

## Traffic networks and wildlife management: economic aspects of wildlife-vehicle collisions in Hungary

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### KEYWORDS

- natural resource
- public road
- sustainability
- value assessment

### ABSTRACT

The public road network puts significant pressure on wildlife species. Road-related mortality is among the first causes of death of huntable species as well. In their case, it causes measurable economic damage to the Hungarian game management sector through wildlife-vehicle collisions (WVCs). Our main goal was to analyze temporospatial patterns of roadkills from the perspective of wildlife management and quantify the economic loss of the sector using WVC data from the Hungarian Game Management Database and legally established wildlife management values of huntable species. We found that a total of 318,480 collisions were reported by game management units during the study period. Our investigation found that the highest annual economic damage suffered by the sector was in 2021 with 5.768 million euros between 2000 and 2021. According to our study, the most threatened species are pheasant (*Phasianus colchicus*), brown hare (*Lepus europeus*), and roe deer (*Capreolus capreolus*), their occurrence in WVCs determines the economic loss of counties. Our investigation found that small or big game-dominant counties suffer significantly less financial damage from WVCs than the ones with mixed populations of the two animal groups.

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## Introduction

Habitat fragmentation is threatening biodiversity globally (Crooks et al. 2017). Due to the intensification of anthropogenic impacts, especially the development of road networks, fragmentation degrades wildlife habitats

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worldwide (Bennett 2017). The increasing length of public roads and the larger number of registered vehicles make it even worse year by year (Wilkins et al. 2019; Schwabe et al. 2000). Along with the intensive development of the highway network in Hungary, traffic on public roads has increased significantly. The mean daily traffic was 2519 vehicles/day in 2000 (Thurzó 2001), it has increased by 52.82% to 4026 vehicles/day by 2021 (Janás 2022). At the same time, the number of cars in traffic also rose by 70% (KSH 2022). Road networks put significant pressure on wildlife with their negative effects, especially with wildlife–vehicle collisions (WVCs), which are one of the main causes of mortality for many species (Forman and Alexander 1998). Animal victims of WVCs come from a wide range of taxonomy groups, many of them are endangered animals, but the mortality of huntable species is remarkable due to their population density (Cserkés & Farkas 2015; Borza et al. 2021). The lower volume of traffic causes decrease in WVCs, which was evident during the restrictions due to the COVID-19 epidemic (Bil et al. 2021). Among large mammals, populations of roe deer (*Capreolus capreolus*) red deer (*Cervus elaphus*), and wild boar (*Sus scrofa*) are mostly threatened by WVCs in Hungary, but red fox (*Vulpes vulpes*) and European badger (*Meles meles*) also jeopardized by road traffic (László & Faragó 2013; Markolt et al. 2012; Csányi et al. 2021). However, WVCs are hazardous to human life, and the damage caused in vehicles represents a significant value (Hothorn 2015), the economically measurable damage caused in wildlife is often out of the scope of related literature. Large scale of accidents end up with the death of wild animals involved, yet a lot of WVCs remain unreported for acting authorities (Gkritza 2013). At the same time, the number of collisions involving huntable species shows an increasing trend considering statistical data available for research. (Morelle et al. 2013). The economic loss caused by the mortality of huntable species is suffered by the game management sector, which represents an independent management area within the agricultural sector in Hungary. (Schiberna & Szalai 2015). Depending on the sex and age (therefore the trophy size), the game species hit in collisions can represent market value that can be a painful loss for game management units. Collisions deprive units not only of the income by selling meat, but also the opportunity to sell hunting and related services, which in itself represent high market value in the case of trophy hunting (Tisdell & Wilson 2004). Hungarian hunting market have a high demand of both domestic and foreign hunters for big and small game hunting opportunities (Ristic et al. 2013). Pricing of market participants is typically determined not only by the pricing policy of

competitors, but the quality of habitat, services related to hunting (Martinez-Jauregui et al. 2014), export or import sales, or the organizational form and economic performance of game management units (Little & Berrens 2008). For this reason, it is possible that consumers in different parts of the country may encounter different prices when choosing the same hunting option. This makes it quite difficult to calculate market prices during analyses since averaging from a couple of price lists does not give a representative value. Thus we can meet with different wildlife evaluation methods in studies for determining the economic value of wild animals (Gren et al. 2018). The Act LV. of 1996 on wildlife protection, game management, and hunting regulates the game management sector in Hungary. For the implementation of the Act, the Ministry of Agriculture and Rural Development also issued Decree 79. of 2004 (V. 4.) with detailed rules (Pulay 2004). In the 20. annex of the decree, the legislator established game management value for every huntable species and fallen antlers. The magnitude of these values depends on sex or trophy-measuring properties for different specimens of huntable animals.

