MORTALITY OF LARGE MAMMALS ON RAILWAY TRACKS*

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As linear structures, railways (rail corridors) significantly affect life in the wild, have negative impact on animal population levels, and affect the very form and structure of inhabited biotopes. This article analyses and quantifies mammal mortality on the Plzeň–Horažďovice suburban railway line. The research was conducted over the 12 months from 1 January 2009 to 31 December 2009. During this period total 60 animals were run down, among them, 60% of collisions were with roe deer (*Capreolus capreolus*), 17% with European hare (*Lepus europaeus*), 13% with pheasant (*Phasianus colchicus*), 5% with bird of prey, 3% with wild board (*Sus scrofa*) and 2% with red fox *(Vulpes vulpes)*. The aim of the research was to analyse in detail individual sections of the track, whose land cover, land use, migration rate and wildlife-train collisions vary. The outcome of this work is to evaluate and assess the overall animal mortality and to determine the most affected wildlife species. The aforementioned results show that rail transport is dangerous for wild mammals, and it can be clearly said that the most endangered species is roe deer (*Capreolus capreolus)*.

game; migration; barrier effect; population; population fragmentation

INTRODUCTION

The issue of mammal mortality, often discussed in connection with road transport, is known only marginally in relation to railways. The length of railway lines in the Czech Republic was 9,430 km as at 31 December 2008, of which 3,078 km are electrified railways and 6,352 are non-electrified railways. On average, 9,000 passenger trains criss-cross the Czech Republic every 24 hours. Based on these facts, there is no doubt that with this intensity of rail traffic there are frequent wildlife-train collisions. There are, however, very few Czech studies that have focused on this issue. Foreign publications about the influence of rail transport on wildlife migration and mortality include, for example, Barry, Aitken (1991), Becker, Grauvogel (1991), Gundersen, Andreassen (1998), Rodriguez et al. (1996) and Selmić et al. (2010).

The frequency of wildlife crossing railway lines is influenced by a number of factors, the most significant of them are: (i) character of the surrounding landscape and concentration of mammals in the vicinity, (ii) grade level (height) of the railway in relation to the geomorphology of the surrounding terrain (large mammals run onto the railway particularly in those places where the grade level of the railroad is at the level of the surrounding terrain), (iii) age of the railway (mammals run more often onto newly constructed railways), and (iv) food and migration needs of mammals.

Generally, routes with high traffic create obstacles that are difficult for the mammals to overcome during their migration, and these are directly life-threatening for the mammals due to animal-vehicle collisions (Trocmé, 2003). For large mammals, routes are usually not an absolutely impermeable barrier. That is only the true in cases of high traffic density or fencing. Traffic density, speed of vehicles and overall technical design of routes are the main aspects influencing the extent of the barrier effect (Aanen et al., 1991; Iuell et al., 2003 etc.).

The phenomenon known as population fragmentation is thus becoming a serious and very complicated issue of environmental protection and can have catastrophic consequences for the future structure of ecocenoses, biotopes and consequently also entire ecosystems. Therefore, there are efforts to protect the integrity of valuable areas by means of various legislative instruments not only on the national but currently also on the European level (Hlaváč, Anděl, 2001; Iuell et al., 2003). Isolated locations gradually lose their ability to perform their natural functions as places for the existence of viable animal populations and where these populations are able to reproduce repeatedly.

Monitoring of traffic routes' impacts on wild mammals is described in Clevenger, Waltho (2005), Fahrig, Rytwinski (2009), Saeki, Macdonald (2004) and elsewhere. Mammals and birds tend to be very vulnerable to rail transport, as shown also by studies conducted in Spain, the Netherlands and Czech Republic (Brandjes, Smit, 1999; Van der Grift, 1999; Havlín, 1987). Differences in mortality between species are well documented by the research of train-animal collisions on Spain's Madrid–Sevilla railway line. Along this railway, the annual mortality was estimated to be 36.5 run-down individuals/km (SCV, 1996). Around 57% of these victims were birds and 40% were mammals, while only 3% were reptiles and amphibians. European and North American studies show that many species of wild mammals are often killed by rail transport (Van

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Tighem, 1981; Child, Stuart, 1987; Belant, 1995; Wells, 1996).

