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CROSSINGS FOR ANIMALS – AN EFFECTIVE METHOD OF WILD FAUNA CONSERVATION

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Abstract. The paper characterizes the problem of preservation of wildlife animals in connection with extension of transportation road systems. The constantly evolving transportation infrastructure in Europe, especially in its Midwestern part, on one hand connects, making it easier for people to travel and ship goods, but on the other hand it irreversibly divides and leaves a painful impress on virgin natural areas (fragmentation of the environment). The paper briefly presents the European Ecological Network Nature 2000 as the European Union program concerning the environmental protection. It enumerates possible types of animal crossings together with their characteristics. Some examples of underpasses, overpasses and crossings on the road surface are also presented. It also presents specificity and phases of designing engineering structures of this type, as well as the most common design errors and their influence over the use of such structures by animals. Finally the soil-steel bridge structures made from corrugated plates are characterized in their function as crossings for animals. The conclusion mentions complexity of the problem of animal crossing construction, which can be of use to designers and constructors of this type of engineering structures.

Keywords: animal crossing, road, collision, animal conservation, Nature 2000 program.

1. Introduction

While constructing motorways and express roads, one should take into consideration ways of minimising negative influence of the projects upon wildlife populations. That is because animals are extremely susceptible to changes of external conditions. Therefore, one should realise that any transportation route causes irreversible changes to the natural environment (Beben 2005; Beben, Manko 2006; Konopka 2004; Liu *et al.* 2008; McGuire, Morrall 2000).

The increasing number of motorways and express roads in Europe, especially in its Midwestern part, shows the scope of the challenge that road and environmental services of the entire European Union have to face. Without an effective economic policy and legal changes in line with assumed responsibility for the natural environment, execution of the road system extension plan can be threatened (Pawlak 2007).

A desired compliancy of road extension projects in Europe with environmental laws is sometimes impossible as projects are burdened with the Nature 2000 program, and lack of unshakeable and univocal data about it. Respective requirements of the European Commission are often contradictory with decisions issued by the EU member states. Other factors that hinder efficiency in organisation of road designing and construction are sometimes controversial protests by ecological organisations out of governmental control (Council Directive of European Community 79/409/EEC 1979 and 92/43/EEC 1992; Pawlak 2007).

A possible solution can be achieved through construction of environmentally friendly bridge structures, of which two categories need to be considered (Beben *et al.* 2004):

1. Execution of various types of bridges constructed on the basis of non-invasive technologies and from modern environmentally friendly materials.
2. Structures designed as animal crossings in the form of culverts, ditches, tunnels and even big bridges constructed within (or over) the roadway, the motorway network, in national parks and etc. (Glista *et al.* 2009).

The paper describes the problem of wildlife protection in connection with extension of transportation routes. The European program Nature 2000, which is related to the European Ecological Network, is briefly presented in it. Besides, it gives examples and characterises possible animal crossings. It also outlines specificity of designing this type of engineering structures and points at the most common errors and their influence over the use of the crossings by wild animals. Finally, it characterises the soil-steel bridge structures and their possible use as animal crossings.

2. Characteristics and the scope of the problem

The negative influence caused by extension of a transportation system over fauna populations mainly consists of destroying their natural habitats, causing higher animal death rates (road accidents), fragmentation of sites and hindering migration as well as isolating animal populations (Glista *et al.* 2009; Putmann 1997; Tanner, Perry 2007).

The scope of the problem related to death rate and/or decreasing population of wild animals in relation to extension of road systems is very significant. The majority of animals are killed on local roads where traffic is low and animals aren't afraid to step on roads. Whereas in case of roads where traffic per day is heavier – animals hardly ever cross (Jedrzejewski *et al.* 2006; Konopka 2004; Van Langevelde *et al.* 2009).

Fig. 1 shows percentage of animals (mainly hedgehogs (*Erinaceus*), martens (*Martes*), badgers (*Meles meles*), foxes (*Vulpes*), hares (*Lepus*), roe deer (*Capreolus capreolus*), wild boars (*Sus scrofa*), deer (*Cervus*), elks (*Alces alces*), wolves (*Canis lupus*), lynxes (*Lynx*) or even European bisons (*Bison bonasus*)), which get killed while attempting to cross a road, in relation to traffic density in Poland (research period September 2006–September 2007). It indicates that with traffic of about 2 thousand vehicles per day, the problem appears marginal (cases of animals deaths are rare). The highest death rate is contained within the section of 2.5–7.0 thousand vehicles per day, whereas in the case of motorways and express roads where traffic density amounts to 7.0 thousand vehicles per day – the number of deadly collisions is relatively small due to the fact that such roads constitute a practically impassable barrier for animals, which they only enter in the moments of stress, frightened by a hunter or a predator. A situation when such road separates the habitat of one species can lead to a gradual degeneration or even extinction of the species over a given area (Maranda 2007). The similar investigation was made by Seiler (2003).

