CIRCUMSTANCES PATTERNS OF ANIMAL-VEHICLE COLLISIONS (AVCs) WITH PERSONAL INJURIES IN LITHUANIA

Galinskaitė L.*, Ignatavičius G.

Vilnius University, Saulėtekio al. 7, LT- 10257 Vilnius, Lithuania

Abstract

Animal-vehicle collisions (AVCs) are a major traffic safety concern since they result in substantial economic and medical costs when causing property damages and injuring or killing humans and animals (Jägerbrand Antonson & Ahlström 2018). Recent studies evaluated nonfatal human injuries from animal-vehicle collisions but information on fatal animal-vehicle collisions is limited. This restricted our understanding of when, where, and how frequently injuring, humans animal-vehicle collisions occur, and whether these patterns differentiate from those for total AVCs. We found that over the last 7 years (2013-2019) more than 18,222 collisions with animals (both wild and domestic species) occurred on the roads of Lithuania where 6 people were killed and 158 were injured. Most human-injured collisions occurred in dry-main roads, at nighttime (period of ambient darkness from sunset to sunrise), during the summer months, and in clear weather. In Lithuania, collisions between moose and vehicles cause the highest number of injuries compared to collisions with other animal species. This data is important as it provides insight into factors that may heighten the risk of AVC.

Keywords: *animal, vehicle, collision, fatalities, injuries, human safety*

1. INTRODUCTION

The number of animal-vehicle collisions (AVCs) is steadily increasing worldwide as a result of growing traffic intensities and road networks, which coincide with wildlife habitats (habitat loss, barrier effects, or mortality due to collisions with vehicles). More importantly, these collisions are a serious threat to human safety (injury, death) (Bissonette, Kassar & Cook 2008; Huijser et al. 2008) and the associated economic costs are high. For example, in the United States, deer species cause 1 to 2 million collisions per year associated with 200 deaths and $8.4 billion in direct damage (Donaldson & Lafon 2008; Canal et al. 2018). In Europe, more than 500,000 collisions with ungulates occurred annually, causing about 30,000 injuries and an economic cost of $1 billion (Langbein, Putman & Pokorny 2011; Abra et al. 2019). National Traffic Authority (DGT) in Spain reported that collisions doubled between 2006 and 2012 (on average, 12,433 AVCs per year) in comparison to those reported in 2003 (6,227 AVCs), which caused 2,911 injuries and an estimated annual cost of 105 million € (María & Tellería 2015). In 2016, 264,000 collisions with roe deer or wild boar were officially reported in Germany, which resulted in an economic loss of almost 0.7 billion Euro (Benten et al. 2018). With the length of the global road network expected to expand by 35% - 60% between 2010 and 2050 (Meijer et al. 2018), the public safety risk and ecological threat posed by AVCs will continue to grow worldwide (Laurance et al. 2014).

Statistics from Lithuanian police show that, on average, wild animals in Lithuania cause almost 4,000 traffic accidents per year, injuring 30-40 people and killing one per year after a collision. These estimates include deaths from a crash in which a driver tried to avoid an animal and ran the vehicle off the road or from a direct animal-vehicle collision. Statistics of Lietuvos insurance companies reveals that the average cost of such collisions is about 1.6 thousand Euros. But due to the different size and weight of the animals, damage to the property can be costly. When a deer or a wild boar hits the car, the damage usually increase to 1.7–2.3 thousand euros. Compared collisions with small animals – rabbits, cats or birds - cost on average 500-700 euros (https://www.ld.lt/).

Main species involved in AVCs with social, economic and more important health, consequences consider to be: moose (*Alces alces*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*). Collisions with deer are often nonfatal. While crashes involving moose cause

the most vehicle damage and personal injuries, including death, due to their size (Niemi et al. 2017). Domestic animal vehicle collision (DVCs) are rare but involve significant, human, animal and economic losses. These human injured collisions are often lumped together with general patterns of animal related accidents or even excluded from scientific analyses. It limits our understanding of when, where and how frequently they occur. Previous studies found that most animal vehicle collisions happen during dark conditions (Sullvian 2011). Most deer-vehicle collisions occur during mating season (Langley, Higgins & Herrin 2006). However, temporal patterns remain poorly understood for human-injured risk.