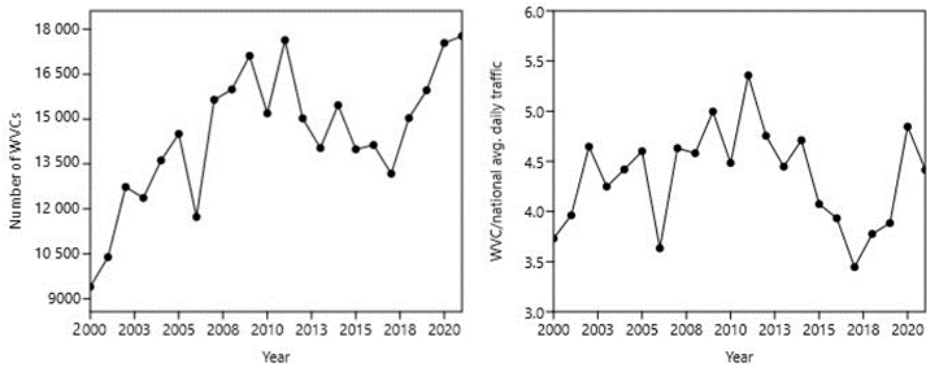
## Materials and methods

In this study, we analyzed yearly statistics of the Hungarian Game Management Database (Csányi et al. 2021) about animals hit in wildlife-vehicle collisions both on the national and county levels between 2000 and 2021. We collected and organized WVC data into a database in Microsoft Excel. For each year we gathered WVC data by county and by every species involved in the statistical yearbooks detailed by sex and age: red deer (*Cervus elaphus*), fallow deer (*Dama dama*), roe deer (*Capreolus capreolus*), mouflon (*Ovis aries*), wild boar (*Sus scrofa*), brown hare (*Lepus europeus*), pheasant (*Phasianus colchicus*) and grey partridge (*Perdix perdix*). Other than that we used additional data sources, for instance, the number of registered vehicles and the length of public roads are based on the dataset of the Hungarian Central Statistical Office. We used the yearly statistics of the Hungarian Road Databank for average national daily traffic. For estimating the economic loss of game management we calculated with the legally established game management value for each species. In the case of big game species the decree provides different values for male and female animals and among males, different values are implemented for different trophy sizes (antler/horn/tusk size). Therefore when we calculated the value of male big game animals hit during collisions, we used weighted averages where weights were calculated

from trophy-evaluation data of the harvested males of certain species for every year of the analysed period. Except for wild boar males because it is not mandatory to submit wild boar tusks for official trophy evaluation under the length of 16 centimeters. Thus in the case of male wild boar, we used the normal average of two different values. In the case of small game species, only pheasant has different values for different sexes, here we used normal average of values too. We used PAST4 software for statistical analyses (Hammer et al. 2001). We checked the normality of WVC data through the Shapiro-Wilk test. The number of animals hit in collisions was found to be normally distributed, so parametric tests were performed (ANOVA, Tukey's pairwise). For analyzing annual trends of WVCs, Spearman's rank correlation analyses were performed.