European and American data on animal deaths on roads are highly worrying. For example, in Spain, the minimal number of mammals, birds, reptiles and amphibians killed in road collisions is estimated at 10 million per year, 4 million in Belgium, in Denmark: 1.5 million mammals, 3.7 million birds and 3 million amphibians. In the USA alone in 1991, there were 500 thousand collisions with deer. In Sweden, yearly losses caused by collisions with elks and roe deer amount at 100 million euro – and this concerns only accidents reported to the police,

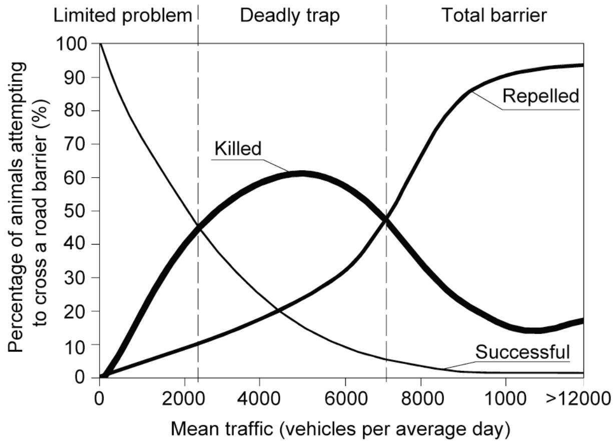

Fig. 1. Percentage of animals attempting to cross a road and getting killed in relation to the traffic density in Poland

therefore the real amount could probably be doubled (Cain *et al.* 2003; Dodd *et al.* 2004; Mata *et al.* 2005; Ng *et al.* 2004).

Table 1 shows a list of selected species getting killed on roads every year. According to the statistics, 34 706 roe deer, 428 deer, 1 552 foxes and as many as 36 243 hares were killed on Austrian roads in 1997. In Germany, these numbers were lower, but still very high. In the year 2000, 14 906 roe deer, 3 901 foxes and 2 333 hares died in road collisions in this country. The analysis shows that in Poland (the year 2007), less animals of the given species died (about 7 500 reports to the police), but this is mainly due to fewer cars and relatively poorly developed road system. Besides, not all cases of collision with an animal are reported to the police, while relevant forestry services can influence the numbers presented in the statistics. Real losses in population of various animal species can be much higher (Mata *et al.* 2005; Seiler 2003; Van Langevelde *et al.* 2009).

When new roads are constructed, life of animals in those given ecosystems changes dramatically, as a result of the so called cut-through effect. It appears that preservation of ecological passages is of highest importance even for such mobile animals as birds, game or protected species.

Table 1. The number of animals of selected common species killed on roads of selected European countries every year (Jedrzejewski *et al.* 2006)

Species (*Latin*)	Country and year			
	Austria (1997/98)	Switzerland (1998)	Germany (Baden-Wurtemberg) (2000/01)	Poland * (2007)
Roe deer (*Capreolus capreolus*)	34 706	8776	14 906	4875
Deer (*Cervus*)	428	430	15	54
Fallow deer (*Dama dama*)	–	–	26	45
Wild boar (*Sus scrofa*)	112	–	1282	641
Badger (*Meles meles*)	741	–	1615	430
Pine martens (*Martes martes*) and Stone martens (*Martes foina*)	842	–	488	350
Weasel (*Mustela*)	303	–	53	25
Fox (*Vulpes*)	1552	–	3901	550
Hare (*Lepus*)	36 243	–	2333	480

Note: * data from police statistics.

When a habitat is divided into several islands separated by roads, genetic diversity of the isolated population falls considerably. To slow the process down, green bridges and tunnels for animals have been initiated in Europe. The first structure of this type was constructed in 1962, in a large forest complex Fontainebleau near Paris. However this structure was too narrow and it did not meet its designed function; therefore, construction of another broad ecoduct for animals on the motorway towards Paris was planned to be finished by 2008 as the forests are inhabited by approx. 800 deer and 800 wild boars. Long research on behaviour of these species in the habitat under consideration proved that species of hoofed plant eaters, i.e., deer and wild boars, have defined spatial requirements and at the same time their migration trails cross transportation lines. An animal population inhabiting a given territory looks for and chooses a rich area to find attractive food, a reproduction place or a peaceful daily refuge (Di Giulio *et al.* 2009; Jedrzejewski *et al.* 2006).

The structure of the road can also create ecological barriers – for instance, using protective fencing makes animal migrations completely impossible. Also, constructing roads on embankments or in excavated ditches makes it even more difficult. Location of a road is of importance as well – the barrier effect is closely related to the natural value and susceptibility of the habitats, through which a road cuts (Cain *et al.* 2003; Dodd *et al.* 2004).

An ecological barrier is now defined as a complex interaction of a death rate, physical limitations, changes and effects which impose limits over a given species upon its freedom to cross a road. Existence of ecological barriers results in division of habitats into smaller sites (fragmentation of habitats) and difficulties in migration of organisms inhabiting these fragmented habitats (isolation of habitats) (Jedrzejewski *et al.* 2006).