Although analysis of fatal injuries related to animal-vehicle collisions is more limited, recently studies pay more attention to general patterns of animal-vehicle collisions. Important to characterize the risk factors surrounding accident with large animals in order to develop knowledge prevention strategies. This could reduce economic cost associated with these collisions, as well as injuries and mortality. This study looks at animal vehicle collision data from the Lithuania police database to describe and distinguish circumstances and patterns of fatal/injured to human animal-vehicle collisions.

2. MATERIALS AND METHODS

2.1. Materials

Collision data was provided by the Lithuania Police Department. Data included 158 serious human injuries and 6 fatal collisions involving wild and domestic species in the Lithuania (2013 (n=16), 2014 (n = 9), 2015 (n = 26), 2016 (n = 29), 2017 (n = 22), 2018 (n = 36)), 2019 (n=26). The information was obtained from accident reports, occurred throughout the roads of Lithuania. Each record indicates an environmental condition around the time of the crash. The hour-level road condition (dry, wet, icy and snow covered) this data were obtained from weather station, were accident took place. In addition to administrative information, reports contained the date, of the collision, time, the location, the identity of the road, the species involved in the accident.

2.2. Methods

First, we studied the wildlife species that were reported in these accidents. Second, we analyzed influence of environmental variables (road weather condition, meteorological condition). The third step in our analysis was to study relationship between human injured AVCs and date and time of the collision. We used a polar histogram to assess differences temporal distributions of wild (WVCs) and domestic (DAVCs) species.

3. RESULTS

3.1. Wildlife Species

18,222 collisions with animals were reported by Lithuanian police department between 2013 and 2019, including 6 human fatalities, 158 human injuries, and thousands of animal deaths. In the category of wild species, moose take the largest part of accidents with close up to 55.48%, followed by other species including roe deer 9.15%, red deer 4.88%, wild boar 1.22%, and bison 1.83%.

Large livestock (e.g. cow, horse, bull) make up to 4.8% of injured to human collision, small domestic animals (e.g. cat, dog) 7.9% (Fig. 1). Four out of the six fatal to human collisions occurred with a moose, data show one fatal accident occurred when driver lost control of their vehicles trying to avoid a collision with roe deer. One fatal accident occurred when car hit the a cow.

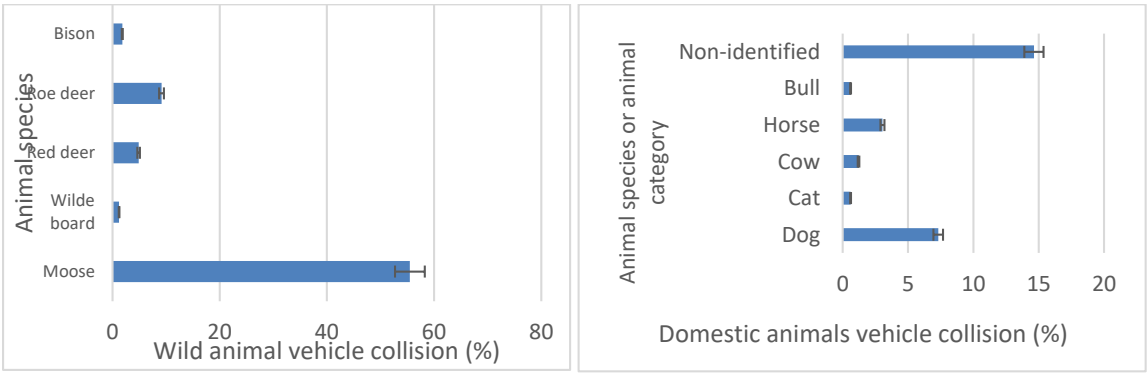


Fig. 1. Wilde and domestic animal species involved in injured to human collisions, in Lithuania 2013-2019

