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Methodological aspects of monitoring of large mammals along traffic corridors: A case study (Lagomorpha, Carnivora, Artiodactyla)

Různé metodické aspekty sledování velkých savců podél dopravních koridorů: Případová studie (Lagomorpha, Carnivora, Artiodactyla)

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Abstract. Roads comprise an extensive network in the Czech Republic that fragments the landscape. Such linear structures significantly and negatively affects wildlife and animal populations, and influences the appearance and structure of habitats. This study was aimed to monitor the occurence of lagomorphs, artiodactyls, and carnivorans in the vicinity of roads in the Nová Pec – Přední Zvonková – Zadní Zvonková – state border area using a combination of several methods. With the aid of tracking in snow, night monitoring, and photo traps, the incidence of 18 species of mammals from monitored groups was evidenced in an extended area along the monitored traffic ways. Differences in results between the individual methods were due to the use of different methodological procedures in the vegetation and non-vegetation seasons. For this reason, the observation frequency for individual species also varied.

Key words. Wildlife, monitoring, migration, road, habitat fragmentation.

INTRODUCTION

Roads have a wide spectrum of ecological effects, both direct and indirect, and impact on animals (Forman & Alexander 1998, Iuell et al. 2003, Trombulak & Frissel 2000). This results in frequent animal-vehicle collisions, reduced reproductive potential (Bjurlin & Cypher 2003), decreased dispersion of populations, and increased mortality (Mader 1984), as well as altered population density (Bjurlin & Cypher 2003), biological diversity (Chen & Roberts 2008), and food availability (Bjurlin & Cypher 2003). Traffic also cause disturbance and stress of animals (Alexandr & Waters 2000, Clarke et al. 1998, Lodé 2000, Olsson & Widen 2008, Shepard et al. 2008, Whittington et al. 2005).

Some countries have issued their own comprehensive reference guides concerning the impacts of roads on populations of large mammals (e.g. Broker & Vastenhout 1995, Ericsson & Skoog 1996, Hlaváč & Anděl 2001, Müller & Berthould 1997).

Possibilities and methods of wildlife monitoring play an important role in evaluating the impact of human transportation infrastructure upon animals. Methods of monitoring mammals and their habitat preferences during migration of selected species have been described by e.g. Aberg et al. (2000) or Swenson & Angelstam (1993) and, specifically in the Czech Republic by e.g. Bufka et al. (2003), Červený et al. (2007), Kocurová et al. (2004) and/or Šustr & Jirsa (2007).

General census methodologies have been presented by Caughley (1977) and Eberhardt (1978). Their methods emphasized the use of all technical possibilities as well as the variability among mammal populations. According to these authors, mammal monitoring methods can be divided into direct and indirect ones.

Direct methods include, for example: (a) drive counts – this technique requires a large number of observers who walk in a line through the area of interest and record the mammals moving among them. This method was supported, for example, by McCullough (1979); (b) aerial counts – this method is suitable in open locations, such as grasslands, open shrublands, deciduous forests in winter, etc. where animals are recorded directly by the pilot or by assistant observers (e.g. Bleich 1983); (c) transect counts – this method consists in walking or riding (a horse, a bike, etc.) through the field along pre-planned transects (e.g. Burnham et al. 1980, Kie & White 1985); (d) spotlight counts – a method consisting in animal census at night using spotlights (e.g. Progulske & Duerre 1964); (e) Remote sensing – thermal infrared sensing equipment which monitors animals from an aircraft (e.g. Parker & Driscoll 1972); (f) Infrared flash camera – animal monitoring using photo traps and video cameras (e.g. Veenbaas 2003, Pfister et al. 1997).

Indirect methods include, for example: (a) mark-recapture methods (Caughley 1977), (b) Change-in-ratio and related methods (Caughley 1977), (c) track and trail counts – monitoring of footprint paths in the snow (Salwasser 1976), (d) footprint paths on sand and paper sheets (Veenbaas 2003), (e) pellet-group counts (Connolly 1981).

