Title

Use of Existing Mitigation Measures by Amphibians, Reptiles, and Small to Medium-Size Mammals in Hungary: Crossing Structures Can Function as Multiple Species-Oriented Measures

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Use of Existing Mitigation Measures by Amphibians, Reptiles, and Small to Medium-Size Mammals in Hungary: Crossing Structures Can Function As Multiple Species-Oriented Measures

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Abstract: The effects of roads and railways on animals such as direct mortality caused by these infrastructure elements were recognised as early as the end of the nineteenth century. In the first half of the twentieth century further evidence gathered related to different vertebrate groups. Besides the increasing amount of information available on the environmental impact of roads and railways in the second half of the twentieth century, crossing structures, game bridges, amphibian tunnels and game passages were built as mitigation measures to provide corridors over or under roads and railways, especially in Europe. In most cases, however, they were aimed to help one animal group or species. With the development of an ecosystem-level approach, however, the investigation of the possible involvement of these constructions in helping non-target groups also started together with building green bridges. A further recognition of the special needs of certain species also led to the development of new structural elements, for example tunnels built within green bridges to help burrowing animals to cross.

Mitigation measures representing all animal crossing structures in Hungary were selected to study their use by amphibians, reptiles and small to medium-sized mammals. They included a toad tunnel system with eight tunnels and approximately five-hundred meter concrete fences along road 8518. and six tunnels under the bicycle road running along the same road stretch at Lake Fert?, one wet and two dry passages of one meter in diameter under the M1 motorway with 60 centimetre high concrete fences and two twelve meter wide game bridges with game fences over the same motorway. All sites are located in the same, Arrabonicum fauna district in the western part of Hungary. Due to differences in the studied animal groups a complex sampling methodology was applied. Besides site visits during the day to find the shed skins of reptiles, footprints of mammals on sand beds or their droppings in the passages, the mitigation measure use of amphibians was also investigated in night visits especially during the breeding season while mammals were also caught by baited traps and hair traps were also used. To check the efficiency of the toad tunnel system the frequency of amphibian road kills were also studied.

Amphibians were found both in the tunnel system and the wet passage under the road, but their presence was not proved either in the dry passages or on the game bridges. The tunnel system worked very efficiently, i.e. it lowered road kills by at least 90%, which can even be improved by maintenance. As a consequence, more amphibians died on the bicycle road and a side road nearby than on the main road. The mitigation measure use of reptiles was proved at all investigated sites even if none of the constructions were planned to provide corridors for that animal group. Grass snakes were found in toad tunnels and passages, sand lizards on game bridges. An important difference between them was that snakes moved through the tunnels while lizards lived on them and used game bridges as a habitat. Small mammals used all investigated measures, vole and mice species were trapped in all of them. What is more, they used tunnels as part of their habitats. Besides, shrews were present in toad tunnels as well the presence of foxes and martens was also indicated. However, their road kill was low in the section studied.

During the study period eight species of amphibians as well as mammals and two reptiles were proved to utilise the investigated crossing structures. Besides providing corridors, large constructions, such as game bridges also function as habitats e.g. for lizards. The use of large, mammal-oriented mitigation measures by amphibians and reptiles is needed to study further as well as efforts should be made to construct more passages or alter existing structures in the future to lower habitat fragmentation along transportation infrastructure.

