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APPLYING OF INDICATOR VERTEBRATE SPECIES TO ENVIRONMENTAL ASSESSMENT IN THE LANDSCAPE: DANUBE – ODER – ELBE WATER CANAL IN THE CZECH REPUBLIC

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ABSTRACT

The aim of the study is to assess potential impact of construction of the Danube – Oder – Elbe (DOL) water canal on populations of vertebrate species – amphibians, reptiles, birds and mammals – and present using these species as bioindicators on landscape level. For analysis of the data, the canal route was divided into smaller sections which were assessed separately. The following criteria were analysed: 1) current occurrence of target vertebrate species, 2) identification of species affected by canal construction, including evaluation of their numbers, 3) identification of affected species protected by Czech legislation, 4) identification of affected species protected by EU legislation, 5) impact assessment of the DOL project on Special Protection Areas (SPAs) and Special Areas of Conservation (SACs), 6) data synthesis and impact assessment of the DOL vertebrates in the particular catchment areas. It is apparent that the most important negative impacts on vertebrate populations and their habitats in case of implementation of the DOL plan can be expected in the following sections of the Morava river: Hodonín – Břeclav, Kroměříž – Otrokovice, Veselí na Moravě – Hodonín, Troubky – Kroměříž, Doubravice – Střelice; of the Oder river: Jeseník nad Odrou – Ostrava, Ostrava – state border; and of the Elbe river: Česká Třebová – Pardubice. In case of construction of the DOL canal, disturbance, damage or loss of vertebrate habitats will occur at least at 6 out of 9 studied sections in the Morava catchment area, at 3 of 4 sections in the Oder catchment area and at 2 of 3 sections in the Elbe catchment area.

Key words: Amphibians, bioindicators, birds, environmental impact assessments, floodplain, mammals, reptiles, water transport canal, waterway.

INTRODUCTION

Construction of large technical structures in the landscape affects wildlife as well as the inanimate nature and has an essential impact on habitats of different species. In Central European floodplains, construction of the Danube – Oder – Elbe waterway (further referred

to as DOL) is one of the long-term planned projects, discussed by both its advocates and opponents for several decades already (Machar *et al*., 2015; Kovář, 2007). The aim of this project is to strengthen regional infrastructure with emphasis on the economy and ecology of waterway transport. In the upshot, the canal would be an interconnection of Black, Baltic and North Seas. This proposed structure would be unparalleled in the history of the Czech Republic, concerning its extent and economic demands. In the Czech Republic, the DOL route is included in several adopted regional strategic documents (spatial development principles) and is a part of local plans of numerous municipalities (Glacová, 2004). In the main national document of regional planning in the Czech Republic (Spatial Development Policy), further examination of DOL was recommended, despite the fact that an earlier study had shown a significant negative impact of the project on the Natura 2000 network (Machar, 2007). The DOL route would affect wide river floodplains of eight biogeographic regions within all four biogeographic subprovinces of the Czech Republic (Buček & Lacina, 2006). Potential impacts of this project on the landscape of the Czech Republic have been assessed by scientists first in the last two decades (Buček & Kříž, 1989; Kolektiv, 1990; Prax, 1990; Vlček *et al.*, 1992). Considering the scale of the DOL project, it is obvious that the construction would have a substantial impact on the landscape of floodplains of large rivers in Central Europe (Buček & Machar, 2012). The DOL project exceeds boundaries of the Czech Republic and is of European importance (European Commission, 2004). Despite the fact that it has been refused by many ecologists (e.g. Malanson, 1993; Štěrba *et al.*, 2008), the project is included in the Trans-European Transport Networks.

This paper focuses on the diversity of indicator vertebrate species in floodplains of the Morava, Oder and Elbe Rivers in the Czech Republic. The aim of the present study is to assess potential impact of construction of the DOL water canal on populations of vertebrate species – amphibians, reptiles, birds and mammals – and present using these species as bioindicators on landscape level.

MATERIAL AND METHODS

Considering that various species of vertebrates are sensitive towards different landscape and habitat changes, several factors were taken into account. Direct disturbance during the construction, namely the excessive stress on organisms along the construction route, is particularly important. Therefore the assessment was first focused on direct disturbance factors. However, further irreversible changes in the landscape and habitats may also occur after the construction is finished. Although several route variants of the individual branches of the canal have been prepared, in this study we assess the route of the „General solution of the Danube – Oder – Elbe waterway, situation 2002“ (Hydroprojekt, 1968), where the 1 : 50 000 maps show not only the canal itself (bed width 50 m, canal width incl. banks 150 m) and its route, but also the construction zone (width 650 m, or even more in some parts), which would affect or damage the given areas along the canal route in a long term. The maps also show hydrologically affected areas, where construction of the canal would cause disruption of ground- and mainly surface water. Therefore, not only the changes of habitats which are important for breeding of the particular vertebrate species, but also changes of habitats used for foraging, wintering and as migration corridors have to be considered. Clear negative impacts can be found in species associated with water (e.g. amphibians) as a result of changes in hydrological conditions, mainly at breeding sites. The situation in mammals is complicated, because of mainly species inhabiting larger territories. Construction of the DOL canal may result in the decline of food sources, changes or disruption of migration corridors,

population fragmentation and the overall weakening of population vitality. A similar situation may occur in birds, which use a certain habitat as a breeding site, foraging habitat, migration corridor or wintering grounds.

In case all the above mentioned catchment areas would be connected, possible effect of the DOL canal on further spreading of non-native animal species, mainly of the American Mink (*Mustela vison*), Racoon Dog (*Nyctereutes procyonoides*) and Racoon (*Procyon lotor*), should also be considered. Non-indigenous carnivores affect species which become their prey (e.g. ground-nesting birds, small terrestrial vertebrates), but also populations of related autochthonous carnivore species (e.g. mustelids). Basic information related to density and total amount of vertebrate assessed species comes from literature (Plesník, 2004).

For further analysis of the data, the canal route was divided into smaller sections which were assessed separately. The following criteria were analysed: 1) current occurrence of target vertebrate species, 2) identification of species affected by canal construction, including evaluation of their numbers, 3) identification of affected species protected by Czech legislation, 4) identification of affected species protected by EU legislation, 5) impact assessment of the DOL project on Special Protection Areas (SPAs) and Special Areas of Conservation (SACs), 6) data synthesis and impact assessment of the DOL vertebrates in the particular catchment areas. The affected species were classified into four categories of conservation status (Anonymous, 1992): vulnerable species – population and vitality of the species will be affected, however, extent of the impact cannot be determined; endangered species – population and vitality of the species will be affected, with an expected long-term decline of up to 20 % in the analysed section; highly endangered species – population and vitality of the species will be affected, with an expected long-term decline of 20-50 % in the analysed section; critically endangered species – population and vitality of the species will be affected, with an expected long-term decline of over 50 % in the analysed section (the species is at risk of extinction in the analysed section). The conservation status was determined only in species whose populations will be directly affected as a result of the DOL canal construction. They include mainly species associated with wetland habitats, species highly sensitive to disturbance, other sensitive species, species which are a protected phenomenon in specially protected areas, SACs and SPAs, and species which are infrequent or rare in the Czech Republic. If there were doubts whether the species would or would not be affected by the canal construction, the total national population of the given species was taken into account.

