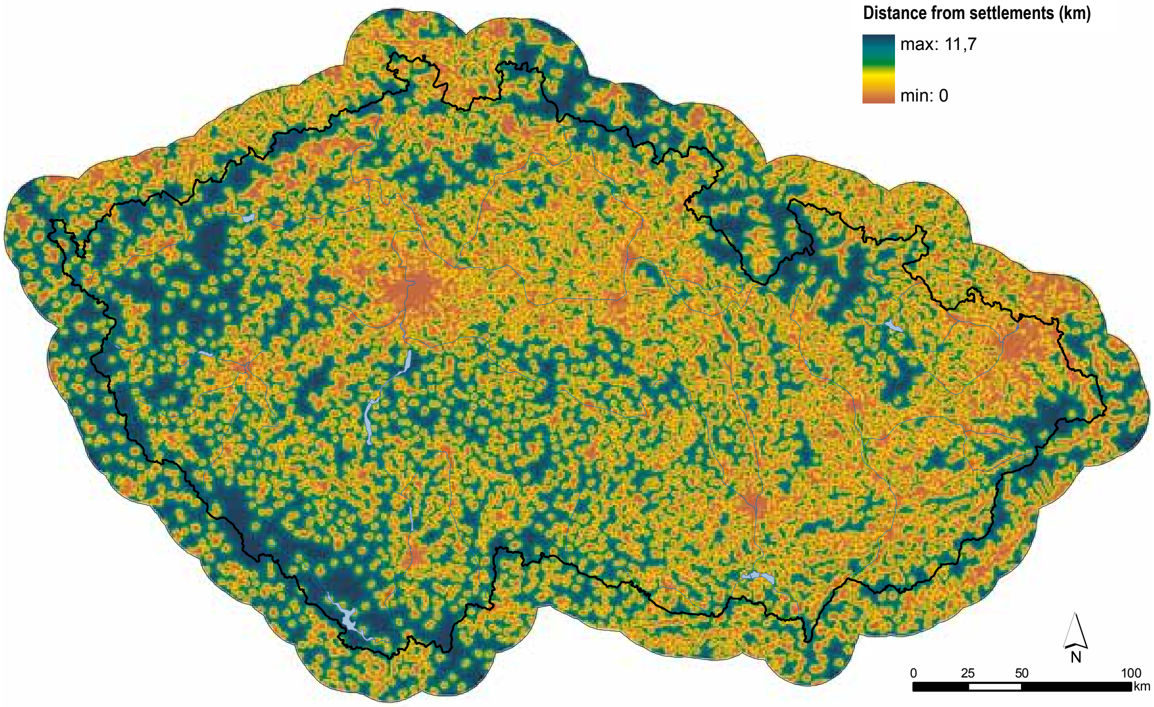


Fig. 4.6. *Distance from the nearest settlement (source: CORINE Land Cover 2006, EEA 2009).*

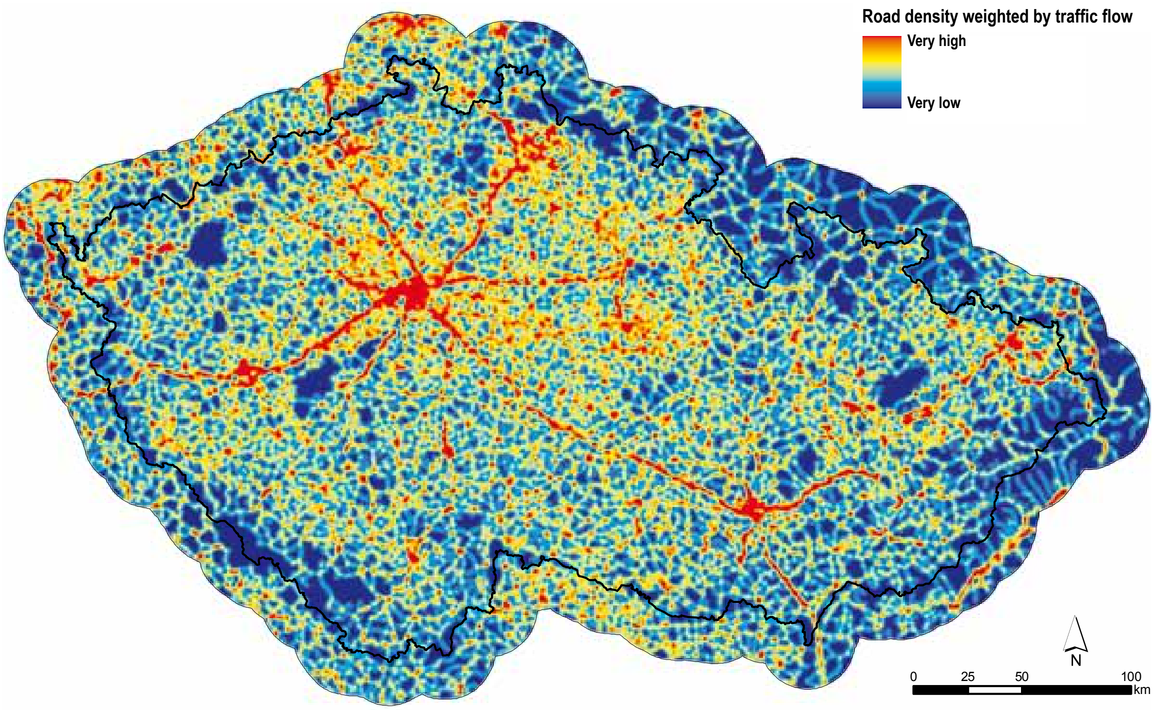


Fig. 4.7. *Road density weighted by traffic flow (source: OpenStreetMap ©, geofabrik.de).*

4.2.3. Processing the Habitat Model

Depending on the character of the records and the methods of their collection, we have to select a type of models that differ in the processing methods. The AOPK database includes only standard records, which predestined the modelling to the use of only-presence data. The following models were selected in this respect:

- Environmental Niche Factor Analysis (ENFA), which is applied within a standalone programme BIOMAPPER (Hirzel et al. 2002).
- Model based on calculation of Mahalanobis distance, i.e. a geometric distance from the ideal value of the given variable (Eastmann 2006). This algorithm is used in Habitat Modelling extension Land Change Modeler for ArcGIS, developed by Clark Labs in the USA (Eastmann 2006).

Both of the above-mentioned models were implemented to establish habitat models for the given focal species. The outputs were compared and only those of the model applying Mahalanobis distance were used for further processing. The spatial requirements were further analysed over the models using the Corridor Designer tools (Majka et al. 2007).

4.3. OUTPUTS OF THE HABITAT MODEL AND APPLICATION

The model outputs constitute a grid characterising the suitability of the environment for the given species at the scale from 0 to 100% (see Fig. 4.8. to 4.10.) and tabular results expressing the contribution of individual environment variables to the spatial distribution of the range of habitats.

The model outputs clearly demonstrate the relation of the above-stated aspects of the environment to the geographic distribution of habitats favourable for the occurrence of large carnivores. Obviously, the largest areas offering suitable conditions for the permanent occurrence of the studied species are located in mountain forests. Large carnivores inhabit the Šumava, the Moravskoslezské

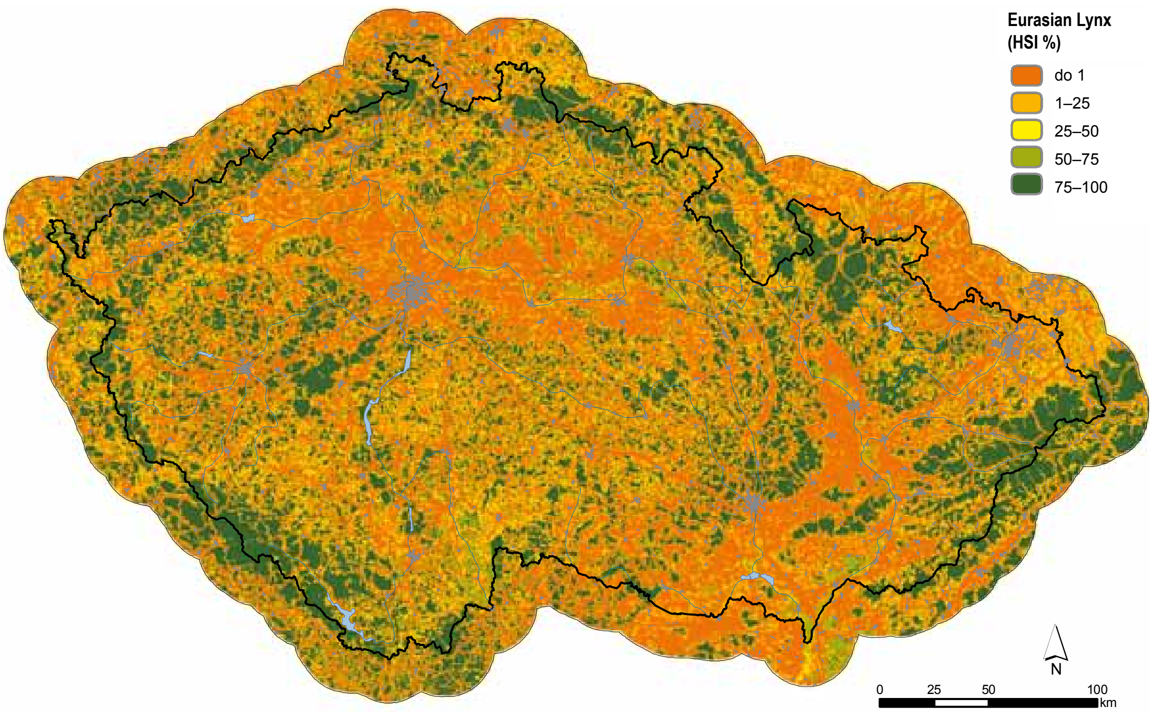


Fig. 4.8. *Habitat model outputs – Eurasian Lynx.*

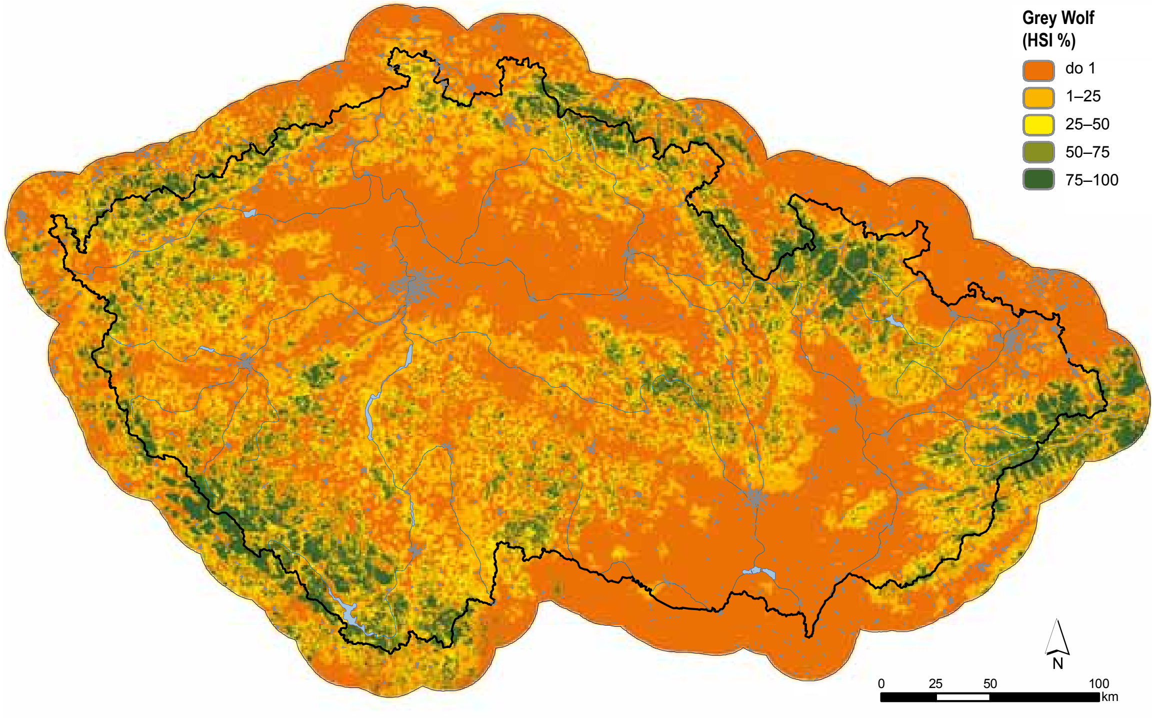


Fig. 4.9. *Habitat model outputs – Grey Wolf.*

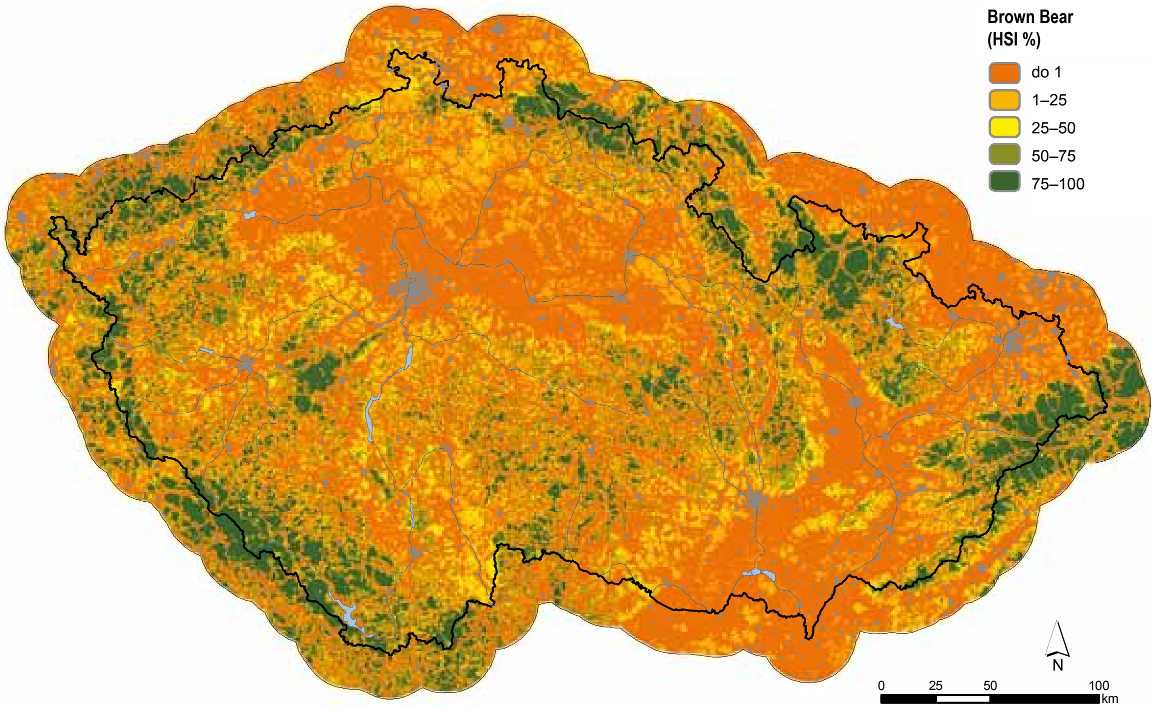


Fig. 4.10. *Habitat model outputs – Brown Bear.*

Beskydy, and the Javorníky Mts. A great potential for their occurrence was ascertained in the wider area of the Hrubý Jeseník Mts., Kralický Sněžník, the Rychlebské hory Mts., the Krkonoše, and in the adjacent forest complexes in the Jizerské hory Mts., on both sides of the state border.

A notable share of suitable habitats can also be found in the Novohradské hory Mts. and neighbouring Waldviertel in Austria, along both sides of the state border in the Český les, and in the Krušné hory Mts. The size of inland areas is limited, so they can sustain a smaller number of individual animals. These are mainly preserved military zones, i.e. the Brdy Mts., Boletice, Hradiště, the Doupovské hory Mts., Libavá, and military training area Březina. Highlands in certain Protected Landscape Areas, such as the Slavkovský les or the Žďárské vrchy Hills, or some still legally unprotected areas, such as the region of Nová Bystřice, also involve areas with a relatively high proportion of less fragmented suitable habitats. Islands of habitats suitable for all carnivores may be found in a number of forest complexes, at middle and high elevations and more distant from towns and roads.

It is reasonable to verify each model confronting it with an independent data set. However, such data sets are not available in the AOPK database for the Brown Bear and the Grey Wolf. Data on the Eurasian Lynx may be verified and complemented when compared to the telemetry data acquired by the staff of the Administration of the National Park and PLA Šumava. For these reasons, only the habitat

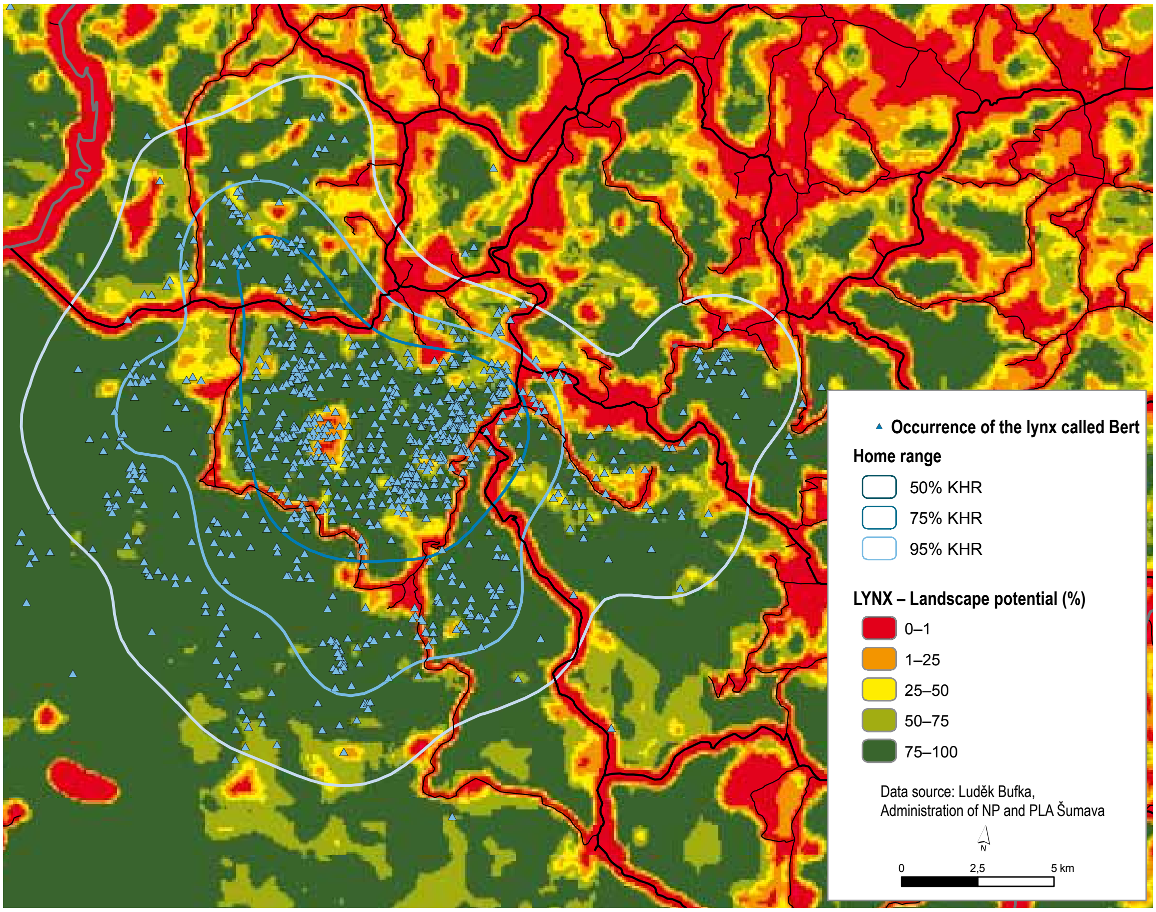


Fig. 4.11. *Illustration of various shares of suitability of habitats in the home range of an adult male lynx (source: database of the Administration of NP and PLA Šumava; own calculations).*

model data concerning the Eurasian Lynx were used for further analyses aimed at delimiting concrete areas with potential occurrence of the focal species. The model outputs were compared to the detailed findings regarding the movement of animals monitored by GPS telemetry.

The analysis showed that even home ranges of residential males of the lynx contain a high share of unsuitable habitats. On the other hand, the favourable environment forms quite a continuous matrix. The adult male Bert occupied a very favourable environment within a wider area of the Šumava Mts. It was verified that within its home range expressed as 95% kernel home range, the most suitable habitat (Habitat Suitability Index – HSI over 75%) was represented merely on 69% of the total area. By contrast, 18% of the given area is covered by unsuitable and the worst habitats respectively (HSI 0–25%) (see Fig. 4.11.).

The basic indicators, such as the proportion of habitat suitability classes and their connectivity and fragmentation, were calculated. These calculations involved home ranges of selected residential adult and dispersing juvenile males, which had been monitored by GPS telemetry in National Park and Protected Landscape Area Šumava. The obtained data were used to adjust the spatial parameters for the delimitation of particular sites suitable for the permanent or minimum temporary occurrence of the lynx.

For the purpose of the study, the defined sites are understood as core areas and stepping stones. The continuous network of potential migration corridors is established on their basis. They were delimited according to the results of expert surveys and evaluations. At the same time, the potential corridors were modelled using least-cost path modelling (for more information, see Romportl et al./subm./).

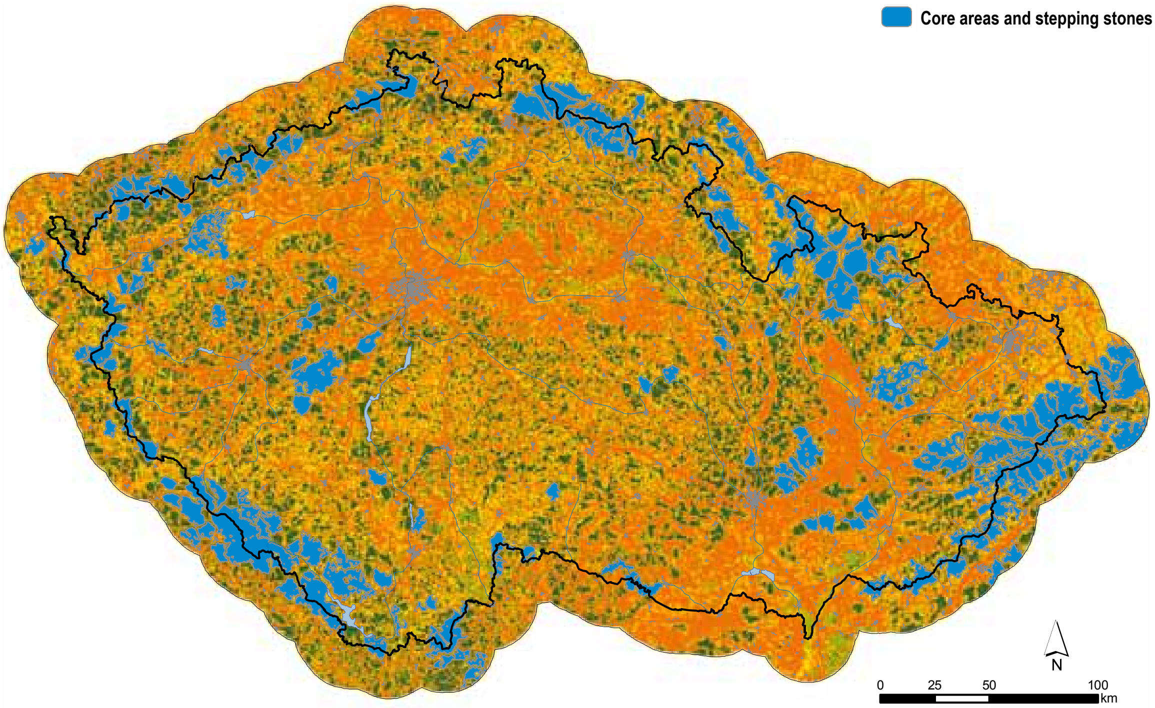


Fig. 4.12. *Delimitation of core areas, areas with potential temporary occurrence, and stepping stones (source: database of the Administration of NP and PLA Šumava, own calculations).*

4.4. DISCUSSION AND CONCLUSION

The aim of the above-presented part of the project was to analyse the landscape potential to host the studied species in the Czech Republic, including the adjacent areas in neighbouring countries. Repeatable quantitative methods based on objective spatial data were applied to this end. As a practical outcome, core areas and stepping stones were defined, which serve as the basis for determination of migration corridors.