Introduction

The effects of roads and railways on animals, such as direct mortality caused by these infrastructure elements, were recognised as early as the end of the nineteenth century (Barbour 1895). In the first half of the twentieth century further evidence gathered related to different vertebrate groups (as an example, see Savage 1935). Different impacts of transport infrastructure have been proven to exist in all continents (for less studied regions, see, for example, Fischer et al. 2004 for South America, Sing and Sharma 2001 for India) and for all terrestrial vertebrate classes. There was a continuous increase of information on the environmental impact of roads and railways in the second half of the twentieth century, e.g., on the negative correlation of road density and the amphibian abundance (DeMaynadier and Hunter 2000; Houlahan and Findlay 2003), especially with more vagile species (Carr and Fahrig 2001) as well as genetic isolation (Vos et al. 2001), road crossing differences between U.S. snake species (Andrews and Gibbons 2006) and the limitation of small mammal movement by roads and heavy traffic (Oxley et al. 1974, Richardson et al. 1997, Wilkins 1982). An important tool to lessen the effects of already existing roads was vertebrate road mortality analyses, which were conducted in different parts of the northern hemisphere to select road mortality hotspots (Ascen?ao and Mira 2006). Recommendations were also made to take these effects into consideration even in landscape level planning (Mazerolle 2004). As a result of all these findings and citizen movements to save amphibians as well as safety issues, crossing structures, game bridges, amphibian tunnels and game passages were built as mitigation measures to provide corridors over or under roads and railways, especially in Europe and North America. Later, a further recognition of the special needs of certain species also led to the development of new structural elements, for example, tunnels built within green bridges to help burrowing animals to cross. In most cases, mitigation measures were aimed to help one animal group or species. With the development of an ecosystem-level approach, however, the investigation of the possible involvement of these constructions in helping non-target groups also started together with building green bridges.

Aim of study

The building of mitigation measures becomes more frequent along Central-European roads after the millenium, especially on motorways (for an overview on amphibian tunnel systems in the region, see Puky 2003). However, their monitoring and improvement are often missing. Consequently, little is known about their effectiveness and even less information is available on what non-target species use these constructions. To improve our knowledge, different types of mitigation measures were selected in the northwestern part of Hungary to gather information on their use by target as well as by non-target species. The aim of this paper is to summarise the characteristics of amphibian, reptile, and small to medium-size mammal use of the studied mitigation measures, describe their possible ecological functions for the different groups and make suggestions to help the crossing of a wider range of animals through these constructions.

Sites and Methods

Sampling sites and dates

Sampling sites were selected according to a number of factors. Mitigation measures in good condition (e.g., with no missing fences) surrounded by semi-natural vegetation and different habitats suitable for all three investigated taxa were favoured. Roads with high traffic volume were chosen, three of the four sites (two game bridges and one culvert system) are situated along the M1 motorway, and the fourth site is situated along road 8518, which is a busy local road. All sites are located in the same Arrabonicum fauna district in the western part of Hungary.

The 136.805-835 km passage system of the M1 motorway (see photo 1) consists of three 34-m passages with a diameter of 1 m each. They are connected by 60-cm-high concrete fences and extending to an additional 50-m stretch from the passage on the side in both directions. Light shafts in the middle of the passages help more natural light and moisture conditions to develop. There is a forest patch on the left side of the road at the mitigation measure, and a stream flows through the central passage forming a standing water area before entering it on the left side. The right side of the road is for agricultural use (see figure 1).

Photo 1. M1 Motorway

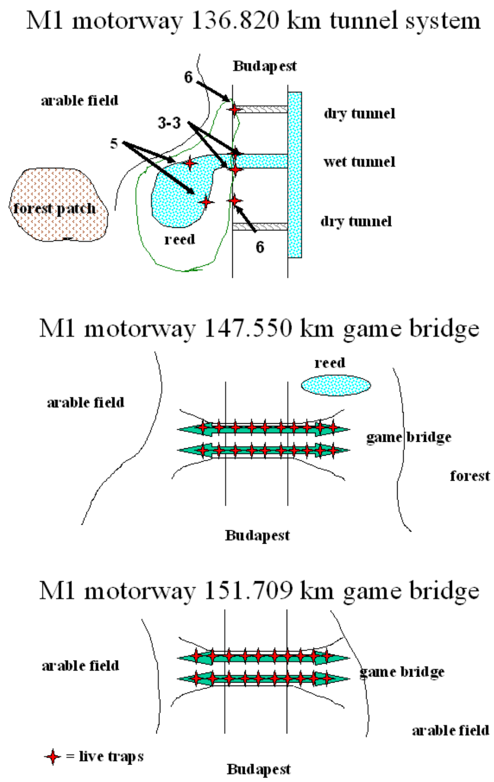

Figure 1. M1 Motorway.

The 147.514-km game bridge of the M1 motorway (see photo 2) has a width of 12 m. There is a forest patch on its right side together with a temporary water body. On the left side there are agricultural fields and extensive water bodies of the Hanság area. There is game fence to lead roe deer and other game species onto the game bridge, which has planted bushes along its edges (see figure 1).

