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Bat casualties by road traffic (Brno-Vienna)

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We studied the impact of road E461, Brno-Vienna, on bat mortality, with the goal to predict this impact after the road has been reconstructed and turned into highway, R52. In the Czech territory, two proposed road sections of E461 were selected, 3.5 and 4.5 km long, and divided into segments 100 m in length. Bat carcasses were picked up from emergency stopping lanes, and bat activity was recorded by ultrasound detectors along the road and 100 m away on both sides from the central strip. From May to October 2007, 25 checks of bat mortality performed at weekly intervals revealed 119 bat carcasses representing 11 or 12 species. *Pipistrellus nathusii*, *P. pygmaeus* and *Myotis daubentonii* were the most frequent traffic casualties. The greatest mortality was documented from early July to mid-October, with a peak in September. Monitoring bat activity by ultrasound detectors (one night per month in May, June and September) yielded 12 bat species and 3 species couples (*Myotis mystacinus*/*brandtii*, *M. emarginatus*/*alcathoe*, *Plecotus auritus*/*austriacus*), mostly the same taxa as found dead on the road. Significantly greater bat numbers were revealed in the section where the road was situated between two artificial lakes, as compared to a road section without any lakes directly adjacent to the road. In the former section, significant correlation was found between the number of carcasses found and the activity detected, according to road segments.

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Key words: road traffic, bat mortality, ultrasound detection

Introduction

Roads and highways exert a significant impact on wildlife, from habitat destruction and fragmentation to direct killing of animals due to traffic (Spellerberg 1998, Seiler 2001, Slater 2002). Traffic casualties were found among all groups of semi-terrestrial and terrestrial vertebrates, from amphibians, frogs in particular (Langton 1989, Fahrig *et al*. 1995, Vos and Chardon 1998), through birds (Zande *et al*. 1980, Havlín 1987, Reijnen *et al*. 1995) to mammals (Hodson 1966, Bakowski and Kozakiewicz 1988, Romin and Bissonette 1996). Concerning small mammals, barrier effects of roads on movements of rodents and shrews were often reported (Oxley *et al*. 1974, Adams and Geis 1983, Kozakiewicz 1993, Rico *et al*. 2007a, b); however, small mammals could also inhabit the green median strip of a highway (Adams 1984) and were able to repopulate rapidly an area isolated by roads (Korn

1991). In such studies, bats were only rarely included and no bats were reported among 921 carcasses (23 taxa) in a study on a Moravian road (Holišová and Obrtel 1986). Most studies dealing with the effects of road traffic on bats were published by German (Kock 1974, Rackow and Schlegel 1994, Kiefer *et al*. 1995, Haensel and Rackow 1996, Stratman 2006) and Polish (Lesiński 2007) authors. A brochure for the use of designers and road managers, containing general information on bats and tips to avoid or mitigate adverse effects of roads on bats in Europe was published in the Netherlands (Limpens *et al*. 2005).

The aim of this study was to reveal the potential risk for bats caused by the reconstruction and extension of an existing road into a highway in Central Europe by: (1) gathering information on casual bat observations along the road in the past; (2) collecting bat carcasses along two selected road alignments; and (3) recording ultrasound signals of bats at the same road alignments and their surroundings during one summer season (May–September). Following the results we then discuss measurements to minimize bat mortality.

Study area

The road E461 connects the city of Brno with Vienna in a N-S direction and is 50 km long in the Czech Republic and 74 km in Austria. On the Czech side, only minor part of the road adjacent to Brno has been turned into a four-lane highway, the reconstruction of the rest is scheduled in near future. To study bat activity, reveal the number of bat casualties and species numbers, we selected two road alignments of the new R 52 as study areas, namely the northern section R5204 between Pohořelice and Ivaň (3.5 km) and the southern section R5205 between Ivaň and Perná (4.5 km) (48°57'N, 16°31'E – 48°52'N, 16°35'E). Both are located along the existing E461 (Fig. 1). Henceforth, we use the technical terminology (R5204 and R5205) throughout this paper, although the construction of the highway R52 has not started yet. We divided each of the two proposed road alignments (R5204 and R5205) into 100 m long segments. The main difference concerning the habitats in close neighbourhood consisted in two large artificial lakes on either side of R5205 between segments 4 and 23, while R5204 had only a stream feeding fishponds running under two bridges in segments 3 and 6 (Fig. 1).