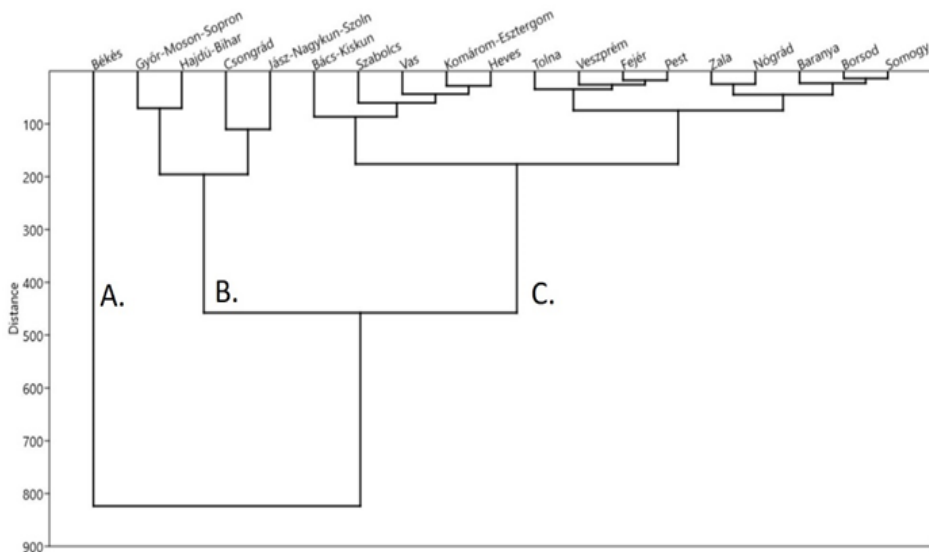
## **Results**

Firstly, all the WVC data from the Hungarian Game Management Database were gathered, so that we could identify quantitative trends and temporospatial patterns of collisions. We found out that a total of 318,480 collisions were reported by game management units between 2000 and 2021. The lowest yearly number of WVCs is 9,401 (in 2000), the highest is 17,775 (2021), and the mean value is 14,476.36 for the period. The yearly value of WVCs increased from 2000 until 2011 with unique setbacks in 2006 and 2010. It can be observed that there was a trend of decrease and stagnation between 2012 and 2017. From 2018, the rise in the number of WVCs can be seen year by year. For the next step, we divided the absolute values of WVCs by the cross-sectional national average daily traffic data for each year. In this case, the trend of collisions is rather stagnating than increasing (Figure 1). Calculating with absolute numbers, linear correlation can be recognized in the annual trend (Spearman's rank correlation.  $r=0.608$ ;  $p=0.0027$ ), but in the case of area-specific tendency, no significant connection can be identified ( $r=-0.029$ ;  $p=0.894$ ).



**Figure 1. Development of wildlife – vehicle collisions in absolute value and with the national average daily traffic 2000–2021**

For analyzing spatial patterns of WVCs, we gathered collision data for each county of Hungary for every year of the studied period. Instead of absolute values, we expressed the number of WVCs in each county per 100 km of public roads for better comparison in statistical analysis. Due to high variance, it was necessary to classify the counties ( $n = 19$ ) according to the mean value

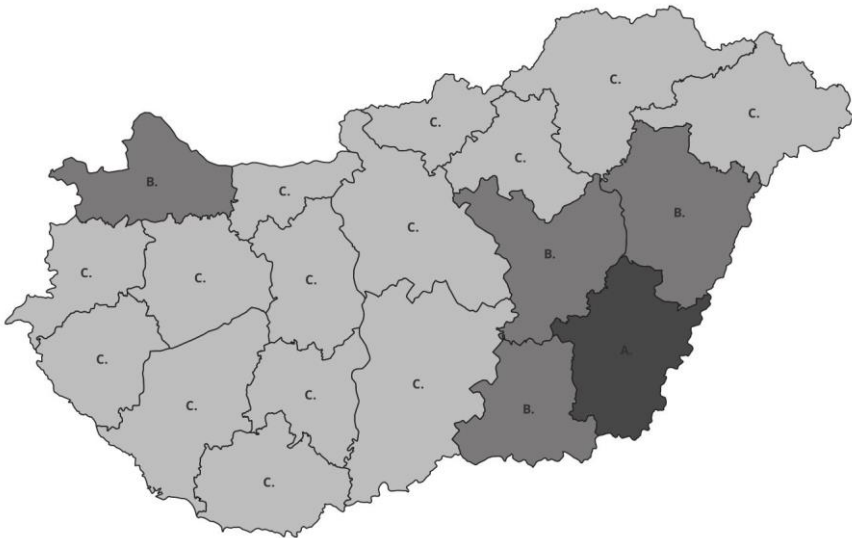


**Figure 2. Grouping of counties by number of WVCs per 100 km**

of collisions to differentiate groups with similar WVC characteristics. For this purpose, cluster analysis (Ward's method) was performed, and three

main groups (A., B., C.) were separated based on the yearly number of collisions per 100 km (Figure 2).