The outputs of habitat models are influenced by the character of the input data, particularly by the quantity a precision of the data reflecting the occurrence of the given species and by the absence of other relevant data on the quality of the environment. Due to the limited amount of records of the wolf and the bear, and the absence of independent data that would verify the model, the subsequent spatial analyses used only the outputs of the lynx habitat model. The Eurasian Lynx appears to be an ideal model species as sufficient data and information are available as to its occurrence, spatial requirements, and dispersal. Thanks to telemetry monitoring, the modelled corridors can be compared to the actual occurrence of the migrating animals. It was proven, however, that the lynx also moves through highly unsuitable habitats within its home range.

The landscape potential models and the subsequent delimitation of corridors are based on a presumption that the focal species does not substantially change its behaviour during its long-distance migration and that it will use the environment equally to the site of its permanent occurrence. This presumption has been subject to criticism in several studies though (e.g., Horskins et al. 2006). Despite this fact, no other methodology concept based on mathematical and statistical analysis has been introduced yet. Landscape genetics probably represent the most precise approach how to define the spatial requirements of the species and how to determine the existing migration barriers. Models based on formalised expert assessment that issue from multicriteria analysis constitute another option. This type of model is addressed in the following chapter. Habitat models currently remain the most widespread tool applied to delimit the ecological networks predestined for biodiversity conservation.

The outputs of the project are implemented at two blended levels. The primary outputs of the applied research are acquired at the theoretical and methodological level and involve the afore-presented habitat preference model. At the practical and technical level, these outputs have to be transformed into current planning practices. This is the only way to reduce successfully the negative impacts of changes in the landscape on the populations of large mammals. The main outputs of the project, i.e. more precise delimitation and complementation of Significant Migration Areas and the proposal of Long-Distance Migration Corridors (presented in chapters 6 and 7), should contribute to the above-mentioned goals.

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5.

Landscape Potential Model for the Occurrence and Migration of Focal Species of Large Mammals

Petr Anděl, Leoš Petržílka, Ivana Gorčicová, Jaroslav Červený & Pavel Šustr

5.1. INTRODUCTION

Mathematical modelling of the landscape potential is a convenient tool for finding solutions to landscape connectivity issues and proposing protection measures. Individual models enable classification of the given area with respect to its conditions and suitability for the occurrence or migration of the focal species. The preceding chapter described a model based on a statistical analysis of the conditions in the area of occurrence. The present chapter introduces a model built upon expert evaluation of suitability for migration through a formalised multicriteria analysis.

Mathematical models always only approximate the real conditions or represent one of the options enabling prediction if certain input presumptions are defined. They stem from a number of simplified hypotheses and thus have to be viewed critically with respect to their strong and weak points. When interpreted, they provide a valuable ground for the practice of nature conservation.

5.2. METHODS

The fundamental strategy of the model ensues from the conclusions of a literature research on biology and ecology of the focal species (Chapter 2.). The research implies that the evaluation has to differentiate the following:

- Behaviour of individual focal species – the principal difference can be observed between carnivores (lynx, wolf, bear) and ungulates (elk, red deer). For practical

reasons, the Eurasian Lynx and the Red Deer had been chosen as representatives of both groups. These are species showing most frequent long-distance migration and the protection measures regarding the landscape connectivity should mainly focus on them.
- Behaviour of individual animals in the areas of their permanent occurrence and during migration – the conclusions of national and foreign studies, supported by telemetric data on movement of the model animals, definitely prove that their behaviour within the home range and areas of their permanent occurrence in general differs considerably from that in an open landscape and during long-distance migrations. This closely relates to their preferences given to habitats and sensitivity to anthropogenic barriers. It is not possible to merge the two categories (i.e. permanent occurrence and migration).

The afore-mentioned classification underlines the necessity to describe the species' behaviour through the model in four different situations, for the purposes of the project marked as: lynx – occurrence, lynx – migration, elk – occurrence, elk – migration. The outputs of the modelling are four individual models processed using a single method and based on various input data.

Multicriteria evaluation is the principle of the model. It is, in fact, a modified method of the total environmental quality indicator (Říha 1995). Each species shows its own level of probability of occurrence on a specified site, which may be expressed as a potential of the given place to host the species (understood as the landscape potential). The evaluation methodology consists of three fundamental steps:

- selection of relevant indicators characterising the suitable habitat,
- determination of the level of acceptability in each category of parameters inherent to habitats and barriers,
- determination of the algorithm for the calculation and modelling of the resulting potential of the given area.

The text below gives a brief description of individual steps. For more details on methodology, see Anděl (2003).

5.2.1. Selection of Relevant Indicators Characterising the Habitat

Indicators were selected pursuant to the results of the literature research; they were further divided into two groups and each group was characterised with four parameters.

- Habitat parameters – characterise the natural conditions of the sites. These involve the type of habitat, elevation, diversity of the terrain, and extent of continuous territories.
- Anthropogenic disturbance – with respect to the objectives of the project addressing the landscape connectivity and the influencing factors, the potential migration barriers were assessed separately in a single block.

As will be explained further in this document, this division allows individual evaluation of natural and anthropogenic factors.

The individual parameters were represented by a various number of categories, i.e. basic units for the delimitation in the landscape and for expert evaluation.

Chart 5.1. gives an overview of the parameters and their categories, including the data sources.

5.2.2. Determination of the Level of Acceptability in Each Category of Parameters Inherent to Habitats and Barriers

The level of acceptability in individual categories of both habitat and barrier parameters was assessed by an independent team of 10 experts, professionals involved in the subject of large mammals, their migration, and the effects of landscape fragmentation. Each expert assessed the acceptability of the given category separately for each of the four situations (lynx – occurrence, lynx – migration, elk – occurrence, elk – migration) and assigned them arbitrary values in a closed interval /0; 1/, where the extreme values are: 1.0 – theoretically ideal situation, the category is entirely acceptable, 0.0 – the category is entirely unacceptable.

Chart 5.1. *Parameters and their categories.*

No.	Parameter	Category and data source
Habitat parameters		
1	Habitats	Seven categories were determined: (i) coniferous forest, (ii) mixed forest, (iii) broadleaf forest, (iv) meadows and pastures, (v) mires, wetlands, and water bodies, (vi) fields, (vii) settlements and anthropogenic areas. Data source: CORINE Land Cover 2006 (EEA 2009).
2	Elevation	Four categories were determined: (i) lowlands up to 300 m a.s.l., (ii) uplands 300–500 m a.s.l., (iii) highlands 500–800 m a.s.l., (iv) mountains over 800 m a.s.l. Data source: ARC ČR 500 (Czech Office for Surveying, Mapping and Cadastre 2005)
3	Heterogeneity of terrain	Five categories were determined based on the contour line interval in a regular hexagonal grid (20 km^2). Data source: ARC ČR 500 (Czech Office for Surveying, Mapping and Cadastre 2005).
4	Extent of continuous territories	Five categories were determined based on the continuous area of the forest and adjacent semi-natural habitats: (i) over 100 km^2, (ii) 30–100 km^2, (iii) 10–30 km^2, (iv) 1–10 km^2, (v) below 1 km^2. Source data: CORINE Land Cover 2006 (EEA 2009).
Parameters of anthropogenic disturbance		
5	Transport	Four categories of communications were determined: (i) motorways, expressways, and high-speed rails, (ii) first class roads and transit backbone network of rails, (iii) second class roads and transit complementary network of rails, (iv) third class roads and other rails. In each communication, the assessment involved the main body and both the inner and outer buffer zones with the width weighted by traffic flow. Data source: road database (Road and Motorway Directorate 2005), railway database (Ministry of Transport).
6	Settlements	Four categories were determined based on the extent: (i) over 20 km^2, (ii) 5–20 km^2, (iii) up to 5 km^2, (iv) scattered structures. Inner and outer buffer zones were defined around settlements (except scattered structures) according to the size of settlements. Data source: CORINE Land Cover 2006 (EEA 2009), database of settlements ARC ČR 500 (Czech Office for Surveying, Mapping and Cadastre 2005).
7	Non-forest areas	Four categories were determined as buffer zones according to their distance from the forest edge: (i) up to 200 m, (ii) 200–500 m, (iii) 500–2000 m, (iv) over 2000 m. Data source: CORINE Land Cover 2006 (EEA 2009).
8	Fences	Two categories were determined, characteristic with the existing or potential fencing: (i) orchards and vineyards, (ii) pastures. Data source: CORINE Land Cover 2006 (EEA 2009).

The values applied in the model were determined as an arithmetic mean, excluding the maximum and minimum extreme values.

5.2.3. Determination of Algorithm for the Calculation and Modelling of the Resulting Potential

The actual model was produced through Standard GIS operations. The aim of the calculations was to define the general acceptability of the given area for the permanent occurrence or migration of the species. Calculations were made for each polygon separately, which was formed by interlaying individual layers of parameters in two subsequent steps. First, habitat preferences and anthropogenic barriers were processed, followed by the final synthesis. The geometrical mean of evaluated parameters was used as algorithm to calculate the habitat preferences, whereas the minimum value of acceptability was applied when assessing barriers. The synthesis gave preference to the minimum values of acceptability, i.e. less favourable situations. This approach was applied to encompass all factors that limit or inhibit the occurrence or migration of the species.

5.3. MODEL OUTPUTS

The model outputs are depicted in the following figures: lynx – occurrence (Fig. 5.1.), lynx – migration (Fig. 5.2.), elk – occurrence (Fig. 5.3.), elk – migration (Fig. 5.4.). The maps distinguish five colours representing five levels of acceptability with 20% intervals. The scale starts with the red colour, which stands for unacceptable areas, and continues with orange, yellow, and light green, while dark green shows the optimum situation, i.e. areas highly suitable for the occurrence or migration of the species.

Chart 5.2. displays an overview of areas that fall into individual categories.

The final maps classify the territory of the Czech Republic with respect to the acceptability of conditions for the occurrence and migration of the Eurasian Lynx and the Eurasian Elk and represent useful groundwork for the preparation of Significant Migration Areas and Long-Distance Migration Corridors.

The results also indicate certain general tendencies that should be taken into consideration within the protection of landscape connectivity. Some of these results will be further addressed in this report.

Differences between the Eurasian Lynx and the Eurasian Elk

The models clearly reflect differences in the behaviour in the Eurasian Lynx and the Eurasian Elk. The lynx shows higher specific requirements on habitats, especially for its permanent occurrence, but also for migration. It is obviously dependent on vast forested mountain complexes, while lowlands abounding with fields result unsuitable. The extensive areas indicated in red and orange in the map represent these unsuitable habitats.

According to the model, the elk is more tolerant and may be expected to occupy temporarily less suitable habitats. This is supported by records from the past, when its populations temporarily inhabited small areas near Nymburk and near Tábor. The species becomes even more tolerant during its migration periods. The elk is known to move through fields, in an open terrain, and in the vicinity of settlements. The higher share of green in the model map illustrates acceptable areas and supports the fact.

Data on individual classes are stated in Chart 5.2. and in Figure 5.5., which compares them. The graph indicates the share of each class of acceptability in the total area of the Czech Republic; always showing the potential lower than or equal to the given class. (Computing to 100%, we may determine the proportion of areas with a higher potential.).

Chart 5.2. *Extent of individual classes of acceptability (% of the territory of the Czech Republic).*

Acceptability		Lynx		Elk	
Classes	(%)	Occurrence	Migration	Occurrence	Migration
“Unacceptable”	0–20	38.1	10.4	17.4	10.4
Low	21–40	27.5	29.4	20.0	3.7
Medium	41–60	6.5	24.4	28.8	13.1
High	61–80	8.3	10.5	7.4	38.4
“Optimum”	81–100	19.4	25.2	26.2	34.2

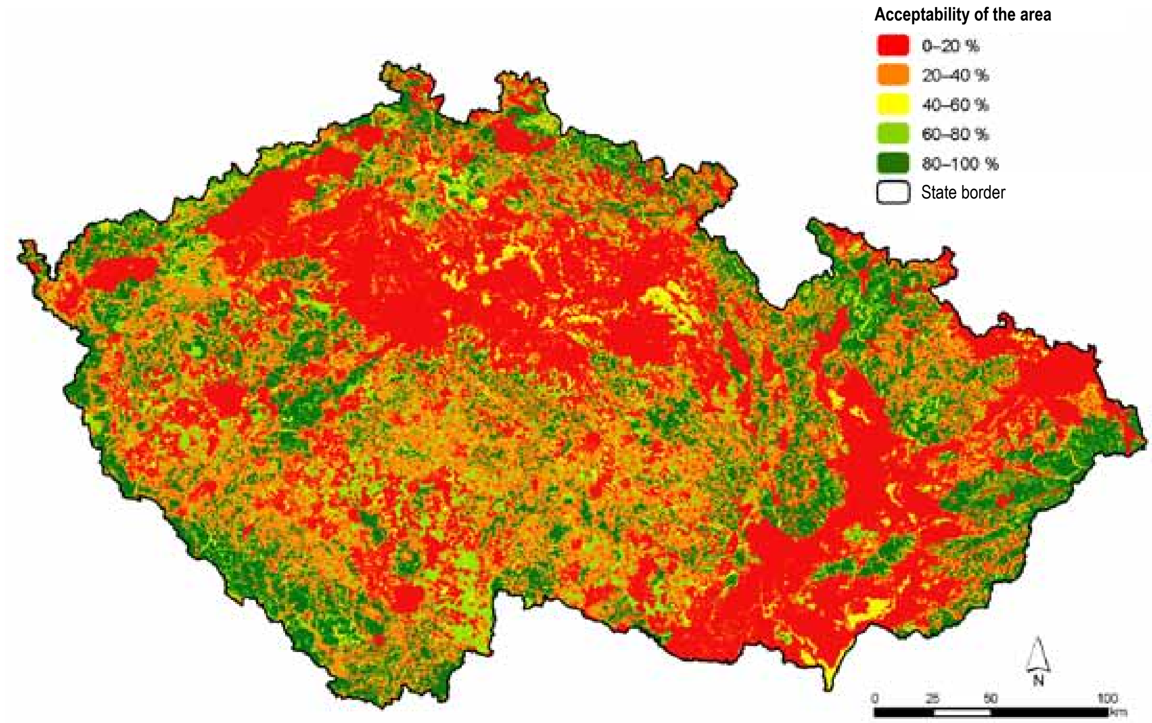

Fig. 5.1. *Model of the landscape potential for the permanent occurrence of the Eurasian Lynx.*

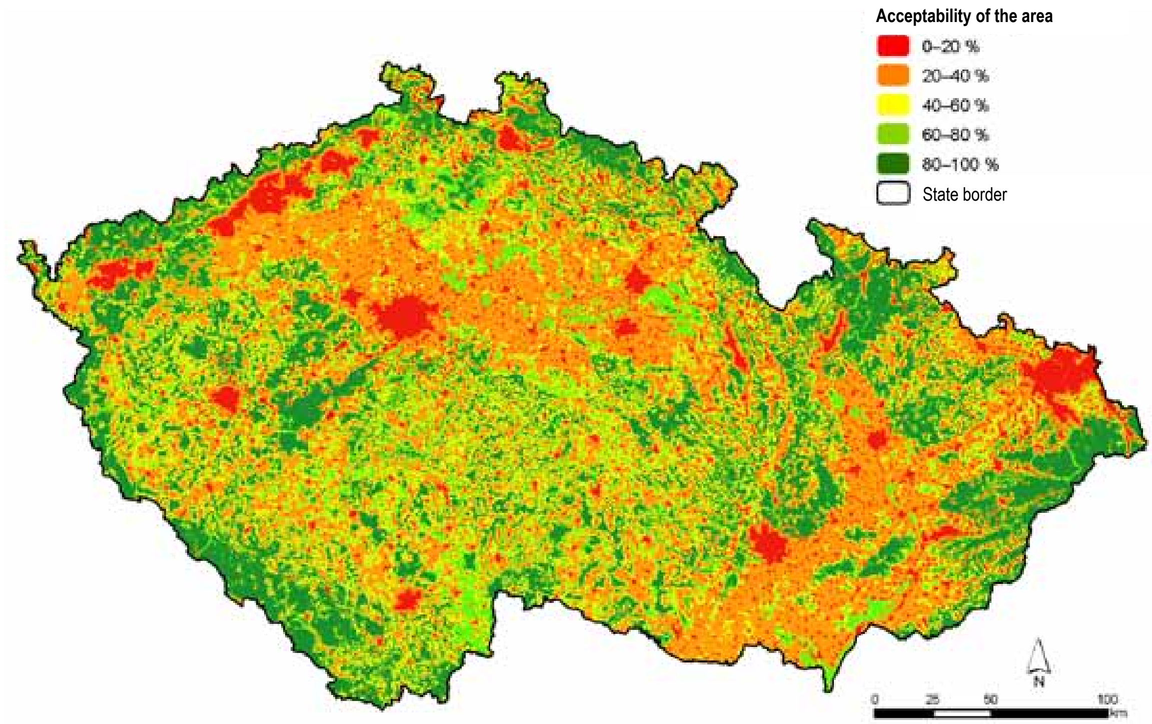

Fig. 5.2. *Model of the landscape potential for migration of the Eurasian Lynx.*

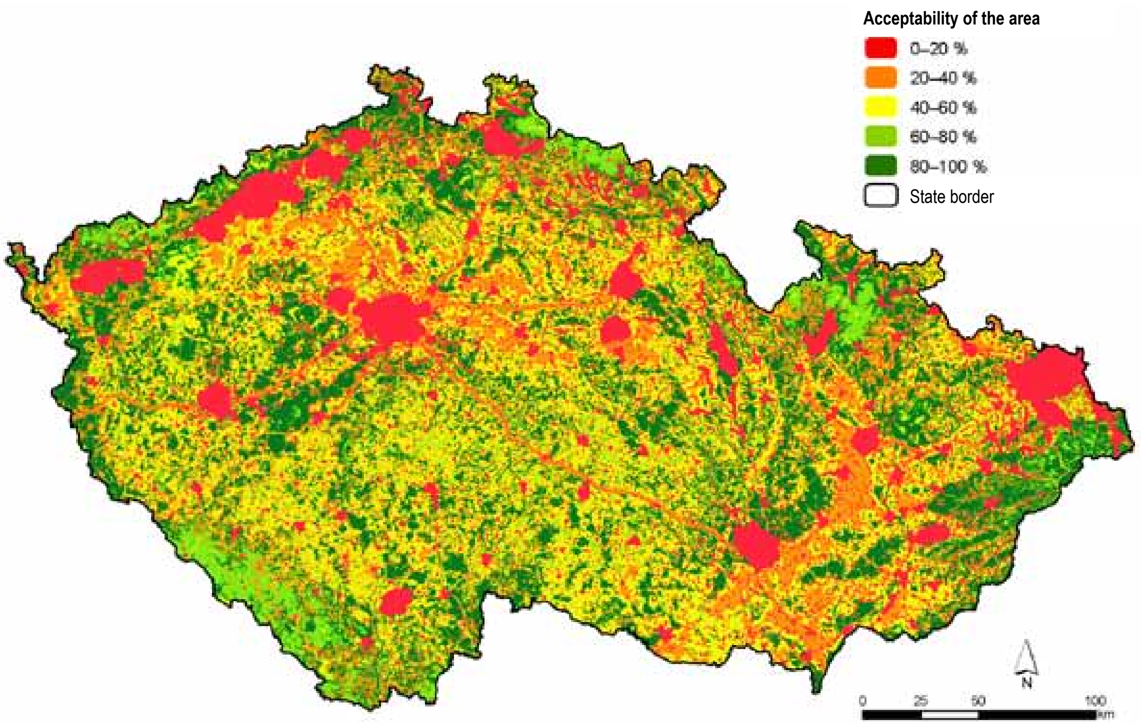

Fig. 5.3. *Model of the landscape potential for the permanent occurrence of the Eurasian Elk.*

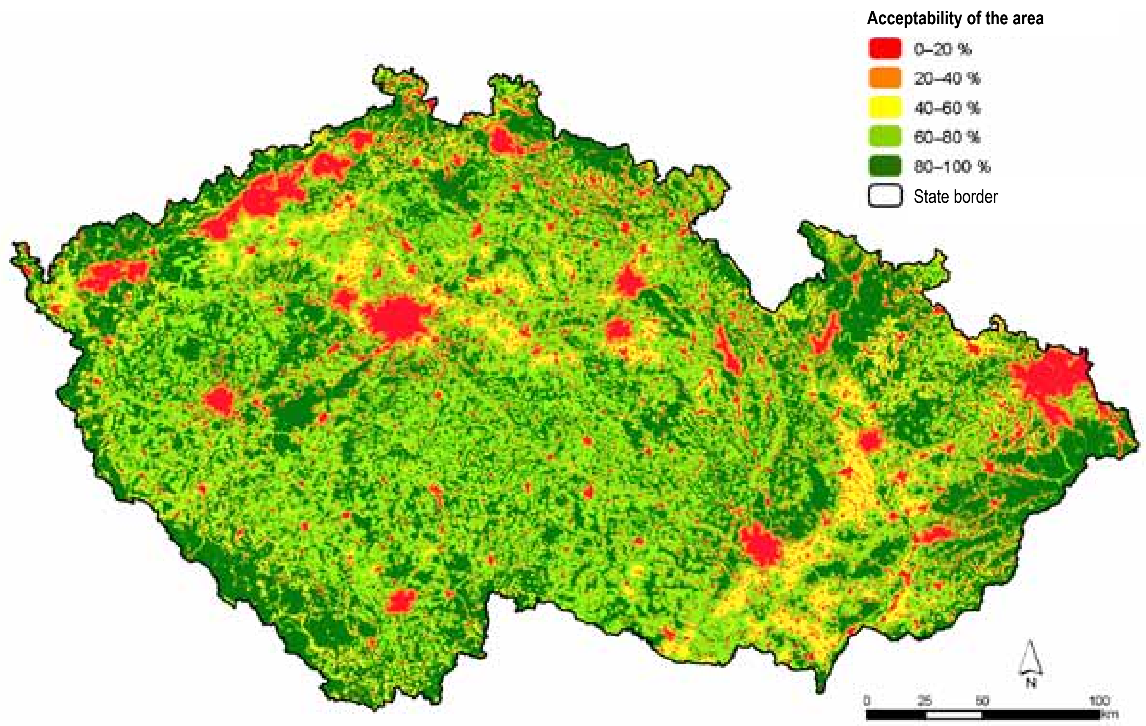

Fig. 5.4. *Model of the landscape potential for migration of the Eurasian Elk.*

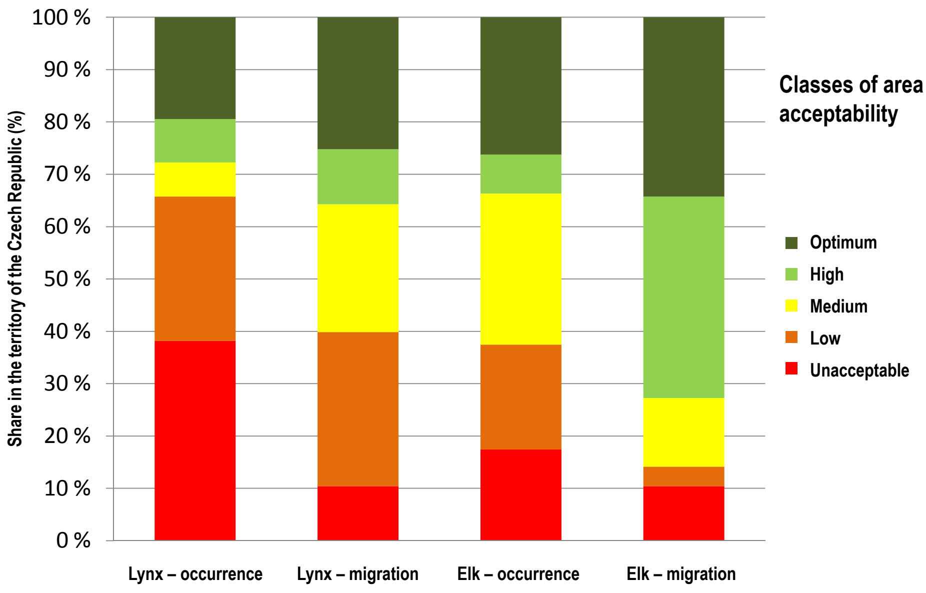

Fig. 5.5. *Areas of individual classes of acceptability (% of the territory of the Czech Republic).*

The models generally reflect two types of tendencies. In a simplified manner, we may state that the specific requirements on the habitat and other conditions are:

- higher in the lynx than in the elk;
- higher in case of permanent occurrence than during migration.