Methods

From 5th May to 21st October 2007 we searched along the either side of R5204 and R5205 for bat carcasses. We searched along emergency stopping lanes and up to 5 m beyond the road edges. Each search was performed by one

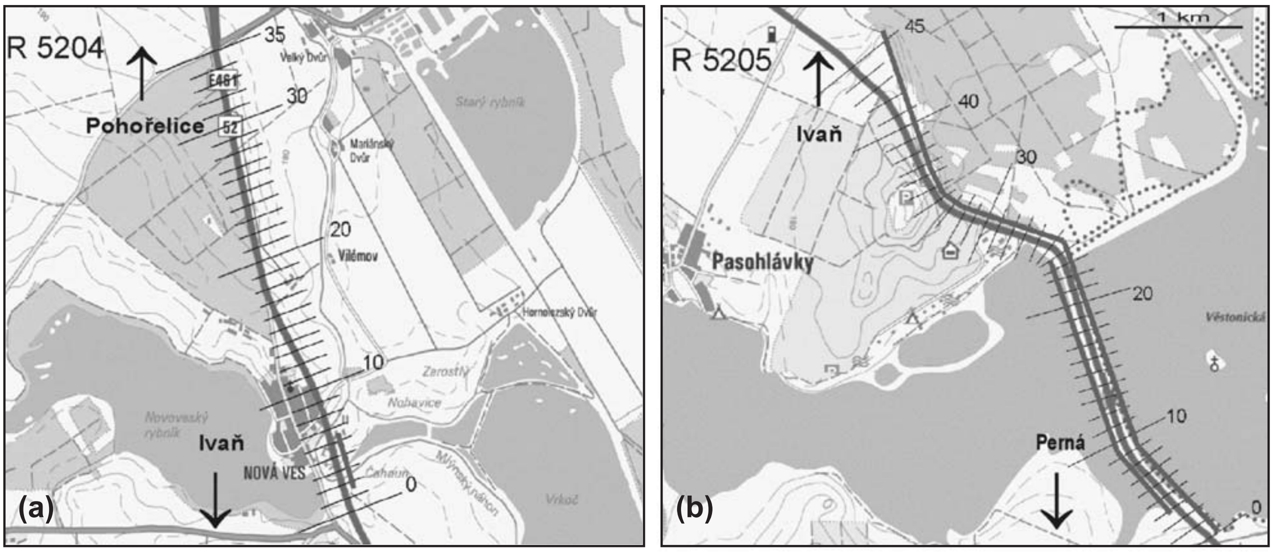

Fig. 1. The two road alignments (N48°57', E16°31' – N48°52', E16°35') with marked segments selected to study the mortality and activity of bats. (a) Section 5204 had a length of 3.5 km and was divided into 35 segments, each 100 m long. (b) Section 5205 had a length of 4.5 km and was divided into 45 segments, each 100 m long.

person wearing emergency vest and laboratory gloves, and walking slowly along the emergency stopping lanes. Bats were searched in early hours at roughly one week intervals (4–10 days), alternating the section to start with. All bats found were dead, their carcasses varying from well preserved to mere remnants. Each carcass was individually stored in a paper bag and labelled with date, section, segment and on which side of the road (west or east) it was found, stored in a refrigerator, and identified to species level using a stereo-microscope Olympus XL-9. Sex and age could only be determined in a minority of the samples and hence were taken out of the analysis.