This paper aims mainly to compare various methods of monitoring large mammals in the vicinity of a linear structure. As a monitored area we chose the surroundings of a section of the III/1634 road from the Přední Zvonková intersection to the state border, which is part of the Sites of Community Importance Šumava and the Šumava Protected Landscape Area. From the perspective of migration and abundance of large mammals, especially red deer (*Cervus elaphus*), European elk (*Alces alces*), and Eurasian lynx (*Lynx lynx*), this area is included in the category of extraordinary importance (Anděl et al. 2005).

MATERIAL AND METHODS

Monitored area

The section of the road III/1634 from the Přední Zvonková (48°44' N, 14° 00' E) intersection to the state border is located at the altitude of 770 m a. s. l. (Přední Zvonková) to 860 m a. s. l. (border crossing). Except for the area of Zadní Zvonková, where there is the edge of a forest on the bordering ridge, and the last section before the state border which leads through the forest, most of the communication leads through non-forested areas. The non-forested area is comprised of cultivated pastures and meadows, as well as protected areas, and numerous linear, scattered and clustered greeneries. The area is drained by the Hamry stream, Pestřice river, and the Schwarzenberg channel.

From the climatological viewpoint, the monitored area belongs to the MT 3 moderate climatic region. Average annual temperature reaches 6.2 °C, average precipitation is 797 mm, and the average January temperature is 3.6 °C (values from the nearest meteorological station Nová Pec, Želnavské Myslivny). According to data from the former Zvonková meteorological station (824 m a. s. l.), there are on average 104 days with snow cover in the monitored area and an average snow depth of 65 cm (Vesecký 1961). During the monitored period of 2009/2010, snow cover lasted for 109 days from 19 November 2009 to 31 March 2010 at the nearest station where snow characteristics are monitored in Volary (760 m a. s. l.).

Among mammals, we monitored only larger species that may potentially be threatened by road transportation or may cause collisions with passing vehicles. These included lagomorphs (*Lepus europaeus*), artiodactyls (*Sus scrofa*, *Cervus elaphus*, *Capreolus capreolus*, *Alces alces*) and carnivors (*Mustela erminea*, *Mustela nivalis*, *M. putorius*, *Martes martes*, *M. foina*, *Meles meles*, *Lutra lutra*, *Vulpes vulpes*, *Nyctereutes procyonoides*, *Lynx lynx*). In addition, we monitored also hedgehog (*Erinaceus europaeus*) and red squirrel (*Sciurus vulgaris*).

M e t h o d s

There were used three counting methods in the research.

Animal count in the snow
In the winter period with snow cover, the frequency of animal road crossings was examined on the base of recording of footprints and footprint paths. Tracking was carried out three times per month from 19 November 2009 to 16 March 2010. During every examination of the site, all footprint paths on both sides of the road were destroyed in order to prevent potential repeated recording during the follow-up inspection. We recorded the total numbers of road crossings as well as estimated numbers of individuals which had entered the road.

Animal count using night vision devices
In the periods without snow cover, 4–30 October 2009 and 6 April – 14 August 2010, the point count method was used from sunset to sunrise, always three times per month. Monitoring was carried out using standard binoculars with good light intensity (at twilight) and night vision binoculars, i.e. night vision devices, (at absolute darkness) at four stable points along the communication.