From among all of the forms of negative influence caused by roads, creation of ecological barriers, which hinder or make crossing of a road impossible, is of the utmost concern due to its negative environmental effects. Fig. 2 shows different forms of influence of transportation routes over selected groups of animals.

The problem of industry development in Lithuania and related landscape transformation was presented by Bauža (2007).

The concepts pertaining to efficiency of metropolitan transportation systems were indicated by Behbahani and Haghigh (2009). A neural model was used to measure and assess land use and transportation system efficiency.

The problem of protection of natural resources (The Kovada Lake National Park, Turkey) was presented by Alkan *et al.* (2009). They mentioned that a natural resource under legal protection cannot be sufficient for protection–development of this natural resource.

The breakthrough in matters environmental protection was the international conference in Rio de Janeiro, which took place in 1992, and during which the convention related to protection of natural resources of the Earth was signed. The main purpose of this convention was to protect biological variety, well-balanced use and farming as well as the fair-share of advantages derived from the genetic reserves. To implement the Rio de Janeiro convention, the EU established the European Ecological Network Nature 2000.

The European Ecological Network Nature 2000 is a network of nature preservation sites on the territory of the European Union. It aims to conserve its biodiversity. The program embraces the following:

- sites classified as Special Protected Areas (SPA) – according to Council Directive 79/409/EEC on conservation of wild birds (Council Directive 79/409/EEC 1979),
- sites classified as Sites of Community Importance (SCI) – according to the Council Directive 92/43/EEC on conservation of natural habitats and wild fauna and flora. It concerns natural habitats specified in appendix I and species of fauna and flora listed in appendix II to the Directive (Council Directive 92/43/EEC 1992).

The Nature 2000 areas include areas of utmost importance from the point of view of protection of endangered or very rare species of plants and animals and characteristic natural habitats with meaning to protection of natural value all over Europe.

The EU member states have been obliged to delimit protected areas, i.e. the Nature 2000 sites over their respective territories. Detailed legal solutions concerning creation and protection of ecological networks as a part of Nature 2000 program were passed in the form of national environmental protection laws. They introduced "Nature 2000 sites" as a new, separate form of environmental conservation, whereas at the same time they could overlap or cover other forms of legal protection of a given country.

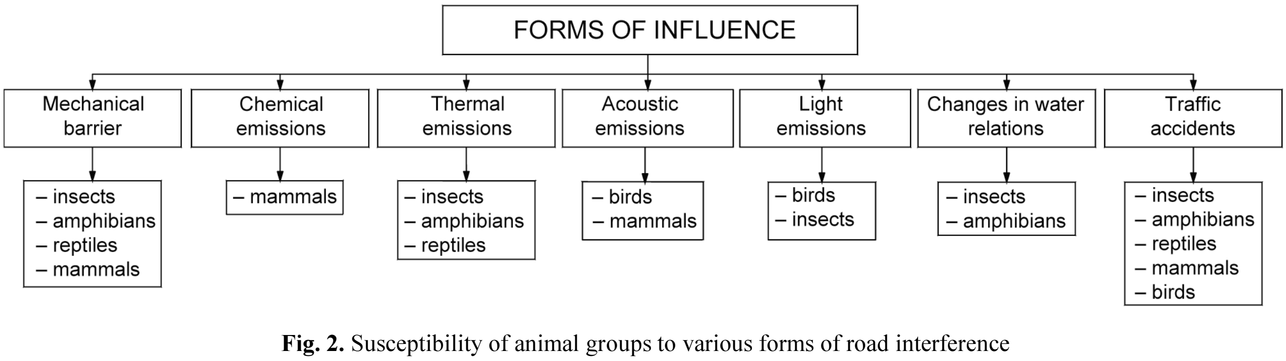

Fig. 2. Susceptibility of animal groups to various forms of road interference

For example in Poland, the proposed area of habitats under special conservation covers about 3.7% of the territory, whereas the sites of bird protection constitute more than 8%. As complementation of the above areas, some extra-governmental environmental organisations have proposed an additional list of sites, which, in total, cover almost 19% of Poland's territory. In other countries, the situation is much better as far as protection with Nature 2000 is concerned, mainly due to earlier accession of those countries to frameworks of the EU. Basing on data of 2005, approx. 44% of the territory of Spain, 35% – of Sweden, 30% – of Italy, 25% – of Germany and 20% – of France fall under the Nature 2000 program.

Fig. 4. Example of an overpass for animals in Germany

3. Types of animal crossings

3.1. General crossings descriptions

From the point of view of ecologists, fragmentation of animal life caused by roads is a much bigger problem than collisions in which individual animals die. Isolation of earlier mentioned populations of large animals will lead to extinction of species in some parts of Europe. Big animals must migrate and contact with other groups, otherwise they will not survive. That is why relevant technical solutions need to be applied, for example animal crossings of relevant overall dimensions (Di Giulio *et al.* 2009; Van Bohemen 1998).