During three nights, on 16th May, 17th July and 20th September, two independent observers recorded bat activity with bat detectors (D240x and D980, AB Pettersson Elektronik, Sweden) and stereo-recorders DAT TCD D8 and a WM D6C (both Sony, US). Each monitoring started after sunset and continued until midnight and altogether 18 hours of observation were obtained. The observers walked simultaneously along the two road sections up to 100 m from the central strip to both directions off the proposed road alignments. The observers recorded bat passes or determined them directly in the field. Detectors were tuned to peak frequency and measured the duration of the time interval during which the bat signals were heard (Zahn and Maier 1997). The activity was recorded either as commuting flight (no feeding buzz was heard during one minute) or as foraging (a minute with feeding buzz). Only search-phase signals were analysed on PC, because they exhibit consistency in structure throughout the call sequence (Fenton and Bell 1981). Bat activity was classified into three categories, ie, low (only one sequence, several pulses bounded by periods without pulses, of echolocation calls), medium (2–5 sequences), high activity (more than five sequences). Sibling species, *Plecotus auritus/austriacus*, *Myotis mystacinus/brandtii* and *Myotis emarginatus/alcathoe* were not distinguished apart and were evaluated as species couples. We analysed the records, using the software BatSoundPro 3.3.1b (AB Pettersson Elektronik, Sweden), and used the relative number of bat positive minutes out of the total of minutes of monitoring, total time walking along one road alignment as a measure of bat activity (McAney and Fairley 1988). Statistical software Statistica for Windows 8.0 (StatSoft, Tulsa, OK, US, 2007) was applied to data analyses. Spearman correlation coefficient was used to check possible correlation between activity level and number of carcasses. Contingency table was used to analyse the number of carcasses between two sections. The Yates correction was applied if testing for independence in a contingency table.

Results

Bat mortality

During 25 searches for dead bats in 2007 we collected 119 carcasses of 11 bat species and 2 couples of species (see Table 1), a further 14 specimens were only determined down to genus or family level (Table 1). *Pipistrellus nathusii* (n = 32) and *P. pygmaeus* (n = 32) were the most frequent road traffic casualties, followed by *Myotis daubentonii* (n = 19). The number of killed bats belonging to the first two species was most likely even higher than specified in the table and probably also among 12 *Pipistrellus* sp. not identified to species level (Table 1). Morphological identification of *Myotis alcathoe*, not recorded in the territory so far, was confirmed genetically (analyses were performed at the Department of Population Biology, Institute of Vertebrate Biology, ASCR at Studenec, Czech

Table 1. Past and present records of bats along the two selected road alignments combined, Pohořelice-Perná, including road casualties and results of bat detecting (+++ for high; ++ for medium and + for low bat activity recorded). Earlier studies concern investigations implemented in a 2 km wide belt along the two road alignments (Řehák *et al*. 2003, Hanák and Anděra 2005, 2006, Anděra and Hanák 2007 and own unpublished data).

Species/Family	Earlier studies	Carcasses (n)	Ultrasound recording
Rhinolophus hipposideros	+		
Myotis brandtii		1	
M. alcathoe		1	
M. emarginatus	+	2	
M. nattereri		1	+
M. bechsteinii			+
M. myotis			+
M. daubentonii	+	19	+++
M. emarginatus / alcathoe			+
M. mystacinus / brandtii		1	++
Eptesicus serotinus	+	4	++
Nyctalus noctula	+	1	+++
N. leisleri		1	+
Pipistrelus pipistrellus	+	2	+
P. pygmaeus	+	32	+++
P. nathusii	+	32	+++
P. pipistrellus / pygmaeus		8	
Pipistrellus sp.		12	
Hypsugo savii			+
Plecotus auritus	+		
P. austriacus	+		
Barbastella barbastellus			+
P. auritus / austriacus			+
Vespertilionidae gen. sp.		2	
Total number of species	10	11–12	15–18
Total number of specimens		119	