Barriers in the Evaluation of Migration

At the scale of the herein presented maps, we may observe only the main tendencies and classification in the territory of the Czech Republic. Although the maps delimit areas with the cumulative effect of barriers and unsuitable habitats, they do not depict numerous small-scale barriers, which may have a decisive impact on the permeability of the area. For instance, motorways accompanied with noise barriers are solely 40 m wide but entirely inhibit any passage.

When displayed at a larger scale, the maps at least partly identify the types of barriers but the level of their permeability is still undeterminable. Figure 5.6. shows a model at a local scale, which illustrates the linear barrier formed by the motorway, including its buffer zone. Nevertheless, the model cannot give details on the existence of migration objects or technical obstacles (walls, fences) and thus does not define the actual permeability.

It may be generally concluded that the models of the landscape potential may serve as a convenient basis for the evaluation of the landscape with respect to its potential for permanent occurrence or migration. Nevertheless, they do not represent an automatic tool for corridor determination. The necessary detailed field survey and particular assessment are irreplaceable.

Significance of Continuous Territories for the Permanent Occurrence of the Eurasian Lynx

Existence of large and continuous areas providing suitable habitats constitutes a crucial parameter in the evaluation of the potential of the given area for the permanent occurrence of the lynx. Thus, this requirement was listed as the fourth habitat parameter (Chapter 5.2.). The areas identified in this analysis compose of main and comple-

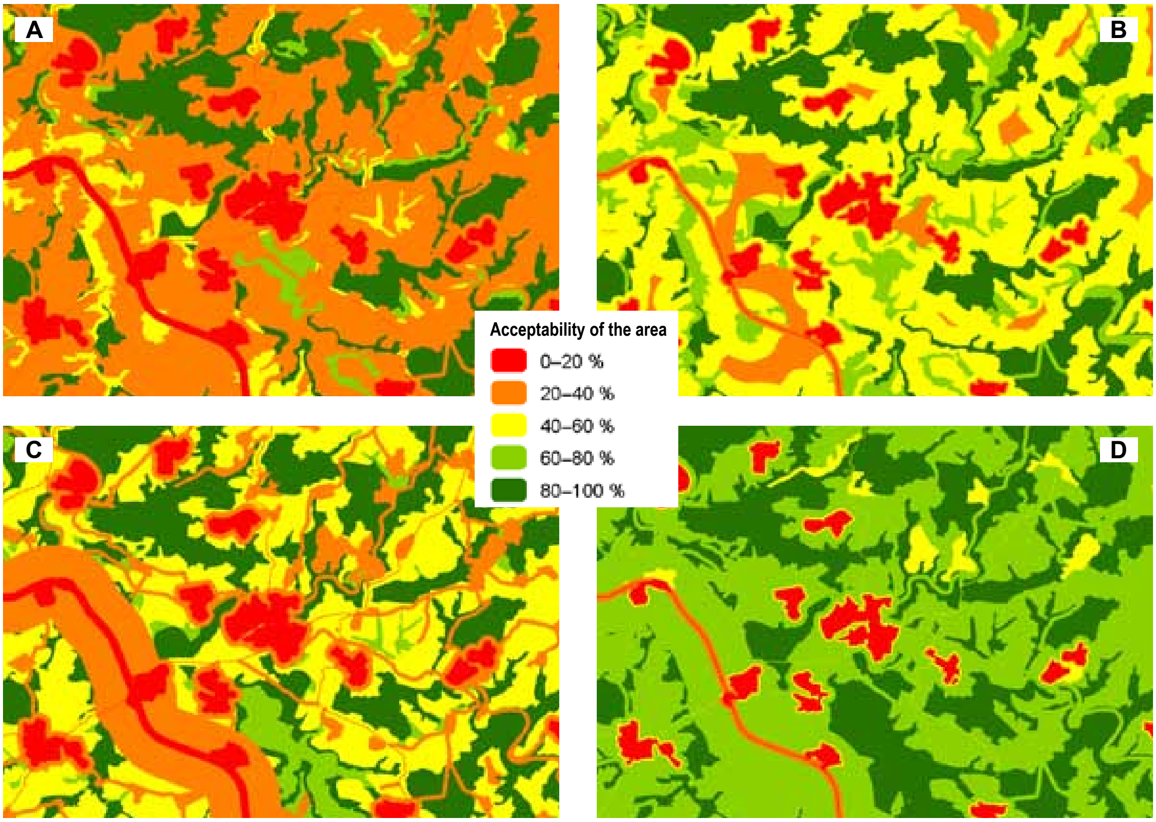

Fig. 5.6. *Models of the landscape potential at a detailed scale – a) occurrence of the Eurasian Lynx, b) migration of the Eurasian Lynx, c) occurrence of the Eurasian Elk, d) migration of the Eurasian Elk.*

mentary habitats. The main habitats involve forests, mires, and wetlands, while the complementary habitats comprise meadows, pastures, and semi-natural habitats adjacent to the main habitat (i.e. prevailingly a forest) at a maximum distance of 500 m from its edge. As a precondition, the territory was supposed to form a continuous network of minimum 100 km^2. Linear barriers are not considered as interrupting in this case as they are addressed in the section on anthropogenic barriers.

This way demarcated areas cover 37 520 km^2, i.e. approximately 48% of the Czech Republic. They consist in 76% of forests and other main habitats, and in 24% of complementary habitats (meadows and pastures). This rate is consistent with the documented fact that the lynx uses not only forests in its home range, but also other habitats. Figure 5.7. shows the distribution of these vast areas.

From the point of view of natural conditions, the presented facts prove the existence of a number of continuous forest habitats in the Czech Republic, which, with their sufficient extent, provide adequate conditions for the permanent occurrence of the Eurasian Lynx. They represent areas with a natural potential for the future occurrence of the species. The significance of these forest habitats is derived from the fact that approximately 95% of all records on the species occurrence listed in the AOPK database come from them. It is hence efficient to secure their connection through Significant Migration Areas and Long-Distance Migration Corridors.

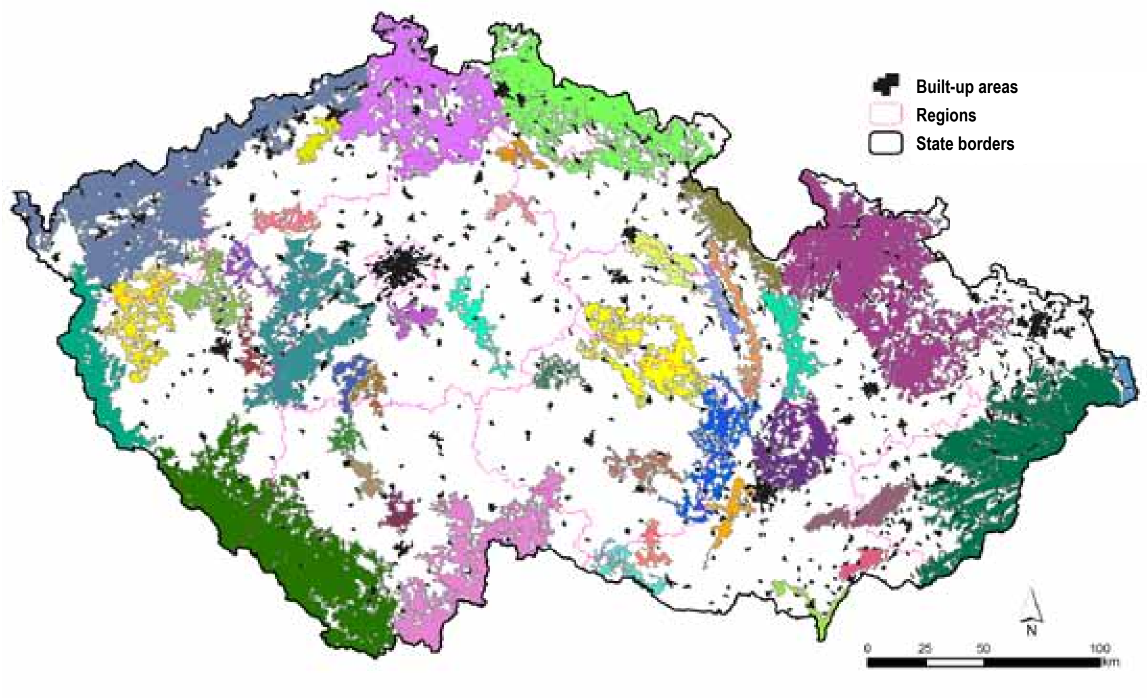

Fig. 5.7. *Continuous areas of over 100 km² providing suitable habitats for the occurrence of the Eurasian Lynx.*

5.4. DISCUSSION

5.4.1. Strong and Weak Points of the Model

Interpretation of each model should consider the output data and the fundamental presumptions and evaluate its strong and weak points. The subjective approach of each expert is perceived as the main uncertainty in the methodology. In particular, when the evaluation is conducted in an independent and individual manner (each expert works separately without any common discussion), certain disagreements and evaluation based on individual opinions cannot be fully avoided. On the other side, such an approach will secure highly valuable personal opinions not affected by external factors, such as strong personalities in a team.

The subjective approach of the respondents has its positive points, too. Each of them undertakes the given task comprehensively based on their acquired experience, literature, and own practice. The assessment of individual classes seeks, above all, the logical trends (e.g., when comparing habitats, evaluating various distances from disturbing agents, etc.). As the model is grounded on general regularities and logical trends, its potential use in practice is higher. Diverse opinions and experience of experts serve as a positive factor in this respect.

Simple algorithms were selected for calculations in the presented models. All parameters were assigned equal importance; the model processes the parameters separately and their mutual relations are not assessed. For practical reasons, experts divided the parameters into discrete classes and did not express them through functional dependence. All the data could have been processed using more complicated procedures. Nevertheless, with respect to the designed objective, i.e. to create a basic model as groundwork for the proposal of measures aimed at protecting the landscape connectivity, the authors did not consider such procedures purposeful.

The model was verified by comparison with the records of the Eurasian Lynx and the results of this verification prove the appropriateness of the selected approach – see the following chapter.

5.4.2. Comparison of the Model Outputs and Records of Species

One of the basic options how to verify the model based on expert evaluation is to compare it with the records of the species in the AOPK database. These records were not used as input data for the model and thus represent an independent set for comparison. The general hypothesis for verification says that the sites of recorded occurrence should prevailingly match with the areas demarcated in the model as areas with a high potential for occurrence or migration of the Eurasian Lynx and the Eurasian Elk. In other words, we presume that there is a close relationship between the density of occurrence of a species and the landscape potential of acceptability.

The records on the occurrence of the Eurasian Elk did not suffice to be used for comparison. The model outputs were thus verified comparing data on the Eurasian Lynx.

The interpretations should take into account the characteristics of the available data, which are particularly the following:

- Data do not represent any random selection regarding the distribution of the species in the Czech Republic. In principle, they are influenced by two main areas of the species distribution, which serve for its dispersal, i.e. the Šumava Mts. (reintroduction of the lynx in the mid 20th century) and the Beskydy Mts. (population supported from Slovakia) (see Chapter 8.).
- The total number of records is influenced by the intensity of monitoring. For example, long-term research programmes and telemetry monitoring have been conducted in the Šumava Mts. in much higher numbers than in other mountains, where just occasional observations are generally documented. In consequence, the vast majority of data comes from the two areas of permanent occurrence of the species (i.e. the Šumava and the Beskydy Mts.).
- Data do not differentiate between permanent occurrence and migration.
- Data from various periods are not represented equally.

Chart 5.3. *Numbers of records and their density by models and individual levels of acceptability.*

Acceptability of area		Lynx – occurrence		Lynx – migration	
	(%)	Number of records	Density of records	Number of records	Density of records
		%	n/100 km²	%	n/100 km²
"Unacceptable"	0–20	1.00	0.03	0.10	0.10
Low	21–40	10.12	0.47	0.80	0.03
Medium	41–60	3.61	0.70	9.62	0.50
High	61–80	14.63	2.23	5.91	0.71
"Optimum"	81–100	70.64	4.61	83.57	4.20

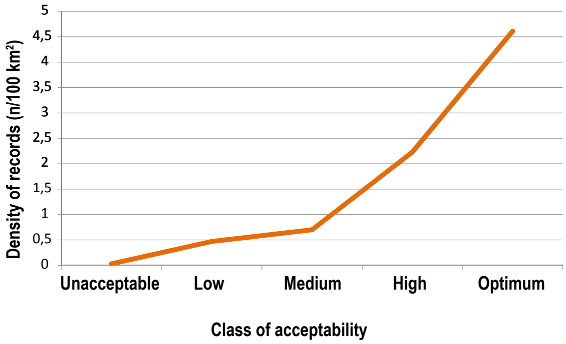

Fig. 5.8. *Relation of the density of records and the level of acceptability of the given area – Eurasian Lynx; occurrence.*

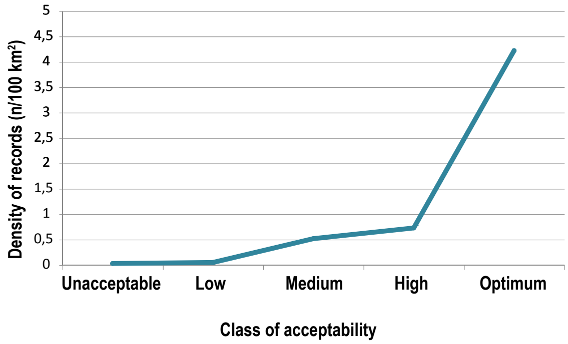

Fig. 5.9. *Relation of the density of records and the level of acceptability of the given area – Eurasian Lynx; migration.*

Despite the above-stated imperfections, the data collected in the AOPK database constitute a basis of a high value and their use for verification is purposeful.

The following two characteristics were applied to verify the data when the models had been established:

- The number of records (% of the total number) falling into the given class of acceptability. This is the simplest characteristic assuming that a considerable majority of records will be classed as of high or optimum acceptability.
- Density of records in the given class, i.e. the number of records related to the size of the given class (records/100 km²). This characteristic is more detailed, takes into consideration the size of individual classes in the Czech Republic, and models the probability of the lynx occurrence in the given category.

The results are stated in Chart 5.3 and in Figures 5.8. and 5.9., and depict the relation between the density of records and the level of acceptability as determined in the created models.

The values in the chart show a very high conformity of the model data with the records. In model "lynx – occurrence", 85% of all records are marked in the first 2 classes of the best acceptability and 70% in the top class (i.e. optimum acceptability). The model "lynx – migration" shows even better results (approx. 90% and 84% respectively), which is consistent with the outputs discussed in Chapter 5.3.

The implicit surprising fact that 10% of all records are found in model "lynx – occurrence" in areas of low acceptability has two reasons. First, the database of records does not distinguish between permanent occurrence and migration, so sites suitable merely for migration are compared to conditions for permanent occurrence. Second, the comparison involves only the percentage of occurrence in the given category and the total area of that category within the Czech Republic is not taken into account. Thus, the density of records (i.e. the number of records related to the unit area of the given category) becomes a more appropriate parameter for comparison. It is a model of expected probability of occurrence of the species in the given area.

The evaluation of the density of records proves that the models reflect the main trends in the acceptability of areas. The density of records grows fluently from the class of an "unacceptable" area (0.03–0.01 records per 100 km^2) to an "optimum" area (4.61 and 4.2 records per 100 km^2). Differences are evident not only between the extreme classes, where they exceed two orders, but also between any other neighbouring classes. This is also demonstrated by values in Figures 5.8 and 5.9.

In conclusion, we may state that the classification of areas by the level of their acceptability for the occurrence or migration of the Eurasian Lynx is in broad conformity with the distribution determined by the actual records. The model may hence be utilised to predict the potentially suitable conditions for the occurrence and migration of the species.

5.5. PARTIAL CONCLUSION ON LANDSCAPE POTENTIAL MODELS

Four partial models were established using the method of multicriteria analysis based on formalised expert evaluation. They describe the landscape potential of an area for (i) permanent occurrence of the lynx, (ii) migration of the lynx, (iii) permanent occurrence of the elk, and (iv) migration of the elk. The models underwent successful verification being compared to the available records of the species supplied from the AOPK database. The presented models lay a suitable basis for the proposal of Significant Migration Areas and Long-Distance Migration Corridors. However, under no circumstances can they substitute the individual evaluations and field surveys focused on the permeability of barriers.

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6.

Significant Migration Areas

Petr Anděl, Václav Hlaváč, Ivana Gorčicová & Leoš Petržílka

6.1. DEFINITION AND ROLE IN THE SYSTEM OF PROTECTION OF LANDSCAPE CONNECTIVITY

Significant Migration Areas are part of the concept of the protection of landscape connectivity for large mammals that are subject to the study. Under the concept of the protection of landscape connectivity (Anděl & Gorčicová 2007) and with regard to the administrative and technical aspects, three hierarchically arranged types of areas are defined:

1) Significant Migration Areas – as top units, relate to nature conservation as a whole.

2) Long-Distance Migration Corridors – as basic units, secure the minimum connectivity of the landscape.

3) Migration Routes – as detailed units, are predestined to technical and investment measures.

Significant Migration Areas have the following qualities:

- They represent areas necessary to ensure long-term existence of populations of focal species of large mammals in the Czech Republic (Eurasian Lynx, Brown Bear, Grey wolf, Eurasian Elk, and Red Deer). They comprise areas providing conditions for the permanent occurrence of the species as well as those securing sufficient connectivity for their migration. Both types of areas naturally overlap one another.
- They comprise and connect all areas in the Czech Republic where the permanent occurrence of the mentioned species is documented.
- Their basic role is to protect the connectivity of the landscape as a whole. From this point of view, they constitu-

te the crucial category.
- They typically have a surface character and cover a considerable part of the Czech territory. They are of linear character only where they pass through a highly fragmented landscape containing just remains of suitable habitats.
- They form a continuous network and do not comprise small isolated areas (if these cannot be functionally connected to the main network).

The concept of Significant Migration Areas as a single continuous network in the entire country underlines the fundamental ecological fact that large mammals require for their existence both the space for their permanent occurrence and areas allowing any type of movement through an open landscape. No precise borders can be delineated between these areas as they penetrate one another. We may solely presume which parts are used for permanent occurrence and which rather for temporary occurrence or migration. For these reasons, it is imperative to understand an SMA as a habitat of the focal species.

The first map of SMAs was published by the Agency for Nature Conservation and Landscape Protection of the Czech Republic in 2008 as a territorial analytic data source under Act No. 183/2006 Coll., on town and country planning and building code (the Building Act) and under Decree No. 500/2006 Coll., on land-use analytical data, land-use planning documentation and method of recording land-use planning activities (hereinafter referred to as the “territorial analytic data source”). The map was based on classification of the territory of the Czech Republic with respect to the significance for migration (Hlaváč & Anděl 2001) and was further complemented using records of the focal species and transformed from originally 5 categories of significance into 2 categories (i.e. SMAs and non-SMAs). The map of SMAs published in 2008 covered approximately 67% of the Czech Republic. One of the objectives of the present project was to refine this map on the grounds of new knowledge and more detailed analyses.

6.2. METHODOLOGY OF DELIMITATION OF SIGNIFICANT MIGRATION AREAS

The process of delimitation of SMAs builds on the following background material:

- Map of SMAs published by AOPK in 2008
- Records of the focal species
- Map of migration barriers
- Outputs of mathematical models (habitat model and model of the landscape potential)

Areas characteristic with a low potential for the occurrence and migration of the species were removed from the original layer of SMAs in the GIS environment. This gave rise to certain enclaves of unsuitable habitats, mainly of large settlements and open non-forest landscapes. Smaller settlements were not removed from the layer deliberately as animals frequently migrate in their immediate vicinity. It has to be noted though that all the proposed regulations for SMAs do not generally relate to main urban areas (neither to those inside SMAs).

The layer was complemented with locations showing more frequent records of the focal species, and, based on mathematical models, with larger areas with a high landscape potential (Chapter 5.) and a high share of suitable and preferred habitats (Chapter 4). The continuity of the layer was retained and no islands of secluded areas were incorporated.

Compared to its predecessor from 2008, the current map reflects more precisely the significance of individual areas for the sustainable existence of the focal species of large mammals.

The basic scale of the SMA map of 1: 500 000 should be taken into account in practical use. Although the process of delimitation involved work with a higher resolution, the final map cannot be viewed automatically at the scale of 1: 50 000. In case of any preparations of further maps derived from SMAs that require a better resolution (e.g., within the process of spatial planning), the layer needs to be transformed into the required more detailed scale.

6.3. DESCRIPTION AND CHARACTERISTICS OF SIGNIFICANT MIGRATION AREAS

6.3.1. Output Maps

The synoptic map of SMAs may be found in Figure 6.1. The final map will be published by the Agency for Nature Conservation and Landscape Protection of the Czech Republic as a territorial analytic data source and in printed form at the scale of 1: 650 000.

The total area of SMAs is 33 508 km^2, i.e. approximately 42% of the area of the Czech Republic.

6.3.2. Significant Migration Areas Compared to Records of Species

Comparison of delimited Significant Migration Areas with the records on the occurrence of species in the AOPK database represents an important criterion. The outputs of this comparison are stated in Figures 6.2. to 6.5., which illustrate that SMAs cover an absolute majority of areas with documented occurrence of the focal species. The following figures support the fact. SMAs involve 89% of sites with documented occurrence of the Eurasian Lynx, 95% of sites with documented occurrence of the Grey Wolf, and 90% of sites documenting occurrence of the Brown Bear.

The subsequent part compares the distribution of SMAs in relation to the administrative division of the Czech Republic, the natural conditions, records of species, and selected categories of nature conservation.