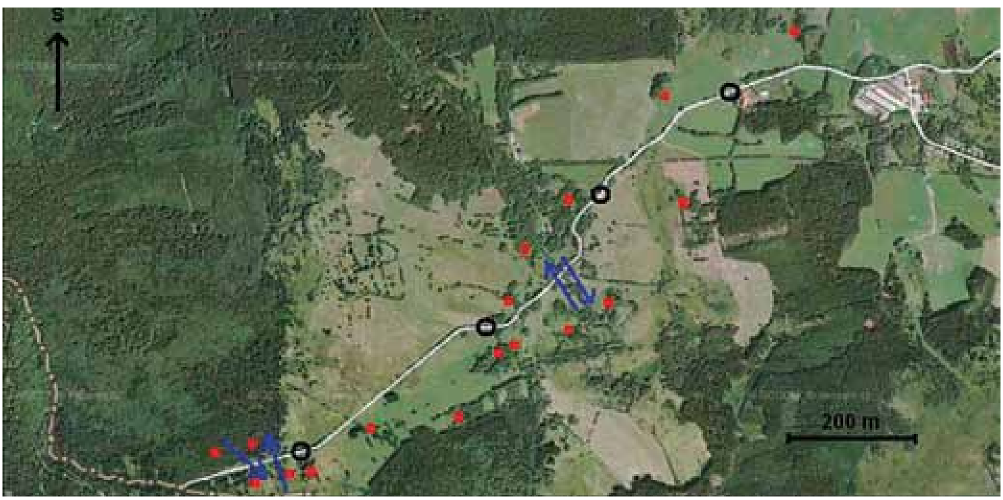

Fig. 1. Monitored section of the road III/1634 from Přední Zvonková intersection to the state border. Legend: → anticipated and actual most frequent direction of migrations of the sudied species; ■ locations of photo traps; **O** points of night monitoring.
Obr. 1. Sledovaný úsek silnice III/1634 Přední Zvonková (křižovatka) – státní hranice. Vysvětlivky: → odhadované a skutečné nejfrekventovanější směry migrace sledovaných živočichů; ■ umístění fotopastí; **O** body nočního sledování.

Table 1. Identified species of mammals according to monitoring method: winter tracking (average number of fresh footprint paths over the road on snow), night monitoring (average number of crossings/night), and photo traps (monitored species)
Tab. 1. Zjištěné druhy savců jednotlivými metodami sledování: zimním stopováním (průměrný počet čerstvých řad otisků ve sněhu přes cestu), nočním sledováním (průměrný počet přechodů za noc) a fotopastmi (sledovaný druh)

species \ method / druh \ metoda	winter tracking / zimní stopování	night monitoring / noční sledování	photo traps / fotopasti
Lepus europaeus	91	45	Yes
Sus scrofa	47	81	Yes
Cervus elaphus	32	37	Yes
Capreolus capreolus	157	105	Yes
Alces alces	0	1	No
Martes sp.	11	9	Yes
Meles meles	2	3	Yes
Lutra lutra	0	1	No
Vulpes vulpes	149	41	Yes
Lynx lynx	1	1	No

Monitoring using photo traps
During the period 19 November – 28 December 2009 and from 6 April – 26 June 2010, five automatic still cameras, so-called photo traps, were gradually installed at 16 covered places in the surroundings of the monitored section of the communication (more preciously location of photo traps and points of night monitoring at Fig. 1). To avoid theft, these cameras were not installed in the area during the period of intense touristic activity. Though records were kept of the acquired images, they were only summarized in a list of identified species. The reason for this lies in the fact that the results obtained in no way expanded the knowledge acquired using the aforementioned methods and population densities of the monitored mammal species could not be determined or estimated from the results achieved.

The dependence of animal road crossings among the respective species of mammals for individual monitoring methods (winter tracking and night monitoring) was evaluated statistically using the non-parametric Kruskal-Wallis ANOVA test. Differences between mammal crossings for individual monitoring methods (winter tracking and night monitoring) were graphically represented by means of cluster analysis.

RESULTS

According to monitoring method was recorded following species variability and their number, during monitored period (Table 1).

Winter tracking

In 16 winter inspections, at least eight species of mammals crossing the road were observed in the monitored section (for the most part, it was not possible to distinguish reliably between European pine marten and beech marten based on footprints in the snow).

The aim was to monitor the occurrence of mammals from orders of rabbits, artiodactyls and carnivores in the neighbourhood of communications Nová Pec – Přední Zvonková – Zadní Zvonková – state border by combination of several methods. More accurate data on the occurrence of individual orders (lagomorphs, artiodactyls and carnivores), their number, date of observation, assumed number and real number of recorded individuals see Figs. 2–4.