An important issue, however, is what part of a population is actually affected by mortality on routes, or, more precisely, railways. The published data vary considerably depending on the specific research location. For example, Iuell et al. (2003) and Trocmé (2003) state that transportation kills some 5% of the population of common species (red fox, roe deer, wild boar). Swiss research (Righetti et al., 2003) focused on deaths of roe deer and red deer (data from 1999) points to the fact that mortality caused by traffic is clearly the most common cause of death for both species (49.3% for roe deer, 33.2% for red deer). The second most commonly stated cause of death of roe deer *(Capreolus capreolus)* is agricultural technology (19.8%), followed by other factors (9.1%), then age and diseases (7.1%). The second most common cause of death of red deer *(Cervus elaphus)* is other accidents (fall, avalanche, etc.), followed by other causes (14.7%), and then age and diseases (12.2%). The results show that the specific situation in a given territory must always be taken into account.

Species particularly sensitive to barrier effect and traffic mortality are: (i) rare species with small local populations and large individual territories, such as large carnivores (otter, lynx, etc.), (ii) species that migrate daily or seasonally between local biotopes (some ungulates use various environments during daytime and because of that they must cross roads and railways in most cases), (iii) species with long seasonal migrations from summer to winter territories, such as moose or reindeer (Pfister, 1999; Iuell et al., 2003).

According to Huijser and McGowen (2003), animal-vehicle collisions affect human beings' safety, their property and the animal population itself. In the USA, the total number of collisions with large ungulates has been estimated at more than 1 million a year.

Similar figures are available in Europe as well. In Europe (apart from Russia), more than a half million vehicle-ungulate collisions are recorded each year. These cause at least 300 human deaths, 30,000 human injuries, and property damage of more than EUR 1 billion (Trocmé, 2003). These figures show an increasing trend. Some species of mammals have come to the brink of extinction due to collisions with vehicles and trains.

MATERIAL AND METHODS

The period of study was from January to December 2009 and was monitored section of the railway line between Plzeň and Horažďovice suburb is interwoven with 18 hunting districts: Horažďovice, Velký Bor, Třebomyslice, Pačejov, Milčice, Štírka Myslív, Nekvasovy, Mohelnice, Klášter, Srby Sedliště, Chejlava, Vlčice, Ždírec, Blovice, Zdemyslice, Žákava, Šťáhlavy and Starý Plzenec. Roe deer (*Capreolus capreolus*) populate all of those hunting districts named, and there are small numbers of common pheasant (*Phasianus colchicus*) and European hare *(Lepus europaeus)*. Moreover, wild boar (*Sus scrofa*) and red fox *(Vulpes vulpes)* regularly occur in all of the hunting districts. Moufflon *(Ovis musimon),* fallow deer *(Dama dama)* and red deer (*Cervus elaphus*) occur locally along the monitored railway. In the Velký Bor hunting district, rock partridge (*Alectoris graeca)* occurs as well.

Species of animals occurring in individual localities were obtained from individual gamekeepers or workers of municipal environmental departments. Along the railway line in the monitored section, fields and grasslands make up 84.2%, forest 10.1% and brush 5.7% of the represented biotopes. The railway line was monitored by train drivers who passed through this section within the monitored period. They recorded the numbers of run-down animals along the line and localized the surroundings of any site of collision (forest, field, brushwood). Data acquired in this way were continuously collected and recorded in a field diary. In addition, the precise kilometer mark of the finding was recorded for every run-down animal according to the track kilometer system of the Czech Railways, particularly to enable precise identification of the section of railway with the highest number of run-down animals and to exclude inaccuracies arising from the possibility that two train drivers would record the same run-down animal for a kilometer of track. Game species that was run down by the driver when driving was recorded, as well as wildlife that was seen along the track and had been already run down by another rail vehicle. During the entire period, several walking inspections along the track were carried out, whereby photo documentation was taken and the surroundings of the track were described in individual sections. Also a video record of the railway track on the line between Plzeň and Horažďovice suburb was made using a video camera placed behind the front window of the train as agreed with the train driver.

