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# Utilisation of a wide underpass by mammals on an expressway in the Western Carpathians, S Poland

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**Abstract.** Transport infrastructure is a critical threat to populations of animals; wildlife crossing structures are therefore commonly applied as a measure to sustain animal movements across roads and railways. Research on the efficiency of crossing structures is needed to provide scientific underpinnings to conservation efforts. Year-round monitoring of a large underpass on the S69 expressway in the western Polish Carpathians revealed that the crossing structure was mainly used by wild mammals (68.6 %), followed by domestic animals (22.1 %) and people (9.3 %). Wild mammals (14 species) were represented by both game and protected species, including large-bodied species like red deer *Cervus elaphus*, roe deer *Capreolus capreolus* and wild boar *Sus scrofa*. The Shannon species diversity index and Shannon's evenness index varied seasonally, with the highest number of species recorded in summer and lowest in winter. Red deer neither avoided nor selected for the wildlife crossing structure, while roe deer selected for it, and wild boar avoided it. This study indicates that large underpasses in mountains are used by a rich community of mammals, even if located close to human settlements.

**Key words:** wildlife crossing structures, post-investment monitoring, habitat defragmentation

## Introduction

Transport infrastructure is considered a critical threat for populations of animals and the integrity of protected areas (Trombulak & Frissell 2000, Benítez-López et al. 2010, Selva et al. 2011). Roads, especially those with high traffic volume, may act as a barrier to animal movement (Shepard et al. 2008), due to behavioural avoidance or direct mortality (Bąkowski & Kozakiewicz 1988, Gryz & Krauze 2008, Kozakiewicz et al. 1999, Leblond et al. 2013). The subsequent reduction in landscape connectivity hampers the dispersal (Huck et al. 2010) and migration of terrestrial animals (Cushman 2006), and limits their access to suitable habitats (Eigenbrod et al. 2008) and reproductive partners (Epps et al. 2005). This affects long term population persistence and viability (Ramp & Ben-Ami 2006, Jackson & Fahrig 2011).

Wildlife crossing structures, whose construction and dimensions vary from culverts and narrow tunnels to wide land bridges (Huijser et al. 2009, Huijser & McGowen 2010), are nowadays the most commonly applied measures to mitigate habitat fragmentation and sustain animal movements across roads and railways (Forman et al. 2003, Jędrzejewski et al. 2009). Nonetheless, utilisation of a given passage by animals heavily depends not only on its location and dimension, but also on the behaviour and body size of the species, as well as the human activity on and in the vicinity of the structure (van der Grift et al. 2013). Thus, post-investment evaluation of whether wildlife crossing structures are actually used by the species for which they were designed is required (van der Ree et al. 2015).

In spite of numerous studies on the utilisation of crossing structures by animals worldwide (van der Grift & van der Ree 2015), such research has rarely been conducted in Poland (Górna & Czerniak 2009), especially in the mountains. Research on the efficiency of measures mitigating habitat fragmentation for multiple species in the Carpathian Mountains, which

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are one of the most important hotspots for European biodiversity (Bálint et al. 2011), is needed to provide scientific underpinnings to conservation efforts.

The purpose of our study was to assess the species composition and temporal pattern of activity of mammals on the large underpass built on a newly established section of an expressway running between two Natura 2000 sites – Beskid Żywiecki (PLH240006) and Beskid Śląski (PLH240005). Special attention was paid to check if the crossing structure secured the movement of large-bodied species such as red deer *Cervus elaphus*, roe deer *Capreolus capreolus* and wild boar *Sus scrofa*.

## Study Area

The wildlife crossing structure is located near Laliki village on a section of the S69 express road between Milówka and Zwardoń near the Polish-Slovak border (49°31′2″ N, 18°59′1″ E). The road runs through the Beskid Żywiecki Mountains, which are a part of the western-most Polish Carpathian Mountains (Fig. 1). The animal passage is mainly surrounded by Norway spruce *Picea abies* forest and small meadows. In the adjacent area there is one inhabited house and a small ski-lift and ski-route active throughout the winter. The local railway line and local asphalt road are situated parallel to S69 (150-200 m apart).