Animal crossings can be divided in accordance with the scheme presented in Fig. 3, where three main groups have been selected, namely: overpasses, underpasses and crossings on the road level.

Overpasses can be landscape bridges, green bridges and passes over tunnels. The width of landscape bridges should be over 100 m and should be covered with natural vegetation. It is also advisable to preserve unchanged structure of the surrounding landscape. They should ensure continuity of landscape formations, of habitat areas and migration corridors for all types of animals (Beben, Manko 2006).

In the case of big overpasses, so called green bridges, their width should be contained within the scope of 30–100 m. These structures are characterised by natural ground and vegetation covering, and their suggested width should not be smaller than 50 m. Depending on their width and top layer, they can be used by various groups of animals from amphibians and reptiles to big mammals. An example of such animal bridge built in Germany is shown in Fig. 4 (Beben *et al.* 2004; Clevenger, Waltho 2005).

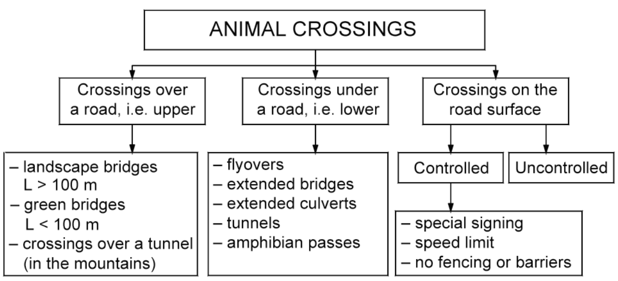

Fig. 3. Scheme representing classification of animal crossings

Rivers and river valleys form natural corridors and natural habitats for many species of wild animals inhabiting uncultivated areas. When animals meet a transportation route, which obstructs their migration path (for example a river corridor), they have to enter the road, which increases the risk of collision with vehicles. In such cases, use of underpasses is advisable. Underpasses can be of following types: flyovers, small bridges, tunnels and culverts.

The best solution when a road has to cross a river is a bridge with a big distance between its spans. It allows free water flow and maintains continuity of the natural river bank system, and it also makes it possible for various species to go under the road. Effectiveness of this type of a passage will depend upon dimensions and height of the bridge and continuity of preservation of natural vegetation lane on the river bank. The minimal clearance for medium sized animals like deer should amount to 2.5 m so that the traffic above is of a minimum interference. In the case of areas inhabited by bigger animals, bigger passes should be built, at least 4.0 m high and 20–50 m wide. Most commonly they are made of concrete and steel with top covered in natural ground. They are suitable for mammals like foxes, badgers, hedgehogs, martens, hares, rabbits and local migrations of hoofed wild animals such as deer, roe deer and wild boars. At the same time, such form of crossing – an ecobrigde – has minimal influence on fish and invertebrate living and migrating in the river current (Beben, Manko 2006; Clevenger *et al.* 2001).

More often underground passes for small animals are used in the form of tunnels and culverts of round, elliptic, rectangular cross-sections, the width of which is contained within the scope of 0.50–2.00 m (Fig. 5a).

They are usually made of concrete, plastic or steel with a natural ground top layer. They are aimed mainly at small animals hunting at night, such as badgers, foxes, martens, hedgehogs and other rodents (Beben, Manko 2006; Clevenger *et al.* 2001). In this case, a guiding system should also be designed (wire nets and fencings) which would lead animals to the passage (Dood *et al.* 2004). Culverts for amphibians form a distinctive type of a crossing (Fig. 5b); many solutions of various parameters are used, however a small tunnel of 1.00–2.00 m in width and natural ground top layer is a common structure.

a)

b)

Fig. 5. Underpasses in the Czech Republic: a) for small animals (the A4 Motorway, Poland), b) for amphibians (Jedrzejewski 2007)

In this case, special guiding systems are used, which at the same time protect animals against entering the road. They have a form of concrete gutters (with inlets to the tunnels) and vertical concrete or plastic fencings of 0.40–0.60 m in height.

If a road goes over the terrain or when it crosses a valley or a canyon with natural vegetation and landscape structure, flyovers should be used to preserve continuity of migration paths of all species. In mountainous areas, they are often a structural element of a road exerted by topography (Fig. 6). In plain conditions, they are mainly built due to environmental reasons, for instance over river valleys or over swampy areas. The higher the flyovers are, the better they meet their function (the suggested minimal clearance is 6.0 m) (Beben, Manko 2006).

Fig. 6. Example of a flyover over a valley in Croatia (Jedrzejewski 2007)

Animal crossings on the road surface are most common (it is an unconscious action rather than the result of a well-thought-out analysis). Well considered solutions consist of special signage that signals possibility of appearance of animals crossing the road, as well as information of the section length (Fig. 7).