When calculating the number of collisions of the most affected animals the number of trains on the line between Plzeň and Horažďovice suburb was first determined according to the Czech Railways timetable for 2008/2009, with differentiation for weekdays, Saturdays, Sundays and public holidays. When calculating the animal-rail vehicle collision for each month separately, the procedure was such that the number of run-down individuals of the given species in individual months was divided by the number of train kilometers for each month, which gave the number of run-down individuals per 1 km of track. The data obtained were further examined to identify, in which biotope the animal-train collisions occurred.

The monitored section of the railway is traversed by 326 passenger trains per week. Moreover, it was necessary to add freight trains, which amounted to 126 according to the findings of the drivers. Daily average for the monitored section of the track is thus 65 passenger and freight trains.

Statistical analysis was carried out using Kruskal-Wallis ANOVA and basic statistical variables. Numbers of individual species of animals run down on the track were compared. This test also analysed in which locations (forest, field, brush) the collisions are most frequent. Further-

more, the measured data were analysed using chi-square test (observed vs. expected frequency). This test was used to determine whether the species of mammals are run down with the same regularity in individual months. The differences between run-down species of animals and between the localities where the collisions occur were graphically illustrated using cluster analysis.

RESULTS AND DISCUSSION

The data obtained were evaluated by a combination of several procedures on the basis of which we found that out of the total number of 60 wildlife-rail vehicle collisions 2 individuals were run down in January, 15 individuals in February, 4 in March, 5 in April, 4 in May, 3 in June, 4 in July, 5 in August, 5 in September, 4 in October, 4 in November, and 5 in December (Fig. 1).

By means of Kruskal-Wallis ANOVA, we recorded a statistically significant difference between the animals. [H (5, N = 72) = 40,89313 p = 0.0000) and Chi-square = 34,95201 sv = 5 p = 0.0000]

According to this test we recorded statistically significant difference in number of run down animals between roe deer (*Capreolus capreolus*) and pheasant (*Phasianus colchicus*) (p = 0.469), between roe deer (*Capreolus capreolus*) and wild board (*Sus scrofa*) (p = 0.0001), between roe deer (*Capreolus capreolus*) and red fox *(Vulpes vulpes)* (p = 0.0000), and between roe deer (*Capreolus capreolus*) and bird of prey (p = 0.0002).

When we examined the regularity of animal-train collisions in individual months in the monitored section of track using chi-square test (observed vs. expected frequency), we obtained these results:

- Roe Deer – chi-square = 12.66667, sv = 11, p = 0.315674
- Hare – chi-square = 6.800027, sv = 11, p = 0.815037
- Pheasant – chi-square = 1.000000, sv = 1, p = 0.317311

These results show that at the significance level of p = 0.05 there was no demonstration as to a statistically significant difference in animal-vehicle collisions between individual months.

Figs 2 and 3 indicate mortalities for individual species, which most often occur in places where there is a field or meadow. This can be explained by the fact that the landscape in the surroundings of the monitored track is mostly made up by fields or meadows (84.2%), where animals migrate to obtain food.

Fig. 4 clearly demonstrates how animal-vehicle collisions occur more frequently in fields and meadows, but Kruskal-Wallis ANOVA showed no statistically significant difference between the localities of the environments where these collisions occur [H (2, N = 18) = 4.012346,