The more detailed results interpreted using cluster analysis according to methods winter tracking (Fig. 5) shows that the most distinguished difference number of foot print tracks among monitored species was recorded especially at badger and lynx, whose transitions were recorded at least.

According to Kruskal-Wallis test for data with non-normal distribution H [(7; N=128) =80.827, p=0.0000], a statistically significant difference was recorded among road crossings of individual species based on winter tracking (Table 2). Marked in bold are statistically significant differences between mammals at significance level p=0.05.

N i g h t   m o n i t o r i n g

In 22 night examinations, at least 10 species of mammals (it is impossible to distinguish reliably between European pine marten and beech marten according to their silhouettes) crossing the road were observed in the monitored section. It was always emphasized, however, that the same individuals must not be counted multiple times.

According to Kruskal-Wallis test for data with non-normal distribution H [(9; N=220) =87.110; p=0.0000], a statistically significant difference was recorded among road crossings of individual species based on night monitoring (Table 3). Statistically significant differences between mammals are shown in bold at significance level p=0.05. The more detailed results interpreted using cluster analysis according to methods night monitoring (Fig. 6) shows that the most distinguished difference number of observations among monitored species was recorded again especially at badger and lynx, whose transitions were recorded at least.

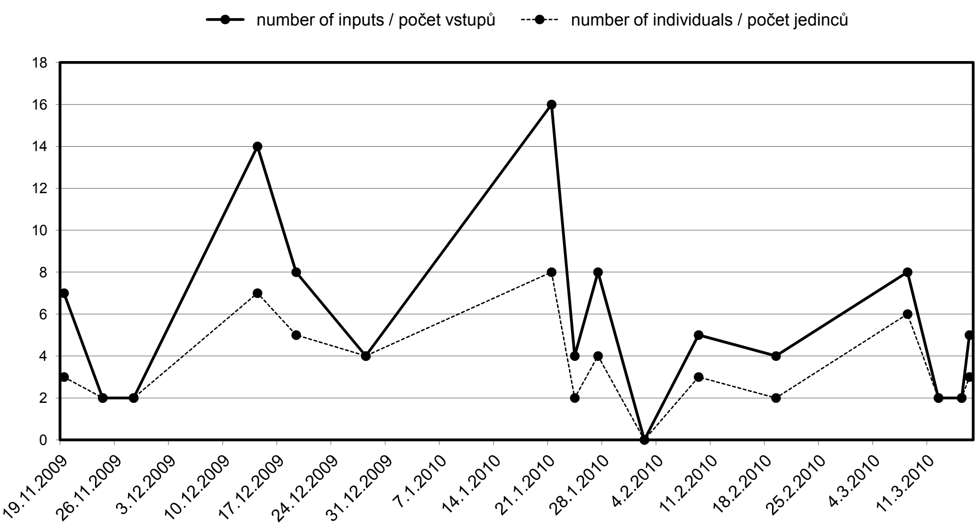

Fig. 2. Number of inputs and assumed number of European hare (*Lepus europaeus*) individuals on the road.
Obr. 2. Počet vstupů a předpokládaný počet jedinců zajíce polního (*Lepus europaeus*) na silnici.