Individual branches of the canal were assessed separately and the results were then pooled for the particular catchment areas (Morava, Oder, Elbe). Identification of the separately assessed sections (Fig. 2) was based on geomorphological and geographic criteria. Larger towns were mostly used as landmarks of these sections. The sections are not of the same length. The aim was to assess which vertebrate species would be affected in the analysed section, to what extent, and where possible, what model of population development could be expected after the DOL canal construction was finished. For the purpose of this study, the following sections were identified in the Morava catchment area: Doubravice – Střelice (M1), Střelice – Olomouc (M2), Olomouc – Troubky (M3), Troubky – Kroměříž (M4), Kroměříž – Otrokovice (M5), Otrokovice – Staré Město u Uherského Hradiště (M6), Staré Město u Uherského Hradiště – Veselí nad Moravou (M7), Veselí nad Moravou – Hodonín (M8), Hodonín – Břeclav (M9); in the Oder catchment area: Rokytnice – Hranice na Moravě (O1), Hranice na Moravě – Jeseník nad Odrou (O2), Jeseník nad Odrou – Ostrava (O3), Ostrava – Czech border (O4); in the Elbe catchment area: Doubravice – Česká Třebová (L1), Česká Třebová – Pardubice (L2), Pardubice – Chvaletice (L3). The remaining navigable part of the Elbe river from Chvaletice to the Czech border near Hřensko (L4) was assessed in

a limited extent only (assessment of the occurrence of recorded species and possible negative impact of shipping on their populations), as the planned changes include only deepening of the river bed there.

Table 1: Numbers of protected areas designated based on national and EU legislation (SPAs, SACs) affected by potential construction of the Danube – Oder – Elbe canal (construction works or changes in water regime) in the particular sections of the Morava (M 1-9) catchment area

	M1	M2	M3	M4	M5	M6	M7	M8	M9	**Total**
National park										**0**
Protected Landscape Area	1									**1**
Nature Park					2			1	1	**4**
National Nature Reserve	1	1		1					2	**5**
National Natural Monument				1				1		**2**
Nature Reserve	6	6	1			2	1	2	3	**21**
Natural Monument	5	5	1	1	2	1	1	2		**18**
SPA	1							1	1	**3**
SAC	1	2	2	1	2	1	3	5	3	**20**
Total	**15**	**14**	**4**	**4**	**6**	**4**	**5**	**12**	**10**	**74**

Table 2: Numbers of protected areas designated based on national and EU legislation (SPAs, SACs) affected by potential construction of the Danube – Oder – Elbe canal (construction works or changes in water regime) in the particular sections of the Oder (O 1-4) catchment area

	O1	O2	O3	O4	**Total**
National park					**0**
Protected Landscape Area			1		**1**
Nature Park					**0**
National Nature Reserve	1		1		**2**
National Natural Monument				1	**1**
Nature Reserve	1	1	8		**10**
Natural Monument	1		4		**5**
SPA			1	1	**2**
SAC	2		2		**4**
Total	**5**	**1**	**17**	**2**	**25**

Table 3: Numbers of protected areas designated based on national and EU legislation (SPAs, SACs) affected by potential construction of the Danube – Oder – Elbe canal (construction works or changes in water regime) in the particular sections of the Elbe (L 1-4) catchment area (L4 – from Chvaletice to the border with Germany near Hřensko)

	L1	L2	L3	L4	**Total**
National park				1	**1**
Protected Landscape Area				2	**2**
Nature Park	2	1		3	**6**
National Nature Reserve				1	**1**
National Natural Monument					**0**
Nature Reserve		1		13	**14**
Natural Monument		2	4	6	**12**
SPA				1	**1**
SAC	2	3	2	14	**21**
Total	**4**	**7**	**6**	**41**	**58**

Table 4: Numbers of protected areas designated based on national and EU legislation (SPAs, SACs) affected by potential construction of the Danube – Oder – Elbe canal (construction works or changes in water regime) in the Czech Republic.

Impact of the potential construction of the Danube – Oder – Elbe canal on Special Protection Areas (SPAs) in the Czech Republic and on the protected bird species living in these areas was analysed by Chytil (2003).

	Total
National park	1
Protected Landscape Area	4
Nature Park	10
National Nature Reserve	8
National Natural Monument	3
Nature Reserve	45
Natural Monument	35
SPA	6
SAC	45
Total	**157**

RESULTS AND DISCUSSION

Impact assessment of the DOL project on amphibian populations

Altogether 15 amphibian species (75 % of the total number of 20 species recorded in the Czech Republic) were found in the studied part of the Morava catchment area (M 1–9); 14 species (70 %) in the Oder catchment area (O 1–4) and 15 species (75 %) in the Elbe catchment area (L 1–3). The recorded species belong to two orders – Urodela and Anura, covering 6 families.

In the Morava catchment area (M 1–9), all 15 recorded amphibian species (100 %) are threatened by potential construction of the DOL canal. Of them, 13 species (87 %) are specially protected by national legislation (critically endangered – 4, highly endangered – 6, endangered – 3) and 9 species (60 %) by EU legislation (Annexes II and IV of the Habitats Directive). In the Oder catchment area (O 1–4), all 14 recorded amphibian species (100 %) are threatened by potential construction of the DOL canal. Of them, 13 species (93 %) are specially protected by national legislation (critically endangered – 3, highly endangered – 6, endangered – 4) and 7 species (50 %) by EU legislation (Annexes II and IV of the Habitats Directive). In the Elbe catchment area (L 1–3), all 15 recorded amphibian species (100 %) are threatened by potential construction of the DOL canal. Of them, 14 species (93 %) are specially protected by national legislation (critically endangered – 4, highly endangered – 7, endangered – 3) and 8 species (53 %) by EU legislation (Annexes II and IV of the Habitats Directive).

Impact assessment of the DOL project on reptile populations

Altogether 8 reptile species (80 % of the total number of 10 species recorded in the Czech Republic) were found in the studied part of the Morava catchment area (M 1–9), and 6 reptile species (60 %) in both the Oder (O 1–4) and Elbe (L 1–3) catchment areas. The total numbers do not include historical findings of the European Pond Turtle (*Emys orbicularis*) in the Morava catchment area (M 1), which have not been confirmed recently. The recorded reptile species belong to the order Squamata, covering 4 families.

In the Morava catchment area (M 1–9), 7 of 8 recorded reptile species (88 %) are threatened by potential construction of the DOL canal. The only species which would not be affected by the construction is the Common European Adder (*Vipera berus*). All 7 reptile species (100 %) affected by the canal construction are specially protected by national legislation (critically endangered – 1, highly endangered – 5, endangered – 1) and 4 species (57 %) by EU legislation (Annex IV of the Habitats Directive). In the Oder catchment area (M 1–9), all 6 recorded reptile species (100 %) are threatened by potential construction of the DOL canal. Of them, 6 species (100 %) are specially protected by national legislation (critically endangered – 1, highly endangered – 4, endangered – 1) and 2 species (33 %) by EU legislation (Annex IV of the Habitats Directive). In the Elbe catchment area (L 1–3), all 6 recorded reptile species (100 %) are threatened by potential construction of the DOL canal. Of them, 6 species (100 %) are specially protected by national legislation (critically endangered – 1, highly endangered – 4, endangered – 1) and 2 species (33 %) by EU legislation (Annex IV of the Habitats Directive).