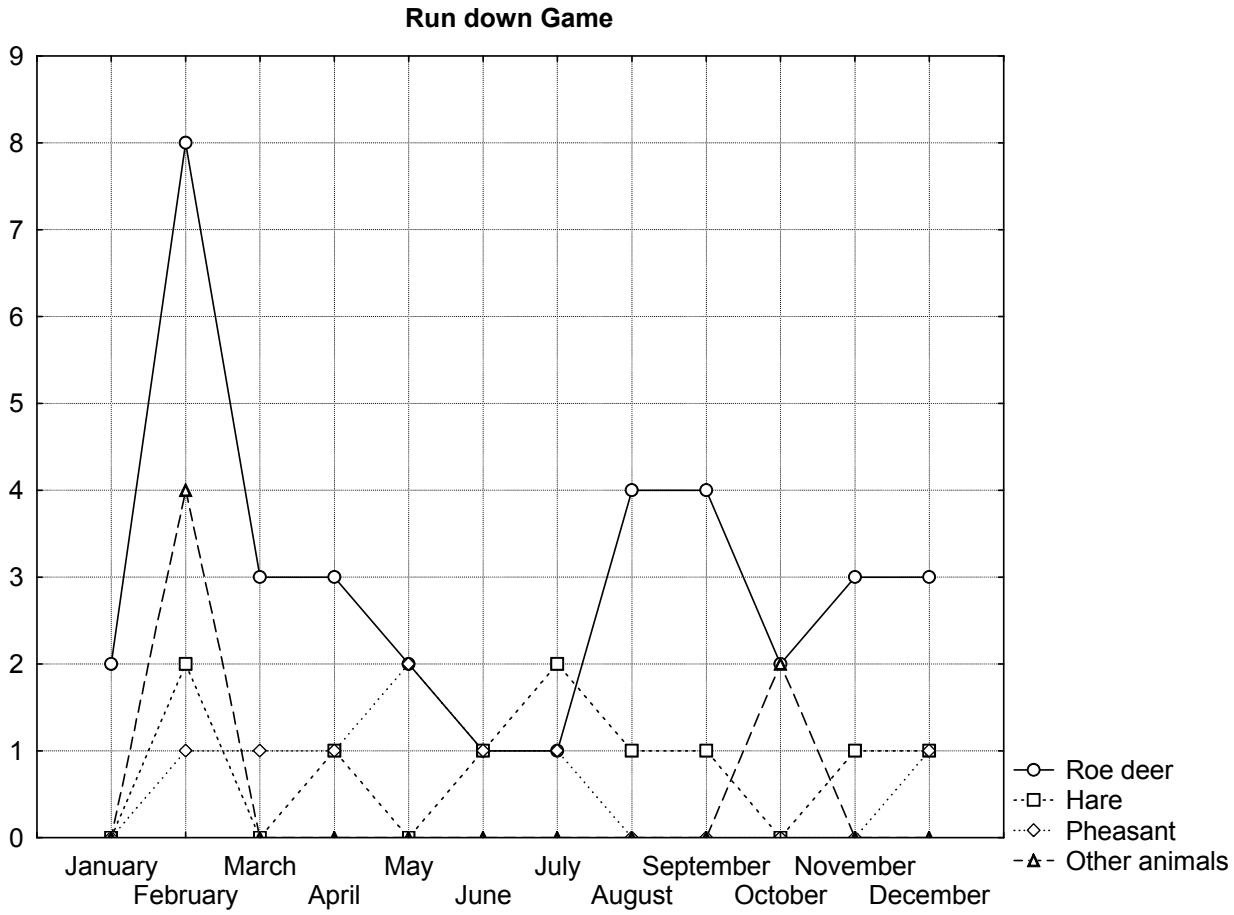
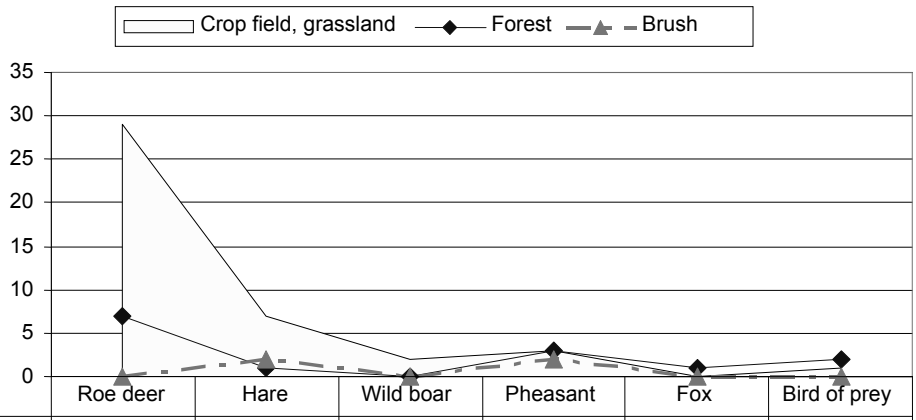