Photo 2. 147.514-km Game Bridge of the M1 Motorway.

The 151.709-km game bridge of the M1 motorway (see photo 3) has a width of 12 m. Its vegation is similar to that of the other game bridge, but it is surrounded by arable fields on both sides. On the left side there is a dirt road and a deep ditch running along the motorway. A game fence leads roe deer and other game species onto the game bridge (see figure 1).

Photo 3. 151.709-km Game Bridge of the M1 Motorway

The fourth sampling site has been the focus of amphibian road mortality mitigation in Hungary for nearly two decades. Amphibian patrol by volunteers was gradually replaced by temporary and then by permanent mitigation measures (Kárpáti 1988, Frank et al. 1991). There is a sophisticated amphibian tunnel system between 16.870 and 17.256 km of the 8518 road at Fert?boz consisting of eight 8- to 9-m long tunnels of 0.59-0.88 m in diameter (square shape tunnels also exist) under the main road and an additional six tunnels with 33-57 cm diameter under the adjacent bicycle road (see photo 4). Five of the eight tunnels under the road have light shafts. An approximately 500-m concrete fence of a 50-cm height connects the tunnels along both sides of the road and the left side of the bicycle road. There is a forest on the left side of the road, while a mosaic of different habitats including reed can be found to the right of the bicycle road, towards Lake Fert? (see figure 2).

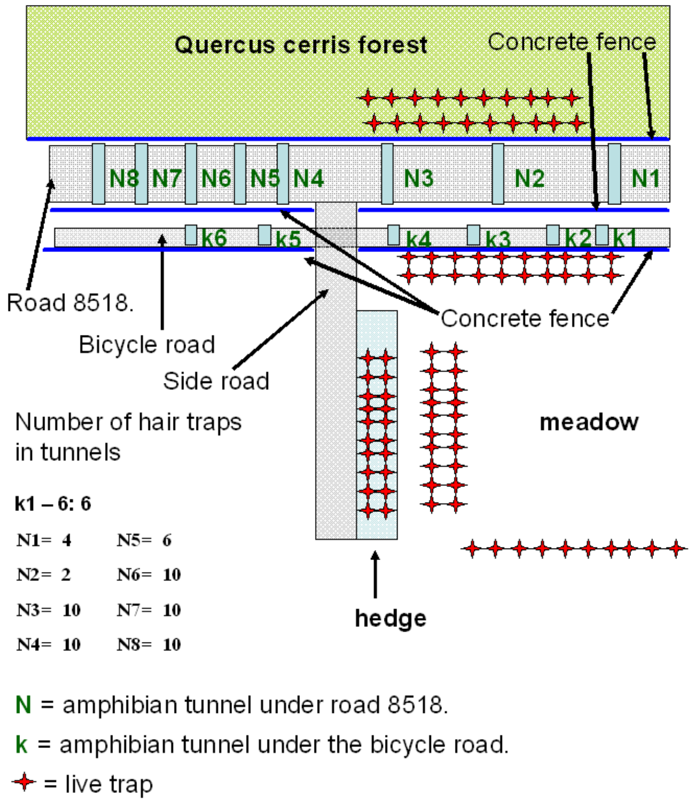

Figure 2. Sampling was carried out between 31 January 2004 and 19 October 2004.

Photo 4. Sophisticated amphibian tunnel system.

Methods

Due to differences in the studied animal groups, a complex sampling methodology was applied. Besides conducting site visits during the day to find the shed skins of reptiles, footprints of mammals on sand beds, or their droppings in the passages, site visits at night were also conducted to determine the mitigation measure use of amphibians, especially during the breeding season. Amphibian-specific methods (audial surveys, netting, road transects at night, torching, visual encounter surveys) were discussed in previous papers presented at ICOET in 2003 (Puky 2003). As with routinely used other methods applied for all groups (road kill investigation, track registration), they are not discussed here in detail. Reptiles were also detected by the visual encounter surveys of the mitigation measures and, as a by-product of a new sampling method, hair trapping.