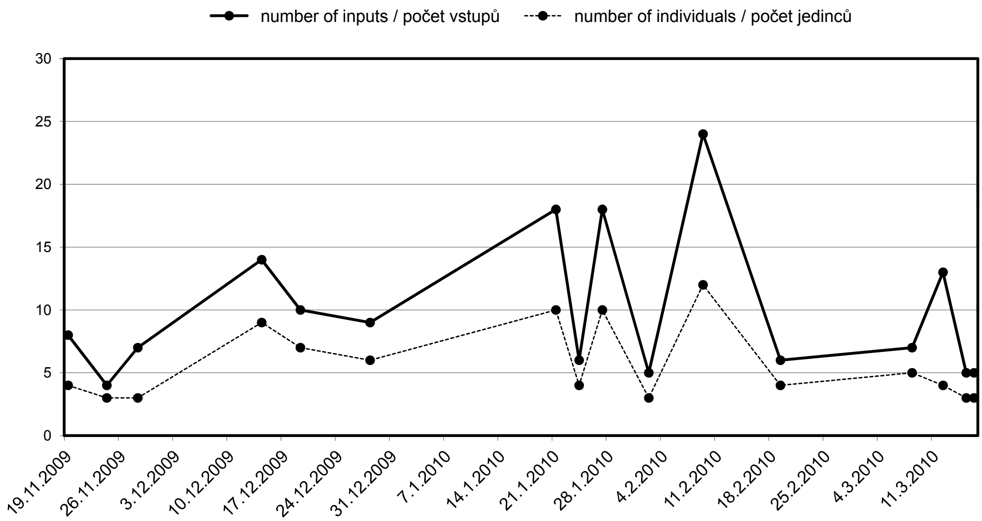

Fig. 3. Number of inputs and assumed number of roe deer (*Capreolus capreolus*) individuals on the road.
Obr. 3. Počet vstupů a předpokládaný počet jedinců srnce obecného (*Capreolus capreolus*) na silnici.

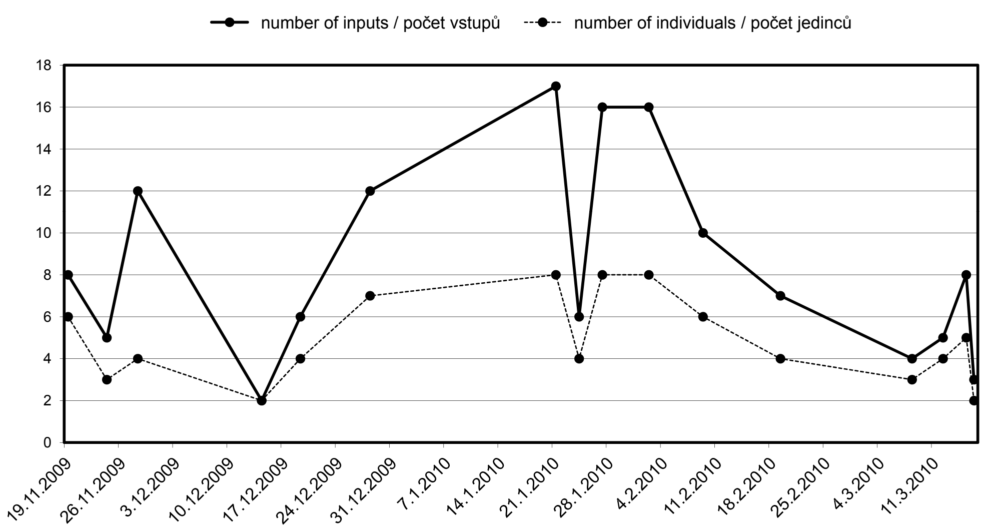

Fig. 4. Number of inputs and assumed number of red fox (*Vulpes vulpes*) individuals on the road.
Obr. 4. Počet vstupů a předpokládaný počet jedinců lišky obecné (*Vulpes vulpes*) na silnici.

Table 2. Comparison of the numbers of road crossings among recorded species based on winter tracking (p-value, Kruskal-Wallis ANOVA). Statistically significant differences between species are **bold** typped at significance level p=0.05
Tab. 2. Srovnání počtů přechodů silnice při zimním stopování zaznamenanými druhy (hodnota p, Kruskal-Wallisova ANOVA). Statisticky významné rozdíly mezi druhy jsou vyznčeny **tučně** při hodnotě p nižší než 0.05