Fig. 1. Mortality of roe deer (*Capreolus capreolus*), European hare *(Lepus europaeus)* and common pheasant (*Phasianus colchicus*) and other animals in the monitored part of the railway



	Roe deer	Hare	Wild boar	Pheasant	Fox	Bird of prey
Crop field, grassland	29	7	2	3	0	1
Forest	7	1	0	3	1	2
Brush	0	2	0	2	0	0

Fig. 2. Mortality of animals in different types of environment

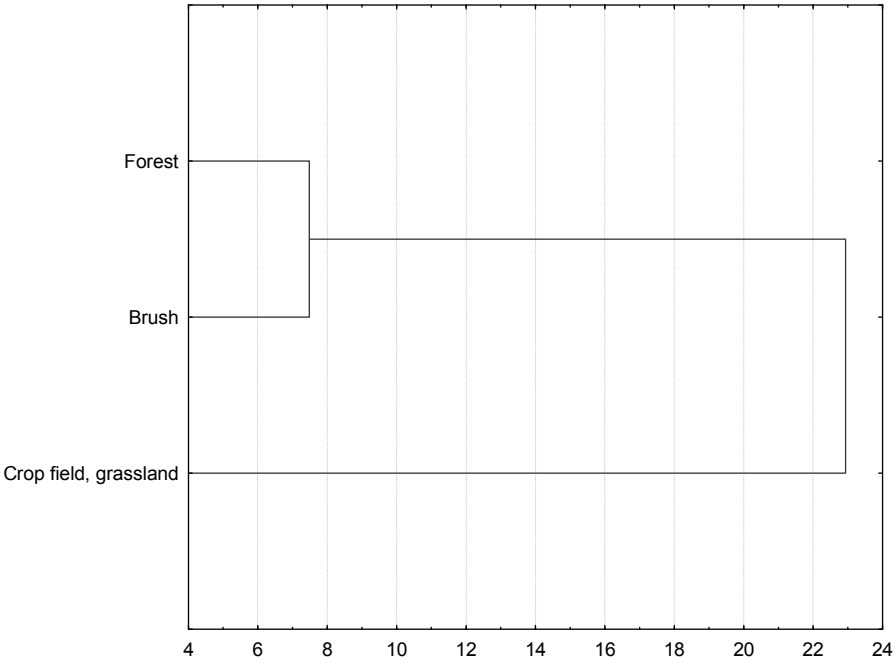


Fig. 3. Results of cluster analysis comparing animal mortality, depending on the type of environment

$p = 0.1345$ and chi-square = 1.333333 df = 2 $p = 0.5134$], and that was true also in relation to the different dimensions of individual areas that had not been taken into account.

At present, further research is known in the Czech Republic that is being conducted on the railway line between Trhový Štěpánov and Benešov u Prahy (J a n k o v s k ý , Č e c h , 2001). It is a 33-km railway track, which crosses a number of very different biotopes and allows a more comprehensive view on the entire issue. The first research on this track was carried out in winter 1999–2000 and consisted of several walking examinations along the track and analyses of skeletal findings of animals run down by trains. The analysis showed that the most affected species mainly comprise roe deer (*Capreolus capreolus*) and European hare (*Lepus europaeus*). Leporids were run down in 32%, even-toed ungulates in 22% (roe deer in the absolute majority of cases), carnivores in 18%, birds in 10%, insectivora in 4% and reptiles in 2% of cases. Findings of body residues occurred in those sections where the line does not form a distinct height barrier, whether with its embankment or ditch. In these places, which are substantially elevated and often overgrown with brush, numerous carcasses of pheasants were found. Although there are several busy roe deer passages crossing the ditched railway, skeletal remains were never found at these intersections or in their vicinity. All killed individuals of roe deer *(Capreolus capreolus)* and European hare (*Lepus europaeus*) were found on open, flat sections of the track, in the vicinity of which the animals stayed over the long term. The most frequent animal-train collisions occur at night, according to Czech Railways personnel. In com-