This is the simplest type of animal crossing that may deprive a road section of fencing. A minimal width of such pass is 200 m, whereas the recommended one amounts to 500 m. Often, additional speed limitation on this section of the road (to 50 km/hr) is imposed. Such road section needs to meet the level of the surrounding ground or only slightly differ in height, and it cannot have lighting or protective barriers. A solution of this type is practically the only one (except for fencing and reflective elements) which can be used at reconstruction or renovation of the existing roads. In such cases, the existing horizontal alignment is not exceeded, also no major changes to the road vertical alignment are introduced. Such solutions are used in big (long) forest complexes and in places where it is impossible to build an animal crossing in the form of a tunnel or a bridge. Moreover, such crossing can be located only on roads with relatively low traffic load of no more than 5 000 vehicles per day and on roads which are not located on crossings with migration corridors of national and international importance (Beben *et al.* 2004; Seiler 2003).

a)

b)

Fig. 7. Example of crossing on the road surface: a) for animals (the USA), b) for amphibians (France)

Threshold values of level changing, causing considerable limitations to the possibility of migration of wild animals on the road level, have been presented below:

a) for invertebrate (without capability of active flying), such as amphibians, reptiles and small mammals – embankments of > 1.0 m and excavations of >1.5 m in depth,
b) for all groups and species of ground animals including big mammals – embankments of > 2.0 m and excavations of > 3.0 m in depth.

In each of the above cases, slopes of maximum 1:2 inclination are possible. Modification of the vertical alignment of the ground that would exceed the above values causes limitations to migration to such an extent that only individuals will try to cross the road, whereas the majority of animals will migrate along the embankment bases and top edges of excavations (Maranda 2007).

Crossings for animals on the road surface are however characterised by low effectiveness (rather numerous collisions with animals) as many drivers tend to exceed speed limits.

Recently, warning reflectors to scare away animals were introduced. They reflect the light of vehicles to the roadside terrain at a right angle (Fig. 8).

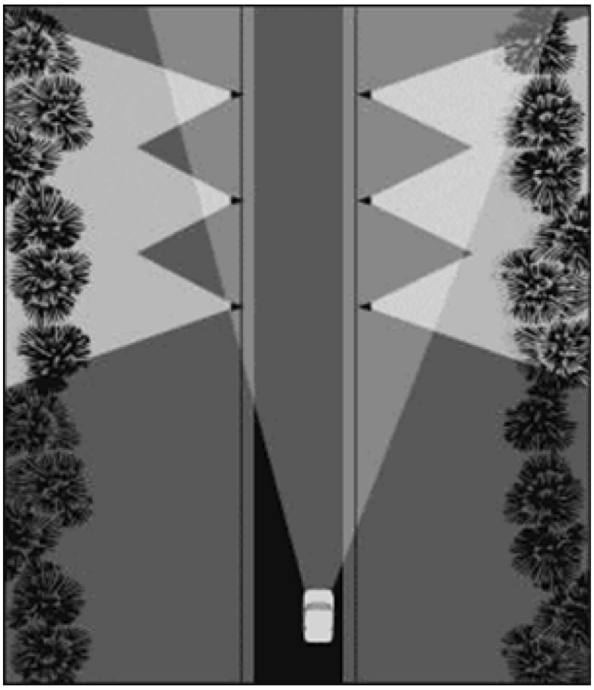

Fig. 8. The fence of light created by reflexion of vehicle lights

3.2. Specificity of designing animal crossings

Before starting to design a wildlife crossing, it is necessary to undertake the following:

1. Make a research on species of animals inhabiting the area (arrangements with forestry officials would be required).
2. Ascertain migration ways of animals (location of animal crossings must coincide with animal migration trails).
3. Establish preliminary geometrical parameters (vertical and horizontal) as well as the number of crossings (arrangements with forestry officials would be required).

At the time of execution of road works projects, bearing in mind protection of the environment, one should use both legal and technical instruments, in accordance with the scheme presented in Fig. 9.

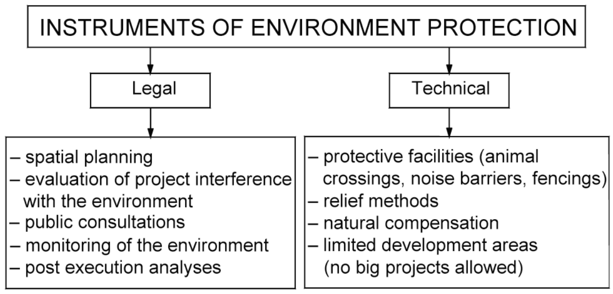

Fig. 9. Scheme representing instruments of environmental protection

In case of a motorway and an express road construction, the main way to protect environmentally valuable areas is to avoid them, wherever possible, during the planning and designing phase of such projects. Due to specificity of this type of projects (linear objects), avoiding interference with the natural environment is very often impossible. In such cases, the rule of minimising the negative influence and compensating losses of nature (natural compensation) is applied.

Relevant laws define natural compensation as a set of actions undertaken especially through construction works, earthworks, land reclamation, afforestation, planting trees and creating vegetation groups, leading to reinstatement of natural balance over a given area, compensating losses caused to the environment by execution of a given construction project and preservation of continuity of landscape values.