3.2. The effects of road weather conditions

Road weather variability proved to be a significant factor in human injured animal vehicle collisions in Lithuania. Simplify the analysis, dangerous road conditions were combined into four categories: dry, wet, icy road surface and snow surface. For the road weather conditions, dry road had the highest (77.43%) accidents percentage. 20.12% of human injuries occurred on wet road surfaces. The other two road weather condition categories had 1.21% of recorded accidents. The comparison of the road weather conditions relative accident risks showed that dry road surface had the highest relative accident risk. Even though the standard error bars do not overlap between dry and wet road conditions (Fig. 2), the difference is not statistically significant ($p>0.17$ (by chi-square test)).

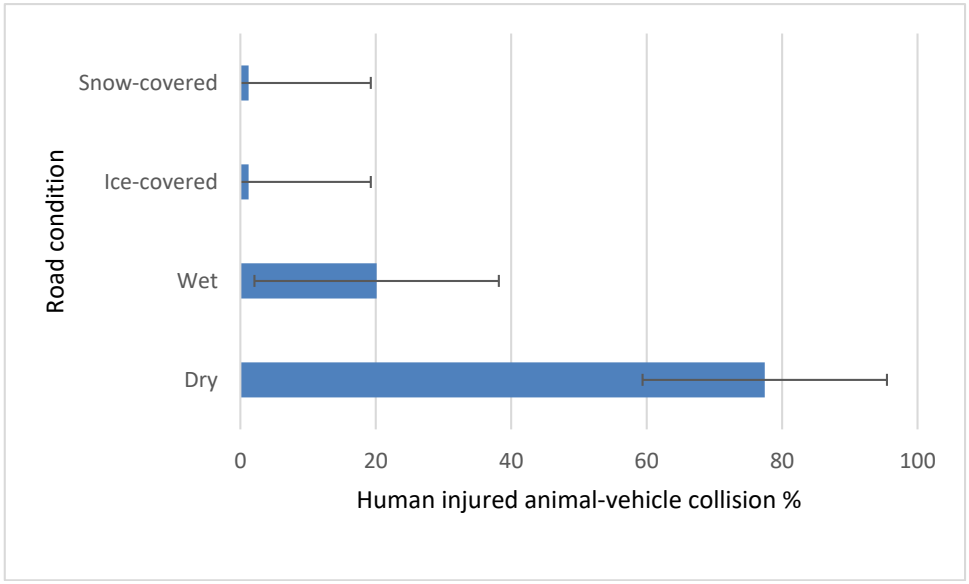


Fig. 2. Human injured animal-vehicle collisions according to road condition n=164

3.3. Weather/meteorological condition

As well as road weather conditions, environmental conditions were combined into four categories: Clear weather, overcast, fog and rain. Each record indicates an environmental condition around the time of the crash. According to our data more than 52.43% of all 164 accidents occurred in clear weather. In addition 35.9% took place in overcast weather, and more than 7.9% were recorded in rain. Less than 3.6% in fog environmental conditions. Most of the human injured animal-vehicle collisions

occurred under clear weather conditions, which indicate that in this case the difficult weather is not a major incident influencing factor. The standard error bars do overlap between clear and overcast meteorological conditions as well as fog and rain (Fig. 3), this indicates the difference between these means is not statistically significant ($p>0.05$ (by chi-square test)).