Construction of this section of S69 started in 2005 and finished at the end of 2008. On average 1300 vehicles use the road per day (Generalny Pomiar Ruchu 2010). The width of the road is ca. 15 m, and in some parts there are high embankments. The entire length of S69 is tightly fenced on both sides with a metal mesh fence 2.2-2.4 m high, with the grid diameter of the

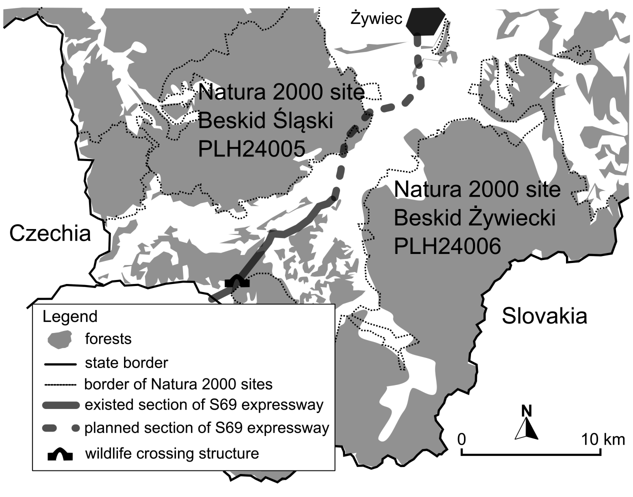


**Fig. 1.** Location of the wildlife crossing structure on S69 expressway between two Natura 2000 sites in the western Polish Carpathian Mountains.

fence decreasing towards the ground (Jędrzejewski et al. 2009), that prevents terrestrial animals crossing the road outside of animal passages. The wildlife crossing structure is under a 200 m long fly-over of the S69 road (Fig. 2) that varies in height from 3.9 to 6.3 m. The area under the viaduct is covered with soil and overgrown with grass and herbs. The only exception is a small stream, a tributary of a bigger water course nearby, whose banks have been stabilised with large stones. On one side of the passage, at the entrance, several trees have been planted to funnel animals through the structure.

There is a rich community of terrestrial mammals within the study area, consisting of large herbivores – red deer, roe deer and wild boar (whose share in the ungulate community, based on hunter inventories, is 27.4 %, 54.8 % and 17.8 %, respectively); carnivores – brown bear *Ursus arctos*, wolf *Canis lupus*, Eurasian lynx *Lynx lynx*, otter *Lutra lutra*, red fox *Vulpes vulpes*, European badger *Meles meles*, stone marten *Martes foina*, pine marten *M. martes*, common polecat *Mustela putorius*, stoat *M. erminea* and least weasel *M. nivalis*; lagomorphs – European hare *Lepus europaeus*, as well as numerous rodents, soricomorphs and bats (Pucek & Raczyński 1983, Brzeziński et al. 1996, Niedziałkowska et al. 2006, Nowak et al. 2008, Mysłajek et al. 2007, 2009, 2012).

## Material and Methods

The study lasted 12 months, from July 2010 to June 2011. The main method applied was the identification and counting of animal tracks left on a sand-belt built for this purpose by the General Directorate of National Roads and Motorways. The sand-belt, which is about 200 m long, stretched the entire length of the viaduct with the exception of a short section (3 m long) for the stream and its embankments. The trench in the ground, with a width of 2.5 m and depth of 20 cm, was covered with geotextile – a fabric made from polypropylene, impenetrable to plant roots – and then filled with fine sand. The structure was checked from 3 to 6 times per month. Every check consisted of two visits. During the first visit, all tracks of animals and people were identified and counted, and then the sand was carefully raked to cover all holes. The second visit took place after 1-3 days, when track recognition and counting, as well as sand raking was repeated (van der Grift & van der Ree 2015). During winter, when snow covered the ground under the viaduct, only single checks were done 1-3 days after fresh snowfall. In total the crossing structure was checked 42 times during the study period. Animal tracks were

**Fig. 2.** The wildlife crossing structure underpass near Laliki village on the S69 express road in western Polish Carpathians (photographed by Robert W. Mysłajek).

identified with the help of field guides (Jędrzejewski & Sidorovich 2010), by biologists experienced in mammal tracking.

Data from all visits were used to obtain the species composition of mammals which utilize the crossing structure, but only the results of visits repeated after 1-3 days were used to calculate the number of animals using the space under the viaduct. The number of individuals was calculated for a single day by dividing the number of tracks by the number of days between visits. Dominance (D%) was calculated to describe the structure of animal species using the passage according to the formula: D% = $(N_i/N) \times 100$, where $N_i$ is the number of individuals of a given species and N is the number of individuals of all species. Using the Biodiversity Calculator (Danoff-Burg & Xu 2006), the Shannon species diversity index (H') and Shannon's evenness index (E) were calculated for all wild mammals (Magurran 1998), except for small terrestrial rodents, whose identification based on tracks was not possible.