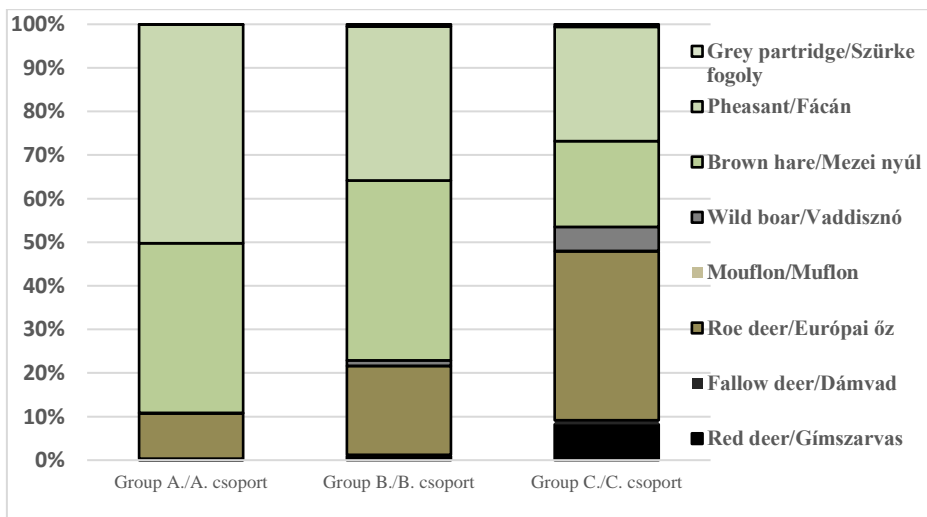
The difference between the groups was significant (ANOVA:  $F_{(2, 63)}=260.6$ ,  $p<0.001$ ). Tukey's pairwise test also proved the differences between the groups (A. $\leftrightarrow$ B.:  $Q=22.53$ ,  $p<0.001$ ; B. $\leftrightarrow$ C.:  $Q=8.76$ ,  $p<0.001$ ; A. $\leftrightarrow$ C.:  $Q=31.29$ ,  $p<0.001$ ). Group A. includes Békés county with an average of 186.21 animals hit in WVCs per 100 km. Group B. contains four counties (Jász-Nagykun-Szolnok, Hajdú-Bihar, Csongrád-Csanád and Győr-Moson-Sopron) with an average of 73.84 animals. Group C. includes fourteen counties (Bács-Kiskun, Szabolcs-Szatmár-Bereg, Vas, Komárom-Esztergom, Heves, Tolna, Veszprém, Fejér, Pest, Zala, Nógrád, Baranya, Borsod, Somogy) with 30.16 mean value. The cluster analysis divided the counties into one group with a higher average, one with a middle and one with a lower mean number of collisions (Figure 3).



**Figure 3. Spatial characteristics of WVCs according to the cluster analysis**

For analyzing the characteristics of economic loss, all the species involved in roadkills were determined in all groups. Firstly, we estimated the average values of the distribution of species in groups by the average of each year's distribution during the study period. As a result, different distributions of species can be identified. In Group A., the presence of small game species are dominant, brown hare, pheasant, and grey partridge take an average of

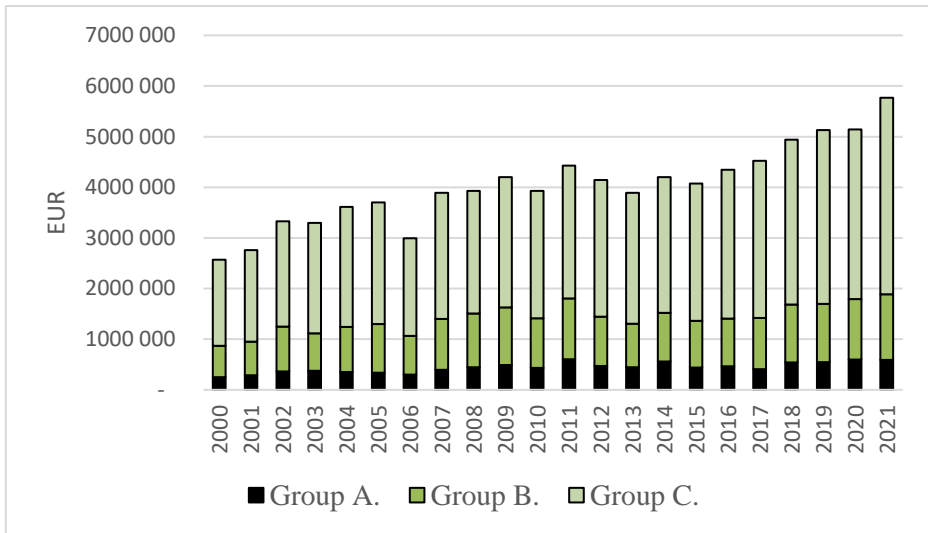
89.13% of all WVCs, roe deer were the victim in only 10.34% of collisions. Other species are involved in only 0.53% of all roadkills. In Group B. small game have a smaller share, these species were hit in an average of 77.13% of total WVCs. In this group, roe deer was killed in 20.38% of collisions, other big game species like red deer (0.97%) and wild boar (1.25%) also have increased share. Group C. is big game species are in focus: roe deer (38.70%), red deer (8.19%), wild boar (5.51%), and fallow deer (0.94%) take most of the share. Small game species were involved in an average of 46.51% of all collisions (Figure 4).