		1	2	3	4	5	6	7	8
1	*Lepus europaeus*		0.395	0.360	1.000	**0.036**	***0.001***	1.000	***0.001***
2	*Sus scrofa*	0.395		1.000	***0.002***	1.000	1.000	***0.009***	1.000
3	*Cervus elaphus*	0.360	1.000		***0.002***	1.000	1.000	***0.008***	1.000
4	*Capreolus capreolus*	1.000	***0.002***	***0.002***		***0.000***	***0.000***	1.000	***0.000***
5	*Martes* sp.	***0.036***	1.000	1.000	***0.000***		1.000	***0.000***	1.000
6	*Meles meles*	***0.001***	1.000	1.000	***0.000***	1.000		***0.000***	1.000
7	*Vulpes vulpes*	1.000	***0.009***	***0.008***	1.000	***0.000***	***0.000***		***0.000***
8	*Lynx lynx*	***0.001***	1.000	1.000	***0.000***	1.000	1.000	***0.000***	

P h o t o   t r a p s

The following species of mammals were identified by this method: *Capreolus capreolus*, *Cervus elaphus*, *Sus scrofa*, *Vulpes vulpes*, *Lepus europaeus*, *Martes foina*, and *Meles meles* (Table 1). The species are ranked according to decreasing numbers of acquired images. This method seemed to be only of supplementary value. It facilitates the identification of individual species, and particularly large mammals, but not their number.

Lepus europaeus, *Capreolus capreolus*, and *Vulpes vulpes* were the most frequently monitored by the winter tracking method. *Sus scrofa*, on the other hand, was most often observed by the night

Table 3. Comparison of the numbers of road crossings among recorded species based on night monitoring (p-value, Kruskal-Wallis ANOVA). Statistically significant differences between species are **bold** typped at significance level p=0.05
Tab. 3. Srovnání počtů přechodů silnice při nočním sledování zaznamenanými druhy (hodnota p, Kruskal-Wallisova ANOVA). Statisticky významné rozdíly mezi druhy jsou vyznačeny **tučně** při hodnotě p nižší než 0.05

		1	2	3	4	5	6	7	8	9	10
1	*Lepus europaeus*		1.000	1.000	1.000	0.779	0.057	1.000	***0.014***	***0.014***	***0.014***
2	*Sus scrofa*	1.000		1.000	1.000	1.000	0.209	1.000	0.060	0.060	0.060
3	*Cervus elaphus*	1.000	1.000		0.172	1.000	1.000	1.000	0.616	0.616	0.616
4	*Capreolus capreolus*	1.000	1.000	0.172		***0.002***	***0.000***	1.000	***0.000***	***0.000***	***0.000***
5	*Martes* sp.	0.779	1.000	1.000	***0.002***		1.000	1.000	1.000	1.000	1.000
6	*Meles meles*	0.057	0.209	1.000	***0.000***	1.000		0.084	1.000	1.000	1.000
7	*Vulpes vulpes*	1.000	1.000	1.000	1.000	1.000	0.084		***0.022***	***0.022***	***0.022***
8	*Alces alces*	***0.014***	0.060	0.616	***0.000***	1.000	1.000	***0.022***		1.000	1.000
9	*Lynx lynx*	***0.014***	0.060	0.616	***0.000***	1.000	1.000	***0.022***	1.000		1.000
10	*Lutra lutra*	***0.014***	0.060	0.616	***0.000***	1.000	1.000	***0.022***	1.000	1.000	