The preferences of ungulate species for the crossing structure were obtained using the selectivity index D from Jacobs (1974): $D = (r - p)/(r + p - 2rp)$, where r is the contribution (fraction) of a given species to the total number of ungulates recorded on the sand-belt, and *p* – the contribution of the species to the ungulate community in the study area. D varies from –1 (total avoidance), to 0 (random choice) to 1 (the strongest positive selection). The species structure of the ungulate community in the study area was estimated on the basis of hunters' inventories provided by the forest district in Ujsoły. Every year, at the end of March, hunters and staff of the state forest service attempt to estimate ungulate numbers based on their field observations and subjective expert opinions (Borowik et al. 2013). Although these statistics may not precisely show the actual numbers of each species (Wawrzyniak et al. 2010), they are commonly used to get the relative shares of the game mammals in the ungulate community in given areas (Jędrzejewski et al. 2012).

## Results

The majority of the tracks recorded on the sand-belt situated on the wildlife crossing structure under S69 belonged to wild mammals (68.6 %), but a substantial number of tracks were also left by domestic animals (22.1 %), and evidence of human presence accounted for only 9.3 % (Table 1). Wild mammals (14 species) were represented mostly by game species – red deer, roe deer, wild boar, European hare, red fox, martens, European badger and common polecat, while protected species – such as mole, otter, hedgehog, red squirrel, least weasel and stoat – were less abundant. Tracks of small rodents were observed regularly, but were not numerous. Both domestic dogs and cats frequently visited the crossing structure, although tracks of dogs were four times more abundant than tracks of cats. Human activity on the crossing structure was not high, although signs of people's presence were recorded on a regular basis. Pedestrians were the most common, but signs of various vehicles such as bikes, motorbikes, all-terrain vehicles, tractors and cars were recorded several times (Table 1).

The Shannon species diversity index (H') and Shannon's evenness index (E) calculated for all wild mammals, with the exception of small terrestrial rodents (Table 1), accounted for H' = 1.693 and E = 0.642. Both indexes varied seasonally, with the highest number of species recorded in summer and lowest in winter. The only mammals using the crossing structure throughout the entire year were red

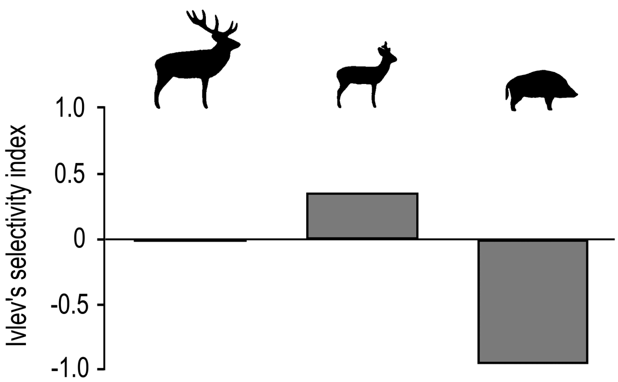


**Fig. 3.** Red deer, roe deer and wild boar preferences for the crossing structure on the S69 expressway near Laliki expressed using Ivlev's selectivity index, D (modified by Jacobs 1974) varying from –1 (complete avoidance) to 1 (the strongest positive selection).

**Table 1.** Number, dominance and activity of wild animals, domestic animals and humans on the wildlife crossing structure on S69 expressway in Laliki, Poland, 2010-2011.

| Species | Number of crossings | Dominance D% | N individuals/day (SD) |
|---|---|---|---|
| red deer *Cervus elaphus* | 273 | 9.6 | 1.5 (0.9) |
| roe deer *Capreolus capreolus* | 811 | 28.5 | 6.1 (3.6) |
| wild boar *Sus scrofa* | 4 | 0.1 | 0.1 (0.2) |
| European hare *Lepus europaeus* | 147 | 5.2 | 2.4 (3.8) |
| red fox *Vulpes vulpes* | 395 | 13.9 | 5.0 (4.5) |
| otter *Lutra lutra* | 15 | 0.5 | < 0.01 |
| marten *Martes* sp. | 55 | 1.9 | 0.3 (0.3) |
| European badger *Meles meles* | 41 | 1.4 | 0.3 (0.5) |
| stoat *Mustela erminea* | 7 | 0.2 | 0.2 (0.6) |
| least weasel *Mustela nivalis* | 62 | 2.2 | 0.9 (2.4) |
| common polecat *Mustela putorius* | 7 | 0.2 | < 0.01 |
| red squirrel *Sciurus vulgaris* | 56 | 2.0 | 1.4 (3.6) |
| small rodents Rodentia | 73 | 2.6 | 1.1 (1.8) |
| mole *Talpa europea* | 4 | 0.1 | < 0.01 |
| hedgehog *Erinaceus* sp. | 4 | 0.1 | 0.1 (0.3) |
| wild animals total | 1954 | 68.6 | 19.5 (8.5) |
| domestic dog *Canis lupus familiaris* | 514 | 18.0 | 4.7 (8.8) |
| domestic cat *Felis silvestris catus* | 116 | 4.1 | 1.0 (0.7) |
| domestic animals total | 630 | 22.1 | 5.7 (9.1) |
| humans (pedestrians) | 240 | 8.4 | 2.8 (4.0) |
| humans (vehicles) | 17 | 0.8 | 0.2 (0.3) |
| humans total | 264 | 9.3 | 3.0 (4.2) |
| Total | 2848 | 100.0 | 28.1 (16.4) |