Landscape changes with important impact on amphibians and reptiles

The DOL route in the Morava and Oder catchment areas has an important specific character. It goes through relatively well-preserved or only little damaged remnants of floodplain forests. Hardwood forests with dominant oak trees (*Quercus robur*) prevails in the Morava catchment area. Softwood forests with dominant willow (*Salix alba*, *Salix fragilis*),

black poplar (*Populus nigra*) and common alder (*Alnus glutinosa*) trees prevail in the Oder catchment area, along the Bečva river and at the upper course of Oder. In the section between Bartošovice and the Polish boundary, hardwood forests with dominant oak trees (*Quercus sp.*) prevail. Specific amphibian and reptile species are associated with this vegetation zone and vegetation cover, with respect to chemical composition of soil and water environment, as well as water regime.

The upper part of the Elbe branch of the DOL canal is different, as it does not goes through a floodplain of a large river or its river bed. It runs through the valley of the Třebůvka brook and causes a considerable damage to the most valuable part of the valley between Loštice and Pěčíkov; it flows to the Elbe river first in Pardubice. In this section, valuable wetland habitats of lowland hilly areas are found, which would be damaged or destroyed by the potential construction of the DOL canal (spanning, covering, perforation, construction of a large number of lock chambers – height of the DOL canal is determined by the highest point on the route 280-300 m a.s.l.). In case of construction, a part of the Třebůvka brook and the landscape below Bouzov would be destroyed.

Negative factors affecting amphibian and reptile populations

Factors with the highest risk include: reduction of the total area of floodplain forests; fragmentation of landscape (habitats) and of the preserved remnants of floodplain forests with complete and impassable separation; changes in water regime – overflows necessary for the function of floodplain forests will be disabled; climate changes – decrease of air temperature and increase of relative air humidity, which will have a negative impact on thermophilous and xerophytic species; disruption of river beds and their function in the landscape – self-cleaning ability of river banks and bottom will be eliminated, species dependent on these habitats will become extinct rapidly; destruction of the natural composition of organisms, together with significant reduction of the self-cleaning ability of river beds; blocking of transverse migrations; blocking of longitudinal migration of organisms – destruction of the most important natural migration route between the Black and Baltic Seas and the Atlantic; mortality of individuals along the DOL canal route during the construction as well as when the canal will be in operation; destruction of wintering sites and their inaccessibility; destruction of roosting and breeding sites and their inaccessibility; loss of foraging grounds and their inaccessibility; disruption of tens of water courses and source areas.

Impact assessment of the DOL project on bird populations

Altogether 299 bird species were recorded in the Morava catchment area (studied sections M 1–9), 277 species in the Oder catchment area (studied sections O1–O4) and 202 bird species in the Elbe catchment area (studied sections L1–L3). Rare or declining species are most threatened, due to large-scale landscape changes (draining of floodplains, wetland degradation and loss), as well as species confined to specific habitats (e.g. xerothermic species) and species which have been breeding in the Czech Republic only in recent years and in single pairs (e.g. Goosander, Eastern Imperial Eagle, Common Crane).

In the studied part of the Morava catchment area, altogether 156 breeding bird species were found (52 % of the total number of 299 bird species recorded there). Potential construction of the DOL canal will have a significant negative impact on 98 bird species (33 % of the total of 299 recorded species). Of them, 70 species (71 %) are specially protected by national legislation (critically endangered – 12, highly endangered – 36, endangered – 22) and 32 species (33 %) by EU legislation (Annex I of the Birds Directive). Of the total number of 98 bird species affected by DOL canal construction, 90 species (92 %) breed in the studied

area. These species are potentially threatened by the loss (reduction, change) of breeding and foraging habitats, and many of them also by disturbance during construction works. The remaining 8 affected species (8 %) winter regularly in the studied area. Their wintering grounds and foraging habitats are threatened. Concerning species associated with wetlands, grebes, Ciconiiformes, Anseriformes, Gruiformes and Charadriiformes are most threatened. Species breeding in open habitats will also be affected. In the area of Bzenecká Doubrava, the canal route goes through the Váté písky National Natural Monument, where it affects populations of the European Nightjar (*Caprimulgus europaeus*) and Woodlark (*Lullula arborea*).

In the studied part of the Oder catchment area, the total of 141 breeding bird species were found (51 % of the total number of 277 bird species recorded there). All breeding bird species will be affected by potential construction of the DOL canal. Significant negative impact is expected in 102 bird species (37 % of the total number of 277 recorded species). Of them, 68 species (67 %) are specially protected by national legislation (critically endangered – 14, highly endangered – 32, endangered – 22) and 29 species (28 %) by EU legislation (Annex I of the Birds Directive). Of the total number of 102 species affected by DOL canal construction, 91 species (89 %) breed in the studied area. These species are potentially threatened by the loss (reduction, change) of breeding and foraging habitats, and many of them also by disturbance during construction works. The remaining 11 affected species (11 %) winter regularly in the studied part of the Oder catchment area. Their wintering grounds and foraging habitats are threatened.

In the studied part of the Elbe catchment area between Doubravice and Chvaletice (L 1–3), altogether 157 breeding bird species were found (78 % of the total number of 202 bird species recorded there). The relatively high number of breeding species is due to the presence of different habitat types along the DOL canal route (valley of the Třebůvka brook in the hilly area of Zábřežská vrchovina, lowlands in the Pardubice region). Potential construction of the DOL canal will have a significant negative impact on 53 bird species (26 % of the total number of 202 recorded species) in this part of the Elbe catchment area. Of them, 32 species (30 %) are specially protected by national legislation (critically endangered – 1, highly endangered – 15, endangered – 16) and 11 species (21 %) by EU legislation (Annex I of the Birds Directive). All 53 species (100 %) affected by DOL construction breed in the studied area. These species are potentially threatened by the loss (reduction, change) of breeding and foraging habitats, and also by disturbance during construction works.

Impact assessment of the DOL project on mammal populations

Altogether 72 mammal species (73 % of the total number of 99 mammal species recorded in the Czech Republic) were found in the studied part of the Morava catchment area (M 1–9). Note: the country total includes non-native species, often kept only in game enclosures (White-tailed Deer, Sika Deer, Barbary Sheep, Wild Goat etc.), and also montane species (e.g. Chamois, Alpine Shrew, Northern Birch Mouse), whose natural occurrence in floodplains of the studied area can be excluded. Altogether 63 mammal species (64 % of the total number of 99 mammal species recorded in the Czech Republic) were found in the studied part of the Oder catchment area (O 1–4). Altogether 47 mammal species (48 % of the total number of 99 mammal species recorded in the Czech Republic) were found in the studied part of the Elbe catchment area (L 1–3). All recorded mammal species (except for e.g. the Elk, *Alces alces*) are likely to breed in the studied areas.

Different level of threat to the above mentioned mammal species is not only a result of their different level of adaptability, enabling them to survive in unsuitable conditions, but it is mainly a consequence of different population densities and reproductive strategies. Rare

species, mainly those with a limited or patchy range in the Czech Republic (Bicolored Shrew *Crocidura leucodon*, Ural Field Mouse *Apodemus microps*) and species with low reproductive potential (bats, ungulates apart from game preserves) will be most threatened. This means that the negative effect of factors resulting from the construction of the DOL canal can be identical in many species, but the consequences for their further existence in the area of interest may be different for the above mentioned reasons. On the other hand, the character of intervention in particular parts of the route may represent a different level of threat in the same species.