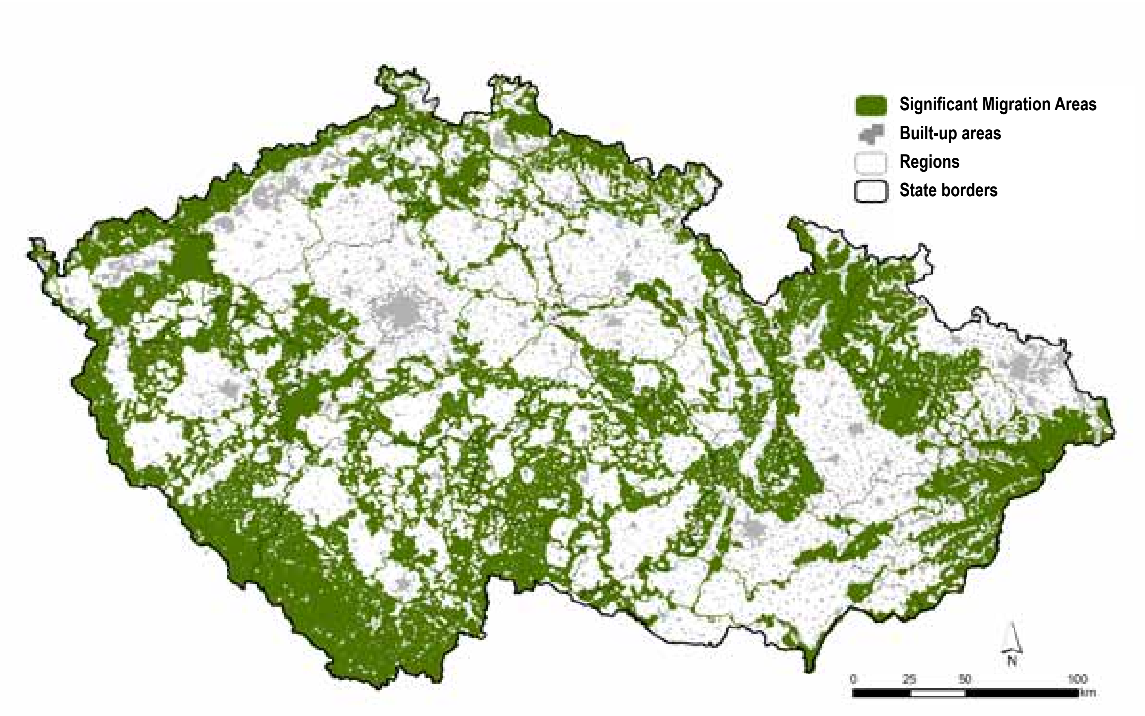

Fig. 6.1. *Synoptic map of Significant Migration Areas.*

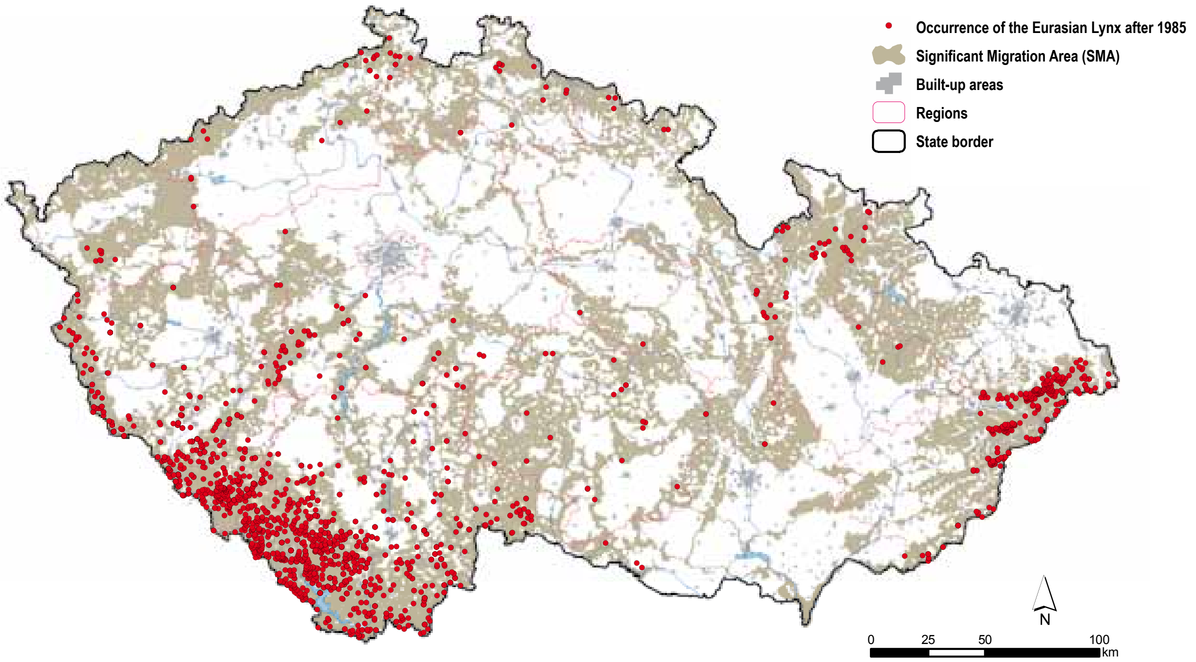

Fig. 6.2. *Records of the Eurasian Lynx supplied from the AOPK database and compared with SMAs.*

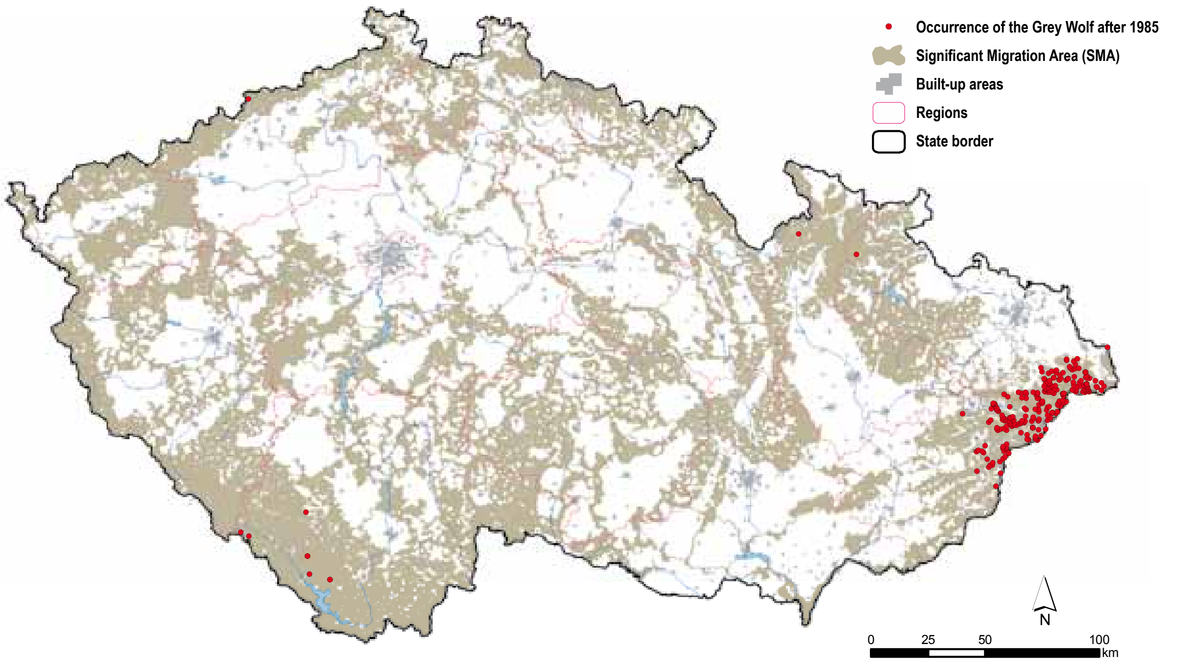

Fig. 6.3. *Records of the Grey Wolf supplied from the AOPK database and compared with SMAs.*

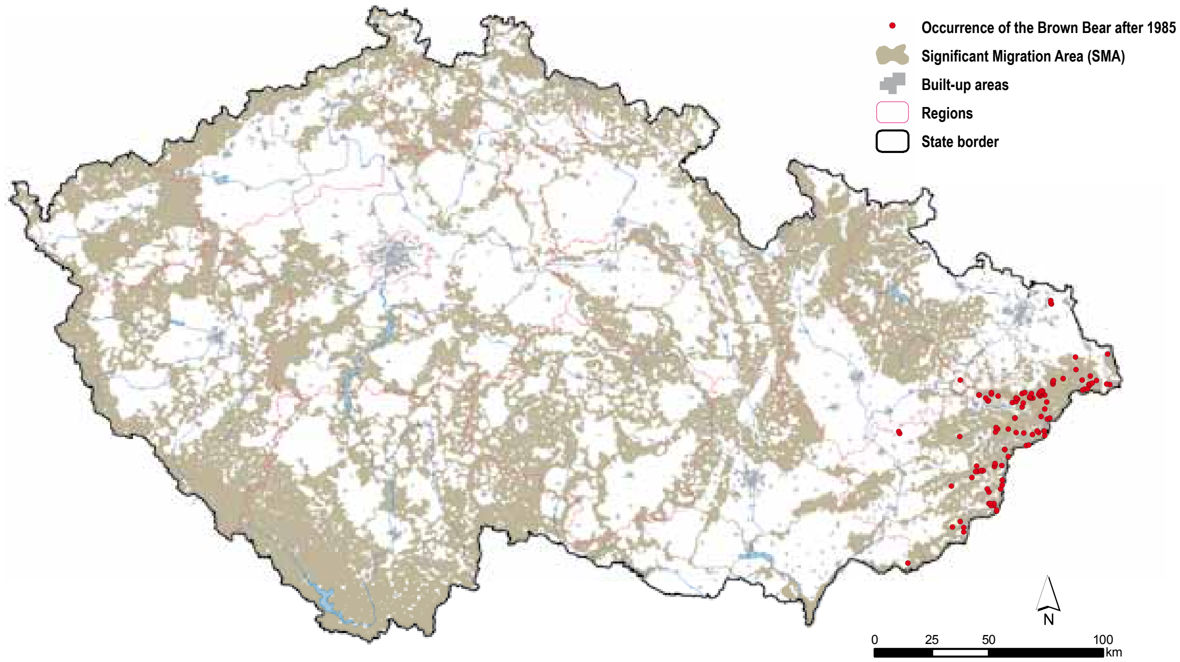

Fig. 6.4. *Records of the Brown Bear supplied from the AOPK database and compared with SMAs.*

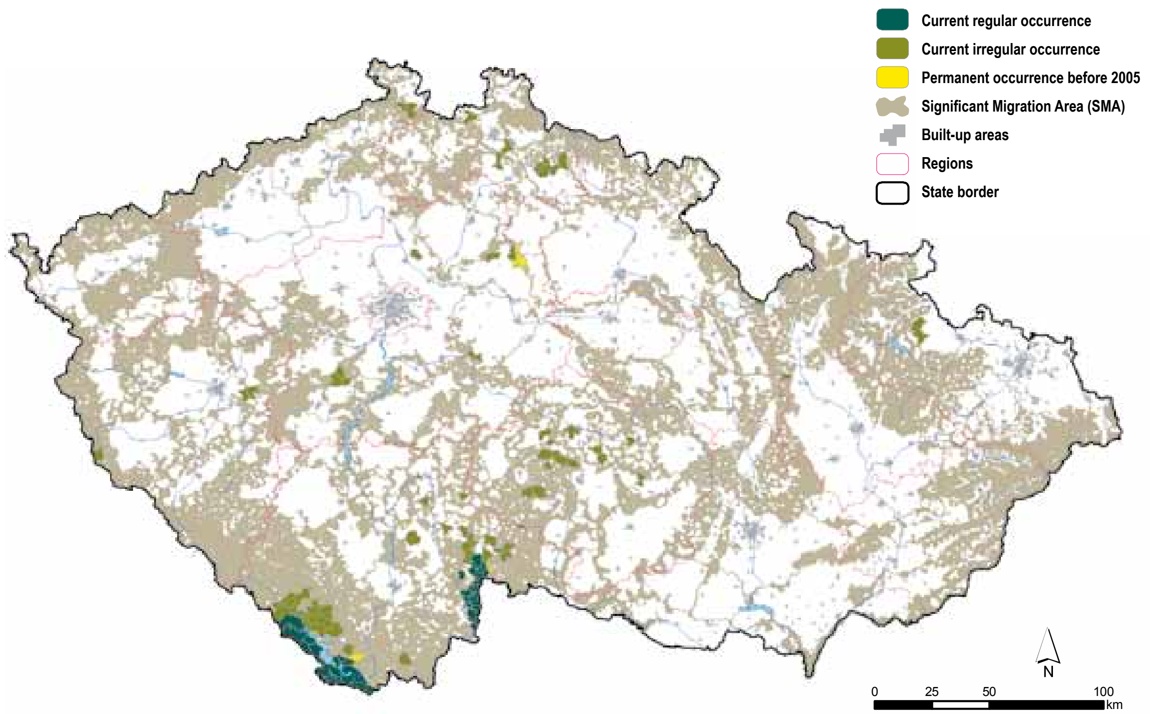

Fig. 6.5. *Records of the Eurasian Elk supplied from the AOPK database and compared with SMAs.*

6.4. DISTRIBUTION OF SIGNIFICANT MIGRATION AREAS IN THE CZECH REPUBLIC

The synoptic map in Fig. 6.1. illustrates that SMAs are not distributed evenly over the territory of the Czech Republic. This is a logical consequence of various natural conditions and ecological requirements of the focal species, which largely prefer vast forest areas of border mountain ranges.

6.4.1. Distribution of SMAs by Regions

The size of SMAs in individual regions and their share on the total area of SMAs in the Czech Republic are recorded in the chart below.

Chart 6.1. *Size of SMAs by regions.*

Region	Size of SMA (km^2)	Share of SMA in the region (%)
South Bohemia	6 230	61.8
South Moravia	2 131	30.1
Karlovy Vary	1 922	57.9
Hradec Králové	1 469	30.8
Liberec	1 585	50.1
Moravia Silesia	2 478	44.5
Olomouc	2 104	40.9
Pardubice	1 610	35.6
Plzeň	4 067	53.7
Prague	0	0
Central Bohemia	3 128	28.4
Ústí nad Labem	1 701	31.8
Vysočina	3 136	45.3
Zlín	1 938	48.9

The South Bohemian Region and the Plzeň Region have the largest area of SMAs (total over 10 000 km^2). The Šumava Mts. are the largest complex of habitats suitable for large mammals in the country and form a considerable part of SMAs. This is reflected in the share that SMAs have in individual regions. The South Bohemian Region shows the highest share (62% of the region), followed by the Region of Karlovy Vary (58%), and the Plzeň Region (54%). Regions with a high density of settlement and industry naturally have a significantly lower share of SMAs – the Central Bohemia Region (28%), the Hradec Králové Region (31%), the Ústí nad Labem Region (32%). No SMA has been delimited in the capital of Prague.

It should be noted though that protection of SMAs is equally important in all regions. In areas with a high share of SMAs, the protection focuses on the integrity of suitable habitats, while in other areas SMAs often represent the last space enabling connectivity of the landscape for migration.

6.4.2. SMAs by Elevation

The following chart gives figures concerning the size of SMAs in lowlands, uplands, highlands, and mountains.

Chart 6.2. *Size of SMAs by elevation.*

Elevation	Size of SMA (km^2)	Share of SMAs in the total area of the Czech Republic (%)
Lowlands (up to 300 m a.s.l.)	1 938	5.9
Uplands (300–500 m a.s.l.)	12 125	36.4
Highlands (500–800 m a.s.l.)	16 103	47.9
Mountains (over 800 m a.s.l.)	3 263	9.8

The majority of SMAs can be found in uplands and highlands (total 84%), which relates to the high proportion of these elevations in the Czech Republic and to their high forest cover. The low size of SMAs in mountains (9.8%) is given by their small total area in the country since 98% of the mountains are covered with Significant Migration Areas.

Despite the low percentage of SMAs in lowlands (5.9% of the total area of SMAs), their protection will often become crucial with the view to securing the landscape connectivity in the Czech Republic. Lowlands currently contain the densest network of migration barriers (high density of settlements, related transport infrastructure, vast non-forest areas with a minimum share of dispersed vegetation). The problem worsens due to the considerable pressure on further land take in the open landscape. The vital issue is that these areas are not generally perceived as relating to migration of large mammals. Their significance for the landscape connectivity in the entire Czech Republic is being underestimated and protection measures are hard to enforce.

6.4.3. SMAs by Habitat Type

The subsequent chart gives a basic view of the representation of habitat types (in accordance with CORINE Land Cover 2006) within SMAs.

Chart 6.3. *Size of SMAs by habitat type.*

Category	Size of SMA (km^2)	Share of SMA in the total area of the Czech Republic (%)
Anthropogenic	14	0.0
Agricultural (arable land)	5 734	17.1
Meadows and pastures	5 473	16.4
Water bodies, wetlands	297	0.9
Forests	21 982	65.6

Obviously, the chart indicates that approximately 65% of all SMAs are located in forest habitats. This is consistent with the overall concept of Significant Migration Areas proposed for large mammals dependent on the forest environment. Nevertheless, arable land constitutes a notable part of SMAs (17%), concentrated mainly in lowlands. As stated above, these areas are frequently hardly permeable.

6.5. RELATION OF SIGNIFICANT MIGRATION AREAS TO SELECTED CATEGORIES OF NATURE CONSERVATION

The relation of Significant Migration Areas to certain categories of nature conservation is of high importance. The subjects of conservation in specially protected areas (protected areas under national legislation), the Natura 2000 sites, the territorial systems of ecological stability, natural parks, and in significant landscape components on the one side and in Significant Migration Areas on the other side mutually overlap, and the applied protection tools may complement one another. From the long-term perspective of nature conservation, the connection of a number of these areas through SMAs is a positive step. The maps only indicate areas that overlap with SMAs.

6.5.1. Specially Protected Areas

The overlap of Significant Migration Areas with national parks (NP) and protected landscape areas (PLA) is illustrated in Figure 6.6. and summarised in the chart below.

Chart 6.4. *Area of SMAs in national parks and protected landscape areas.*

Category	Size of SMA (km^2)	Size of SMA (% of the total area of SMAs)
National parks	1 149	3.4
Protected landscape areas	7 837	23.3
Total	8 986	26.7

Approximately a quarter of all SMAs can be found in large-scale specially protected areas. The protection of SMAs may thus be secured by implementing also the existing protection regime of specially protected areas. Protected landscape areas (as a category of specially protected areas) will play a key role in this respect.

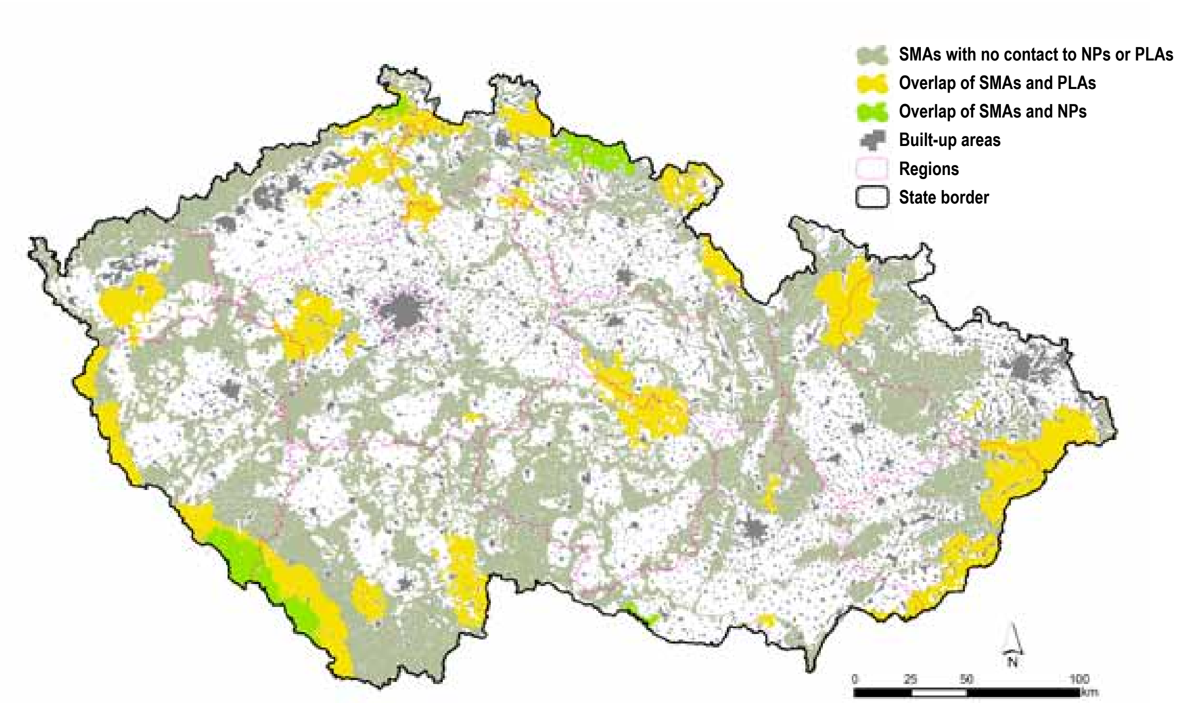

Fig. 6.6. *Overlap of Significant Migration Areas with national parks and protected landscape areas.*

Hundreds of small-scale specially protected areas overlap with SMAs.

Taking into consideration the diversity of the subjects of conservation in the mentioned areas, the mere analysis of the overlap of SMAs and small-scale specially protected areas (SSPA) does not suffice. When evaluating the potential significance of the protection of SSPAs aimed at protecting SMAs, it is essential to conduct detailed assessment of the conformity of the subjects of conservation in both types of areas (with respect to forest-dependent large mammals of interest in SMAs) (see Chapter 9.).

6.5.2. Natura 2000

The overlap of Significant Migration Areas with Special Protection Areas (SPA) and Sites of Community Importance (SCI) is defined in Figure 6.7. and summarised in the following chart.

Chart 6.5. *Overlap of SMAs and Natura 2000 network.*

Category	Size of SMA (km^2)	Size of SMA (% of the total area of SMAs)
Special Protection Areas (SPA)	5 717	17.0
Sites of Community Importance (SCI)	6 066	18.0

From the point of view of the Natura 2000 network, 87% of Special Protection Areas and 84% of Sites of Community Importance are covered with Significant Migration Areas. From the point of view of SMAs, 17% of these areas are located within Special Protection Areas and 18% within Sites of Community Importance. Significant Migration Areas involve SCIs, which secure conservation of large carnivores, namely SCI Beskydy (Eurasian Lynx, Grey Wolf, Brown Bear), SCI Šumava (Eurasian Lynx), SCI Boletice (Eurasian Lynx), and SCI Blanský les (Eurasian Lynx).