**Table 2.** Seasonal changes in the species diversity of wild animals recorded on the wildlife crossing structure on the S69 expressway in Laliki, Poland, 2010-2011.

| Species | Spring | | Summer | | Autumn | | Winter | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| *Cervus elaphus* | 66 | 10.1 | 62 | 11.5 | 133 | 26.9 | 12 | 6.5 |
| *Capreolus capreolus* | 365 | 55.8 | 147 | 27.2 | 242 | 48.9 | 57 | 30.6 |
| *Sus scrofa* | - | - | - | - | 3 | 0.6 | 1 | 0.5 |
| *Vulpes vulpes* | 114 | 17.4 | 141 | 26.1 | 48 | 9.7 | 92 | 49.5 |
| *Lutra lutra* | 8 | 1.2 | 2 | 0.4 | 5 | 1.0 | - | - |
| *Martes* sp. | 14 | 2.1 | 20 | 3.7 | 20 | 4.0 | 1 | 0.5 |
| *Meles meles* | 27 | 4.1 | 9 | 1.7 | 1 | 0.2 | 4 | 2.2 |
| *Mustela erminea* | - | - | 5 | 0.9 | 2 | 0.4 | - | - |
| *Mustela putorius* | - | - | 1 | 0.2 | - | - | - | - |
| *Mustela nivalis* | 1 | 0.2 | 56 | 10.4 | 5 | 1.0 | - | - |
| *Lepus europaeus* | 57 | 8.7 | 71 | 13.1 | - | - | 19 | 10.2 |
| *Sciurus vulgaris* | 1 | 0.2 | 22 | 4.1 | 33 | 6.7 | - | - |
| *Talpa europea* | - | - | 4 | 0.7 | - | - | - | - |
| *Erinaceus* sp. | 1 | 0.2 | - | - | 3 | 0.6 | - | - |
| Total | 654 | 100.0 | 540 | 100.0 | 495 | 100.0 | 186 | 100.0 |
| Shannon diversity index H’ | 1.372 | | 1.888 | | 1.429 | | 1.090 | |
| Shannon evenness index E | 0.596 | | 0.760 | | 0.596 | | 0.609 | |

deer, roe deer, red fox, badger and martens (Table 2). The species structure of wild ungulates recorded on the wildlife crossing structure differed significantly from the ungulate community observed in the study area (Chi$^2$ test, $\chi^2 = 218.129$, df = 2, $p < 0.001$); however, the preferences of individual species towards the passage varied. Red deer neither avoided nor selected for the crossing structure, roe deer selected for it, while wild boar highly avoided it (Fig. 3).

## Discussion

This paper presents the utilisation of a large wildlife crossing structure constructed under a fly-over of an express road in the Polish Carpathians. The passage was mainly used in summer by 14 species of wild animals, including wild ungulates, medium-sized mammals (including the protected otter) and rodents.

The wildlife crossing structure investigated in our project was at the time the only object designed to ensure the movement of animals across studied section of the S69 expressway. Thus, we were unable to compare the patterns of response of wild animals to other fauna passes, varying in dimension, construction and location, in adjacent areas. However, even this initial study delivers important results that may be useful for the design of future measures mitigating the negative impacts of transport infrastructure in similar environments.

We are aware that calculations based solely on the number of tracks left by animals on the sand-beds are a possible source of bias which may have influenced the results of our study. Track-pads and camera traps are the most common methods for passage monitoring, although they are not equally informative (van der Grift & van der Ree 2015). Discrepancies in the results of comparative analyses of methods used for monitoring of wildlife crossing structures makes it impossible to get a general picture. For example, Gužvica et al. (2014) argued that monitoring of carnivores is most effective with trail cameras; while in contrast, Ford et al. (2009) showed that they were more likely to be detected by sand-beds, and showed the opposite results for ungulates. Detection of crossing events is affected not only by the species composition and number of animals using the crossing structure, but also by the length and position of sand beds, weather conditions, and granulometric composition of the track-pad material (Ford et al. 2009, Gužvica et al. 2014, van der Grift & van der Ree 2015). In our study the sand-bed was situated under the fly-over; therefore, it was not affected by weather conditions such as heavy rainfall which could have damaged the tracks.