In the Morava catchment area (M 1–9), altogether 31 mammal species (43 % of 72 recorded species) are threatened by potential construction of the DOL canal. Of them, 15 species (48 %) are protected by national legislation (critically endangered – 3, highly endangered – 7, endangered – 5) and 11 species (36 %) by EU legislation (Annexes II and IV of the Habitats Directive). In the Oder catchment area (O 1–4), altogether 18 mammal species (29 % of 63 recorded species) are threatened by potential construction of the DOL canal. Of them, 11 species (61 %) are protected by national legislation (critically endangered – 1, highly endangered – 6, endangered – 4) and 7 species (39 %) by EU legislation (Annexes II and IV of the Habitats Directive). In the Elbe catchment area (L 1–3), altogether 33 mammal species (70 % of 47 recorded species) are threatened by potential construction of the DOL canal. Of them, 8 species (24 %) are protected by national legislation (critically endangered - 2, highly endangered – 1, endangered - 5) and 4 species (12 %) by EU legislation (Annexes II and IV of the Habitats Directive).

Landscape changes with significant impact on mammals

Effects of the canal construction on populations of individual mammal species will be both direct and indirect. Direct threats are immediate interventions to the environment of individual species (places of reproduction, hunting grounds, migration corridors) by disturbance during construction works and the associated habitat destruction. Cutting of trees and understorey can be expected in areas where the canal goes through a forest, causing the loss of shelters of many mammal species, such as dens of small carnivores, tree hollows with bat roosts etc. Logically, species living on the route of the planned canal will be threatened directly. This is especially true for species associated with wetlands, finding their shelters or food there (European Otter *Lutra lutra*, Eurasian Beaver *Castor fiber*, water shrews of the genus *Neomys*, Eurasian Harvest Mouse *Micromys minutus*, partly also Striped Field Mouse *Apodemus agrarius*). These habitats would be largely lost either already during construction works or later as a result of changes in water regime in the altered landscape. Regarding that, it should be stressed that certain valuable studied parts of the canal route are threatened more than others. Routing of the canal through floodplain forests can be considered particularly unsuitable. This is true for parts of Litovelské Pomoraví, floodplains between Olomouc and Otrokovice and especially for unique floodplains of the Lower Morava and Lower Dyje rivers including their confluence. A similar situation is found in the floodplains of Poodří and in the alluvium of border meanders of the Oder river near Bohumín.

While the direct threats are related to species typical for floodplain landscapes, indirect threats will affect all mammal species in the area of interest, both resident or migrating. The most important negative factors are as follows: 1) Large-scale cutting of trees will cause thinning or even destruction of forests, mainly of littoral stands. Microclimatic conditions in forest refugia (light, air flow, temperature) will change, which will definitely affect the current habitat conditions of many mammal species associated with forest stands. 2) Construction of the canal will affect substantially water regime of the landscape, even beyond boundaries of the now delimited area, and will influence not only species associated

with the aquatic environment but also steppe species (European Ground Squirrel *Spermophilus citellus*, European Hamster *Cricetus cricetus*). Faster runoff of water from landscape, caused by straightening and channelisation of watercourses will have very negative consequences. As a result, gradual loss of wetlands, mainly meanders, arms and pools with rich littoral stands of both softwood and hardwood floodplain forests can be expected. Their gradual filling with soil and drying out will make it impossible for wetland mammal species (water shrews of the genus *Neomys*, some bat and rodent species etc.) to live there. Even in cases when the canal will go through the current river bed, although already partly channelised, the banks will be modified and the current river bed will be deepened, resulting in destruction of the bottom and loss of the littoral zone, and thus causing destruction of both aquatic and terrestrial ecosystems. These changes will directly affect mammals associated with the littoral zone and the watercourse (European Otter, Eurasian Beaver) and will cause a decrease in food availability (mainly in insectivorous species – bats, insectivores; piscivorous species – European Otter; macrophytophagous species – Eurasian Beaver). At the first sight it seems that the route of the canal leading through open farmland, far from the original watercourse, is the most suitable variant with the lowest risks for biota. However, even in this case the water will be converted to the canal, causing water deficit in the current watercourses in river floodplains and thus resulting in similar changes of wetland habitats in the alluvium.

DOL canal as a new migration barrier

It is obvious that the linear character of the proposed canal route creates an insurmountable migration barrier for terrestrial mammal species. Mainly large species will be affected substantially (Elk, Brown Bear *Ursus arctos*, Eurasian Lynx *Lynx lynx* etc.). The canal intersecting the landscape will have similar consequences on landscape fragmentation as highways. This barrier will prevent migration of mammals between winter and summer sites, breeding sites, hunting grounds etc. Landscape fragmentation will block gene flow within populations with subsequent reduction of genetic diversity. Natural watercourses with littoral stands are not a significant problem for most species of large mammals. However, banks and surroundings of giant technical structures (highways, canals) are a problem. Fig. 1 shows long-distance migration corridors of mammals in the Czech Republic. The DOL canal route obviously crosses two most important migration corridors of large mammals: in the Elbe part (L1) between Doubravice and Česká Třebová (most important migration route of the Elk, connecting populations in southern Bohemia and Poland), and in the Oder part in the Moravská brána area (O2) between Hranice na Moravě and Jeseník nad Odrou, where mainly populations of large mammals from the Beskydy and Jeseníky Mts. and northern Bohemia pass through.

Fig. 1: Long-distance migration corridors of large mammals versus route of DOL water canal in the Czech Republic

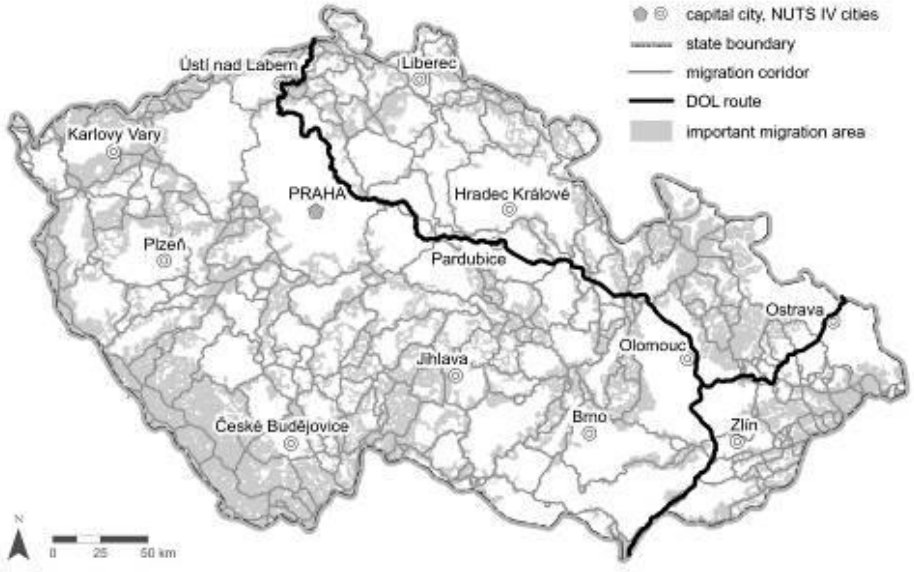
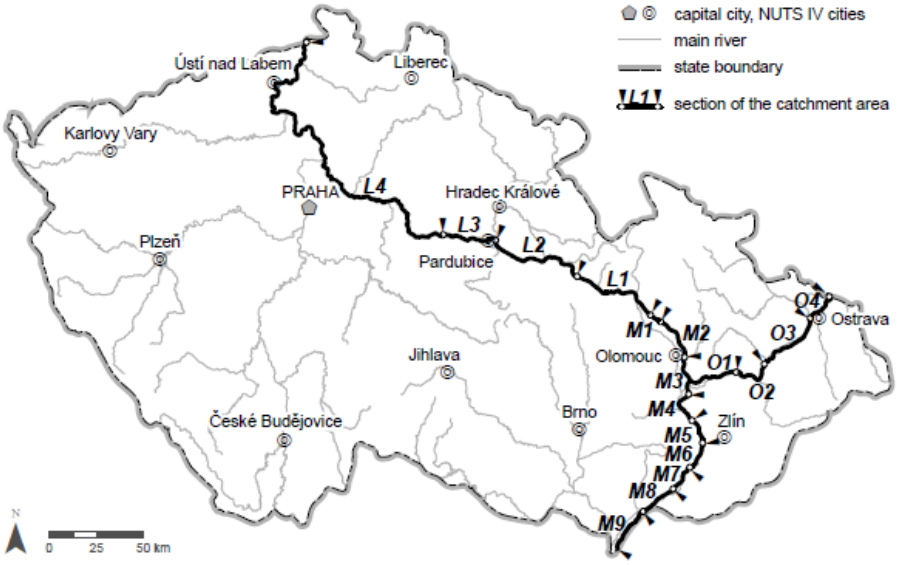