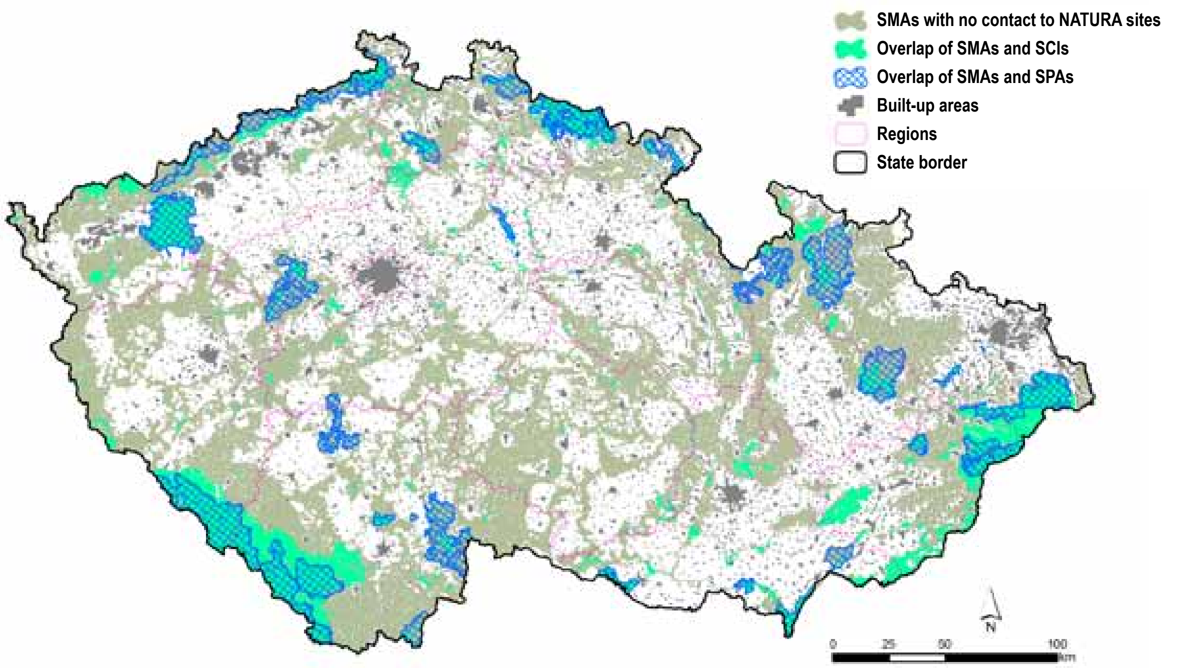

Fig. 6.7. *Overlap of Significant Migration Areas and Natura 2000 network.*

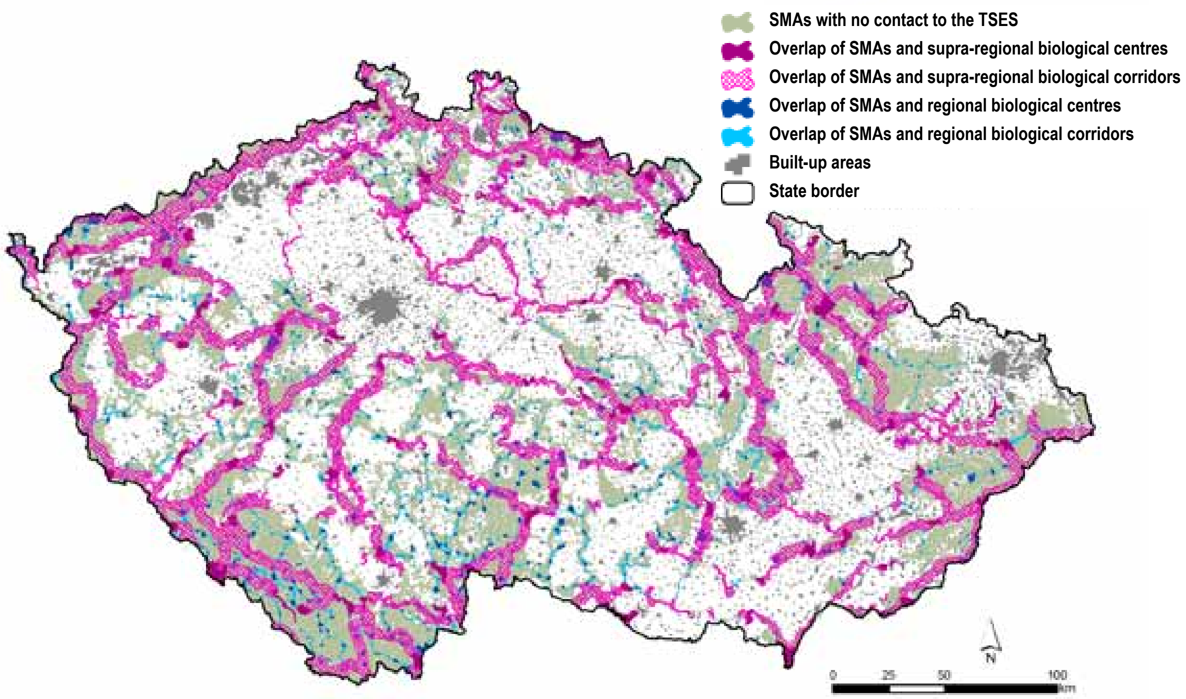

Fig. 6.8. *Significant Migration Areas and the territorial system of ecological stability.*

6.5.3. Territorial System of Ecological Stability

Figure 6.8. depicts the overlap of Significant Migration Areas and the supra-regional and regional territorial system of ecological stability (TSES).

The overlap of Significant Migration Areas and the territorial system of ecological stability is essential as both systems aim at protecting the landscape connectivity, though on distinct methodology bases. Comparison at the supra-regional level of the TSES is most appropriate. Approximately 85% of supra-regional biological centres are covered with SMAs.

Supra-regional biological corridors with buffer zones of 2 km from the axis represent a large-scale category exceeding 20 000 km^2. Approximately 50% of their total area coincide with SMAs. From the opposite angle, about 35% of SMAs are located within supra-regional biological corridors.

6.5.4. Natural Parks

Overlap of Significant Migration Areas and natural parks is shown in Figure 6.9.

Chart 6.6. *Overlap of SMAs and natural parks.*

Category	Size of SMA (km^2)	Size of SMA (% of the total area of SMAs)
Natural parks	5 419	16.1

Pursuant to the act on the conservation of nature and the landscape, natural parks are determined to secure protection of the landscape character. For this reason, they are mostly designated in areas characteristic with a harmonious natural landscape, a mosaic of forest and agricultural habitats and water bodies. Equally, these areas provide favourable conditions for the occurrence and migration of large mammals. This corresponds with the considerable overlap of the two categories. Approximately 70% of all natural parks are to be found within SMAs, while 16% of all SMAs in the Czech Republic are part of natural parks.

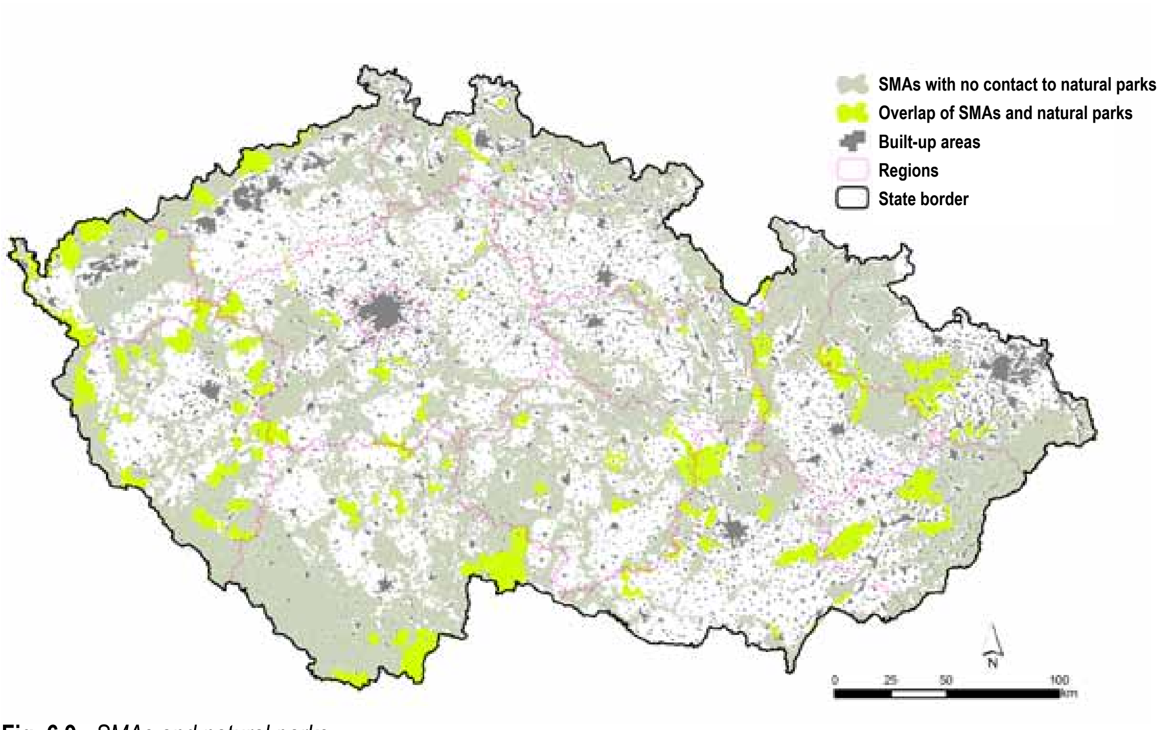

Fig. 6.9. *SMAs and natural parks.*

6.5.5. Significant Landscape Component

Significant landscape components (SLC) are a category established to protect near-natural ecosystems. Their comprehensive list is laid down by a legal regulation (forests, mires, watercourses, ponds, lakes, and floodplains) and they may be registered by nature conservation bodies. All these components form an important skeleton of the landscape that is preferably used by animals for migration. Thus, the large overlap of significant landscape components and SMAs is obvious. Total 65% of SMAs are covered with forests. Including other SLCs, we acquire an even larger overlap of the categories.

6.6. PARTIAL CONCLUSION ON SIGNIFICANT MIGRATION AREAS

Within the protection of landscape connectivity for large mammals, Significant Migration Areas constitute the top territorial category. They comprise both areas of permanent occurrence and areas necessary to secure the migration connectivity of the species populations. Both types of areas overlap within SMAs.

Within the frame of the present project, SMAs have been further specified reaching an area of 33 508 km^2, i.e. 42% of the total area of the Czech Republic. However, they should not be viewed as a new large-scale protection category. Significant Migration Areas are covered in 85% with areas already protected under other categories of nature conservation. SMAs simply bring a new element into the system of nature conservation, i.e. a higher emphasis not only on the quality of the habitats as such, but also and mainly on their connectivity. They are fundamentally designed to protect the connectivity of the landscape as a whole. This should primarily be considered within the processes of spatial planning (see Chapter 9.).

LITERATURA

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7.

Long-Distance Migration Corridors

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7.1. DEFINITION AND ROLE IN THE SYSTEM OF PROTECTION OF LANDSCAPE CONNECTIVITY

Long-Distance Migration Corridors (LDMC) are part of the concept aimed at the protection of landscape connectivity for large mammals. On the three-level hierarchical scale of the protection of landscape connectivity (Significant Migration Areas – Long-Distance Migration Corridors – Migration Routes), they represent the central element playing a key role as to long-term sustainability of landscape connectivity. Their principal function is to connect populations of large mammals on the national and Central European level.

LDMCs have the following principal characteristics:

- They connect areas that are significant for the permanent and temporary occurrence of large mammals.
- They are conceived as a vital minimum (not as an ideal situation) to retain the permeability of the landscape for large mammals at present and with the view to long-term sustainability.
- They are components of Significant Migration Areas. In case SMAs extend over a vast area (mostly mountain ranges, areas of permanent occurrence, e.g., the Šumava Mts.), LDMCs represent only one of the numerous potential migration corridors. By contrast, they provide the only opportunity for migration of large mammals through the landscape on sites with limited migration permeability and narrow linear SMAs. Protection of

the last existing permeable routes is, in fact, the key role of LDMCs.

- LDMCs are designed as linear structures in the landscape tens of kilometres in length and on average 500 m in width.
- Urban areas are not included in LDMCs, even when they are situated within the given zone, i.e. 250 m from the axis on each side of the corridor. Regulations required for LDMCs do not apply to urban areas.
- They represent locations with a higher probability of occurrence of large mammals.
- They are designed to achieve maximum permeability along their entire length. The individual spots of currently existing impermeable barriers are viewed as "critical sites". These are rather exceptional cases preconditioned by feasible substitutional solutions to acquire permeability. Such solutions may be demanding both financially and organisationally (construction of ecoducts, planting of vegetation) but may not be seen as impossible (e.g., removal of an urban area). In the future, the critical sites have to be addressed in detail, i.e. by delimiting precisely the Migration Routes (MT). Spots with multiple migration barriers or with an otherwise significantly reduced or complicated permeability are viewed as "limited sites".

The purpose of LDMCs is to secure the permeability of the landscape for animals restricted to the forest environment and to provide conditions for interaction of their populations. This is a fundamental prerequisite for the long-term existence of the species. The corridors are designed sufficiently wide to enable undisturbed migration of all fauna, including species with the highest environmental requirements (large carnivores, red deer, elk). The proposed density of their network constitutes the vital minimum for the long-term existence of the populations.

LDMCs provide and instrument for the coordination of interests of nature conservation and spatial development. A number of conflicts arise when LDMCs are neither delimited nor subject to any protection measures. Entities investing in industrial, transport, and urban development do not have access to any material that would inform them in time, i.e. at the very beginning of their investment activities, on the fact that the site of interest may constitute a migration corridor and that its protection is the interest of nature conservation. On the other hand, a Significant Migration Corridor, which required notable investment efforts to secure its permeability, may be degraded in another place by a newly constructed barrier.

As LDMCs have not been demarcated yet, the above-mentioned conflicts in spatial planning do arise. For this reason, the present project was designed to propose Long-Distance Migration Corridors as its basic output.

7.2. METHODOLOGY OF DELIMITING LONG-DISTANCE MIGRATION CORRIDORS

7.2.1. Background Material

The methodology concerning LDMCs aimed at their delimitation at the professional level and based on current knowledge. This required use of a wide range of background material:

- Basic geographical maps of the Czech Republic at the scale of 1: 50 000
- Orthophoto maps
- Maps of specially protected areas, maps of sites of the Natura 2000 network
- Maps of the supra-regional and regional territorial system of ecological stability
- Maps of CORINE Land Cover 2005
- Map of Significant Migration Areas
- Map of potential migration barriers
- Outputs of the background research on the ecology and behaviour of large mammals
- Current data on the distribution of the species of large mammals of interest in the Czech Republic
- Outputs of mathematical models (habitat model and model of the landscape potential)
- Consultations with a number of specialists and local professionals

7.2.2. Principles of Delimitation of Long-Distance Migration Corridors

Mapping of LDMCs focused on selecting the most suitable routes for migration of the given species under the actual field conditions. The presented proposal of LDMCs is based on certain key principles, which shall be observed even within the process of spatial planning. Spatial planning will presumably contribute to further specification of migration corridors.

The key principles for delimiting Long-Distance Migration Corridors are:

1) An LDMC shall be delimited with the aim to secure no less than the minimum long-term sustainable permeability of the given area.
2) An LDMC is delimited by its axis and a buffer zone of 250 m in basic width on each of its sides.
3) An LDMC should involve a minimum number of migration obstacles.
4) Currently, the axis of an LDMC always has to be permeable. If this is not the case, an alternative route for the corridor shall be sought. If no alternative exists and the site is the key part of the corridor securing migration of large mammals in the Czech Republic, this site has to be marked as critical and a solution to ensure its permeability shall be proposed. Technical solutions to impermeability have to be feasible.
5) Partial migration barriers may occur within the buffer zone of the corridor. The actual width of the corridor may thus narrow in justified cases but may not exceed the limitations for individual types of barriers (see item 6).
6) The permeability of a barrier is always determined by a combination of its technical and spatial parameters on the one side and by the environmental conditions in the surroundings on the other side. Hence, each contact with a barrier has to be evaluated individually based on an expert field survey. Chart 7.1. gives rather an informative overview of the limiting parameters for the permeability of barriers.
7) LDMCs shall be delimited while giving preference to forest habitats and other habitats facilitating migration (meadows with dispersed vegetation, riparian vegetation, linear vegetation, etc.). Arable land within an LDMC is acceptable merely when no other alternative exists (non-forest areas are also viewed as barriers). In such situations, implementation of escape covers and any type of forest vegetation in fields is highly recommended.
8) The routes of LDMCs should avoid, to the maximum possible extent, any type of built-up areas, particularly

Chart 7.1. *Limiting parameters for permeability of barriers.*

Type of barrier	Criteria defining the barrier as impermeable
Settlement	Continuous settlement or an open distance between municipalities less than 50 m; in case of scattered structures, a distance between objects (fences) less than 10 m
Motorways and roads	Total physical obstacles (noise walls, retaining walls, reinforced steep embankments and cuts, fencing) on any type of road; motorways and expressways lacking migration objects
Railways	Total physical obstacles (noise barriers, retaining walls, reinforced steep embankments and cuts, fencing) on any type of railway; high-speed rails (HSR)
Watercourses	Technically reinforced or otherwise modified banks that completely block any free access to the watercourse; water bodies over 500 m in width
Fenced areas	Stable and high (over 2 m) fencing of wire, concrete, wood, sheet metal; passage between two fenced areas narrower than 10 m
Non-forest area	Distance over 5 km between two forest stands in an open landscape lacking any trees, over 10 km in a landscape with dispersed vegetation

settlements. In case an urban area interferes in the width of the LDMC, i.e. 250 m off the axis on each side, the respective municipality is not considered as part of the LDMC and no related regulations apply to it.

9) In border areas, LDMCs have to be connected to migration networks of the neighbouring countries. The level of this connectivity has to be evaluated to secure its functions and permeability outside the Czech Republic. Should there be a barrier in the close vicinity of the Czech border that inhibits the permeability of the corridor (i.e. the critical site), an alternative solution to the corridor route shall be sought.

10) Any changes in the routes of LDMCs may be made solely on the grounds of a migration study that will provide comprehensive evaluation of the available information and results of a detailed field survey.

7.2.3. Field Mapping and Processing of Outputs

Outputs of field mapping represented the fundamental basis for the proposal of LDMCs. The potential routes of LDMCs derived from the analysis of the background material were verified through a detailed field survey. Particular attention was paid to the contact of LDMCs with potential barriers. The overall permeability of the conflict site was evaluated. In cases, when the site was assessed as impermeable, an alternative solution for the route was sought. The outputs of the field survey were jointly processed in the GIS environment.

The permeability of individual parts of migration corridors varies depending on the natural conditions and existence of barriers. Each section of an LDMC may thus be evaluated throughout the entire scale from “entirely impermeable” to “permeable with no barriers”. The scale of permeability of individual barriers is commented in Chapter 3 – Migration Barriers. Two types of sites with a significantly limited permeability were defined within the mapping process:

- Critical sites (marked as K1) – constitute sections of LDMCs that are entirely impermeable but where feasible measures could be adopted to secure permeability.
- Limited sites (marked as K2) – are sections of LDMCs that are currently permeable only with great efforts, mostly due to multiple barriers.

As to their size, the mentioned sections of LDMCs may vary in length from several tens of meters (e.g., when a motorway crosses the corridor) to several kilometres, when multiple barriers or vast non-forest areas are present. To give a clear view, the critical and limited sites are marked in the map as spots.

The proposed LDMCs are linked to analogical ecological networks that are being prepared in neighbouring countries. For more details on the issue, see Chapter 8.

7.3. DESCRIPTION AND CHARACTERISTICS OF LONG-DISTANCE MIGRATION CORRIDORS

The map of Long-Distance Migration Corridors is the basic output of the project. It is to be published by the Agency for Nature Conservation and Landscape Protection of the Czech Republic as a territorial analytic data source.

The map of LDMCs defines:

- Axes of Long-Distance Migration Corridors
- Numbers assigned to individual LDMC sections
- Critical sites
- Limited sites

The basic scale of the LDMC map is 1 : 50 000, which reflects the level of its details. LDMCs cannot be automatically viewed at the scale of 1 : 10 000 or a scale of cadastral maps. In case a more detailed scale is needed (e.g., within the processes of spatial planning), elaboration of such maps derived from the LDMC map will require further processing of the layer. Figure 7.1. shows a synoptic map of LDMCs.

Despite being surface units, LDMCs have their axes as a basic attribute. Thus, any subsequent evaluation will relate to the mentioned axis and any data on contacts with various types of territories will be defined as the length of the axis passing through the given territory (in km). Equally, the density of corridors is determined as a sum of the mentioned lengths of axes related to the size of the given territorial category (km/km^2).

Total 10 060 km of LDMCs were delimited in the territory of the Czech Republic. Their average density reaches 0.127 km/km^2.

Critical and Limited Sites

Out of all LDMCs determined in the Czech Republic, 28 sections were demarcated as critical sites (K1) and 178 as limited sites (K2). A synoptic map of critical sites is shown in Fig. 7.2., while the map in Fig. 7.3. depicts limited sites of LDMCs.