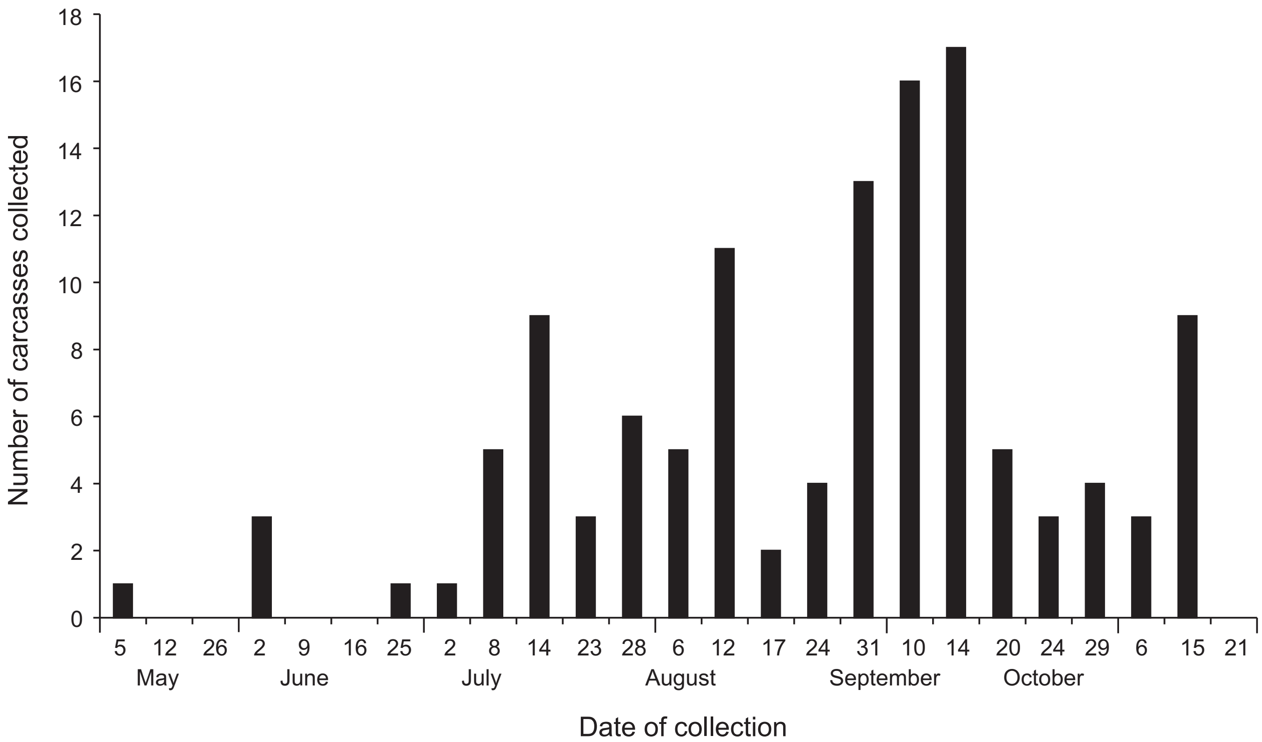

Fig. 2. Total number of bat carcasses found during 25 checks between 5 May and 21 October 2007; n = 119 specimens.