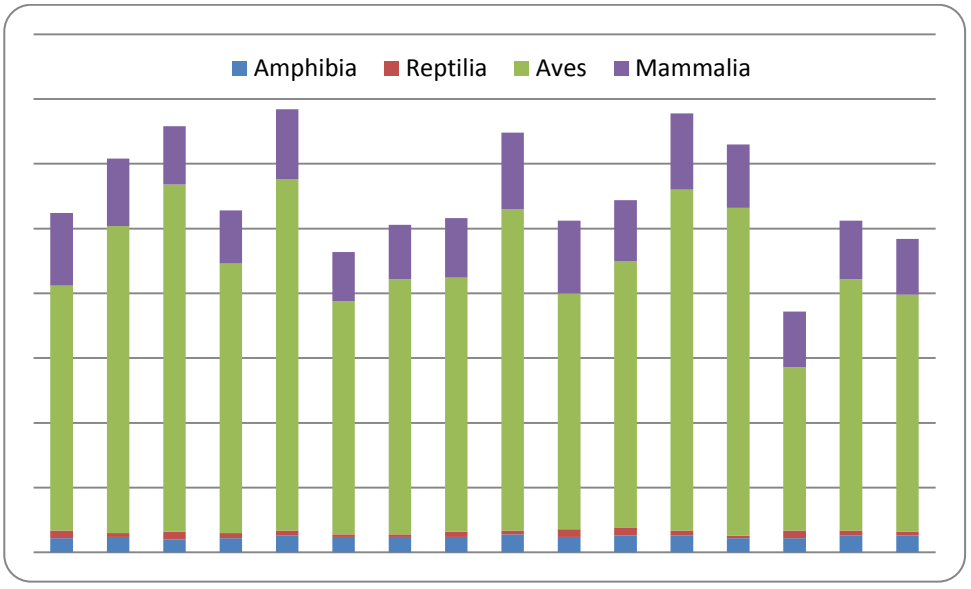
Fig. 2: Sections of DOL water canal in the Czech Republic in order to assessment of impacts to vertebrate species



Impact assessment of the DOL canal on vertebrate populations

Concerning the studied vertebrate classes, the number of species exceeding 300 was recorded only in several sections (Fig. 3). Comparison of the number of vertebrate species significantly affected by DOL canal construction in the studied sections of the Morava (M 1– 9), Oder (O 1–4) and Elbe (L 1–3) catchment areas is shown in Fig. 4. The largest number of vertebrate species significantly affected by DOL canal construction was recorded in the following sections of the Morava river: Hodonín – Břeclav (M9), Veselí na Moravě – Hodonín (M8) and Kroměříž – Otrokovice (M5); of the Oder river: Jeseník nad Odrou – Ostrava (O3), Ostrava – state border (O4); and of the Elbe river: Česká Třebová – Pardubice (L2). The lowest number of affected vertebrate species was found in sections where the canal goes through farmland and does not destruct important habitats (forests, wetlands) – the section Střelice – Olomouc (M2) in the Morava river and the section Rokytnice – Hranice na Moravě (O1) in the Oder river.

Fig. 3: Total numbers of vertebrate (Amphibia, Reptilia, Aves, Mammalia) species recorded in the particular sections of the Morava (M 1-9), Oder (O 1-4) and Elbe (L 1-3) catchment areas



The level of threat to individual vertebrate species in the studied sections of the Morava (M 1–9), Oder (O 1–4) and Elbe (L 1–3) rivers is shown in Fig. 5. The assessed vertebrate species will be affected most severely in the Oder river (O3) in the section Jeseník nad Odrou – Ostrava (Poodří area) and in the Morava river in the section Hodonín – Břeclav (M9) – large area of floodplain forests and meadows. High level of threat of species was also recorded in the Oder river in the section Hranice na Moravě – Jeseník nad Odrou (O2), where the canal goes through a fishpond systém near Polom. Other important sections are found in the Morava river (M8, M5). The highest number of affected vertebrate species, specially protected by national legislation, is found in the Oder (O3, O4) and Morava (M9, M8, M5) rivers, see Fig. 5.

Fig. 4: Vertebrate (Amphibia, Reptilia, Aves, Mammalia) species affected (threatened) by the Danube – Oder – Elbe canal construction in the particular sections of the Morava (M 1-9), Oder (O 1-4) and Elbe (L 1-3) catchment areas.

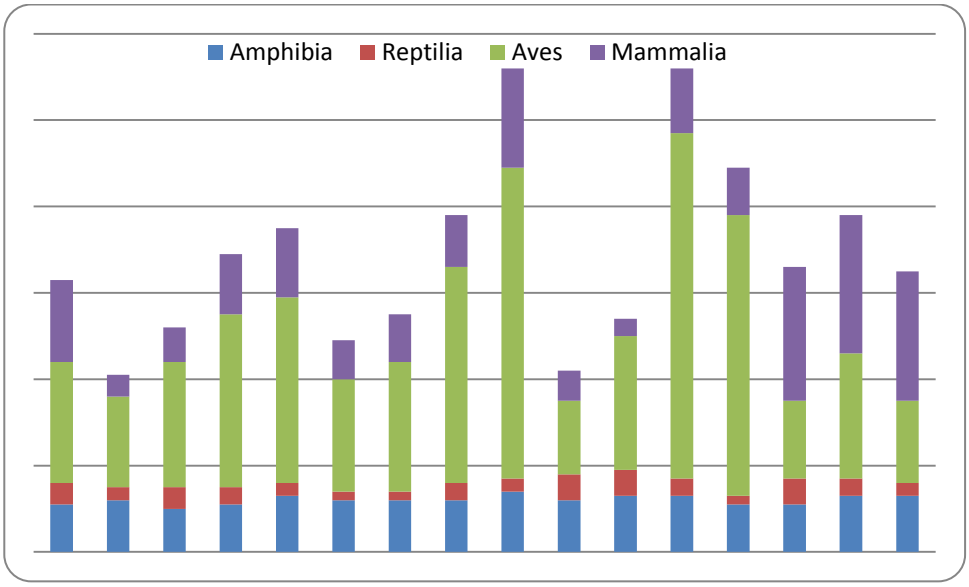


Fig. 5: Level of threat to vertebrate (Amphibia, Reptilia, Aves, Mammalia) species affected by the Danube – Oder – Elbe canal construction in the particular sections of the Morava (M 1-9), Oder (O 1-4) and Elbe (L 1-3) catchment areas.