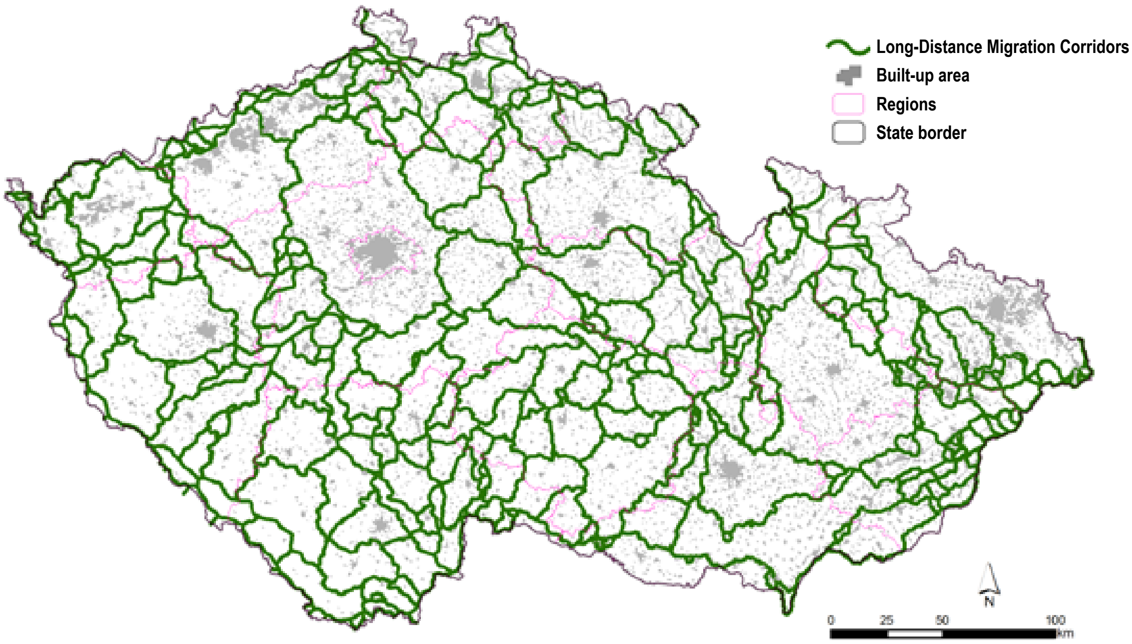

Fig. 7.1. *Synoptic map of Long-Distance Migration Corridors.*

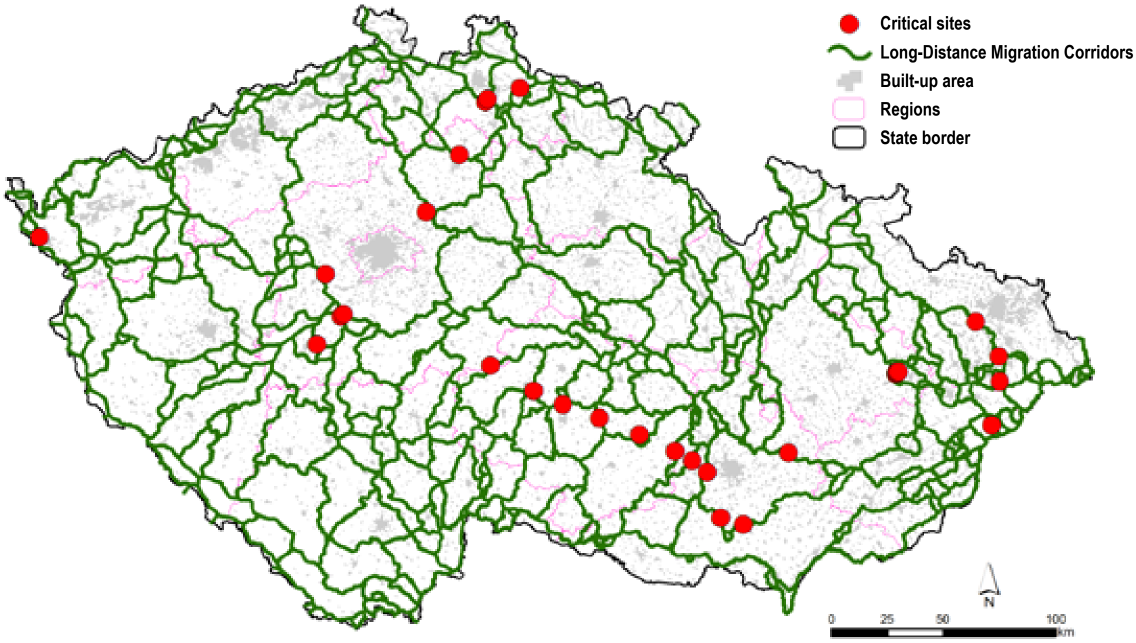

Fig. 7.2. *Synoptic map of critical sites of LDMCs.*

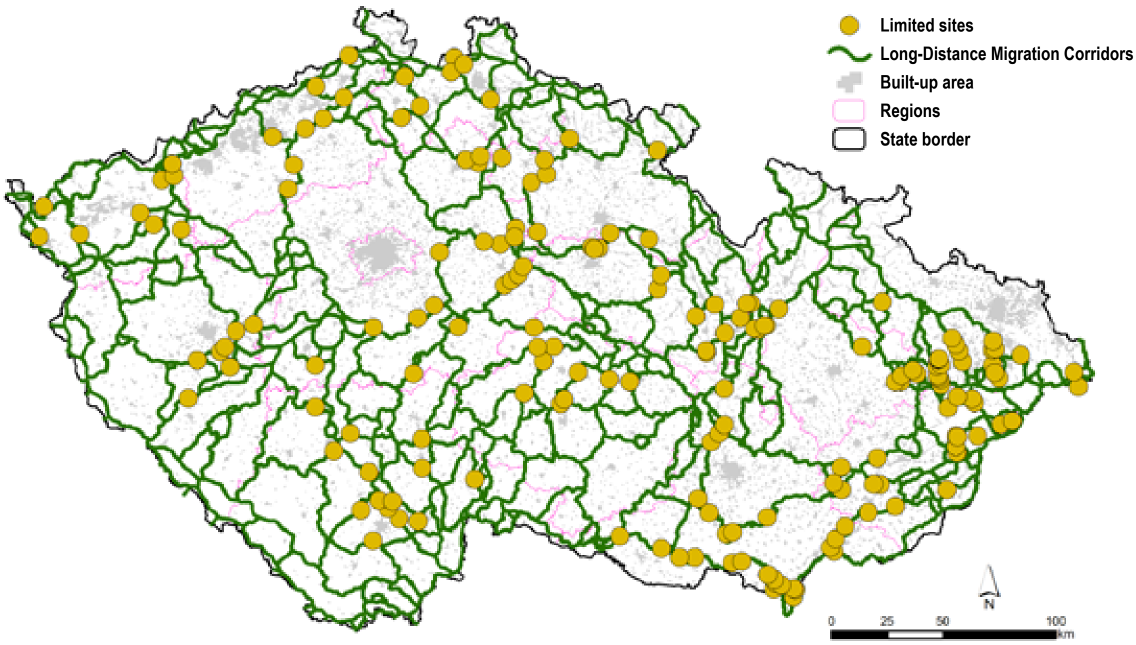

Fig. 7.3. *Synoptic map of limited sites of LDMCs.*

The following Chart 7.2. gives an overview of critical sites of LDMCs.

Chart 7.2. *Critical sites of LDMCs.*

CRITICAL SITE NO.	WORKING NAME	CORRIDOR NO.	TYPE OF BARRIER
100	Velké Němčice	55	Non-forest area, road, motorway D2, fences, settlements
101	Pohořelice	95	Non-forest area, road, expressway R 52
102	Milenov	345	Non-forest area, motorway D47 by a tubosider
103	Lipník nad Bečvou	346	Motorway (D47 lacking a passage), non-forest area
104	Popůvky	211	Motorway D1, road 602
105	Vyškov	191	Non-forest area, railway, 4 roads, motorway D1, settlements
106	Karolinka	205	Non-forest area, railway, road, watercourse, fence
107	Říčany u Brna	214	Motorway D1
108	Devět křížů	236	Motorway D1, road 602
109	Velké Meziříčí	244	Motorway D1, road, non-forest area
110	Trojanovice	283	Settlements, fencing, road, non-forest area
111	Meziříčko	367	Motorway D1
112	Žabník	355	Non-forest area, motorway D47 with an underpass
113	Klokočí	356	Non-forest area, motorway D47 with an underpass
114	Kozlovice	384	Fencing, road, non-forest area, settlement
115	Vysoký kámen	402	Motorway
116	Bystrá	496	Motorway D1
117	Klimkovice	485	Railway, non-forest area, road, settlement
118	Děkanovice	504	Motorway D1
119	Dubenec	603	Road I/4, road I/18, non-forest area, quarry, settlements
120	Voznice	620	Expressway R4, road, built-up area
121	Dobříš	638	Expressway R4, road
122	Beroun	673	Motorway D5, road, railway, settlements, non-forest area
123	Skorkov	767	Expressway R10
124	Skalka	736	Water Reservoir Skalka
125	Chudoplesy	770	Expressway R10, road II/610, non-forest area, impact of settlements
126	Hodkovice n. Mohelkou	846	Expressway R35, railway, impact of settlements
127	Rádlo	847	Expressway R35, railway
128	Tanvald	858	Road I/10, railway, brook

7.4. DISTRIBUTION OF LONG-DISTANCE MIGRATION CORRIDORS IN THE CZECH REPUBLIC

Taking into account the natural conditions in the Czech Republic and the purpose of LDMCs, they cannot be evenly distributed. The subsequent part documents the distribution of LDMCs with respect to the administrative division of the country and the natural conditions.

7.4.1. LDMCs by Regions of the Czech Republic

Chart 7.3. states the density and length of corridors in individual regions of the country.

The total length of LDMCs in each region largely depends on the size of the respective region; natural conditions also have a significant effect. The South Bohemian Region is ranked at the top with the maximum total length of corridors (1 518 km), while the Region of Hradec Králové has the lowest value (457 km), and the Capital of Prague has no delimited corridor at all. The density of corridors provides a more objective comparison. The highest density of LDMCs is in the Region of Zlín (0.183 km/km^2) and the lowest in the Region of Hradec Králové (0.096 km^2). The difference between the maximum and the minimum density of LDMCs is only a double, which proves that each region, despite the diversity of natural conditions in the country, significantly contributes to the connectivity of the Czech landscape. The LDMC map gives a clear view of the fact.

7.4.2. LDMCs by Elevation

Chart 7.4. illustrates the length of LDMCs in lowlands, uplands, highlands, and mountains.

The density of LDMCs obviously increases along with the growing elevation. This reflects the distribution of habitats preferred by the focal species, which are concentrated in mountain areas. Uplands (covering 29% of the Czech Republic) encompass most of the total length of corridors (40.6%). Mountains of over 800 m a.s.l. cover merely 4.2% of the country area but the length of corridors in them reaches 9.2% of all corridors.

7.4.3. Corridors by Habitat Type

Processed on the grounds of the CORINE Land Cover 2006 database, Chart 7.5. below gives the basic view of corridors passing through various types of habitats.

Visibly, approximately 85% of all corridors pass through forest habitats. This reflects the ecological requirements of the studied large mammals and the overall concept of LDMCs, which intentionally implements mainly forest habitats. At the same time, this documents a general relation of LDMCs to conservation of forest ecosystems. It should be noted that the resting 15% of non-forest habitats, where LDMCs have to pass, will play a decisive role determining the overall permeability and functionality of the corridors. Migration barriers that may discontinue the corridor are typically concentrated in these habitats.

Fig. 7.4. *Linear vegetation constitutes a substantial element connecting forest habitats.*

Chart 7.3. *Length and density of LDMCs by region.*

Region	Length of LDMC (km)	Length of LDMC (% of total length)	Density of LDMCs (km/km^2)
South Bohemia	1 518	15.1	0.151
South Moravia	810	8.1	0.115
Karlovy Vary	551	5.5	0.166
Hradec Králové	457	4.5	0.096
Liberec	517	5.1	0.163
Olomouc	537	5.3	0.104
Pardubice	568	5.6	0.126
Plzeň	898	8.9	0.119
Prague	0	0.0	0.000
Moravia-Silesia	703	7.0	0.126
Central Bohemia	1 088	10.8	0.099
Ústí nad Labem	651	6.5	0.122
Vysočina	947	9.4	0.137
Zlín	724	7.2	0.183

Chart 7.4. *Length of LDMCs in lowlands, uplands, highlands, and mountains.*

Elevation	Length of LDMC (km)	Length of LDMC (% of total length)	Density of LDMC (km/km^2)
Lowlands (up to 300 m a.s.l.)	1 111	11.0	0.058
Uplands (300 to 500 m a.s.l.)	3 796	37.7	0.115
Highlands (500 to 800 m a.s.l.)	4 088	40.6	0.177
Mountains (over 800 m a.s.l.)	930	9.2	0.279

Chart 7.5. *Length of LDMCs in various types of habitat.*

Habitat type	Length of LDMC (km)	Length of LDMC (% of total length)	Density of LDMC (km/km^2)
Anthropogenic	4	0.0	0.001
Agricultural – arable land	767	7.6	0.023
Meadows, pastures	602	6.0	0.048
Water bodies, wetlands	28	0.3	0.043
Forests	8 567	85.2	0.312

7.5. RELATION OF LONG-DISTANCE MIGRATION CORRIDORS TO SELECTED CATEGORIES OF NATURE CONSERVATION

The relation of Long-Distance Migration Corridors to various categories of nature conservation plays an important part in their actual protection. In fact, this relation is mutually beneficial. In case of concurrence with another category of nature conservation, the instruments of protection of the given category may be used for the protection of the LDMC. By contrast, LDMCs play their role as an element connecting all components of the respective ecological network. The following part explains the relation of LDMCs to specially protected areas, sites of the Natura 2000 network, natural parks, and the territorial system of ecological stability.

7.5.1. Specially Protected Areas

Figure 7.5. indicates the overlap of Long-Distance Migration Corridors with national parks and protected landscape areas. The summary is given in the chart below.

The network of Long-Distance Migration Corridors connects all national parks and protected landscape areas (except PLA Litovelské Pomoraví). Approximately 25% of

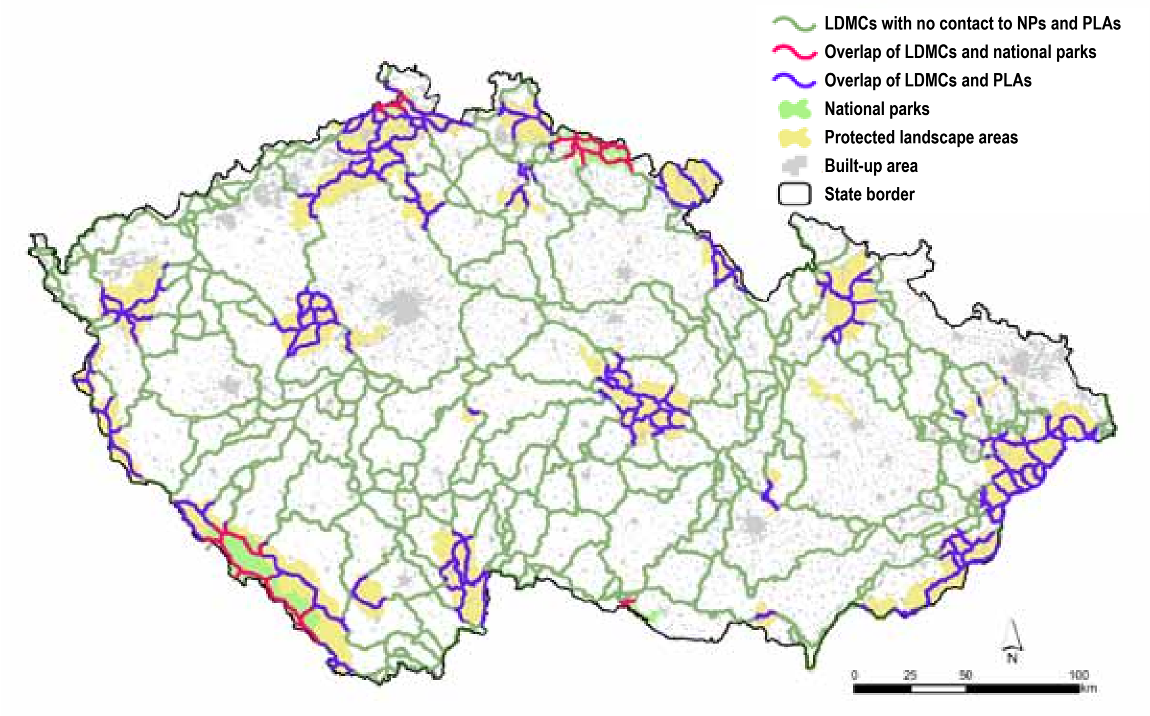

Fig. 7.5. *Contact of Long-Distance Migration Corridors with national parks and protected landscape areas.*

Chart 7.6. *Length and density of LDMCs in national parks and protected landscape areas.*

Habitat type	Length of LDMC (km)	Length of LDMC (% of total length)	Density of LDMC (km/km^2)
National parks	280	2.8	0.235
Protected landscape areas	2 173	21.6	0.210
Total	2 453	24.4	0.203

the total length of LDMCs are located in large-scale specially protected areas.

Thanks to the mentioned overlap, the protection of LDMCs may be secured in the future also by applying measures already existing for national parks and protected landscape areas.

The overlap with small-scale specially protected areas (SSPA) should be addressed from the practical point of view as well. SSPAs differ significantly in size and in the subject of conservation. Approximately 300 of such areas get in contact with LDMCs. With the view to increasing the potential protection of LDMCs, the main significance should be seen particularly in contacts with such SSPAs that are situated outside national parks and PLAs and where forest species or forest ecosystems are subject to conservation.

7.5.2. Natura 2000

Overlaps of Long-Distance Migration Corridors with Special Protection Areas (SPA) and Sites of Community Importance (SCI) are illustrated in Fig. 7.6. and summarised in the following chart.

Total 18.7% of Long-Distance Migration Corridors cover Sites of Community Importance and 15.2% overlap Special Protection Areas. As SPAs and SCIs overlap largely as well, the above-mentioned values cannot be summed. From the practical point of view, the overlap of an LDMC with an SCI is of particular importance where forest

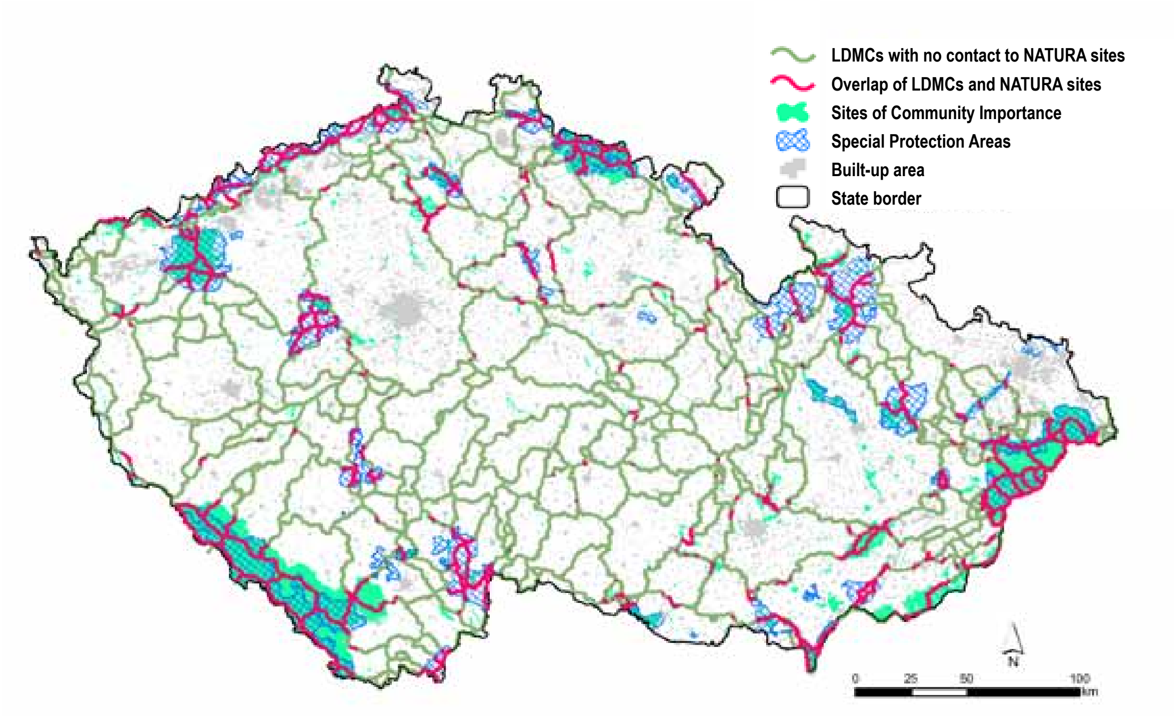

Fig. 7.6. *Contact of Long-Distance Migration Corridors with sites of Natura 2000 network.*

Chart 7.7. *Length and density of LDMCs within the Natura 2000 network.*

Habitat type	Length of LDMC (km)	Length of LDMC (% of total length)	Density of LDMC (km/km^2)
Special Protection Areas (SPA)	1 531	15.2	0.226
Sites of Community Importance (SCI)	1 863	18.7	0.255

species and forest habitats in the SCI are subject to conservation.

7.5.3. Territorial System of Ecological Stability (TSES)

Overlaps of Long-Distance Migration Corridors with the supra-regional and regional systems of ecological stability are illustrated in Figure 7.7.

The territorial system of ecological stability of the landscape represents the only category of nature conservation that forms an ecological network in the landscape, as is the case of Significant Migration Areas and Long-Distance Migration Corridors. The spatial relation of both systems is important with respect to their mutual connectivity and potentially common protection measures. LDMCs connect approximately 70% of supra-regional and 30% of regional biological centres. The buffer zones of supra-regional biological corridors (2 km from the axis to each side) comprise approximately 40% of the length of LDMCs. Despite the fact that both systems share a number of their parts, as may be seen in the map, they cannot be viewed as a single system.

The TSES is based on different methodology, primarily aimed at the protection of both forest and non-forest habitats. This is the reason why the routes of many biological corridors do not coincide with the ideal migration routes for large mammals dependent on the forest environment.

Another methodology issue is that the TSES accepts a discontinued biological corridor, which becomes impermeable for large mammals.

On the other side, the TSES is clearly embedded in the Czech legal regulations and in spatial planning, which is beneficial for the protection of LDMCs. In cases when LDMCs and the TSES can follow the same route, the TSES may be applied as a highly efficient tool to protect LDMCs.

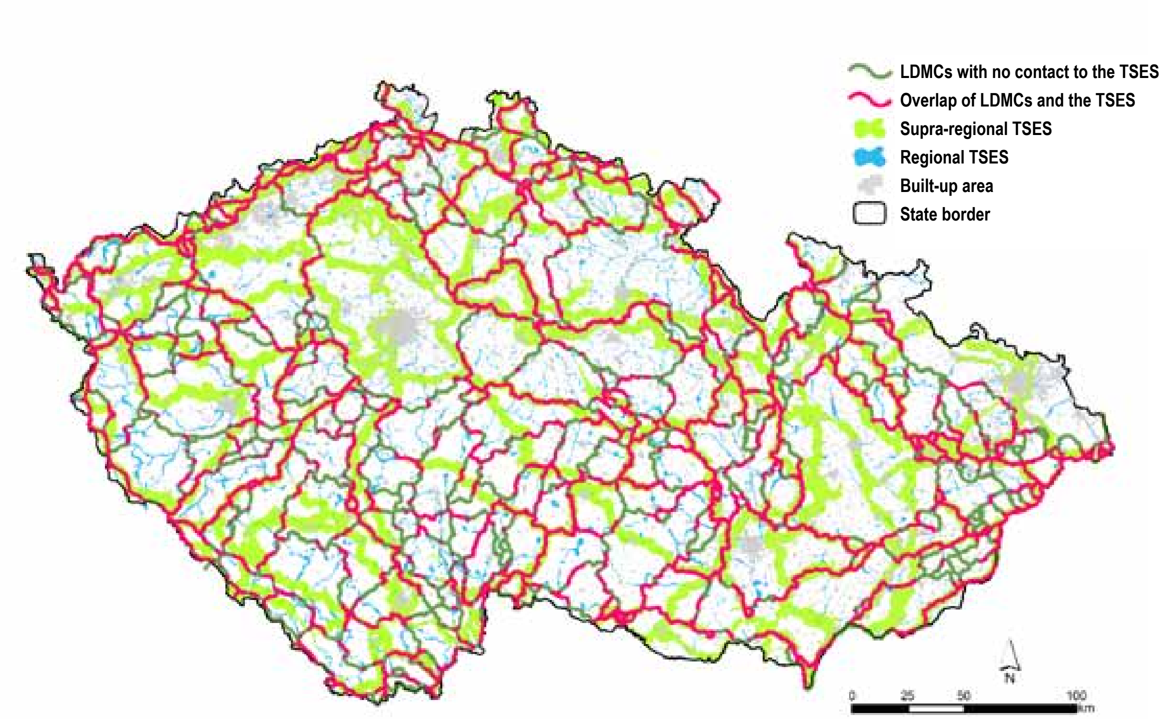

Fig. 7.7. *Long-Distance Migration Corridors and the territorial system of ecological stability.*