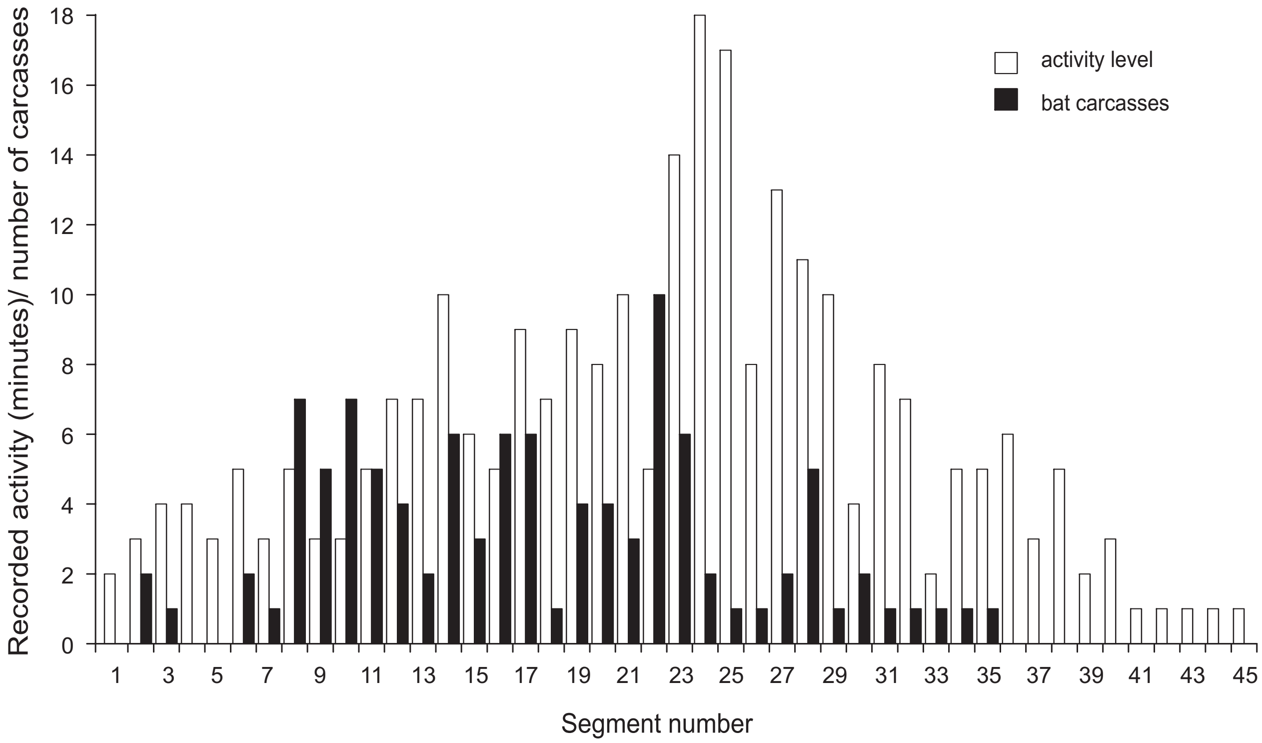

Fig. 3. Flight activity recorded by ultrasound detectors and mortality records of bats on road section R5205, Ivaň-Perná.

Republic). Another carcass may have represented *M. mystacinus,* thus the maximum possible number was 12 bat species killed along the two study areas in summer 2007. Two checks in May, two checks in June and the last check in October were negative. As to the remaining 20 checks, the numbers of carcasses found were small during the first months of collecting. The number increased in early July, culminating at the end of August and in September, and remaining relatively high until the first half of October (Fig. 2). The number of carcasses found differed significantly between the road alignments: n = 106 (89%) in R5205; n = 13 (11%) in R5204 (χ^2 = 38.9, p < 0.001, after Yates correction). Accordingly, 10 species were recorded in R5205 and only 3 in R5204. No difference was found concerning the side of the road, western$_{(W)}$ or eastern$_{(E)}$: R5205, n_W = 54 (50.9%), n_E = 52 (49.1%); R5204, n_W = 6 (46.2 %) n_E = 7 (53.8%).

Bat activity

During the three nights of ultrasonic recordings, 12 species and 3 species couples were recorded, resulting in a minimum of 15 and a maximum of 18 species (Table 1). Overall, the greatest activity (as bat positive minutes) was found in *Nyctalus noctula* (n = 110), *P. pygmaeus* (n = 84), *P. nathusii* (n = 65) and *M. daubentonii* (n = 30). Four species were only recorded by bat detectors and not as road kills, namely *M. myotis* and *Hypsugo savii* in commuting flight and *Myotis bechsteinii* and *Barbastella barbastellus* when foraging in woods far from the road vicinity. The total activity was twice as high in the study area R5205 compared to study area R5204, but species diversity was slightly higher in R5204 with 14–16 species, compared to R5205 with 10–13 species. However, the latter may be biased by the very high activity of *P. pygmaeus*, *N. noctula* and *M. daubentonii* in R5205, whose signals could camouflage those of the rare species. The distribution of flight activity along the road was compared to the number of carcasses per road alignment. In section R5205, a positive correlation was found between activity level and number of carcasses (Spearman correlation coefficient: r_s = 0.37, p < 0.05). Both the carcass numbers and the activity level, in that case