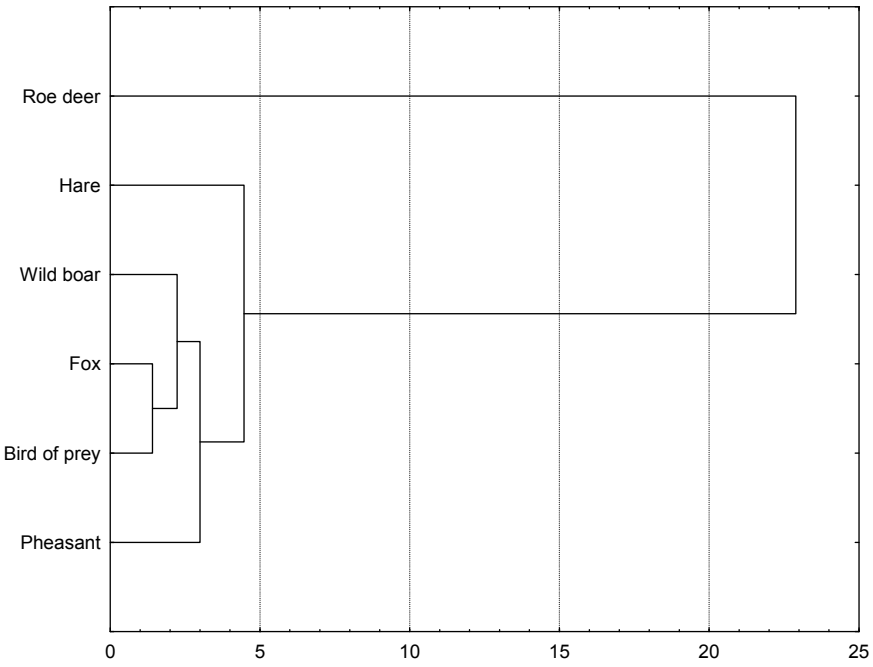


Fig. 4. Results of cluster analysis of comparing animal mortality in the monitored section of track

parison with our results can be found significant similarities, thus that the most affected kind of wildlife is roe deer (*Capreolus capreolus*) and hare (*Lepus europaeus*). The run down were frequently occurred in the open farmed landscape too like in our case study.

In May 2006, another research project on the railway line between Trhový Štěpánov and Benešov u Prahy was conducted. In analysing the second research, an increase in mortality of roe deer (*Capreolus capreolus*) was observed (J a n k o v s k ý , Č e c h , 2008). In comparison with our results, this study indicates the fact that the high number of wildlife collisions with train occur in large forest complexes, too.

A 2008 research project from the Czech Moravian Highlands is known as well. In a 6-km section of the railway line (Dobrá voda u Pelhřimova – Hříběcí), an inventory of foot inspections performed on a regularly weekly basis had as its aim to quantify mortality of large mammals due to rail transport and to identify, which species are the most endangered due to this transport. Animals were searched for with the assistance of a trained blood-tracking dog. Almost the entire section passes through a forest complex. It is a line, which is used for regional trains only, and there is limited rail freight transport. Over the monitored interval (1 year), 10 dead roe deer (*Capreolus capreolus*), 3 European hares (*Lepus europaeus*) and one wild boar (*Sus scrofa*) were found (K u š t a , J e ž e k , 2009).

A n d r e a s s e n et al. (2005) analysed the efficiency of odour fencing, removal of vegetation along track and diversion feeding along a railway line in Norway. The research commenced in 1985 and ended in 1990, during which time 1,045 animal-vehicle collisions were recorded. Reduction of accidents by 46% was proven over the period when actions to reduce mammal mortality were taken on the track. Removal of vegetation and diversion feeding proved to be safe ways to reduce collisions. Noise barriers along the railway line are also very effective, although these create a complete barrier for most animals and significantly contribute to landscape fragmentation and significant increase of barrier effect. The effectiveness of odour fencing appeared to be very questionable in this research. According to the results of this study the most suitable mitigation measures recommended led to reduction of the number of wildlife collisions with train consist in removal of vegetation along the railway tracks.