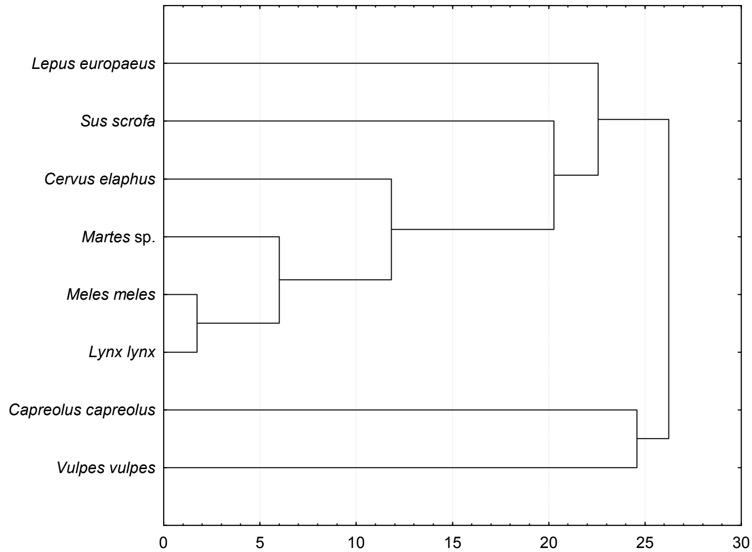

Fig. 5. Cluster analysis of numbers of particular species crossings based on winter tracking.
Obr. 5. Shluková analýza počtů přechodů jednotlivých druhů při zimním stopování.

monitoring method. This is probably due to the biology of this species, which does not occur very often at these altitudes in winter. *Alces alces* and *Lutra lutra* were observed in the surroundings of the road only using the night monitoring method, and in both cases only once.

Only a few small predators were found dead on the monitored stretch of road: one female *Mustela erminea*, one *M. putorius*, one *Martes martes*, two *Vulpes vulpes*, and one *Erinaceus europaeus*.

DISCUSSION

The monitored area is extremely important for the European elk and Eurasian lynx, which belong to specially protected, highly endangered species of mammals (Decree 335/1992). The latter is listed in Annex II of the EU's Habitats Directive and is a subject of protection in the Šumava special conservation area. The individuals of these species which live in low population density throughout Šumava may be endangered by passing vehicles while crossing the roads, thereby threatening their entire populations.

Eight species of mammals were observed by means of winter tracking and 10 by means of night monitoring. Overall, the presence of 18 species was confirmed in the greater area of the monitored communication. These differences arise from the varied methodological procedures in vegetation and non-vegetation seasons. For the same reason, the frequency of observation of individual species also varies. The total number of individuals for the entire monitored period is not evaluated, as this could involve indefinite repetition of road crossings by the same individuals during different examinations, in the case of both winter tracking and night monitoring.

Capreolus capreolus, *Vulpes vulpes*, *Lepus europaeus*, and *Sus scrofa* were the species most often observed according to both methods.

The acquired results suggest the importance of the road for mammal migration in the winter period, particularly if snow cover is high. Under these conditions, it often happens that wildlife does not cross the communication but uses it for moving in less demanding terrain, as is offered by a road cleaned off snow. The probability of animal-vehicle collisions on roads is higher in the winter period than in the vegetation period. In winter, however, road conditions typically do not enable fast driving and thus animals are likely to escape a collision. In the vegetation period, herbivores often feed on the vegetation that grows at the edges of roads and predators in turn search the roads for animals that have been hit as an easily obtainable food source. Generally, the considerable number of wildlife–vehicle collisions (road kill) in this period presumably is due to the high speed of vehicles whereby animals do not manage to move away from the road in time (particularly at blind sections).

Newhouse (2003) evaluated migration along a two-kilometre long section of road in Canada using camera recording of 1,131 observations of large ungulates. The highest intensity of crossings was observed at night (0:00–7:00), followed by evening hours (19:00–0:00), and the lowest during daytime hours (7:00–19:00). The number of passages was two times higher at night (0:00–7:00) than in the evening (19:00–0:00), and more than 15 time higher at night (0:00–7:00) than during the day (7:00–19:00). Nevertheless, more risk events were recorded during the day (more unsuccessful road crossings). This was due to higher traffic intensity. Newhouse (2003) therefore concluded that the risk of animal-vehicle collision was higher during the day.