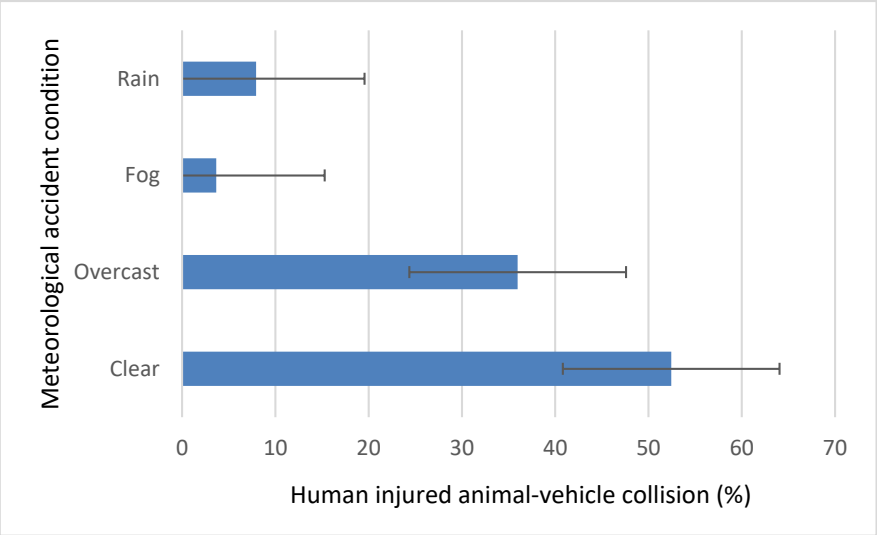


Fig. 3. Human injured animal-vehicle collisions according to meteorological accident condition=164

3.4. Seasonal distribution

Temporal analysis patterns were similar between human injured animal-vehicle collisions and annual wildlife-vehicle collisions. When the total road traffic accidents over the seven years period are distributed more or less evenly. First two collision types had the least common fluctuation during winter and early spring, and most common during summer and fall months. However, injured to human collision exhibited a more subtle peak is observed at May (19.5%) and less at September (14.6%), as well as collision peak for total animal vehicle collisions reached a peak in May (13.2%) about second high peaks were found in November (11.2%) (Fig. 4). Our results suggest a moderate correlation between human injured animal-vehicle collisions, and the total number of animal vehicle collisions ($r=0.65$). Similar trend was found between total number of animal vehicle collisions and total traffic accidents ($r=0.55$).

Moderate correlation was found between human injured animal-vehicle collisions and total road traffic accidents in Lithuania ($r=0.56$) indicating a positive relationship between these two variables. According to our data in Lithuania 0.77% of the reported animal-vehicle collisions resulted in human injuries or fatalities. From total road traffic accidents, human injured animal-vehicle collisions consist of 0.73%. The personal injury rate in collisions with animals was higher in autumn (31.70%), spring (28.65%), and summer (28.65%), compared to winter (10.9%). Nevertheless, personal injury rates differed between months.

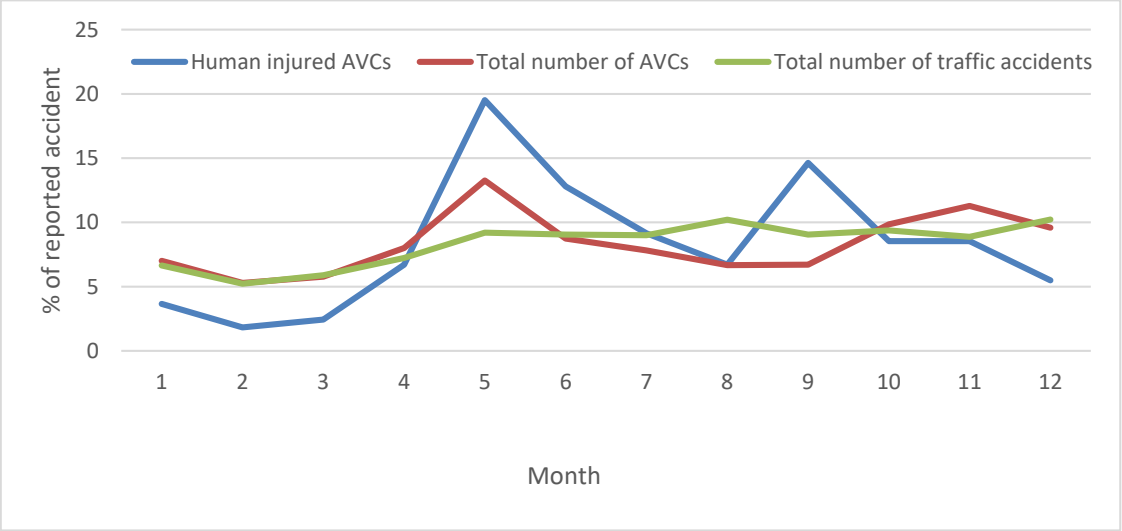


Fig. 4. Proportion (%) of human injured animal-vehicle collisions, total number of animal-vehicle collisions and total road traffic accidents occurring in each month of the year in Lithuania 2013-2019.