At the time of designing animal crossings, the following elements need to be taken into consideration (Beben, Manko 2006; Kurek 2007; Maranda 2007):

1. Ensuring execution of correct guiding funnels; this concerns mainly low angle of entrances to the object.
2. Designing relevant vegetation (bushes and trees) on such structures to encourage animals to use them (this also concerns reinstatement of the original natural infrastructure in the vicinity of the structure).
3. Ensuring relevant functional value of animal crossings (height and width of the structure) and a suitable number of crossings, to make sure they meet their main task:
   - in the case of big mammals, the width of overpasses should be at least 50 m, and the height of underpasses at least 4 m.
   - the number (density) of crossings depends on:
     - importance of the crossed migration corridor,

   - the type of the crossed habitat and the forms of protection it falls under (national and landscape parks),
 - the highest density of crossings (every 1 km) should be used within the borders of national parks, Nature 2000 conservation sites and in big, compact forest complexes.
4. Ensuring that a structure is not elevated more than 1.0 m above its surrounding area (an animal needs to see the opposing side where it is aiming to).
5. Diversifying types of crossings over a given area, so that all species (of different requirements) can cross the road.
6. Creating silent area around ecobridges using noise barriers which deaden noise and interference of light coming from vehicles, especially at nighttimes.
7. Ensuring that functions of animal crossing and crossing for forestry and woodcutting services do not coincide on one structure.
8. Paying attention to technology of construction works.
9. Undertaking consultations and arrangements of construction solutions as well as land development ideas with due services responsible for supervising a given area of natural environment.

It is also very important to hold constant monitoring of animal crossings, which allows estimating their functional value and can be the source of ideas of increasing and maintaining required quality of land development. It can also be of help at constructing new crossings (Clavanger, Waltho 2005). For this purpose, thermo-vision cameras as well as the GPS technology can be used. For example such solution has been used in Spain (Mata *et al.* 2005), Sweden (Olsson *et al.* 2008), and also recently in Poland.

3.3. Design errors in and their influence over the use of a crossing

The most common errors at designing various types of animal crossings are:

- not enough width of a crossing,
- too big angle of inclination of a crossing,
- too steep (lack of gentle exit way from the structure onto the surrounding land) and narrow entrances to the structures (lack of guiding funnels),
- in case of underway culverts – lack of dry passages for amphibians above flooding level,
- situating additional facilities on the structures, for example road signs, walls, barriers, lighting etc. (Fig. 10),
- lack of noise and blinding barriers (Fig. 11),
- inefficient composition with the surrounding environment, for instance in the vicinity of human habitats (Fig. 12),
- lack of high and medium-high vegetation on the structures and in vicinity,
- incorrect top ground layer on the substructure on entrances to objects,
- using vegetation coming from geographically distant parts.

Fig. 10. A view of an animal crossing inlet – a road sign and concrete flower beds

Fig. 11. An example of lack of blinding barriers on an ecobridge in Canada (Jedrzejewski 2007)

Fig. 12. An example of location of an animal crossing in the vicinity of human habitats in Poland (Kurek 2007)

Animal crossings on the A4 motorway in Poland are good examples of the above presented designing errors. However, despite of some transgressions and structural defects, in January and February 2006 (after about five years from its construction), individual trails of deer and wild boars were observed on the snow on animal crossings along the analysed motorway section. The number of game population and its density within the borders of hunting areas where evaluation of environmental changes was held, has increased, which proves that animals have gotten used to living in the neighbourhood of the motorway. It has also been observed that the ecobridges are mainly used at nighttimes by such animals as deer, hares and foxes.

Similar analyses of using animal crossings have been contained among others in the following research papers (Cain *et al.* 2003; Clavanger, Waltho 2005; Dodd *et al.* 2004; Mata *et al.* 2005; Ng *et al.* 2004; Olsson *et al.* 2008).