**Figure 4. Species distribution based on the groups' average WVC data between 2000 and 2021**

As it can be seen in Figure 5, yearly economic loss shows a temporal pattern quite similar to the absolute number of WVCs. It has an increasing trend throughout the study period with unique setbacks. The highest economic damage was reached in 2021 with 5.768 million euros. The share of groups in the game management sector loss shows similar characteristics in every year of the study period. Group A. takes an average of 10.88% of all economic damage, Group B averages at 24.16%, while Group C. has the highest share with an average of 64.96% of the total loss. Considering the average economic loss per WVC value for each group, Group A. has the lowest with 160.33 EUR/WVC, Group B. is the second with 217.52 EUR/WVC, while Group

C. leads with 360.7 EUR/WVC. National average economic loss/WVC is 278.45 EUR/WVC.



**Figure 5. Economic damage of groups in EUR (calculated with 376,74 EUR/HUF) 2000–2021**

## Discussion

The development of public roads and traffic infrastructure has a negative effect on wildlife in both ecological and economic manner. Humanity has to find an answer to the question of how we can compensate these negative effects with sustainable development so that future generations also can experience the natural values that are present nowadays. With our study, our main goal was to analyze roadkills from the perspective of wildlife management and quantify the economic loss of the sector using WVC data from the Hungarian Game Management Database and legally established wildlife management values of huntable species. During our 22-year study period, 318,480 game animals were killed on Hungarian roads according to the game management units' yearly reports. Because of the narrow range of data, we could calculate with „profitable-species” only, since despite the large road mortality of predator species like red fox and european badger, they are not reported among WVC data by the units. Analyzing the temporospatial pattern of WVCs we found a stable growth in the number of killed animals each year with unique setbacks, but it doesn't necessarily correlate with the elevated

traffic on public roads. Notwithstanding the related results mentioned in the introduction, decreased traffic can elevate wildlife road use. Thus the absolute number of WVCs can not decrease (Abraham & Mumma 2021). It allows us to conclude that ecological and habitat differences have a greater impact on the mortality of huntable species than the traffic itself, which also can be seen through our results regarding spatial characteristics. The cluster analysis divided the counties of Hungary into three different groups according to the average number of WVCs per 100 km. The result of classification shows that traditional „small game counties” with a higher rate of agricultural habitats and with lowland locations have a higher number of accidents significantly, because of the greater road-related mortality of these species, especially brown hare and pheasant. These counties belong to Group A. Counties that have habitat types allowing to manage large population density of both small and big game species make a different group (Group B.), while highly forested, traditionally „big game counties” located in Western and Northeastern Hungary got into the third faction (Group C.). According to the roadkill dataset, 64.02% of the total number of collisions caused the death of small game species ( $n = 203,918$ ), and in 35.97% of WVCs large mammals were involved ( $n = 114,562$ ) between 2000 and 2021. The most threatened species are pheasant (33.30%,  $n = 106,041$ ), brown hare (30.27%,  $n = 96,403$ ), and roe deer (27.69%,  $n = 88,185$ ) as the most commonly roadkilled large mammal across Central Eastern Europe (Bíl et al. 2021; László & Faragó 2013). For this reason, it is among the most mentioned species in European WVC-related studies along with wild boar and red deer as well (Pagany 2020). Despite the fact of the relatively high occurrence of roadkilled large wildlife species with high game management values (even higher in the case of males with trophies), the number of accidents with the said three species with less monetary value determines the economic loss of game management units. Counties with a high rate of big game species roadkills have much higher economic loss per roadkilled animals, however, the large number of small game species hits can increase the total economic damage significantly. Most of the WVC-related studies highlight the importance of mitigation measures or propose solutions against roadkills, which are welcome not only for human safety and preventing economic loss but for the sake of wildlife with high value lost on public roads.

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