No collisions of artiodactyls were recorded in the monitored section during the study period. The most frequently hit species included small mustelids, red foxes (2) and the European

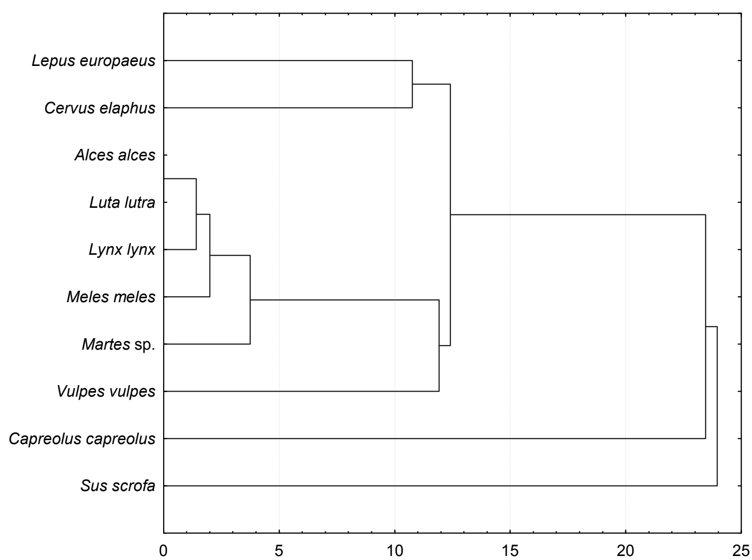

Fig. 6. Cluster analysis of numbers of particular species crossings based on night monitoring.
Obr. 6. Shluková analýza počtů přechodů jednotlivých druhů při nočním sledování.

hedgehog (1). Larger mammals most often used the sections at Zadní Zvonková to cross the communication (edge of the forest extends up to the road) and the forest corridor prior to the state border. These sections are the most risky for wildlife.

It is important to determine what proportion of a population is actually affected by mortality on road networks. The published data significantly differ in relation to specific research locations. For example, Iuell et al. (2003) and Trocmé (2003) state that traffic kills ca. 5% of the population of common species (red fox, roe deer, wild boar). Swiss research (Righetti et al. 2003) on the mortality of roe deer and red deer (data from 1999) also points out that transportation mortality is clearly the most frequent cause of death for both species (roe deer 49.3%, red deer 33.2%). The second most common cause of death for roe deer is due to agricultural machines (19.8%), followed by other factors (9.1%), then age and disease (7.1%). For red deer, the second most frequent cause of death indicated is other accidents (fall, avalanche, etc.), followed by other causes (14.7%), then age and disease (12.2%). The results clearly show that this always depends upon the specific situation in a given area.

SOUHRN

Pozemní komunikace vytvářejí na území ČR rozsáhlou síť, kterou fragmentují krajinu. Liniové stavby podstatně ovlivňují život ve volné přírodě, negativně působí na populační stavy živočichů a ovlivňují samotnou podobu a strukturu obývaných biotopů. Cílem výzkumu bylo monitorovat výskyt savců tří řádů (zajíci, sudokopytníci, šelmy) v okolí komunikace Nová Pec – Přední Zvonková – Zadní Zvonková - státní hranice kombinací několika metod. Pomocí zimního stopování na sněhu, nočního sledování a fotografických pastí byl v širší oblasti sledované komunikace prokázán výskyt 18 druhů savců sledovaných skupin. Rozdíly ve výsledcích mezi jednotlivými metodami vyplývaly z použití odlišných metodických postupů ve vegetační a nevegetační sezóně. Z téhož důvodu byli rozdílné i početnosti pozorování jednotlivých druhů. Zajíc polní, srnec obecný a liška obecná byli nejčastěji monitorováni metodou zimního stopování. Naopak prase divoké metodou nočního pozorování. To je pravděpodobně způsobeno biologií této zvěře, která se v těchto nadmořských výškách v zimním období příliš nevyskytuje. Los evropský a vydra říční byli v okolí silnice monitorováni pouze metodou nočního sledování, a to u obou druhů pouze v jednom případě. Na sledovaném úseku silnice bylo nalezeno pouze několik usmrcených drobných šelem (po 1 ex. lasice hranostaje, tchoře tmavého a kuny lesní a 2 ex. lišky obecné) a jeden ježek západní.

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