3.5. Daily distribution

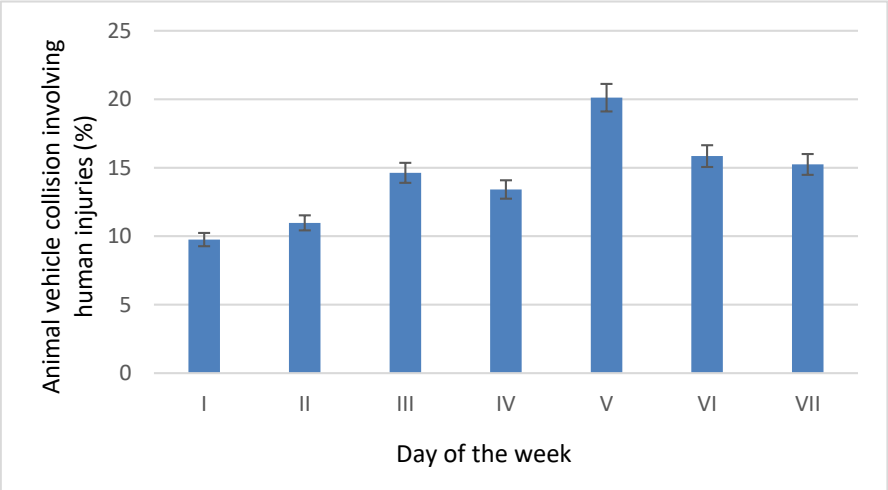


Fig. 5. Daily distribution of human injured animal-vehicle collisions in Lithuania from 2013 – 2019 (n=164)

The patterns of human injured animal-vehicle collisions show a clear peak at the end of the week on Friday (20.12% of all human injured animal-vehicle collisions). Visually, observations show another increase in the number of accidents on Sunday (15.85% of all human injured animal-vehicle collisions). But there are no significant differences with other days of the week. These results have revealed the difficulty of relating any specific variables to the weekly incidence of accidents, underlining the need for reliable data which allow for multivariate analysis.

3.6. Hourly distribution

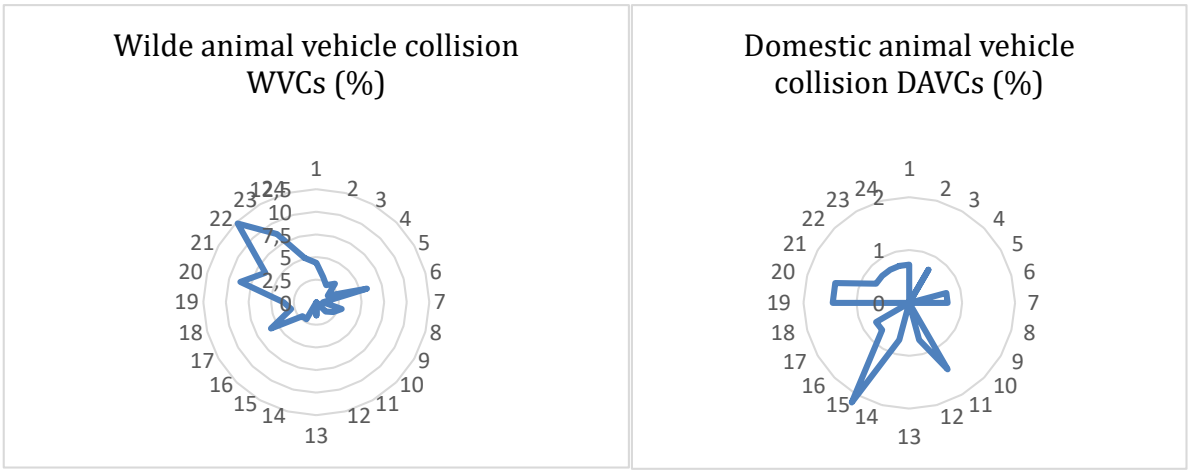


Fig. 6. Hourly distribution patterns of personal injuries animal-vehicle accidents for wild (n=119) and domestic (n=21) species in %.

