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The effect of traffic intensity and animal activity on probability of ungulate-vehicle collisions in the Czech Republic

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ABSTRACT

Traffic infrastructure and its traffic flows has rapidly developed in recent decades. This development brings benefits to society, but on the other hand has many negative impacts on the environment. Among the most significant impacts of road traffic is direct mortality of free-ranging animals due to vehicle collisions.

The main aim of this study was to compare the significance of traffic intensity fluctuation and ungulate behavioural patterns with the probability of ungulate-vehicle collisions (UVCs) occurrence in the Czech Republic. Our research question was whether the probability of UVC occurrence is influenced mainly by vehicle traffic related factors (traffic intensity, road types) or by ungulate locomotory activity.

We used information on UVCs from 2011 to 2013. We used Spearman's rank ρ correlation coefficients to examine relationships between UVCs and traffic intensity fluctuation, and between UVCs and the locomotory activity of red deer and wild boar during 24-h cycles in respective months.

The results indicate that the traffic intensity is not always the main factor causing the UVCs. A thorough analysis of our data showed that the main peaks of UVCs occur at time when animals have the highest locomotory activity. Our study proves high negative correlation between traffic intensity fluctuation and UVCs on motorways and expressways, which means ungulates tend to avoid crossing roads at peak traffic intensity. Next our study clearly shows that locomotory activity of ungulates is a more important factor in probability of UVC incidence than traffic intensity in the case of first-, second-, third-class roads and other roads.

1. Introduction

Road network and vehicle traffic are a significant environmental burden causing loss of biodiversity and threatening public health all over the world (Rhodes et al., 2014; Roger et al., 2011; Trombulak and Frissell, 2000; Wei et al., 2014). Continuously expanding traffic infrastructure has a great impact on populations of free-ranging animals. In the Czech Republic, the total length of motorways is 751.2 km and expressways count for 460 km. The complete network of motorways and expressways is supposed to be almost doubled in the future (944 km of motorways and 1228 km of expressways) (Directorate of Roads and Motorways of the Czech Republic, 2014). Therefore, we can assume there will be increasing pressure on wildlife and the importance of UVCs in the field of conservation ecology.

Among the most negative effects of traffic infrastructure and its traffic flows are direct taking of land and transformation of natural biotopes (Fahrig and Rytwinski, 2009; Iuell et al., 2003; Keken et al., 2013; Kušta et al., 2014a; Santos and Tabarelli, 2002; Trombulak and Frissell, 2000), fragmentation of natural biotopes (Dudaniec et al., 2013; Forman et al., 2003; Iuell et al., 2003), migration impediment (Polak et al., 2014; Rodríguez-Morales et al., 2013; Steiner et al., 2014) and mortality resulting from road-kill (Ascensão et al., 2013; Benítez-López et al., 2010; Bíl et al., 2013; Bissonette and Kassar, 2008; Gkritza et al., 2010; Iuell et al., 2003; Kušta et al., 2014b; Langevelde and Jaarsma, 2004; Neumann et al., 2012; Polak et al., 2014).

Concerning the above, ungulate-vehicle collisions (UVCs) are currently being discussed intensively as these accidents often result not only in property damage, human injuries and casualties, but also in destroying populations of ungulates (Gkritza et al., 2010; Groot and Hazebroek, 1996). The occurrence of UVCs throughout the day and year is not random (Diaz-Varela et al., 2011; Lagos et al., 2012; Madsen et al., 2002; Rodríguez-Morales

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et al., 2013). Its probability correlates with factors regarding the traffic flow on a road network such as traffic intensity, prevalent vehicle type - vehicle dimensions (width and length) (Jaarsma et al., 2006), driving speed (e.g. Diaz-Varela et al., 2011; Thurfjell et al., 2015) and ungulate behaviour and spatial activity (Clair and Forrest, 2009; Litvaitis and Tash, 2008; Mesingset et al., 2013; Steiner et al., 2014; Thurfjell et al., 2015).

Many species of free-ranging animals are killed on roads. However, it is UVCs that most studies deal with. As for the absolute number of collisions or animals killed, ungulates do not represent the biggest amount of the accidents. The main reason why there are so many studies dealing with UVCs is the result of collisions with these animals. An UVC usually leads to major property damage and it may result in human injury or casualty (Groot and Hazebroek, 1996).

In the Czech Republic, most accidents involve roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*) and wild boar (*Sus scrofa*) (Červený et al., 2013; Ministry of Agriculture of the Czech Republic, hereinafter: MACR, 2014; Mrtka and Borkovcová, 2013). These species have been proven to have circadian and seasonal behavioural patterns (Červený et al., 2013; Mesingset et al., 2013). Their activity is thus subject to a number of changes, which are influenced mainly by the season (Dingle and Drake, 2007; Jepsen and Topping, 2004), changes of vegetation and availability of food (Jarolímek et al., 2014), reproductive behaviour etc. (Cagnacci et al., 2011; Červený et al., 2013; Rodríguez-Morales et al., 2013). For instance, during cold winter periods with snow cover, they gather into groups with low spatial activity (Červený et al., 2013). These groups disperse in spring and summer (e.g. Groot and Hazebroek, 1996; Kusta et al., 2014a; Mateos-Quesada, 2005). Herbivorous ungulate circadian rhythms tend to be set by grazing cycles, during which animals are most active (Červený et al., 2013).