The following classification was used in the particular classes to assess the level of threat: vulnerable species = 1, endangered species = 2, highly endangered species = 3, critically endangered species = 4, as well as the totals of these values.

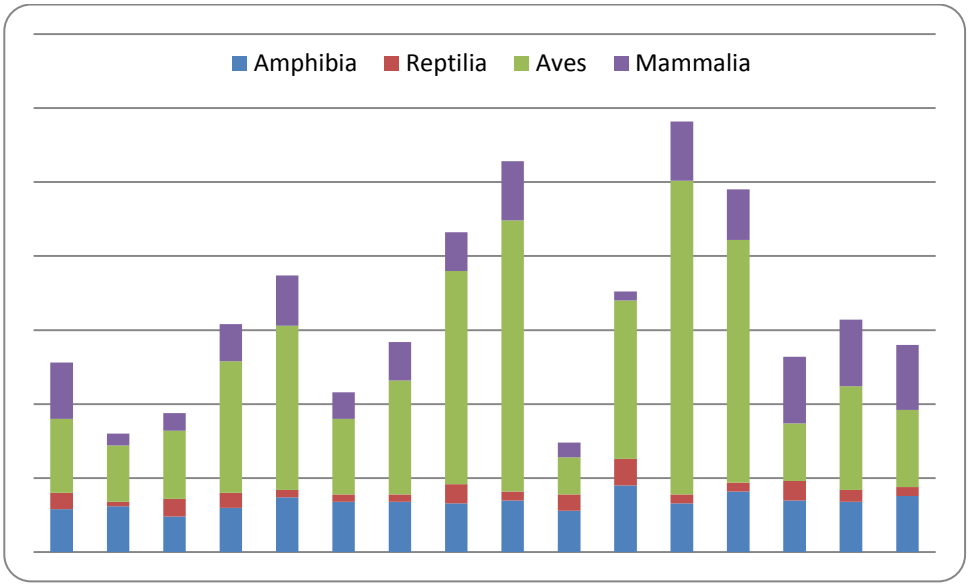
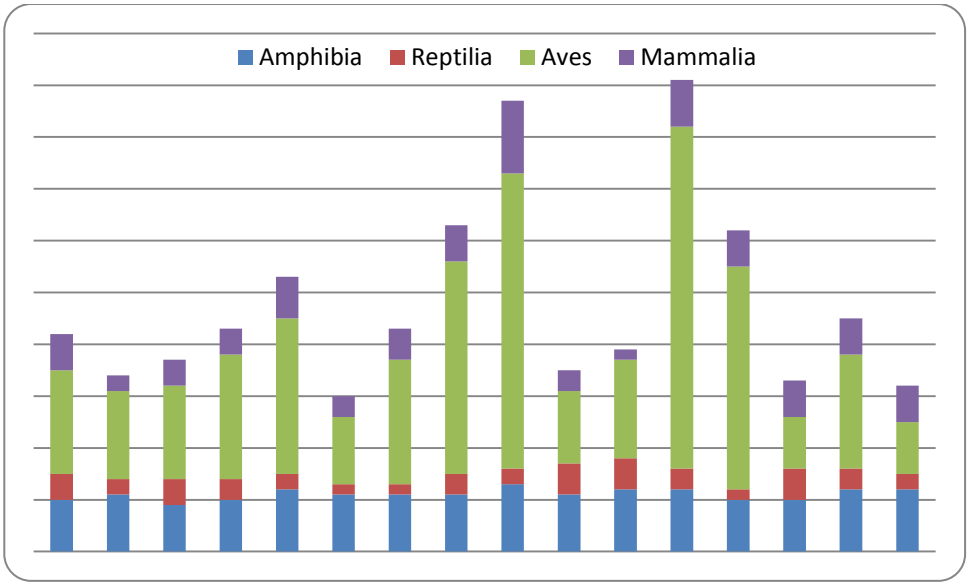


Fig. 6: Numbers of vertebrate (Amphibia, Reptilia, Aves, Mammalia) species affected by the Danube – Oder – Elbe canal construction, protected by national legislation, in the particular sections of the Morava (M 1-9), Oder (O 1-4) and Elbe (L 1-3) catchment areas.



The proportion of specially protected vertebrate species classified in individual conservation categories according to Regulation No. 395/1992 Coll. issued by the Ministry of Environment (endangered, highly endangered, critically endangered) is shown in Fig. 7. Similarly, the highest number affected vertebrate species, specially protected by EU legislation (birds – Annex I of the Birds Directive; amphibians, reptiles, mammals – Annexes II and IV of the Habitats Directive) is found in the Morava (M9, M8, M5) and Oder (O3, O4) rivers, see Fig. 8. The proportion of specially protected species potentially affected by the DOL canal construction or by changes in hydrological regime is shown in Fig. 9. The highest number of affected protected areas is found in the Oder river in the Poodří area (O3), and in the Morava river – Litovelské Pomoraví (M1, M2), Strážnické Pomoraví and Bzenecká Doubrava (M8) and Soutok – Tvrdonicko (M9).

Fig. 7: Assessment of the degree of protection by national legislation of vertebrate (Amphibia, Reptilia, Aves, Mammalia) species affected by the Danube – Oder – Elbe canal construction in the particular sections of the Morava (M 1-9), Oder (O 1-4) and Elbe (L 1-3) catchment areas

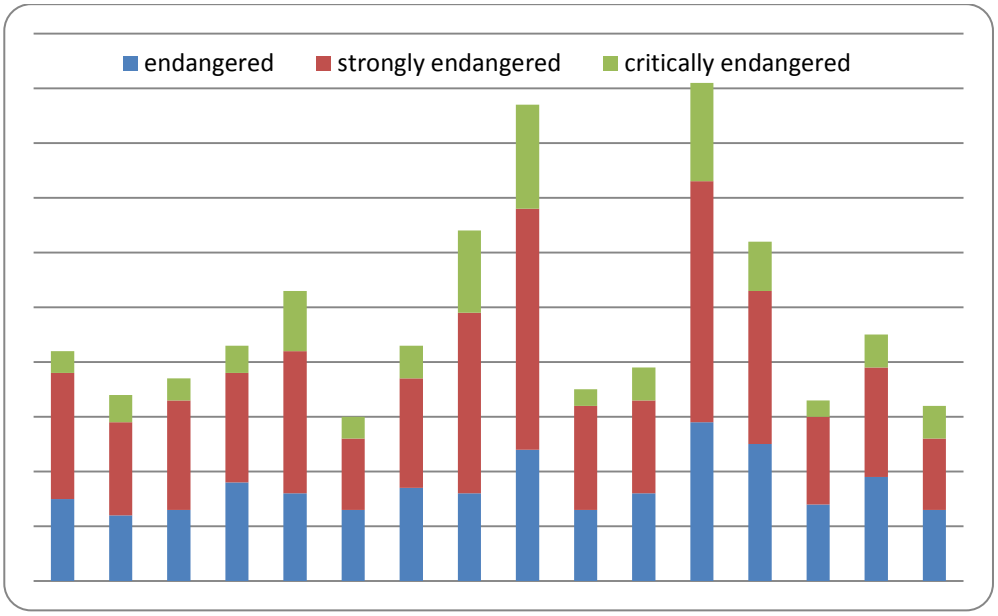


Fig. 8: Assessment of the degree of protection by EU legislation (birds – Annex I of the Birds Directive; amphibians, reptiles, mammals – Annexes II and IV of the Habitats Directive) of vertebrate species affected by the Danube – Oder – Elbe canal construction in the particular sections of the Morava (M 1-9), Oder (O 1-4) and Elbe (L 1-3) catchment areas.