Hourly distribution for wild species and domestic species was not uniformly distributed. To get significant results non-identified accidents (n=24) were not analyzed in this part. Human injured WVCs show a tendency towards night and morning distribution. The first peak for personal injured wild animal-vehicle collisions is obtained at 6 a.m. (5.7%). Evening peak starts at 17 p.m. (5.7%) and reaches the highest point at 22 p.m. (12.3%). (fig.6). While human injured collisions with domestic species are more evenly distributed during daytime. Although there is some fluctuation at 11 a.m. (1,4%), 15 p.m. (2.1%). Visually observation shows another increase in the number of accidents between 19 p.m. and 20 p.m.

4. DISCUSSION

Each year, millions of accidents occur between animals and motor vehicles. They affect property, safety of human, and wildlife, moreover the number of animal-vehicle collisions has increased across the world (Bartonicka et al., 2018). That is why AVCs have always been one of the controversial subjects to research. In spite of the fact that the majority of collisions occur due to human error, animal–vehicle collisions are under-recognised as a road safety issue (Ang et al. 2019). Despite the fact that the number of collisions is growing every year, there is a quite small number of analyzes about personal injuries in AVCs. Limited information about animal-vehicle crashes on human safety leads to discussion or there are differences in AVCs and collisions with animals where humans are injured. Data from Lithuania police department in the period of 2013-2019 were combined to conduct an analysis of the number of persons injured in AVCs during the 6 year period. A total of 164 persons were injured (from them 6 were killed).

In Lithuania, wildlife vehicle collisions are most common cause by ungulates. Accidents involving smaller bodied species usually lead to vehicle damage, meanwhile collisions with a heavy and large animal, for example moose (they can weigh between 200-550 kg), increases the risk of non-fatal or fatal injuries. We found that personal injuries animal vehicle collisions in Lithuania occur more frequently with moose. These results concur well with earlier studies, although research on injury rates in animal-vehicle collisions is limited, some studies suggest that less than 5% of deer-vehicle collisions lead to personal injuries while the injury rate in moose-vehicle collisions (MVCs) is reported to be 10–20% or even higher (Niemi et al. 2017). Results published by Malo, Suarez & Diez 2004, found that human injury results 4% of accidents involving medium-sized animals such as deer *Odocoileus* spp. and 14% - 18% of collisions with larger mammals like moose *Alces alces* L. Remarkably red deer, roe deer, wild boar, European bison, are the species leading to most of the

registered accidents in other regions, had a marginal incidence in the registered collisions. Nevertheless, according to Canal et al. (2018) wild boar are particularly damaging since they caused 47% of collisions, 43% of total injured people and 47% of fatal injuries. Vehicle collision caused by roe deer make up 32.3% of vehicle collisions, 8.6 % of total injured people and fatal injuries conclude of 8.3%. In period of 2003-2016 in Spain, out of 5005 wild boar vehicle accidents, 180 persons were injured (Sáenz & Tellería 2015. In the same period in Sweden, out of a total of 36,087 accidents, around 272 persons were injured (Jägerbrand & Gren 2018). In analyses of domestic species, the large part of accidents resulting in human injuries occur with dogs. Our findings coincide with the results of Canal et al. (2018); Morelle, Lehaire & Lejeune (2013); Wilkins, Kockelman & Jiang (2019).