Routine wildlife monitoring usually includes several sampling methods, such as infrared photography and track plots (see Austin and Garland 2001). Besides the general methods, in this study mammals were also detected by live trapping using the capture-mark-recapture method at each site. Depending on the habitat type they were arranged in a line transect or a quadrat. The traps were baited with a piece of toast spiced with onion. Seeds of sunflower and corn were put into the trap to reduce the mortality (see photo 5). Animals were marked by tattooing or by cutting fingers. Several parameters, for example, length of the body, legs and tail, weight, state of sex, etc., were also recorded.

Photo 5. Seeds of sunflower and corn were put into the trap to reduce the mortality.

Hair samples were also collected along the 8518 road, as they convey a large amount of information. They carry several qualitative and quantitative macroscopic and microscopic characters of the cuticular and medullar patters that enable taxonomic identification even in the absence of any other attributes (see photos 6 and 7).

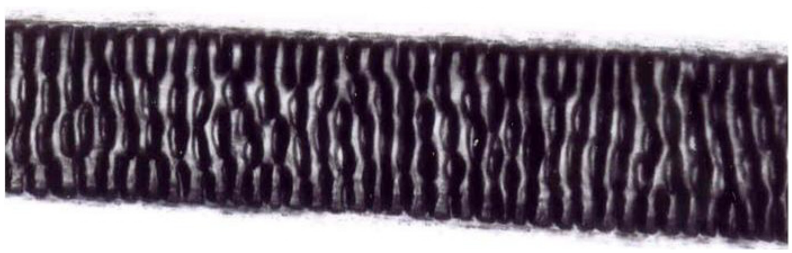

Photo 6. Hair sample collected along the 8518 road.

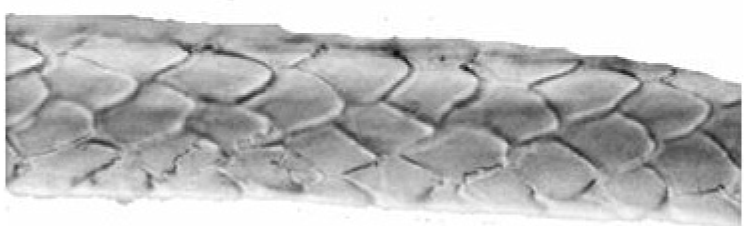

Photo 7. Hair sample collected along the 8518 road.

The basic idea of this method was to beguile the small mammals using some bait into a plastic (or metal) tube that has a sticky surface on its backside (Suckling 1978, Dickman 1986). The visitors of the traps leave their informative dorsal hair on that surface without any disturbance or downer. The principle of applying hair traps remained the same, but the technical parameters and the type of the bait became more diverse, harmonizing with the size and life history of the target animals. In the current project, 101 plastic bottles were used as hair traps in the amphibian tunnels running under road 8518 and the parallel bicycle path. Seeds, bacon, and fruit were used as baits. The 55-m diameter of these plastic bottles seemed to be effective to detect small mammals there. Mammals entering could not pass through them; they appear as blind alleys. This trap provides more hair samples than PVC tubes open at both ends because the animals have to cross it twice, go in, and back out. According to previous studies the visiting rate of hair traps is about 10 percent (Tóth 2002). As suggested by the specific literature, the effectiveness of this method was improved by applying it together with the live-trappings (Lindenmayer et al. 1999).

Table 1 summarizes what methods were used at the individual sites.

	136.805-835 km M1 culvert system	147.514 km M1 game bridge	151.709 km M1 game bridge	8518. road amphibian tunnel system
General methods				
Track etc. registration	X	X	X	
Road kill investigation	(X)	(X)	(X)	X
Methods to detect amphibians				
audial surveys	X	X	X	X
Netting	X	X		X
Road transects at night				X
Torching	X	X	X	X
Visual encounter surveys*	X	X	X	X
Methods to detect mammals				
Live trapping	X	X	X	X
Hair trapping*				X

() limited application due to safety reasons.

* Reptiles were also detected by this method.