Among the protected mammal species using the crossing structure in Laliki, the otter is also a target species for the neighbouring Natura 2000 sites. This semiaquatic mammal is abundant in the region (Brzeziński et al. 1996), and its frequent appearance on the crossing structure might be connected with the presence of the watercourse, as this is its favoured habitat (Romanowski et al. 2013). Incorporation of the stream into the design of the wildlife crossing structure might also support the presence of the common polecat and stoat, both of which are associated with aquatic habitats (Jędrzejewska & Jędrzejewski 1998). Also, small terrestrial and arboreal rodents, as well as insectivores were frequently recorded on the crossing structure throughout the year. Their presence was probably favoured by the dense herbaceous vegetation overgrowing the vicinity of the structure, presence of shrubs on banks of the stream, and proximity of the forest (Kozakiewicz et al. 1999, Rychlik 2000). Such a high abundance of small mammals is associated with a relatively high activity of small carnivores, for which they are an important food source (Goszczyński 1986, Jędrzejewski et al. 1993, 1995, Mysłajek et al. 2013). This shows that environmental enrichment is one of the most important factors contributing towards a higher diversity of species utilizing wildlife crossing structures on roads (Yanes et al. 1995, Clevenger & Waltho 2000, Grilo et al. 2008).

Human related activity can clearly be a deterrent to wildlife at crossing structures (Clevenger & Waltho 2005); thus, the rather high number of people, vehicles, and pets recorded on the wildlife structure in Laliki, which accounted for over 30 % of crossing events (Table 1), may have lowered the activity of wild animals. Domestic dogs and cats are known predators of wild mammals (Hughes & Macdonald 2013, Loss et al. 2013). Moreover, the presence of people and their pets might induce a so-called "landscape of fear" which would negatively affect the duration of wild animal activity (Støen et al. 2015, Suraci et al. 2016). While the activity of people at wildlife crossing structures may be limited by warning signs or landscape elements which prevent free passage or vehicle movement, the deterrence of free-roaming cats and dogs, which are quite common in Poland (Krauze-Gryz et al. 2012, Krauze-Gryz & Gryz 2014), seems to be a serious issue requiring a search for new solutions.

The diversity of species using the wildlife crossing structure in Laliki varied seasonally, with the highest number of species observed in summer and lowest in winter. Mata et al. (2009) also observed that most mammals crossed the expressway more frequently in summer. However, there are some species which have been mostly recorded in winter, e.g. water voles (*Arvicola* spp.) in Spain (Mata et al. 2009) or cougars *Puma concolor* in Canada (Gloyne & Clevenger 2001). The seasonal activity of mammals also varies between types of wildlife crossing structures (Mata et al. 2009). The less intensive use of the crossing structure in winter is mostly caused by the absence of species whose activity is restricted by low temperatures or reduced availability of food (e.g. hedgehogs and mustelids) (Merritt 2010). Therefore, in areas with marked seasons, the monitoring of the permeability of infrastructure to mammals should not be restricted to a single season (Gloyne & Clevenger 2001). Long-term studies also allow the evaluation of the adaptation of different species to wildlife crossing structures (Gagnon et al. 2011).

As in our study, long or open-span bridges (viaducts) have also been used successfully by cervids in other areas (Reed 1981, Ng et al. 2004). Deer not only use crossing structures to travel, but also to forage (Foster & Humphrey 1995). Therefore, the high activity of roe deer at the crossing structure might be favoured by the high availability of grass and herbs, as these are their preferable food (Gębczyńska 1980). In contrast to cervids, the crossing rates of wild boar were low. As revealed by earlier studies, this species seems to avoid open span underpasses and prefers overpasses (Mata et al. 2008, Kusak et al. 2009).

Our results indicate that large underpasses in mountains are used by a rich community of mammals, including large-bodied species such as wild ungulates, even if located close to human settlements. Nonetheless, locating a crossing structure further away from human settlements and reducing the activity of people seems to be a crucial step in mitigating the detrimental effects of transport infrastructure on animal movements, especially in regions linking protected areas such as Natura 2000 sites, which are intended to function as a network (Opermanis et al. 2012).

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