By comparing this research to the aforementioned studies that have already been conducted, we can conclude that the most affected species due to linear structures in the Czech Republic is roe deer (*Capreolus capreolus*), followed by European hare *(Lepus europaeus)*. Mortality is probably the most visible impact of traffic on wild animal species. Millions of individuals are killed and injured every year by land transportation. It is believed that over the last 30 years transportation has become a major human activity causing mammal mortality and has thus overtaken even hunting.

CONCLUSIONS

During research on the 50-km Plzeň–Horažďovice suburb railway line (1 January 2009 – 31 December 2009), 60 animal individuals were run down. Among these, 60% of collisions were with roe deer (*Capreolus capreolus*), 17% with European hare (*Lepus europaeus*), 13% with pheasant (*Phasianus colchicus*), 5% with bird of prey, 3% with wild board (S*us scrofa*) and 2% with red fox *(Vulpes vulpes)* (M a c h , 2010). The data obtained also show that animal mortality on a single track (36 km long) is 52% and on a double track (24 km long) is 48%. Based on this finding, we cannot clearly agree with the statement that common single tracks are not a significant barrier for large mammals and that only multi-track lines are (A n d ě l et al., 2005). The aforementioned results clearly show that

rail transport is a danger for wild animals. The species most endangered by animal-train collisions is the roe deer (*Capreolus capreolus*).

Fragmentation of animals' natural environments and fragmentation of natural ecosystems into smaller and smaller isolated biotopes is one of the greatest global threats to environmental protection and biological diversity (B r o k e r , V a s t e n h o u t , 1995). Maintaining the migration potential of a landscape must be an integral objective of landscape planning policies and landscape planning itself. This assumption is one of the main theoretical bases for the concept of territorial systems of ecological stability. It must be taken into consideration in the case of large linear structures, which are a cause of both landscape fragmentation and decreased possibilities for animal migration (S k l e n i č k a , 2003).

The issue of ensuring migration permeability of the landscape (for species with large space requirements, like large ungulates and large carnivores) has for some time already been given great attention, particularly in relation to transportation structures, and there are currently specialized methodologies describing basic prerequisites and necessary measures (A n d ě l et al., 2006; H l a v á č , A n d ě l , 2001). Methodologies for evaluating fragmentation and migration permeability have been worked out for designing transportation structures. In practice, however, these methodological approaches are used very rarely. Detailed analysis in terms of fragmentation and migration permeability for linear structures is prepared only very rarely, and the implementation of necessary measures is itself also not very common.

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Mortalita velkých savců způsobená železniční dopravou.

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Železniční tratě (koridory) jako liniové stavby podstatně ovlivňují život ve volné přírodě, negativně působí na populační stavy živočichů a ovlivňují samotnou podobu a strukturu obývaných biotopů. Článek analyzuje a kvantifikuje mortalitu savců na železniční trati Plzeň–Horažďovice předměstí. Průzkum byl prováděn po dobu 12 měsíců od 1. ledna 2009 do 31. prosince 2009. Během tohoto období bylo nalezeno 60 uhynulých zvířat. Nejvíce kolizí (60 %) bylo zjištěno u srnce obecného (*Capreolus capreolus*), 17 % u zajíce polního (*Lepus europaeus*), 13 % u bažanta obecného (*Phasianus colchicus*), 5 % u řádu dravců (*Falconiformes*), 3 % u divokých prasat (*Sus scrofa*) a 2 % kolizí u lišky obecné *(Vulpes vulpes).* Cílem bylo podrobně zmapovat jednotlivé úseky tratě, které se liší krajinným typem (land cover), využitím krajiny (land use) a četností migrace a střetů živočichů s vlaky. Výstupem práce je vyhodnocení a posouzení celkové výše mortality zvěře a určení nejvíce ohrožených druhů živočichů. Z uvedených výsledků vyplývá, že železniční doprava je nebezpečím pro volně žijící savce, a jednoznačně lze říci, že nejohroženější zvěří je srnec obecný (*Capreolus capreolus)*.

zvěř; migrace; bariérový efekt; populace; fragmentace populace

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