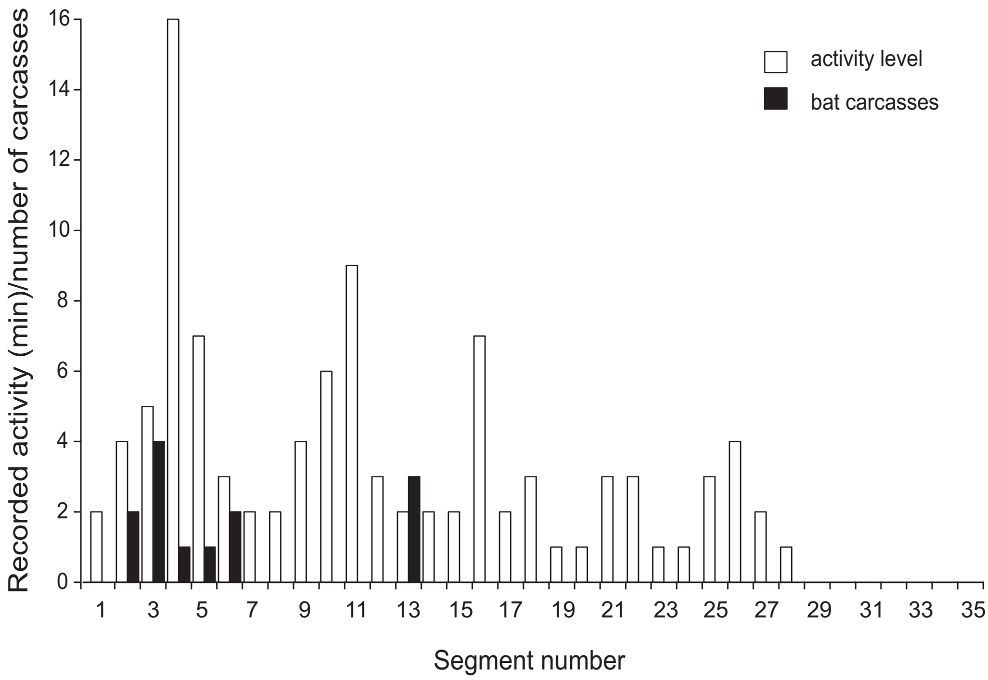

Fig. 4. Flight activity recorded by ultrasound detectors and mortality records of bats on road section R5204, Pohořelice-Ivaň.

mostly of foraging bats, were highest between segments 8 and 23 in R5205 (Fig. 3). No correlation was obtained for data from the section R5204 due to the small number of carcasses found (r_s = 0.07, ns) (Fig. 4).

Discussion

Bat assemblage

This study revealed a typical lowland bat assemblage of 18 to 19 species. Our data show that *P. pygmaeus* was the dominant species throughout the study period (May to October 2007), much more common than *P. pipistrellus*. Riparian woodland is the preferred foraging habitat of *P. pygmaeus* (Davidson-Watts *et al*. 2006) and the region of the extended Pálava Biosphere Reserve neighbouring with R5205 in the SE is inhabited by a strong population of this species (Řehák *et al*. 2003). Alluvial lowlands are also preferred by *P. nathusii*, a species which is considered rare in the Czech Republic (Anděra and Hanák 2007). More recently, it was found to be rather common in lowland habitats rich in water bodies, mainly in South Bohemia and South Moravia (Jahelková *et al*. 2000, Anděra and Hanák 2007). The July increase in numbers, recorded by both collecting carcasses and ultrasound recording, can be attributed to the occurrence of fledged young of these two species. In Germany, similar increase in July and August was reported for *P. pipistrellus* (Rackow and Schlegel 1994, Kiefer *et al*. 1995, Haensel and Rackow 1996). Although we recorded *P. nathusii* throughout the summer season, it was particularly abundant in late September and early October (n = 19, 57.6% of all carcasses found; 23.1% of all bat calls). This may be attributed to mating and autumn migrations. While long migrations (218–923 km) from Germany, Lithuania and Latvia to Bohemia were documented through bat banding (Gaisler *et al*. 2003) no information on migration of the local populations is available.

Eptesicus serotinus and *N. noctula* are further common species foraging over or in a vicinity of the road, while *M. daubentonii*, a typical water gleaner (or trawling species) and we did not record its foraging activity over the road. It is probably killed by road traffic during commuting over the road from one water reservoir to another. The same may explain the high representation of the species among road casualties in Germany and Poland (Haensel and Rackow 1996, Lesiński 2007). The road kill of *M. alcathoe* is of particular interest due to the relatively recent discovery of the species (von Helversen *et al*. 2001). However, it is difficult to distinguish the echolocation calls of *M. alcathoe* from *M. emarginatus* and hence no significant information on the abundance of *M. alcathoe* could be obtained by our ultrasonic recordings. The latest research shows that *M. alcathoe* has a more continuous and wider distribution in Europe than formerly known and that it prefers moist and deciduous forests with old trees and water streams (Niermann *et al*. 2007, Lučan *et al*. 2008). Though our record is the first one in SE Moravia, the species may in fact be more common there, due to the presence of suitable habitats.