Despite the fact that animal vehicle collisions are determined in time and space, these events are also potentially affected by external variables such as adverse road weather and meteorological conditions. We found that major human injury rates in Lithuania occur in dry road conditions. Due to the fact that animals are less likely to move around during inclement weather, personal injures AVCs are more likely to occur in dry weather. It is known that slippery road conditions had the highest accident probability (Malin, Norros & Innamaa 2019). But in human injuries animal vehicle collisions under such conditions occurs less often, as fig. 2 shows. In general there are information which indicate that in clear weather conditions, vehicle speed usually is 1.5 km/h higher in daylight than in the night time (Jägerbrand & Sjöbergh 2016). Compared to all AVCs, 95% of fatal collisions occurred during clear weather. (Huijser et al. 2008). On the other hand, weather conditions, in autumn and winter with frequent rainfall and fog also could contribute to increase the rate of annual AVCs. By avoiding collisions, braking distance increasing (Canal et al. 2018). Additionally species-specific responses to inclement weather conditions may also be contributing to the disparity in accidents rates. The results obtained from this study, are also in line with previous studies. In the United States during a 10–year time period an average 165 deaths in collision with animals occurred in clear weather (Langley, Higgins & Herrin 2006). Condition of clear weather was also a significant factor of severe human injuries related to animal vehicle collisions in Washington (Al-Bdairi, Behnood & Hernandez 2020).

The temporal pattern that we observed in human injured AVCs is also consistent with previous research showing low collision frequencies from winter through early spring and elevated frequencies from late spring and peaking in May through fall, peaking in September. This fall peak has been attributed to increased species-specific behavior and activity level associated with migration and mating behavior, this brings ungulates more frequently in contact with road. For example, increased moose movements during rutting season have been suggested to contribute as a collision peak in September (Niemi et al. 2017). Other species like elk and deer spend more time bedded during winter and show less activity, which can lead to less collisions and human injuries (Al-Bdairi, Behnood & Hernandez 2020). The highest part of collisions with ungulates occurring in autumn can be explained by breeding activity (Jakubas, Rys & Lazarus 2018). In polygynous ungulates, males typically undergo large behavioral and physiological changes during the rut (reproductive period) as they compete for access to females (Richard et al. 2014). Males often decrease time spent feeding (Willisch & Ingold 2007; Brivio et al. 2010) and allocate most of their resources to find and tend estrous females (Mainguy & Côté 2008), resulting in increased rates of movement (Pépin et al. 2009). In addition, this species-specific behaviour increase the risk of WVC (Morelle, Lehaire & Lejeune 2013). Autumn and winter collision peaks previously were also reported for massive animal – moose (Niemi et al. 2017) roe deer and wild boar (Bruinderink & Hazebroek, 1996; Lagos et al. 2012).

Weekly variation in animal related collisions frequency often reflects the weekly dynamic or flow of traffic (Jakubas, Rys & Lazarus 2018). In this study, the highest number of human injured animal vehicle collisions was recorded on Friday, when the traffic is more intense (due to late-night socializing and traveling habits). Comparable results are observed in Canada, where collisions with moose were 42% more frequent on Fridays when road traffic intensity were highest (Dussault et al., 2006). Findings based of previous studies, annual animal related collisions occur more often in weekdays (Diaz-Varela et al., 2011; Lagos et al., 2012; Putzu et al., 2014;). In northern Poland and eastern Poland a reverse pattern, shows a higher number of collisions with ungulates appeare at Mondays (Jakubas, Rys & Lazarus 2018; Kitowski, Letowski & Kepowicz 2014). Those contradictory

results may be caused by different traffic volumes as well as intensity variations in different regions or other factors (e.g. hunting regulations for different animals in different countries).