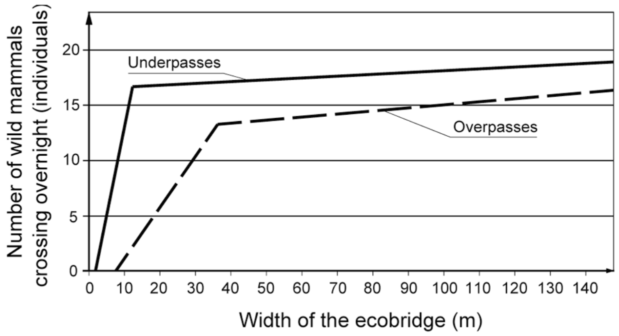

Fig. 13. Frequency rates of using overpasses and underpasses by animals

An analysis of use of selected animal crossings situated on the motorway and expressway in Poland (10 overpasses and 10 underpasses) was also conducted depending on their width (Fig. 13). The above-mentioned observations were made in winters of 2006 and 2007. Tracks of deer, roe deer, marten, hares, foxes and wild boars were observed at the analysed ecobridges mainly at nighttimes. According to the obtained results, overpasses (the width of passage in the range of 40–140 m), a more eager use by animals (mainly by deer, roe deer, wild boars) has been observed. However in case of underpasses (tunnels, flyovers) of width within the scope of 10–140 m, the number of animals can reach 20 individuals per night, mainly foxes, hares, martens and also wild boars. Generally, it has been observed that underpasses are more often used than overpasses. This is probably related to a more natural integration with the surrounding environment – they most often constitute an extension to a migration corridor at the same ground level. In case of overpasses, for example in the form of a viaduct over a road, the solution is an unnatural connection between two areas of natural environment. In this case, an animal heading to the opposite side of a road needs to go up a slope, which always causes anxiety. The similar research of use of overpasses is presented by Jedrzejewski (2007).

Adaptation of existing culverts into animal crossings is not a good solution either. Most often those objects do not meet basic geometrical parameters nor are they located on animal migration trails (Mata *et al.* 2008).

4. Discussion

The constantly evolving transportation infrastructure (roads, railways, airports) in Europe, especially in its Midwestern part, on one hand connects, making it easier for people to travel and ship goods, but on the other hand it irreversibly divides and leaves its painful impress on virgin natural areas (fragmentation of the environment). That is why execution of different engineering projects, especially ones of road and railway type requires sensible actions, bearing in mind not only building of impressive road or railway route, but also preservation of the natural environment in its untouched condition to the highest possible extent.

According to analyses conducted in the paper, animal crossings complemented with suitable fencing weaken the so called barrier effect and accomplish two main functions, namely:

- they create conditions to meet habitation requirements of wild animals, the individual territories of which are cut through by a transportation route. These animals can use both parts of their territory located on the two sides of the road.
- They allow for migration and dispersion of animals migrating for a long distance.

As it has been proved by the analysis of use of animal crossings, animals use them, even the ones transgressing the rules of good designing and engineering practice. This is caused by the fact that animals have gotten used to such crossings and to their vicinity, having at the same time no other alternative to cross the road. It was also been that underpasses tend to be used more often than overpasses by such medium sized animals as hedgehogs, martens, badgers foxes and hares. In case of both crossings types, the animals tend to use them mainly at nighttimes. It is because at night time, the wild animals feel safer than during daytime (less of light and transportation noise level).

Animal death rates on roads also depend on the area that the road crosses. For example there are amphibians and medium sized forest and field-forest mammals (e.g. hedgehogs, martens, badgers, foxes and hares) as well as big mammals (e.g. roe deer, wild boars, deer) that get killed on Polish roads. Collisions with elks, wolves, lynxes or even European bisons are very rare. In other European countries, the situation is similar with the reservation that many animal species do not die, because they have long been extinct, e.g. lynxes, European bisons. Animal death rates vary depending on a season – they are the highest at the time of intensified spring and autumn migrations – and on the time of a day as most accidents happen at dusk. The following animals are most threatened by roads: amphibians and mammals with high spatial requirements: a wolf, a lynx, a brown bear (*Ursus arctos*), an elk, a European bison and a deer.

Minimisation of negative influence of transportation projects on an animal population can be achieved through the following (Fig. 14):

1. Designing transportation routes in such way as to avoid collision with animal migration routes (it is necessary to work out a strategy of motorway and express road development having in mind protection of environmental resources).
2. Constructing well developed animal crossings of relevant geometric parameters.
3. Using fencing to limit collisions with vehicles and to reduce the negative effect of noise and vibrations from roads.

An important element of environmental protection is compensation of losses, the so called natural compensation. However it appears that building green crossings for wild animals is one of the elements of wildlife protection of utmost importance.

Structures of this type constitute a rather big technical problem due to its complex nature, therefore, it is necessary to:

- recognise populations of animal life and their habits,
- locate the structure at the correct place – i.e., on an animal migration trail,
- develop the crossing for animals in an appropriate way (for instance high and medium sized vegetation, blinding screens, suitable paving, etc.),
- use environmentally friendly construction and material solutions,
- design structures of relevant geometric parameters, this especially concerns the width of a crossing and the clearance between the road level and the animal passage.

Many types of construction materials are used to build animal passages. They are steel, concrete, plastic, but it seems that structures made from corrugated steel plate (CSP) elements interacting with the surrounding soil (so called the soil-steel bridge structures) are the best ecobridges for small and medium sized animals, due to their natural characteristics (Beben 2005; Morrison *et al.* 2009; Richmond *et al.* 2007), which are among others:

- Soil cover on the structure needs not be artificially created – it constitutes an integral bearing part of the structure.
- They compose well with the surroundings (they can be finished in a freely selected way: grass or gabions on outlets from ecobridges).