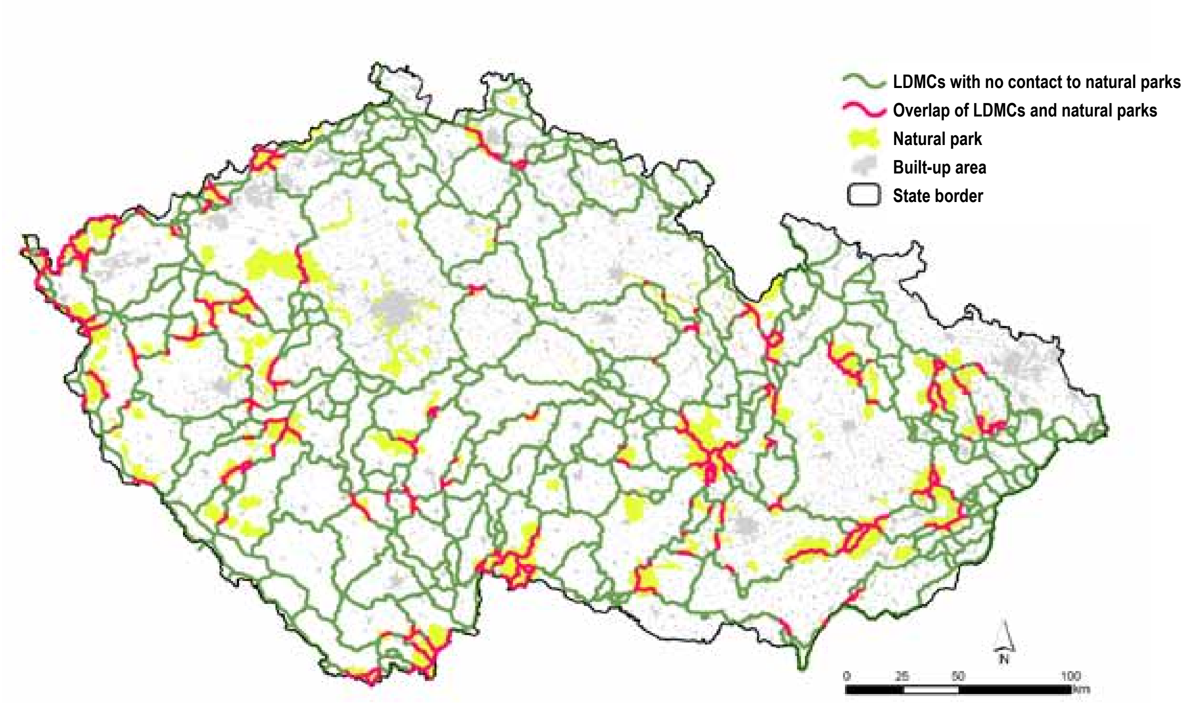

Fig. 7.8. *Long-Distance Migration Corridors and natural parks.*

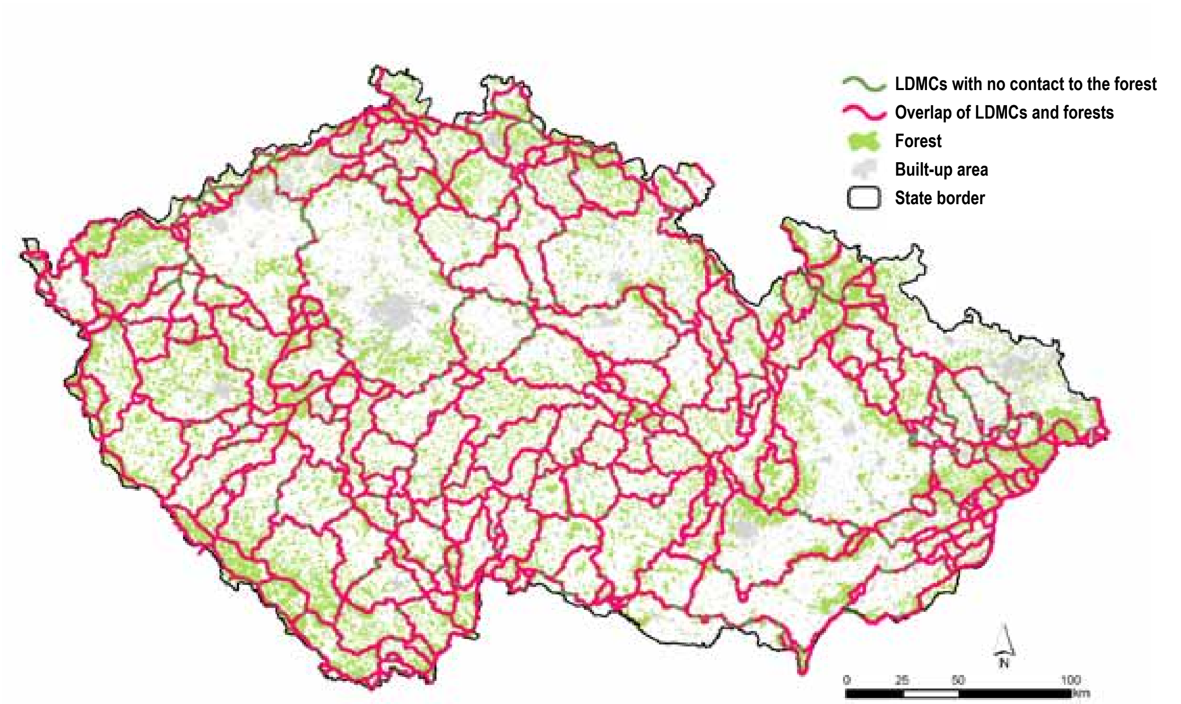

Fig. 7.9. *LDMCs and the forest cover.*

7.5.4. Natural Parks

Overlaps of Long-Distance Migration Corridors and natural parks are depicted in Fig. 7.8.

Natural parks represent a category designated for the conservation of the landscape character. Within a number of investments, such as extensive transport constructions, large warehouse precincts, new residential areas outside existing urban zones, constructions in the open landscape, etc., the interests of conservation of the landscape character frequently resemble the interests of the protection of the landscape connectivity. Many natural parks represent areas that are significant for the permanent and temporary occurrence of the given species as well as for their migration.

Such areas are namely the Novohradské hory Mts., Česká Kanada, parts of the Krušné hory Mts., the Hostýnské vrchy Hills, the Oderské vrchy Hills, etc. For example, natural parks enhance the connectivity of the Carpathian and Sudeten system, or the Šumava and the Brdy Mts.

Long-Distance Migration Corridors connect approximately 60% of natural parks and their total length in natural parks reaches 1 574 km (i.e. 15.8% of their total length in the country).

7.5.5. Significant Landscape Components (SLC)

Significant landscape components constitute a very important frame of natural and semi-natural habitats in the landscape (see Chapter 6.). With respect to the protection of LDMCs, it is essential that, under Czech legislation, forests are also defined as SLCs since 85% of the length of LDMCs pass through them. As an ecological network connecting primarily forest habitats in the landscape, LDMCs contribute to securing its connectivity not only for the focal species but for most of the forest species in general.

LDMCs passing through forests are illustrated in Figure 7.9.

Overlaps of LDMCs and SLCs are of a relatively negligible extent. Their analysis at the level of the Czech Republic is hence not essential. By contrast, when designing detailed Migration Routes at the local level, e.g., in spatial planning, significant landscape components may act as decisive elements, i.e. so called stepping stones, enhancing the permeability of the landscape.

7.6. PARTIAL CONCLUSION ON LONG-DISTANCE MIGRATION CORRIDORS

Long-Distance Migration Corridors serve to connect populations of large mammals at the national and Central European level. They represent the minimum vital extent of connections securing migration opportunities that need to be conserved. They characteristically pass through forests or other semi-natural habitats and continuity with a minimum number of barriers is one of their basic qualities. The total length of LDMCs in the Czech Republic is 10 060 km. However, this number does not suggest an entirely new category in nature conservation, as approximately 90% of all Long-Distance Migration Corridors pass through areas that are already subject to a certain level of nature conservation laid down in the Czech legal system. In addition, LDMCs avoid, to the maximum possible extent, built-up areas and do not include urban areas. Thanks to the above-mentioned facts, no new category of nature conservation is required to ensure effective protection of LDMCs in practice. It is rather necessary to make appropriate use of the existing instruments for the conservation of ecological networks and connectivity of the landscape. LDMCs join other resembling networks that are being designed in the neighbouring countries and have the potential to become part of a pan-European ecological network serving for the migration of large mammals.

8.

Migration Corridors beyond the National Border

Martin Strnad, Tereza Mináriková & Dušan Romportl

8.1. INTRODUCTION

Fragmentation of the landscape due to urban sprawl and fast progressing constructions of roads has become a real issue not only in the Czech Republic. Western Europe is facing much higher fragmentation by transport and settlements (Farrall et al. 2002, Madriñan et al. 2010 in prep). Unless we adopt sufficient measures in the foreseeable future at the national level, the Czech Republic will very probably suffer an irreversible increase in the landscape fragmentation, which will reach the level of Western Europe. Gradual fragmentation of the landscape brings along a number of negative impacts, such as barrier effects, causing a loss of natural connectivity between individual populations of fauna. (Seiler 2002). The subsequent drop in the genetic variability may lead, among other effects, to a further loss of biodiversity at both the national and the European level.

Large carnivores, i.e. the Eurasian Lynx, Brown Bear, and the Grey Wolf, represent one of the groups of animals highly sensitive to landscape fragmentation. Their spatial and habitat requirements on their home range are considerable. These species are currently restricted to forested mountains or submountain areas, where they can live nearly undisturbed by man. Although their subpopulations in Central and Western Europe inhabit relatively large areas, their numbers are poor. The distribution range of large carnivores involves a number of countries in Central and Western Europe, but the species live more dispersed (Figures in Chapter 2) and the potential areas providing suitable environment for the permanent occurrence of their subpopulations are often too distant one from another. Young individuals seeking their new home ranges, which would offer sufficient food supply and undisturbed environment suitable for reproduction, are often forced to migrate long distances regardless the state borders (see Chapter 2.). Moreover, the long-term sustainability of these populations is jeopardised in many countries by other factors (e.g., illegal hunting). Had they not been supported by migrating individuals, a number of populations would have already died out. Populations of large carnivores in Central and Western Europe may rather be characterised as many minor subpopulations that more or less communicate. Such subpopulations are generally less tolerant to various disturbances, such as newly appeared barriers, lost or altered habitats, or escalated illegal hunting. Conservation of these species shall therefore be addressed and secured at the pan-European level (Linnell et al. 2007).

The population of the Eurasian Lynx in the Czech Republic well illustrates the situation. In Central Europe, the largest population of the lynx may be found in Slovakia, in a continuous area of the Carpathians. It counts approximately 2 500 animals that occupy an area of eight European countries (Linnell et al. 2008). From there, the migrating animals penetrate the areas of the Beskydy (Czech-Slovak border) and the Jeseníky Mts. (Czech-Polish border), where their tracks are most frequently found. The Šumava and the Bayerischer Wald Mts. rank among places where a larger population of the species permanently occurs and reproduces. The range of the Eurasian Lynx involves here the Czech Republic, Germany, and Austria. The area probably still retains its migration connectivity to the Carpathian population. The cumulative effect of barriers in Austria and Germany has already severely affected the formerly existing connection to the Alpine population though. Therefore, the migration connectivity to the Carpathian population has to be preserved as the key element securing long-term existence of the lynx population in the Czech Republic, as well as of the populations in Austria and Germany. The Czech Republic is highly responsible to the mentioned countries and should retain the migration connectivity for the lynx populations. In this respect, international cooperation aimed at the protection of the migration potential and connectivity of the landscape is vital not only for the Eurasian Lynx.

8.2. EUROPEAN PROJECTS

Planning and creation of migration corridors and similar ecological networks is one the principal methods aimed at mitigating the impacts of landscape fragmentation. From the European point of view, a number of projects address the issue of landscape fragmentation and its impacts on the diversity of fauna and flora communities. However, their objectives, extent, and methods often substantially differ. Infra Eco Network Europe (IENE) is an initiative that focuses, in a European context, on activities to reduce landscape fragmentation caused mainly by transport and urban infrastructure. It joins involves representatives of state organisations or NGOs involved in nature conservation and research, and its main objective is to create a network of contacts and facilitate intensive exchange of information, knowledge, and experience.

Among the main European projects of ecological networks are the following:

EECONET

It is a project that executes both of the most significant EU directives – Council Directive 79/409/EEC on the conservation of wild birds and Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. Its objective is to create an ecological network NATURA 2000, potentially network Emerald outside the European Union.

ECONNECT

Conservation of biological diversity in the region of Alpine countries is the principal objective of the project. It also intents to connect habitats and existing protected areas that are characteristic with high biological diversity. Enhancing migration of fauna and flora through migration corridors is one of the topics that are being addressed. Various approaches towards reducing the impacts of landscape fragmentation are being applied in seven pilot areas (Berchtesgaden – Salzburg, Isère, Northern Alps, the Rheathian Triangle, the Hohen Tauern region, south-western Alps, and Monte Rosa).

GREENBELT

The aim of this pan-European project is to create a network of protected areas in a vast area extending from the Baltic Sea to the Black Sea. In the Czech Republic, the area is delimited along the former Iron Curtain and spreads along the entire national border with Bavaria and Austria. The project requires international cooperation in order to create a network of national and natural parks and biosphere reserves. It should ideally incorporate protected areas that are perceived as stepping stones connected by suitable habitats.

TransEcoNet

The initial objective of the project TransEcoNet was to establish a uniform information system within national parks situated in transboundary areas in Central Europe. The outputs of the project involve proposals and recommendations regarding sustainable management in the pilot transboundary areas and potential solutions to securing transboundary ecological networks. In the Czech Republic, the areas of interest are the Labské pískovce Sandstone Mountains, the Jizerské hory Mts., the Krkonoše, the Beskydy, the Bílé Karpaty Mts., and Dolní Podyjí (lower River Dyje basin) in the region of Pálava. In Austria, these are the regions of northeast of Weinviertel and northern and southern Burgenland. The project involves National Parks Fertö-Hanság and Örség in Hungary, and parks Goričko and Kozjanski in Slovenia.

BUND Wildkatzenprojekt (Wildcat Rescue Project)

The project of non-governmental organisation BUND (Friends on Earth) was initiated in 2004 by establishing migration corridors for the Wildcat (*Felis silvestris*) between the Thuringian Forest and National Park Hainich. It has a rather exceptional position. Its main objective is to create a network of migration corridors at the national scale. The project is already being implemented beyond Thuringia, namely in Bavaria, Hesse, Lower Saxony, Baden-Württemberg, Rhineland-Palatinate, and other states of Germany.

8.3. SITUATION IN BORDERING COUNTRIES AND CONNECTION TO NETWORKS IN THE CZECH REPUBLIC

With regard to the present project, the mutual connection of the proposed network of migration corridors for large mammals in the Czech Republic to similar networks in neighbouring countries is one of the priorities. Activities concerning planning of migration corridors for the mentioned species of large mammals are currently, to various extents, in progress in nearly all bordering countries, which is a very positive fact (Fig. 8.1.). All the proposed networks of migration corridors were preferably intended for large carnivores, namely for the Grey Wolf and the Eurasian Lynx, and for large hoofed game, such as the Red Deer. They are primarily designed to enable migration of the focal species between the core areas at the supra-regional scale.

The subsequent text gives a more specific description of migration corridors in individual countries or regions.

8.3.1. Poland

A. Preparation of Ecological Network

The network of migration corridors for the Grey Wolf in Poland may be considered as one of the best prepared (Jędrzejewski et al. 2005). Researchers from the Polish Academy of Sciences, Mammal Research Institute, Białowieża have been working on the issue for a long period of time in cooperation with the Association for Nature "Wolf". The network is formed by the migration corridors themselves, but also by stepping stones (i.e. areas with a habitat suitable for the temporary occurrence of the species during migration), and by core areas, which provide conditions for long-term occurrence of the wolf populations. Migration corridors usually copy vast forest complexes and their width is variable. Three main categories of migration corridors may be distinguished according to their level and character: international, national, and local. Their legal protection is grounded on the EU directives

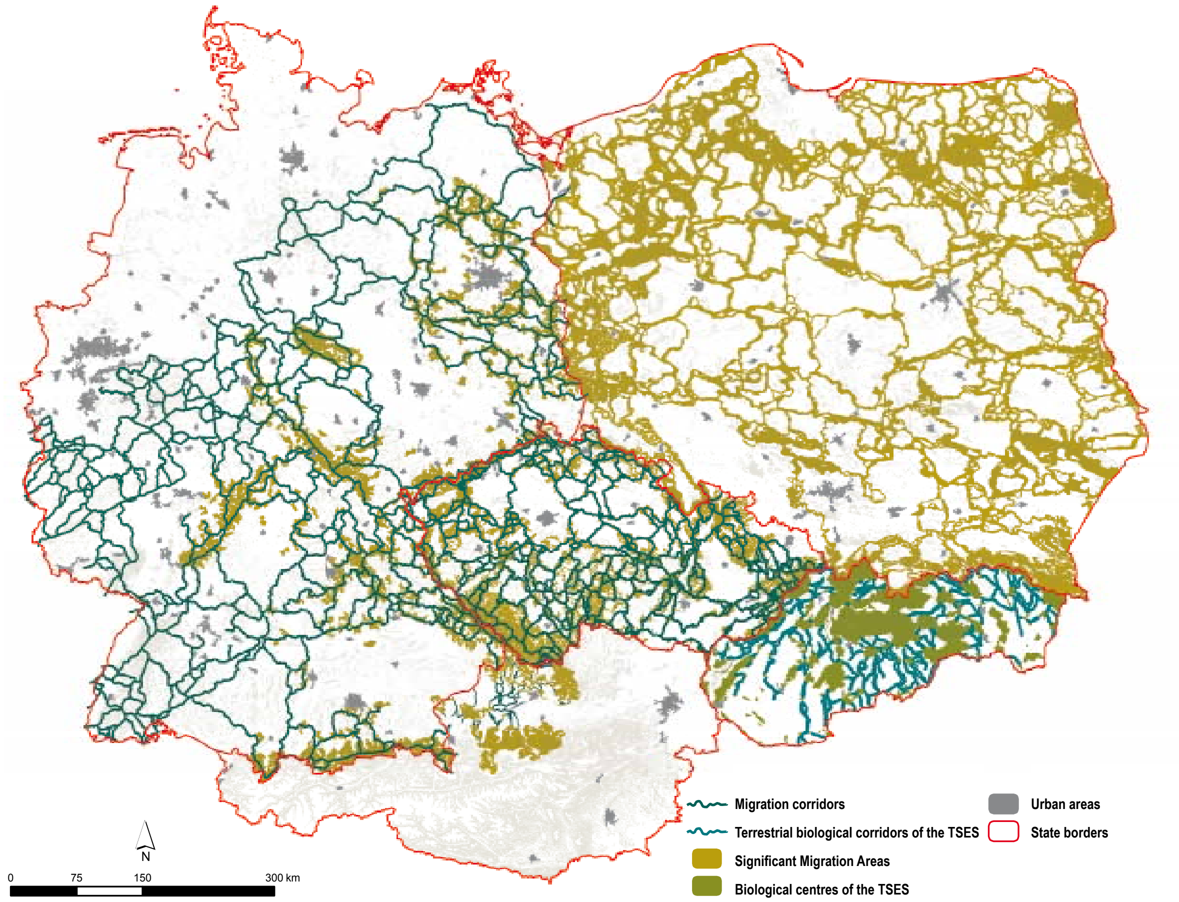

Fig. 8.1. *Working map of proposed migration corridors for large mammals in the Czech Republic, Poland, Germany, Upper Austria, and the terrestrial TSES in Slovakia. Source: Jędrzejewski, W., Nowak, S., Stachura, K., Skierczyński, M., Mysłajek, R. W., Niedziałkowski, K., Jędrzejewska, B., Wójcik, J. M., Zalewska, H., Pilot, M., Hänel, K., Reck, H., Herrmann, M., Klar, N., Schumacher, J., Schumacher, A., Walz, U., Stratmann, L., Oö. Umweltanwaltschaft (2010), Miklós, L., Kočická, E., Kočický, D., Esprit s. r. o.*

(conservation of species of Community interest, environmental impact assessment). They find their practical application as background material for spatial planning at the level of higher administrative units (voivodeships).

B. Connection of the Czech and Polish Ecological Network

The Czech Republic has the longest border with Poland, which is mostly covered with forest complexes in mountain areas. These areas are currently little fragmented by man and thus represent a substantial refuge for most focal species of large mammals.

In general, the entire borderland of the Czech Republic that is characteristic with high elevations may be seen as very important for migration thanks to its still preserved favourable permeability.

The borderland between the Czech Republic, Poland, and Slovakia in the Slezské Beskydy Mts. is a key area with the view to preserving the cross-border connectivity of migration corridors. Here, lynxes, wolves, and bears still migrate across the borders heading towards the Moravskoslezské Beskydy Mts. (see Fig. 8.2.).

The Jeseníky Mts. are also one of the significant areas where cross-border migration of wolves and lynxes is recorded. The current proposal for the given region counts with the connection of the Czech migration corridor to an existing corridor in Poland, leading north-westwards of the town of Javorník, where it continuously penetrates the local forests. In the south of Poland, the Jeseníky Mts. transform into a highly urbanised area with intensively managed farmland. Due to this situation, no other corridor is included in the current Polish proposal for the east of the Jeseníky. Nevertheless, there is an ongoing review of the Polish proposal for migration corridors, which points at another permeable migration area with a high forest cover. Situated northeast of the town of Zlaté Hory, this area has a potential to be incorporated in the Polish network. Regions of the Labské pískovce, the Lužické hory Mts., the Jizerské hory, the Krkonoše, and the Orlické hory Mts. are among important areas for migration of the lynx and the wolf.

At present, transboundary connectivity of migration corridors and conservation of the landscape permeability both in the Czech Republic and in Poland have a substantial influence on migration of the Eurasian Elk. Elks migrate annually to our territory from the Polish source population. Most frequently, they may be observed moving in the regions of Šluknov and Frýdlant. They also penetrate the borders of the Czech Republic in a relatively wide area from the east of the Krkonoše to the Orlické hory Mts., heading southwards. In the future, in addition to the lynx, also wolves may be expected to appear in the region of Frýdlant, coming mainly from the west of Poland.

8.3.2. Germany

A. Preparation of Ecological Network

Germany also offers a well-elaborated nationwide network of migration corridors; see Hänel & Reck (2009), Huckauf & Reck (2009), Herrmann & Klar (2009a, b), Schumacher & Schumacher (2009), Walz & Stratmann (2009). This concept equally counts with three principal interaction elements of a migration network, which includes core areas with both recent and potentially future (based on habitat models) occurrence of the species of interest, namely of the Eurasian Lynx, Wildcat, Grey Wolf, Eurasian Elk, Chamois, and the Red Deer. In addition to core areas, stepping stones with favourable habitats are considered again to be connected by individual corridors. Migration corridors are designed based on models of habitat preferences in individual species and on models simulating connectivity of core areas. In Germany, they are planned throughout the country as a line with an unchangeable protection zone along their full length. Migration corridors are protected as habitats of protected fauna species by the EU legislation and by the German act on nature conservation.

B. Connection of the Czech and German Ecological Network

The border between the Czech Republic, Austria, and Germany, in the regions of the Šumava Mts. and the Český les, is currently a very significant refuge for a permanent cross-border population of the Eurasian Lynx and more connections of Czech corridors to those in Bavaria and Upper Austria are planned here (Fig. 8.1.). Individual animals migrating from the mentioned area may actually be observed in the entire west borderland from the Krušné hory Mts. to the Labské pískovce Sandstone Mountains. These high peaks covered with forests along both sides of the border are perceived as a Significant Migration Area conveying high permeability. Two representatives of corridors pass in parallel here and cross-border connections in highly forested areas are proposed for them. The presently migrating Eurasian Lynx and the Red Deer will very probably be accompanied in the future by wolves coming from the north, from an area approximately 50 km distant from Šluknov, where a small population permanently occupies the German-Polish borderland in Upper Lusatia. This population was formed thanks to successive dispersal from the west of Poland (Kontaktbüro Wolfsregion Lausitz, 2010). Several cross-border corridors are thus planned in the region of Šluknov to reach neighbouring Saxony.

8.3.3. Austria

A. Preparation of Ecological Network

Mainly professionals from the University of Natural Resources and Life Sciences in Vienna stand behind the proposed migration corridors in the country. Their project, however, suggests only general directions for entire Austria on the grounds of habitat models for the lynx and the bear (Köhler 2005, Hafner 2006). Regrettably, such general directions are nearly useless for an R&D project. Other proposals for networks of migration corridors are being elaborated, but only at the level of individual federal states and with lacking coordination. The present project uses information on migration corridors from Upper Austria. As other countries, also Austria counts with a network composed of core areas and stepping stones with a suitable habitat, which are connected through migration corridors. In the target species (Eurasian Lynx), the width of a migration corridor was determined to be 1 km. All corridors are designed in three categories, i.e. of a regional, national, and international significance. As there is no specific legislative rule aimed at the protection of migration corridors at the national level, it is currently secured only through the EU directives (conservation of species of Community interest). In Upper Austria though, preparations of a specific act on the protection of migration corridors are already in progress (Donat & Pöstinger pers. comm. 2010).