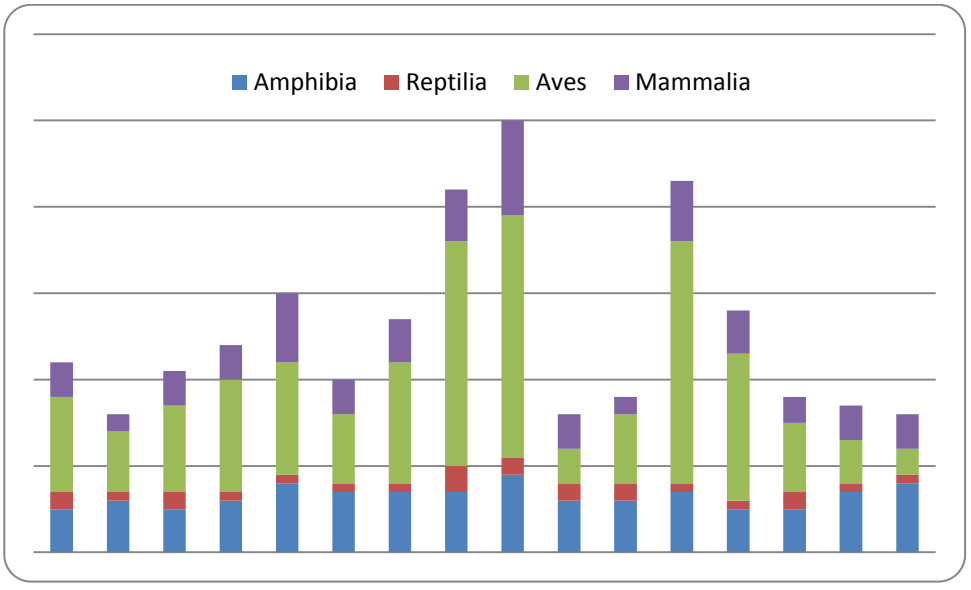
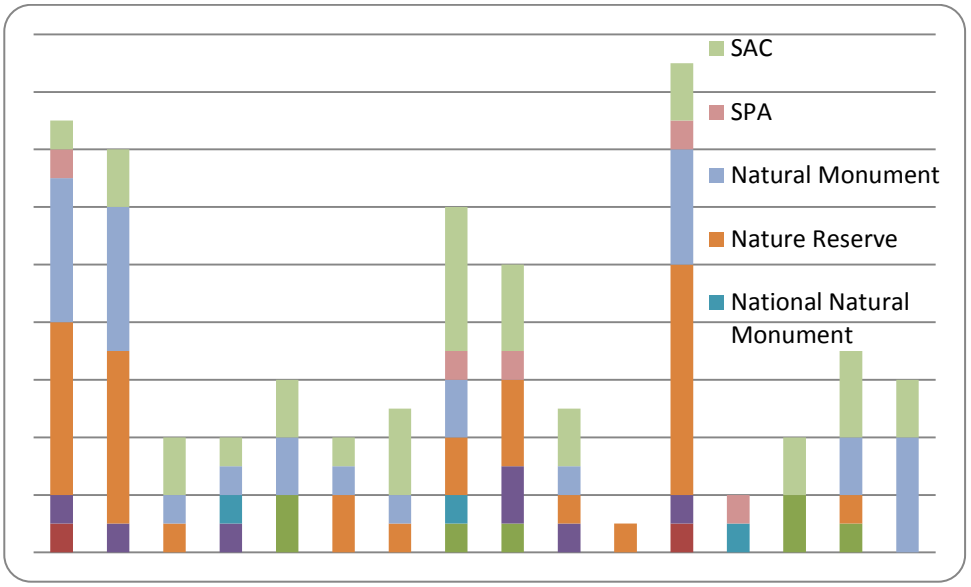


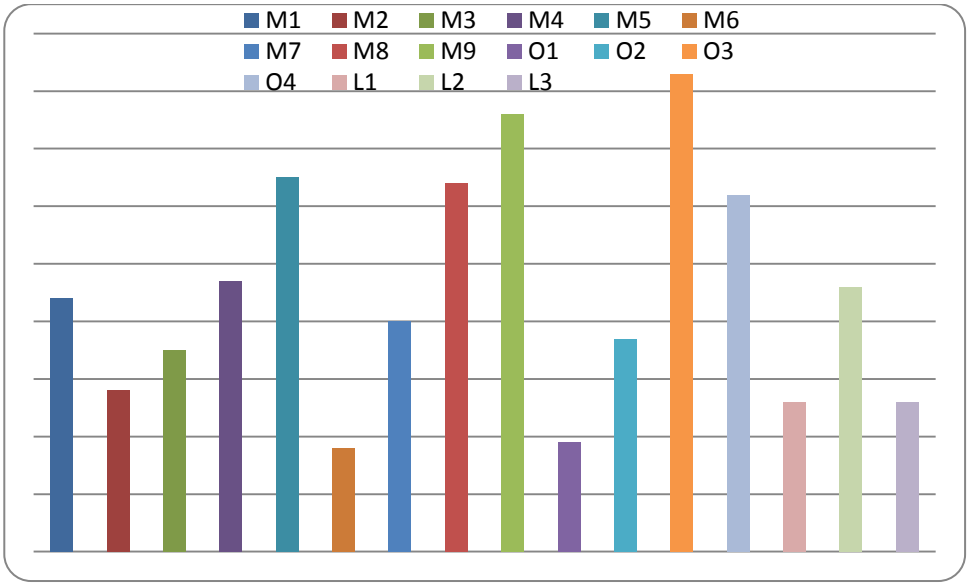
Fig. 9: Overview of specially protected areas designated based on national and EU legislation (SPAs, SACs) affected by the Danube – Oder – Elbe canal construction (construction works or changes in water regime) in the particular sections of the Morava (M 1-9), Oder (O 1-4) and Elbe (L 1-3) catchment areas.

Areas protected by EU legislation (Natura 2000 network) – SPAs (according to the Birds Directive) and SACs (according to the Habitats Directive) are shown in red and orange, areas protected by national legislation are shown in other colours.



The summary assessment of all presented results is shown in Fig. 10, taking account of all assessed variables – the number of recorded vertebrate species, number of affected species, level of threat to individual species, number of species protected by national legislation, number of species protected by EU legislation, number of specially protected areas designated according to national and EU legislation. It is apparent that the most significant negative impacts on vertebrate populations and their habitats in case of implementation of the DOL plan can be expected in the following sections of the Morava river: Hodonín – Břeclav (M9), Kroměříž – Otrokovice (M5), Veselí na Moravě – Hodonín (M8), Troubky – Kroměříž (M4), Doubravice – Střelice (M1); of the Oder river: Jeseník nad Odrou – Ostrava (O3), Ostrava – state border (O4); and of the Elbe river: Česká Třebová – Pardubice (L2).