Results and Discussion

Amphibians

Table 2 shows the presence of amphibian species at the mitigation measures. At the 136.805-835 km culvert system of the M1 motorway five taxa were found; two of them stayed in the central culvert, through which a stream flows. The others could also possibly use this route to move to the other side of the motorway. This is of great importance because due to its heavy traffic load the motorway is a complete barrier for the investigated species. This is also true for the game bridge sections, where no other possible corridor is available for amphibians. In spite of this, however, no amphibian was found on those mitigation measures, although altogether six taxa were detected around them. In earlier years amphibians migrated across the 8518 road by the hundreds of thousands due to historical, geographical, and ecological reasons (Tunner and Kárpáti 1997). Due to the lowering of the water level of Lake Fert? it was less intensive in the middle of the 2000s (pers. comm. of dr. László Kárpáti, head of the Fert?-Hanság National Park Directorate) Still, some migration occurred, and the amphibian tunnel system protected effectively most of the individuals reaching the road at the concrete fences. In comparison with neighbouring road stretches, the number of road-killed amphibians was 30-120 times lower along the mitigation measure, and during the autumn migration there were more dead green frogs on the side road and even on the bicycle road (see figure 2) than the main road itself.

Reptiles

Table 2 shows the presence of reptile species at the mitigation measures. Grass snakes were caught or seen in both underpass systems. Their presence was proved during visual encounter surveys as well as, unexpectedly, by hair trapping as either the shed skin or juveniles were found sticked to the glued surface of the bottle traps (see photo 8). Sand lizards were observed to live on both game bridges of the M1 motorway, and similarly to other roads, such as the M3 motorway, where sand lizards live around the stone heads of amphibian tunnels, no road avoidance was recorded for this species. As observations of snakes and lizards on mitigation measures are relatively rare (for an exception, see Teufert et al. 2004) and incidental (see, e.g., Zuiderwijk 1989), these are important new findings for the area and for these types of mitigation measures as well.

Table 2: Presence of Reptile Species at the Mitigation Measures

	136.805-835 km M1 culvert system	147.514 km M1 game bridge	151.709 km M1 game bridge	8518. road amphibian tunnel system
Amphibians				
Smooth newt *Triturus vulgaris*	X	X		X
Danubian crested newt *Triturus dobrogicus*		X		
Fire-bellied toad *Bombina bombina*	X	X	X	
Common toad *Bufo bufo*		X		X
European treefrog *Hyla arborea*	X	X	X	X
Agile frog *Rana dalmatina*	X			X
Green frogs *Rana esculenta* c.	X	X	X	X
Reptiles				
Sand lizard *Lacerta agilis*		X		
Grass snake *Natrix natrix*	X			X

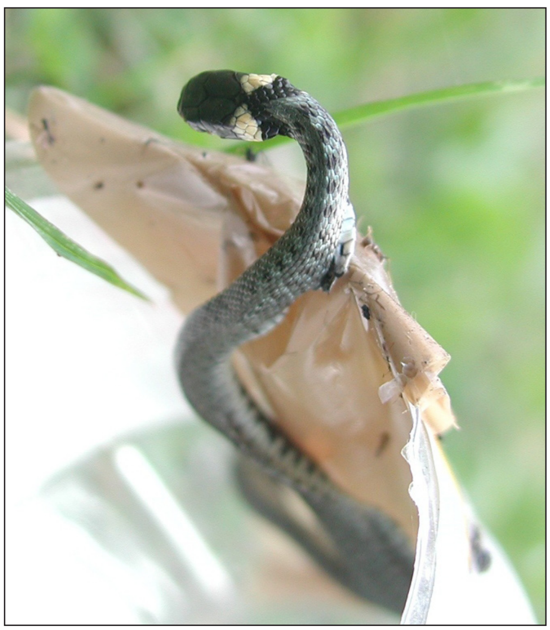

Photo 8.

Mammals

Table 3 shows the presence of small mammals at the mitigation measures. Besides the taxa caught, several other species might exist at the investigated sites; however, their density was too low to detect them.

The two game bridges and the passage system along the M1 motorway had the same fauna composition, altogether five species were detected in the sampling sites, suggesting a similar dominance structure in the small mammal fauna along the investigated stretch of the motorway. Three of these taxa were actually caught in/on the mitigation measures. Only the relative frequency of the two vole and one mouse species differed between those sites (see figure 3). Besides the species caught by trapping, several others, such as deer, were also detected, mainly by their footprints. The most surprising finding was the footprints of a roe deer calf walking into the wet passage.