B. Connection of the Czech and Austrian Ecological Network

The whole border area of Upper Austria fluently transforms into National Park Šumava, which is still home to a stable population of the Eurasian Lynx. Along with the adjacent National Park Bayerischer Wald, it forms a vast core area on the German side, where individuals have been regularly recorded migrating southwards to the right bank of the Lipno Reservoir and further to the Novohradské hory Mts. Several cross-border connections, mostly oriented in the north-south direction, are planned from both of the mentioned particularly important migration areas. Migration corridors in Upper Austria leading to the south should ensure permeability for the lynx between its

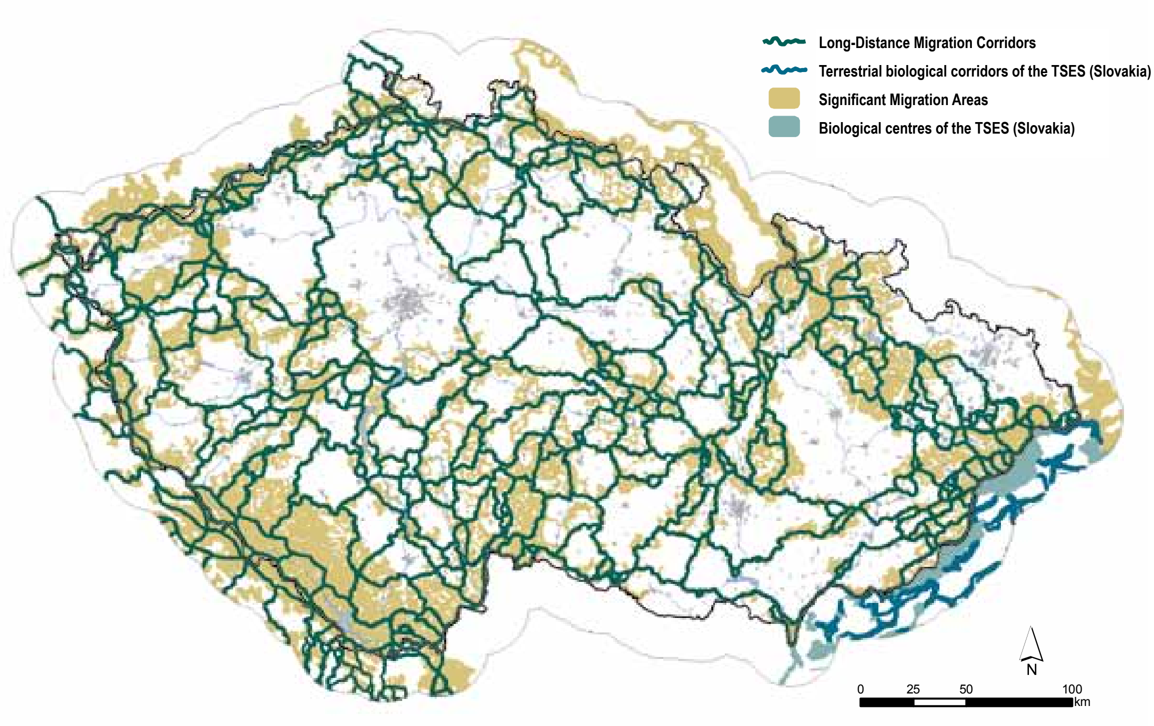

Fig. 8.2. *Map of migration corridors in the Czech Republic and their connections beyond the national border.*

Alpine and Šumava home ranges. In addition, the proposed corridors are supposed to serve for migration of the Red Deer, which also regularly occurs here. The right bank of the Lipno Reservoir is currently the core area with the regularly occurring Eurasian Elk. Elks migrate from here further to Upper Austria.

8.3.4. Slovakia

A. Preparation of Ecological Network

Presently, Slovakia has a single proposal for an ecological network available, i.e. the territorial system of ecological stability (TSES), which is, equally to the Czech Republic, laid down by the act on nature conservation.

The ongoing projects focus on the identification of migration corridors always at the regional or local level; no nationwide network of migration corridors is under preparation at the moment (Finďo et al. 2007). The most significant project currently running in Slovakia is an international project involving various organisations in Slovakia and Austria, e.g., WWF Austria, ASFINAG (Austrian motorway company), National Park Donau-Auen, University of Natural Resources and Life Sciences in Vienna, State Nature Conservancy of the Slovak Republic (ŠOP SR) – PLA Administration Záhorie, Daphne, National Motorway Company (Národná diaľničná spoločnosť), Slovak University of Technology, and Carpathian Wildlife Society. Its objective is to establish an Alpine-Carpathian corridor for large carnivores, i.e. the lynx, wolf, and the bear, as target species. The project defined an area north and south of the town of Malacky as a Significant Migration Area, with four ecoducts planned across the motorway from Brno to Bratislava. The project should secure migration of large carnivores between the Carpathian and the Alpine range of their current distribution.

B. Connection of the Czech and Slovak Ecological Network

In relation to migration of large mammals, the Czech-Slovak borderland in the region of the Moravskoslezské Beskydy and the Javorníky Mts. represents a priority area. The local populations of all three species of large carnivores directly communicate with much larger populations in Slovakia, which, in fact predestine how many migrants will come to our country in the future. It is thus crucial to retain the existing cross-border continuity in this core area for large mammals and help sustain the presence of the critically threatened species, such as the lynx, wolf, or the bear. As the area is also home to the Red Deer, the proposal introduces the highest density of cross-border migration corridors. The area of the former boundary line in Mosty u Jablunkova deserves more attention with the view to preserving the migration potential for large carnivores. It is one of the last places, where the space enabling migration of large mammals has not been sealed yet by a continuous built-up area. Moreover, it is connected to an adjacent large forest complex that is documented to provide migration opportunities between the Slezské Beskydy and the Moravskoslezské Beskydy Mts.

The Makovský průsmyk Mountain Pass is another significant area for the migration of wolves and lynxes. Some records of the bear and the lynx, less frequently also of the wolf, come from the highest elevations of the Bílé Karpaty Mts., which are attached to the core area of Javorníky. Animals migrate between these two mountain ranges east of the village of Střelná, along the state border, characteristic with another continuous forest complex. The future attention should not only be paid to these highly significant migration areas, but also to the adjacent areas. A great part of the borderland in Slovakia is currently involved in biological centres of the TSES of supra-regional importance (PLA Kysuce) or in the terrestrial biological corridor of the TSES (region of Jablunkov and the Lyský průsmyk Mountain Pass).

8.4. PARTIAL CONCLUSION

Fragmentation of the landscape due to fast growing road constructions and urbanisation poses a serious problem in both Central and Western Europe. Its negative impacts are most critical on animal species with large ranges, such as large carnivores. The protection of populations of large carnivores, including the protection of the landscape connectivity for migration, may be efficient solely if conducted at the pan-European level. The herein presented network of migration corridors for large mammals in the Czech Republic and in the surrounding countries (Fig. 8.1.) was designed in cooperation with professionals from bordering countries so as to ensure the mutual connectivity to other networks beyond the national border. Despite certain variations in methods related to planning and creation of migration corridors in individual states, the efforts to maintain the supranational connectivity for populations of fauna restricted to forest habitats (represented by large carnivores, the Eurasian Elk, and the Red Deer) are the only way towards their efficient conservation.

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9.

Measures to Protect Migration Permeability of the Landscape for Large Mammals

Tereza Mináriková, Petr Anděl & Václav Hlaváč

9.1. UNDERLYING THESIS

The proposal for measures to protect migration permeability of the landscape is based on the propositions formulated on the grounds of:

a) analysis of the current situation regarding migration permeability of the landscape,

b) distribution of focal species of large mammals in the territory of the Czech Republic,

c) evaluation of the extent and dynamics of the increase in the number of barriers in the landscape.

Underlying Thesis:

- The density of migration barriers in the Czech landscape has been reaching a level that entirely interrupts the native connection of natural and semi-natural habitats. The landscape ceases to fulfil its original function of an element connecting various populations of species. This phenomenon is known as fragmentation.
- The number of migration barriers in the landscape has been constantly growing. The most significant migration barriers are the following: 1. construction of settlements in the open landscape, 2. construction of transportation infrastructure and an increasing intensity of road traffic, and 3. establishment of fenced areas in the open landscape.

- Fragmentation of the landscape causes fragmentation of populations of wild fauna, which may cause a loss of their genetic variability and reduce their fitness.
- Landscape fragmentation has a severe negative impact on populations of endangered species of large mammals. They require a large home range and their populations exist in many European countries. Thus, conservation measures concerning these species shall be adopted for the entire area of the Czech Republic and shall be implemented in cooperation with other European countries.
- The focal species (Eurasian Lynx, Brown Bear, Grey Wolf, Eurasian Elk, and Red Deer) show the highest requirements on migration corridors of all forest species. By securing favourable conditions for their migration, we simultaneously provide migration opportunities for all other forest species.

Measures aimed at protecting the landscape connectivity for large mammals may be divided into two principal sections:

a) general measures to protect the landscape from fragmentation,

b) specific measures to protect the connectivity of the landscape for large mammals.

9.2 GENERAL MEASURES TO PROTECT THE LANDSCAPE FROM FRAGMENTATION

Securing the connectivity of the landscape for large mammals and thus for all species of wild fauna is part of the comprehensive protection of the landscape from fragmentation. Although individual species have distinct requirements on the permeability of the landscape, certain measures adopted to protect the landscape from fragmentation have a global character. These are principally the following:

- Increasing awareness of both professional and non-professional public concerning the real significance of landscape fragmentation and its subsequent impacts, in particular fragmentation of populations of wild fauna.
- Incorporating protection of the landscape from fragmentation in the national legislation.
- Incorporating landscape fragmentation as an obligatory agenda item in the process of environmental impact assessment.

9.2.1. Increasing Awareness on Fragmentation of the Landscape and Fauna Populations

For long, neither the general public nor professionals have perceived landscape fragmentation as a severe threat to biodiversity. This phenomenon has not been described until recently and has been gaining significance during the past two decades, i.e. the period of considerable development in urbanisation and transport infrastructure, which form the vast majority of migration barriers.

Proposal for Measures:

- Introduce the topic of landscape fragmentation in trainings and further education of civil servants and other staff of state administration and self-governing units (mainly in nature and landscape conservation, spatial planning, and other related sectors).
- Enhance awareness of the professional and non-professional public concerning the seriousness of the impacts of landscape fragmentation.

9.2.2. Implementing Protection of the Landscape from Fragmentation in National Legislation

Act No. 114/1992 on the conservation of nature and the landscape currently in force does not define landscape fragmentation and does not rank it among threats to biological diversity. It neither lays down any limitations or protection measures in this respect. For these reasons, the proposed measures to ensure landscape connectivity are presently based on the general and special conservation of nature defined by the mentioned act (e.g., effect on significant landscape components or specially protected species of fauna). To be incorporated in relevant legislation regulating spatial planning and environmental impact assessment, the issue of landscape fragmentation has to be defined by the principal legal rule on nature conservation.

Proposal for Measures:

- To incorporate protection of the landscape from fragmentation in Act No. 114/1992 Coll., on the conservation of nature and the landscape, and the respective legal regulations (the Building Act and possibly other regulations).

9.2.3. Incorporating Landscape Fragmentation as an Obligatory Agenda Item in the Process of Environmental Impact Assessment

The process of assessment of environmental impacts of intents and concepts should consider all the effects comprehensively, i.e. in theory also including the effects on the fragmentation of fauna and flora populations, fragmentation of ecosystems, and landscape connectivity. However, this is not being applied in practice. Landscape fragmentation issues should be involved in the mentioned processes, both at the legislative level and at the level of implementation.

Proposal for measures:

- Once protection of the landscape from fragmentation is incorporated in Act No. 114/1992 Coll., on the conservation of nature and the landscape, authorisation to publish an implementing regulation shall be established by amending Act No. 100/2001 Coll. on environmental impact assessment. The implementing regulation will subsequently define the contents and extent of assessment of impacts on the landscape connectivity and fragmentation of populations of wild fauna (elaboration of so-called migration studies).
- To prepare binding methodology for the administrative and organisational practices of state administration bodies to comply with the obligations laid down by the proposed regulation to Act No. 100/2001 Coll., on environmental impact assessment.
- To prepare expert methodology for persons authorised to assess environmental impacts of landscape fragmentation, which will recommend practices of assessment of impacts on landscape connectivity and fragmentation of wild fauna populations.

9.3. SPECIFIC MEASURES TO PROTECT LANDSCAPE CONNECTIVITY FOR LARGE MAMMALS

The principal measure proposed by the present document regarding the protection of landscape connectivity for large mammals is to delimit and protect a network of areas that will provide connection within and between areas of permanent and temporary occurrence of large mammals.

This network is composed of three hierarchically arranged components, which are:

- Significant Migration Areas (SMA) – representing the top level of the hierarchy. These relatively large areas are significant since they relate to the occurrence and connectivity of populations of large mammals at the national and Central European level. The concept of their delimitation is detailed in Chapter 6.
- Long-Distance Migration Corridors (LDMC) – as the medium level of the hierarchy. These are specifically delineated migration corridors serving to connect populations of large mammals at the national and Central European level. The concept of their delineation is described in Chapter 7.
- Migration Routes (MR) – are routes delineated on a local level and to a maximum detail. Long-Distance Migration Corridors should be refined into Migration Routes on critical sites on the basis of their particular evaluation: i.e. evaluation of permeability and combination of barriers on the given site, connectivity of habitats used by large mammals, and connection of the Migration Route to respective Long-Distance Migration Corridors (see subchapter 9.3.3.).

Protection of the proposed migration network should be secured by:

- Delimiting SMAs and LDMCs and determining the respective protection measures
  Significant Migration Areas and Long-Distance Migration Corridors shall be defined as individual units with a common concept of delimitation and equal protection measures in the entire territory of the Czech Republic.

This should be established by publishing SMAs and LDMCs as a territorial analytic data source under Act No. 183/2006 Coll., on town and country planning and building code (the Building Act) and under Decree No. 500/2006 Coll., on territorial analytic data, land-use planning documentation and method of recording land-use planning activities. In addition to the delimitation of these areas, limits should be set as to the utilisation and protection of SMAs and LDMCs, which should further be taken into account within the creation of spatial and regulation plans.

- Implementing the existing instruments of nature conservation to secure protection of the proposed areas

  A number of existing instruments of nature conservation already contribute to the protection of these areas, particularly in the following three sectors:

  General nature conservation

  - Territorial system of ecological stability as an instrument for the protection of LDMCs.
  - Protection of the forest, as a significant landscape component, as an instrument contributing to the protection of LDMCs (approx. 85% of the proposed LDMCs pass through forests; see Chapter 6.) and SMAs.
  - Protection of non-forest woody vegetation serving as stepping stones and mitigating the barrier effects of non-forest areas, i.e. places where LDMCs and SMAs lead outside forests.
  - Natural parks (as large-scale areas with significant aesthetic and natural values) represent an instrument enhancing protection of LDMCs and SMAs.

  Special nature conservation

  - Protection measures in small-scale and large-scale specially protected areas, particularly where forest species or ecosystems are subject of conservation. They represent an instrument supporting protection of LDMCs and SMAs.
  - Basic protection of selected specially protected species of fauna (Eurasian Lynx, Brown Bear, Grey Wolf, Eurasian Elk), in particular conservation of their habitats, serves as an instrument for the protection of LDMCs and SMAs.

  Natura 2000 network

  - Conservation of sites of Community importance, above all SCIs designated to protect populations of the Eurasian Lynx, Brown Bear, and the Grey Wolf, represents an instrument for the protection of LDMCs and SMAs.

9.3.1. Significant Migration Areas

Significant Migration Areas are designed to facilitate sustainable existence of the species populations and to secure their migration connectivity. In specially protected species of large mammals (Eurasian Lynx, Brown Bear, Grey Wolf, Eurasian Elk), an SMA may be viewed as a habitat of a specially protected species with respective legal protection. Protection of SMAs mainly involves pro-

tection of the landscape permeability as a whole with the view to providing sufficient quality of forest habitats and variability of their connections. Thus, SMAs are designed as relatively wide areas and the proposed regulations primarily have a framework character.

Proposal for protection measures in SMAs:

- The Agency for Nature Conservation and Landscape Protection of the Czech Republic shall publish updated SMAs as a common territorial analytic data source.
- Following the adoption of the general measures proposed in subchapter 9.2., all intents affecting SMAs should be subject to assessment of impacts on the landscape connectivity and fragmentation of wild fauna populations.

9.3.2. Long-Distance Migration Corridors

Long-Distance Migration Corridors (LDMC) are designed as parts of Significant Migration Areas and represent the actual long-distance passages through a territory. They should not be understood as and ideal state but rather as a minimum securing the permeability of the area for large mammals. LDMCs are approximately 500 m wide linear structures. As the fundamental requirement, they may not be interrupted by any barrier in the future that would completely inhibit migration. LDMCs are much smaller in size than SMAs but stricter protection measures apply to them.

Proposal for protection measures in LDMCs:

- The Agency for Nature Conservation and Landscape Protection of the Czech Republic shall publish LDMCs as an integrated territorial analytic data source.
- Expert methodology shall be drawn up recommending methods of work with the territorial analytic data source of LDMCs for the bodies of state administration, persons authorised to conduct environmental impact assessment, and for the professional public.
- The layer of LDMCs shall be incorporated in the Spatial Development Policy and in the Principles of Regional Spatial Development as a fundamental background material to secure connectivity of the landscape and to maintain conditions for sustainable existence of populations of the given specially protected species (Eurasian Lynx, Brown Bear, Grey Wolf, and Eurasian Elk).

The protection of LDMCs (applying the existing legislative instruments – particularly the TSES, special protection of species, conservation of Natura 2000 network, and specially protected areas – with a potential use of new instruments proposed in subchapter 9.2) should take into consideration the following principles:

a) The general principle does not permit any reduction in the width of the migration corridor by constructions that may negatively influence its use by migrating species. This mainly applies to construction of residential areas, industrial zones, constructions for energy purposes, for recreation, or construction of outdoor lighting.

b) Linear transport structures. In case a migration corridor crosses a significant linear transportation structure (multi-lane roads with central guardrails, fenced corridors of high-speed rails), an adequate migration object should be implemented (underpass or overpass). Their designs shall comply with Technical Conditions No. 180 set by the Ministry of Transport. A respective migration study shall be conducted to propose solutions reflecting the given local conditions. When migration corridors are discontinued by other first class roads and main railways, the actual conditions should be considered to aim the measures at reducing the death rate of animals while not affecting the permeability of the road or the railway.

c) Farmland. The permeability of agricultural land shall be retained along the axis of the migration corridor and 250 m on each of its sides. The main risk is posed by fencing and other migration barriers (fenced pastures, vineyards, plantations of fast-growing tree species, etc.). All non-forest vegetation fulfilling the functions of stepping stones (refuge and resting places) for migrating animals deserves particular attention.

d) Forests. To secure migration of animal species, no specific limitations are required within common practices of forest management, including the use of game-proof fencing of new plantations with the size complying with the respective regulations. However, the function of migration corridors may be negatively affected by structures in the forest that exceed the framework of common forest management practices, e.g., fenced game preserves. When planning such limiting structures, the permeability of the migration corridor should be taken into consideration.

e) Watercourses and other water bodies. If a migration corridor crosses a watercourse, no specific measures are required unless the regulated river banks inhibit any crossing (reinforcement by panels, tiles, fencing, etc.).

9.3.3. Migration Routes

In the system of protection of landscape connectivity, Migration Routes represent the level of physical implementation. They are specified in detail on critical or limited sites of migration corridors and should be subject to implementation of concrete protection measures. The basic map of Migration Routes should have details of a project study at the scale of 1: 5 000, accompanied by a project of protection measures and a financial budget.

Due to the presence of migration barriers and natural conditions, Migration Routes are characteristic with their limited width, which is frequently reduced to the actual minimum of permeability for migrating animals. The length of a Migration Route depends on the type of a barrier and usually varies between 1 and 5 km.

Protection of Migration Routes should be the most rigorous of all three mentioned categories and should be secured at the level of spatial planning in individual municipalities.

Proposal for measures in MRs:

- Within spatial planning, to successively produce a proposal of Migration Routes for all critical sites of LDMCs and include these in spatial planning of municipalities.
- If a technical solution to secure the landscape connectivity is imposed with respect to a newly permitted construction that interferes in an SMA or an LDMC, this shall be specified in the details of a Migration Route.

10.

Conclusion

Petr Anděl

The presented project addresses the issue of landscape permeability for the migration of large mammals. The above-stated text describes how landscape fragmentation limits the species migration and emphasises the necessity to protect the ecological networks with the view to securing sustainable existence of their populations. As its outputs, the herein presented project specifies in more detail and complements Significant Migration Areas, delimits Long-Distance Migration Corridors, and proposes conceptual and systemic measures aimed at protecting the landscape connectivity for large mammals. What has to be mentioned at this stage is a summarised prognosis regarding the development of our landscape in the future.

The evaluation of the future perspectives should build upon the following:

- **Still a relatively favourable state of the landscape in the Czech Republic as opposed to Western Europe.** Landscape fragmentation is not an issue only in our country, but in all Europe. Mainly Western Europe has already experienced the negative impacts of transformation of a natural or harmonised landscape into an entirely anthropogenic industrial and urban space, which it strives to revert now. In this respect, thanks to a certain lag in the development of infrastructure, the situation in the Czech Republic is much more favourable, which still gives us a chance to learn lessons from the mistakes of our western neighbours.
- **Trend of fast deterioration.** The development during the recent decades has shown that the situation worsens very fast, that the landscape suffers more fragmentation each day, and that the overall trend in the development of our territory copies the historic development of western countries. Unless immediate conceptual measures are taken, particularly in spatial planning, the above-mentioned perspective will become more than obvious. The primary causes of the landsca-

pe fragmentation are mainly the fast development of residential areas, constructions in the open landscape outside existing urban areas, and urban sprawl. These phenomena are closely linked to the development of transportation infrastructure, which further fragments the landscape.
- **Landscape connectivity is a vital precondition for conservation of ecosystems.** The landscape in the Czech Republic is fast approaching the breakpoint when its fragmentation will represent a limiting factor for nature conservation as a whole. Conservation of specially protected areas, Natura 2000 sites, and of other valuable ecosystems, is sustainable only if supported by sufficient connectivity of the landscape. Hence, the loss of the landscape connectivity may in the future considerably degrade the efforts devoted to the conservation of species and ecosystems.
- **Irreversible character of the induced changes.** The principal threat of landscape barriers and landscape fragmentation is their mostly irreversible character. Changes in the structure of settlements may never be taken back and natural ecosystems destroyed by direct or indirect interference will never be fully substituted. New barriers appear in the landscape each day and their permanent character will affect the condition of our nature for hundreds of years.

The measures aimed at the protection of landscape connectivity for not only large mammals have been known for many years and the present text depicts them. It should be noted though that these measures are not easy to adopt and their implementation will require great efforts. It is necessary to have the support of the general public; many experts and state institutions involved in nature conservation, spatial planning, and other sectors will have to participate.

By no means do these measures represent disproportionate limitations in the economic development of the society, as is often argued. Long-Distance Migration Corridors pass, in approximately 90% of their total length (!), through areas that are currently subject to a certain level of nature or landscape conservation measures. This means that they do not stand for new elements in nature conservation but primarily for a new approach giving equal importance to the connectivity of ecosystems as to the conservation of habitats. The protection of an ecological network is of the same significance as the protection of sites connected through this network. In substance, the proposed measures represent a change in the concept of the landscape protection with an emphasis on the indispensable cooperation of all who benefit from it.

The above-stated facts imply the following conclusion: a conceptual solution to the protection of the landscape connectivity can no longer be postponed and the present generation is held fully responsible for the state of our nature and the landscape at present and in the distant future.

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