Fig. 10: Assessment of the overall impact of potential construction of the Danube – Oder – Elbe canal on total amount of influenced species of vertebrates (Amphibia, Reptilia, Aves, Mammalia) in the particular sections of the Morava (M 1-9), Oder (O 1-4) and Elbe (L 1-3) catchment areas



In case of construction of the DOL canal, disturbance, damage or loss of vertebrate habitats will occur at least at 6 out of 9 studied sections in the Morava catchment area, at 3 of 4 sections in the Oder catchment area and at 2 of 3 sections in the Elbe catchment area. Wetland habitats and floodplain forests along the canal route are most threatened. Construction of the Elbe branch will affect the whole lower course of the Třebůvka brook including its alluvium. Disruption of migration routes, habitat fragmentation and loss of gene flow is also essential for some mammal, amphibian and reptile species. The fact that the DOL canal route goes through the alluvium of three largest Czech rivers and negatively affects or destructs the last existing fragments of floodplain forests in the country, is an important environmental handicap of the plan. In case of construction of the DOL canal, altogether 157 protected areas found along the canal route or in hydrologically affected areas can be disturbed, damaged or destroyed. Sites of Community Importance protected within the NATURA 2000 network are represented by 51 sites (33 %). Many of the species negatively affected by DOL canal construction are protected by law both at the national level (50 - 80 % of species in the particular classes, 100 % in reptiles) and in the EU (30 – 50 % of species in the particular classes).

International context

Ecosystems of large river floodplains belong to habitats with the highest (and at the same time the most vulnerable) biodiversity among all ecosystems of our planet (Mitsch & Gosselink, 2000). All studied sites with the occurrence of indicator vertebrate species, situated along the DOL route, rank among wetland areas with the highest species richness in the Czech Republic (Chytil *et al.*, 1999). Regarding the conservation of biodiversity in Central Europe, the DOL water canal project interferes with at least three international treaties: the Convention on Wetlands of International Importance especially as Waterfowl

Habitat (Ramsar Convention), the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) and the Convention on Biological Diversity. In this context and considering the status and development of the Czech landscape in the early 21th century, the DOL water canal plan can be regarded as an environmentally high-risk project (Buček, 2003). On the contrary, preparation of a strategic document identifying ecologically optimal and economically acceptable land use of large river floodplains in the Czech Republic is highly needed. A detailed landscape plan (see Sklenička, 2003) of the Morava, Oder and Elbe River floodplains could become a basis for gradual restoration of landscape and ecological functions of floodplains in the Czech Republic (Prach, 2003) and could serve as a ground for the assessment of further plans related with the DOL project.

Concerning the scale and intensity of influencing of the landscape, as well as the amount of necessary investment costs, the DOL project has no parallel in the Czech Republic. Potential construction of the DOL canal would probably be the largest and the most expensive development project in the history of our country (Zeman, 2005), moreover, obviously with an immense impact on the environment (Kubec, 2002). It should be stressed that studies dealing with technical and economical aspects of the construction and functioning have prevailed during the whole DOL project history, already over 250 years long, while studies assessing the influence of the DOL on landscape and environment in the affected floodplain areas of the Czech Republic have appeared first in the late 20th century (Buček, 1997).

When assessing the impact of the DOL project on geobiocoenoses of floodplain forests, it is mainly the reaction of vegetation to changes of water regime (Maděra, 2001) that can be compared with the collected data set (see Prax *et al*., 2008). A certain analogy to the DOL canal plan can be thus found in the Gabčíkovo – Nagymaros waterworks in the Slovak Republic (Zinke, 2002). After these waterworks were finished, the course of the Danube river was transferred into an insulated feed (lateral) artificial canal, which does not enable infiltration of water into the bedrock, and the original river bed (the so-called „old" Danube) is supplied only with the remaining minimum amount of water. This is an ecological situation analogical to what would happen after the DOL canal construction in large river floodplains in the Czech Republic (Holčík, 1992).

The landscape matrix of the Moravian basins and Elbe tables is composed mainly of arable land with intensively used agrocenoses and low ecological stability (Machar *et al*., 2010). In this landscape, wide floodplains of the Morava, Elbe and Oder Rivers have an irreplaceable importance as a true backbone of the ecological network and as supraregional biocorridors of European importance. The current functioning of these corridors is documented e.g. by spontaneous spreading of the Eurasian beaver and formation of new populations of this previously eradicated species in the Morava and Elbe (between Střekov and Hřensko) rivers.

The DOL route goes through wide floodplains of 8 biogeographic regions, belonging to all four biogeographic subprovinces present in the Czech Republic (Culek *et al.*, 1996). Watercourses, their littoral fringes, littoral stands and floodplains made up the thickest and most interconnected natural system of biocorridors in the cultural landscape (Buček *et al.*, 2007). They are essential for water, wetland and moist-loving organisms, which find suitable conditions for their existence in these habitats. However, they are also important for mesophilous species (species which are not confined to water and wetland habitats but use floodplain biocorridors for migrations and spreading). Floodplains of the Morava, Bečva, Oder and Elbe rivers, affected by the DOL route, play a role of supraregional biocorridors in the ecological network, making up a natural and irreplaceable axis of the territorial systems of ecological stability in the Czech Republic (Machar, 2008). Local, regional and supraregional biocentres, enabling permanent existence of water, wetland and moist-loving floodplain communities. To ensure good functioning of the ecological network it is essential

to preserve the continuity and spatial connectivity of floodplain communities in the alluvia of large rivers (Machar, 2009).

Protection of the DOL route in local and regional plans blocks activities which could lead to harmonisation of the landscape (Machar, 2010). Possible renaturalization of the channelized sections of rivers and implementation of a number of measures aimed at revitalisation of river systems are thus blocked. It is not wise to plan new biocentres, biocorridors and interaction elements, making up the territorial system of ecological stability of the landscape, along the DOL route. Territorial protection of the DOL route restricts the development of many settlements and their infrastructure. Conflicts between settlement development and protection of the DOL route happen mainly in towns situated along the Morava river. It is difficult to quantify the consequences of blocking of the harmonic landscape development by territorial protection of the DOL route, because preparation of optimalisation plans is blocked by territorial protection. The only possibility how to reduce this hidden effect of DOL on the landscape, mainly on floodplain areas where most of the DOL route is situated, is to cancel the priority of territorial protection of DOL. In local and regional plans, the DOL route should not be included in the obligatory section. It should be assessed in the guidance part of the plan, in confrontation with the needs of land use optimalisation. Further channelization of rivers, construction of weirs and lock chambers, and changes in water regime of the rivers will cause changes in the type and intensity of the current geomorphological processes both in river beds and in the adjacent floodplains. It should be stressed that natural fluvial processes are the main condition of preservation of the homeorhetic stability of geosystems of river floodplains (Šindlar *et al*., 2010).

The characteristic variety of floodplain biocenoses is dependent on differences in the gradient of soil humidity, mainly on the regime of groundwater level and also on the periodicity and duration of floods (Machar & Pechanec, 2011). Sudden changes in water regime are an important stress factor affecting floodplain biocenoses, which may cause significant disturbance or even loss of the current ecosystems. Changes in water regime during river alteration affect not only the immediate surroundings of the watercourses, but also the whole area of the river floodplain. Experience shows that water management alterations are usually followed by the decrease of groundwater level. Hydrobiocenoses of river lakes and periodic pools are most sensitive to changes in water regime. Floodplain geobiocenoses shift towards rather dry types. Segments of the geobiocene types *Alni glutinosae-saliceta, Querci roboris- fraxineta* and *Ulmi fraxineta-populi* retreat and gradually turn into the driest floodplain group of the geobiocene types *Ulmi fraxineta-carpini*. Due to relative draining, the most affected segments lose their typical floodplain character. Changes in water regime of the biocenoses can be considered as one of the most important impacts of the DOL project, since certain changes in hydrological conditions are unavoidable in the process of making rivers navigable (Klimo *et al*., 2008).

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