Table 3: Presence of Small Mammals at the Mitigation Measures

	136.805-835 km M1 culvert system	147.514 km M1 game bridge	151.709 km M1 game bridge	8518. road amphibian tunnel system
Striped field mouse *Apodemus agrarius*				X
Yellow-necked mouse *Apodemus flavicollis*	X	X	X	X
Wood mouse *Apodemus sylvaticus*	X	X	X	X
Harvest mouse *Micromys minutus*				X
Bank vole *Clethrionomys glareolus*	X	X	X	X
Field vole *Arvicola terrestris*	X	X	X	X
Common vole *Microtus arvalis*	X	X	X	X
Water shrew *Neomys fodiens*				X
Common shrew *Sorex araneus*				X
Bi-coloured white-toothed shrew *Crocidura leucodon*				X

Altogether, 10 small mammal species were trapped in the patchy habitats around the amphibian tunnel system on the 8518 road (see figure 3). The greatest species number was found in a reed stand at the edge of the meadow, while the lowest was recorded in the open meadow, where the individual number of the animals was also the lowest (see figure 4). Similar to other studies investigating the use of drainage culverts and other underpasses under roads or railway lines (e.g. Clevenger et al. 2001, Ng et al. 2004, Rodriguez et al. 1996), small mammals were proven to be present in the tunnels. The same species were detected in both tunnel types, and more individuals were caught in the smaller tunnels under the bicycle road than in the larger ones under the main road. While the species composition of the different microhabitats characteristically differed, traps in road verges on both sides caught more animals than those in the parallel rows 10 m further in the appropriate habitats (meadow on the right, Quercus forest on the left side), indicating edge effects. As such, no road avoidance was recorded for these species. Other sampling methods, e.g., road kill surveys, resulted in a number of mammalian fauna casualties; red squirrel (Sciurus vulgaris) and red fox (Vulpes vulpes) were among them together with a low number of small mammals. Some of them were found on the bicycle road (see figure 2).

Mitigation measure improvement

As a result of the survey of amphibians, reptiles, and small mammal use of the 136.805-835 km passage system, and the two game bridges of the M1 motorway, and the amphibian tunnel system of the 8518 road, the following recommendations have been developed:

1. The high traffic volume of the M1 motorway creates a complete barrier for the taxa studied. As a consequence, the investigated mitigation measures are important crossing opportunities. The step-like entrance of the dry passages in the 136.805-835 km passage system should be improved to provide a better access for amphibians (and small mammals).
2. The 147.514-km game bridge should be developed to provide a corridor for amphibians living in wetlands nearby by setting up amphibian fences.
3. Maintenance (cleaning of tunnels, removal of branches) and, if possible, closing gaps in fences should be applied at the amphibian tunnel system along the 8518 road.

Ecological functions of the studied mitigation measures

The construction of mitigation measures to help animals crossing roads usually has the function of creating corridors for target species. However, the present study proved the use of these constructions other than for migration by altogether two amphibian, two reptile and four small mammal species. Amphibians usually migrate through tunnels and passages, and do not spend much time of them. However, two semi-aquatic taxa of amphibians—fire-bellied toads and green frogs—were detected to use the wet passage from the 136.805-835-km passage system of the M1 motorway as parts of their habitats. It might be more common than originally thought as similar to these results, Danube crested newt, *Triturus dobrogicus*, larvae were found in a similar culvert (M. Puky unpublished data) during another road-related survey along the route of a planned ring-road around Budapest (Puky and Kecskés 1992). In the 136.820-km wet passage, a grass snake was also found most probably hunting for amphibians as they are an important food source for this reptile species. As far as the other reptile findings are concerned, snakes caught in tunnels were in their migration period, but sand lizards also lived on game bridges and used them for hiding places, basking, and feeding grounds. Small mammals were also recorded to use amphibian tunnels for different functions, and they always ran into them after they were released from the traps, although they had other escape routes, indicating they utilised the tunnels as hiding places. Five vole burrows also started in the leaf litter and earth cover of larger amphibian tunnels under the 8718 road. This was also inevitable on game bridges, where several burrows were found, besides animals were also trapped on them.

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