Bat mortality and preventive measures against road kills

Bat species are known to differ by the preferred height above ground of their flight depending on their ecology, wing morphology and echolocation design. Bats flying low over the ground have a higher probability of collision with vehicles. Four risk groups were distinguished among European bat species by Stratman (2006). Open space foragers (see Schnitzler and Kalko 2001 for definition), such as *Nyctalus* sp. or *Vespertilio* sp., typically forage at the heights of 10–50 m above ground and are less endangered by road traffic than low-flying species. These include *Myotis* sp. and *Eptesicus* sp. which forage at 5–10 m and *Pipistrellus* sp. which most often forage only 2–6 m high (Schober and Grimmberger 1998). This is reflected in our study by the low representation of bat carcasses of the abundant species *N. noctula*. A similar low representation of this species among road casualties was found in Poland (Lesiński 2007). The situation is quite different at wind turbines where *N. noctula* is usually the most common victim in Europe (Dürr 2007). Regional differences in the number of road casualties and their species composition and number of victims depend on many factors, such as the character of habitats along the road, width of the respective road, number and speed of vehicles participating in the night traffic (Haensel and Rackow 1996, Stratman 2006, Lesiński 2007). Except for the low representation or absence of high and fast flying bats as road casualties, the species composition and diversity differ among various studies conducted on roads. Only four individuals of *Rhinolophus* species were recorded in Germany (Kock 1974, Haensel and Rackow 1996) and they seem to be at little risk. *R. hipposideros* was only recorded in the past in the study area and could be underrepresented in casualties because of rare species. *Plecotus* species were often reported among road casualties in Germany and their absence in our study possibly reflects the absence of suitable habitats (dense shrubs) near the road in spite of the fact that *Plecotus auritus* and *P. austriacus* were recorded there in the past (see Table 1).

In all studies about wildlife road casualties, potential discrepancy between numbers counted and numbers killed exists and the total death rate can be 12–16 times higher than that observed (Slater 2002). This estimation, however, was based mostly on counting corpses from a moving car. In our study, the search for bat carcasses was made by walking along the road side and therefore the discrepancy may not be as high as stated by Slater (2002). While it is impossible to assess the actual number of bats killed, it would have been probably higher than the number we collected. In addition to bats knocked down on the road and completely smashed by further traffic, others were thrown off the road and lost in the vegetation or in the case of R5205 lost in the artificial lakes. In spite of this, the highest number of bat carcasses was found along the road alignments adjacent to the lakes. Our study is the first one to show the correlation between water habitat and high bat mortality on roads. Future studies are needed to investigate this further.

Limpens *et al*. (2005) summarized the preventive measures to reduce the negative impact of roads on bats during the planning, design, construction and management phases with the emphasis to preserve landscape permeability. Safe road crossing can be achieved by passing over (hop-over vegetation, wall, over or along viaduct) or passing under (culverts, tunnels, bridge over water, under viaduct). According to Wray *et al*. (2006), it is necessary to discourage bats from foraging along the road verge by, eg maintaining attractive linear features (tree lines, hedgerows) perpendicular to the road and safe crossing points at culverts underneath the road. Successful mitigation measures have been shown after a road was opened to traffic. The tunnels proved to be extremely effective in allowing bats to cross under the road safely (Wray *et al*. 2006). Unfortunately in our study, no culverts, tunnels or viaducts will be incorporated in the building of the Czech part of R52 Brno-Vienna. In the two proposed road alignments, R5205 and R5204, no attractive linear features perpendicular to the road exist and the hop-over vegetation (tall trees) is scarce and too far from the road. Therefore, we suggest constructing protecting screens in areas where the bat activity was greatest. We suggest that the screens should be built on either side along segments 4–24 of the proposed road alignment R5205 where the road is sandwiched between the two lakes. We also suggest that screens on one side should be built along segments 1–3 and 25–45 at the eastern side of R5205 neighbouring a floodplain forest, and along segments 2–6 at the eastern side of R5204 where a stream comes to cross the road (Fig. 1). We suggest for the remaining sections (no screens recommended) of the new highway R52, lines of trees be planted perpendicular to the road.

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