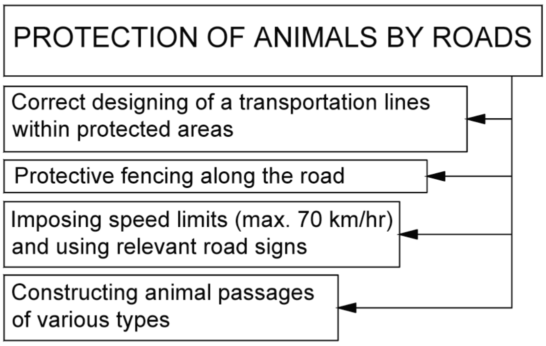

Fig. 14. Scheme of basic animal protection measures

Fig. 15. An example of an overpass for animals (medium and large size) on the A1 Motorway (Poland), made from corrugated steel plate elements

Fig. 16. An example of a typical underpass (elliptical shape) with shelves for amphibians above the high water level in Poland

- They do not cause too much vibration when vehicles run over or under them – the backfill absorbs it.
- They allow possible widening of the animal passage if necessary.
- They do not require use of heavy construction equipments.

Figs 15 and 16 show examples of animal crossings (overpasses and underpasses made from corrugated steel plates).

5. Conclusions

1. The animal crossings are built in a form of overpasses, underpasses and crossings on the road surface. These types of structures are more and more often built in Poland and Europe, as a results of the Natura 2000 requirements.

2. The correctly designed and constructed animal crossings should be of appropriate geometrical parameters (width and height of an object) adapted to the kind of animals as well as made from the environmentally friendly materials, e.g., local soil.

3. The use of existing animal crossings in Poland is mainly dependent on their width, i.e. the wider are the crossings (more from 140 m), the more animals use them. Cases of use of animal crossings were observed mainly at night times. The animals more willingly used objects built from environment-friendly materials and equipped with acoustic screens overgrown with creepers.

4. From conducted observations, it seems that structures made from CSP elements interacting with the surrounding soil are the best ecobridges for small and medium sized animals, due to their natural characteristics.

5. In connection with the above, it was proved beyond any doubt that these types of structures are necessary and unavoidable, because they allow for preservation of genetic diversity of various animal species.

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GYVŪNŲ PERĖJOS – EFEKTYVUS FAUNOS APSAUGOS METODAS

D. Beben

S a n t r a u k a

Straipsnyje apžvelgtos laukinės gyvūnijos išsaugojimo problemos, susijusios su besiplečiančiu transporto tinklu. Nuolat besivystanti transporto infrastruktūra Europoje, ypač Vidurio vakaruose, viena vertus, jungia ir palengvina žmonių mobilumą, sukuria jungtį su uostais, tačiau, kita vertus, daro didelę žalą natūraliai aplinkai (aplinkos fragmentacija). Straipsnyje trumpai pristatoma Europos ekologinio tinklo „Natura 2000“ ES programa, skirta aplinkos apsaugai. Išvardyti galimi gyvūnų perėjų tipai su jiems būdingomis charakteristikomis. Pateikiami požeminių, virš kelio ir perėjų per patį kelią pavyzdžiai. Straipsnyje taip pat apžvelgiama inžinerinių struktūrų projektavimo specifika ir fazės, aptariamos dažniausiai pasitaikančios projektavimo klaidos ir jų įtaka gyvūnams. Galiausiai apibūdinamas dirvos ir plieninių tiltų struktūros, pagamintos iš gofruotų plokštelių, naudojimas gyvūnų perėjoms. Išvadose aptariamas gyvūnų perėjų konstrukcijų problemų kompleksiškumas, į kurį turėtų atkreipti dėmesį gyvūnų perėjas konstruojantys inžinieriai ir dizaineriai.

Reikšminiai žodžiai: gyvūnų perėjos, kelias, susidūrimai, gyvūnų apsauga, programa „Natura 2000“.

ПЕРЕХОД ДЛЯ ЖИВОТНЫХ – ЭФФЕКТИВНЫЙ МЕТОД ОХРАНЫ ФАУНЫ

Д. Бебен

Р е з ю м е

Анализируются проблемы охраны диких животных в связи с расширяющейся транспортной сетью. Постоянно развивающаяся транспортная инфраструктура в Европе, особенно на западе центральной части Европы, с одной стороны, объединяет людей, облегчает их мобильность, открывает доступ к портам, с другой – наносит непоправимый вред натуральной природе. В статье вкратце представлена программа Европейской экологической сети – Natura 2000, касающаяся охраны окружающей среды. Перечислены возможные типы переходов для животных с их типичными характеристиками. Представлены примеры подземных переходов, переходов над дорогой и по самой дороге. Проанализирована специфика и фазы проектирования инженерных структур, а также часто совершаемых ошибок при проектировании и их влияние на животных. Охарактеризовано применение для переходов животных почвенно-стальных структур мостов из гофрированных пластин. Проанализирована комплексность проблем, касающихся конструкций для переходов животных, на которые следует обратить внимание инженерам и дизайнерам при конструировании переходов для животных.

Ключевые слова: переходы для животных, дорога, столкновения, охрана животных, программа Natura 2000.

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