As a result of mainly human action, there has been a shift in free-ranging ungulate activity. The peak of the locomotory activity occurs at sunrise and sunset (Červený et al., 2013; Groot and Hazebroek, 1996; Haikonen and Summala, 2001; Mateos-Quesada, 2005; Steiner et al., 2014; Thurfjell et al., 2015). These behavioural patterns of free-ranging ungulates may cause regularity and cyclicity of UVC occurrence: collisions are most frequent in spring and summer (e.g. Groot and Hazebroek, 1996; Mateos-Quesada, 2005) or during sunrise and sunset (Rodríguez-Morales et al., 2013; Steiner et al., 2014), which may be related to social behaviour of free-ranging ungulates.

Another important factor which is considered a cause of UVCs is traffic intensity level. Most studies only define general traffic intensity, but just a few take into account its fluctuation during a season or 24 h (e.g. Diaz-Varela et al., 2011; Seiler, 2004; Thurfjell et al., 2015). Furthermore, many studies dealing with the relation of traffic intensity fluctuation to UVCs significantly contradict one another. Therefore the impact of traffic intensity fluctuation on UVCs has not yet been fully clarified (Bissonette and Kassar, 2008; Gagnon et al., 2007).

The main objective of this study is to compare the significance of traffic intensity fluctuation and ungulates behavioural patterns with the probability of UVC occurrence in the Czech Republic. Our research question is whether the probability of UVC occurrence is influenced mainly by vehicle traffic related factors (traffic intensity, road types) or by ungulate locomotory activity.

2. Materials and methods

2.1. Study area

Our study was conducted in the Czech Republic, which is a landlocked country with an area of 78,867 km^2, population of 10,512,400 inhabitants, and population density of 133 inhabitants/km^2 (Czech Statistical Office, hereinafter: CSO, 2014). The climate is moderate, transitory between continental and oceanic. The largest part of the territory is covered by arable lands (38%). Forests account for 34% of the territory, other agricultural plots (e.g. permanent grassland) for 15%, built-up and other areas for 11%, and water surface covers 2% (CSO, 2014).

According to the Road and Motorway Directorate of the Czech Republic (2014), the total length of road infrastructure in the Czech Republic is 55,757 km. The motorway density is 9.81 km/1000 km^2.

2.2. Data collection

2.2.1. Wildlife-vehicle collision

We used information on wildlife-vehicle collisions in the Czech Republic compiled by the Traffic Police of the Czech Republic during 2011–2013 (Police of the Czech Republic, 2014). The data collected for each collision included the date, time, and the exact GPS position. However, the animal species involved is not recorded by the police. The data from the Traffic Police are not records of all wildlife-vehicle collisions in the Czech Republic, but only records of such accidents in which the character of the accident led to the requirement for a police officer to have visited the scene of an accident (death of persons, injury of persons, total damage exceeding 100,000 CZK or damage caused to a third party).

We assumed that the data represent collisions mainly with roe deer, red deer, and wild boar. These are the most numerous ungulate species in the Czech Republic and they are also subject to hunting; in 2014, 100,395 roe deer, 169,484 wild boars and 23,378 red deer were shot (MACR, 2014).

We used the following road categories for the purpose of this study: (i) Motorways and expressways, (ii) First-class roads, (iii) Second-class roads, Third-class roads and other roads (Fig. 1). A motorway is a road communication designed for fast-moving, long-distance and international traffic by road motor vehicles, and it is constructed without crossings at grade, with separated points allowing the link-up with entry and exit and with separated direction driving lanes. An expressway is a road with limited access, constructed for fast-moving traffic, and has similar technical equipment as the motorway. First-class roads are designed especially for long-distance and international traffic. Second-class roads are designed for traffic between districts. Third-class roads and other roads are designed for linking communities with one another or for their linking to other road communications (Fig. 1).

Traffic intensity information for respective roads was based on methodology by Bartoš and Martolos (2012), the authors of the guidelines for estimating road traffic intensity. The guidelines were approved by the Czech Ministry of Transport. Traffic intensity is set for respective months and road categories based on direct counting of passing vehicles. For the purpose of this study, traffic intensity was specifically set as the average percentage distribution of traffic intensity at each hour of the day (hereinafter traffic intensity fluctuation) during each month of the year and on respective road categories.

2.2.2. Activity of free ranging animals

Many studies present wild animal circadian activity in a similar way. Daily locomotory activity of most species of ungulates thus exhibit bimodal distribution during a 24 h cycle, with a significant correlation of activity peaks at sunrise and sunset even in different types of landscape, which was proved by studies about (i) red deer in the Alps (Georgii and Schröder, 1983), in North America (Green and Bear, 1990), in Northern Sweden (Cederlund, 1989), in Germany (Berger et al., 2002), in Germany and North America (Ensing et al., 2014), in Poland (Kamler et al., 2007); (ii) roe deer