As well as reporting such seasonal patterns, a number of studies have found that the majority of animal vehicle accidents occur particularly at dusk or dawn (during the hours of darkness) (Langbein, Putman & Pokorny 2011; Torsten et al. 2015; Abra et al. 2019; Vazquez et al. 2019). These accidents reflect the nocturnal behaviour of animals living in areas disturbed by human, forcing them to switch most of their foraging activities during night when risk of being seen or disturbed by humans is lowered (Cahill, Llimona & Gràcia 2003). Visual conditions at night time are not really good either (darkness, presence of fog) and can also partly explain a higher number of accident events (Morelle, Lehaire & Lejeune 2013). We didn't achieve a deep review of the causal factors of human injured collisions with domestic animals, however we might suspect the main reason for these events is considered to be escapement of cattles and dogs. The contrasting pattern that we observed—with two major peaks, first at 3 p.m. another centered from 7 p.m. to 20 p.m. period. To our knowledge this pattern has not been previously documented and is more difficult to explain it. Information on activity patterns of domestic animals is scarce but results suggests that domestic animals are primarily diurnal (Arnold & Dudzinski 1978; Van Rees & Hutson 1983; Stott, Stephenson & Hanford 2018), making activity level an unlikely explanation for the observed late evening peak (Creech et al. 2019). In our option the most valid explanation is related to light conditions as well as traffic volume. Although further investigation is needed.

5. CONCLUSIONS

In conclusion, the accident number of human injuries from animal-vehicle collisions in Lithuania is considerably lower comparing to available statistics from other countries, but it still is a significant public health problem and concern. While the factors affecting the number of AVCs and their circadian and seasonal distribution are analyzed relatively well in the previous study, the temporal model of personal injuries is understudied. Future studies should be focused on drawing clearer distinctions between human injuries, animal vehicle collision accidents and total AVCs.

REFERENCES

1. Abra, FD, Granziera, BM, Huijser, MP, Ferraz, KMPMdB, Haddad, CM & Paolino, RM 2019, 'Pay or prevent? Human safety, costs to society and legal perspectives on animal-vehicle collisions in São Paulo state, Brazil', *PLoS ONE*, vol. 13, no. 9, viewed 16 January 2021, <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0215152>.
2. Al-Bdairi, NSS, Behnood, A & Hernandez, S 2020, 'Temporal stability of driver injury severities in animal-vehicle collisions: A random parameters with heterogeneity in means (and variances) approach', *Analytic Methods in Accident Research*, vol. 26, pp. 100-120, viewed 17 January 2021, <https://www.sciencedirect.com/science/article/pii/S2213665720300105>.
3. Ang, JA, Gabbe, B, Cameron, P & Beck, B 2019, 'Animal–vehicle collisions in Victoria, Australia: An under-recognised cause of road traffic crashes', *Emergency Medicine Australasia*, vol. 31, no. 5, pp. 851-855, viewed 16 January 2021, <https://onlinelibrary.wiley.com/doi/full/10.1111/1742-6723.13361>.
4. Arnold, G, & Dudzinski, M 1978, *Ethology of free-ranging domestic animals.* Elsevier, Amsterdam.
5. Bartonicka, T, Andrasik, R, Dula, M, Sedonik, J, Bill, M 2018, 'Identification of Local Factors CausingClustering of Animal-Vehicle Collisions', The Journal of Wildlife Management, vol. 82, no. 2, pp.1-8, viewed 10 April 202, <https://www.researchgate.net/publication/324564075_Identification_of_local_factors_causing_clustering_of_animal-vehicle_collisions>

6. Benten, A, Hothorn, T, Vor, T, & Ammer, C 2018, 'Wildlife warning reflectors do not mitigate wildlife–vehicle collisions on roads', *Accident Analysis and Prevention*, vol. 120, pp. 64-73, viewed 20 March 2021, <doi: 10.1016/j.aap.2018.08.003.>
7. Bissonette, J, Kassar, C, & Cook, J 2008, 'Assessment of costs associated with deer–vehicle collisions: human death and injury, vehicle damage, and deer loss', *Human-Wildlife Conflicts*, vol. 2, no.1, pp. 17–27, viewed 19 January 2021, <https://doi.org/10.26077/ns32-mk60>.
8. Brivio, F, Grignolio, S, & Apollonio, M 2010, 'To feed or not to feed? Testing different hypotheses on rut-induced hypophagia in a mountain ungulate', *Ethology*, vol. 116, pp. 406–415, viewed 10 April 2021, < https://doi.org/10.1111/j.1439-0310.2010.01753.x>.
9. Bruinderink, GG, & Hazebroek, E 1996, 'Ungulate traffic collisions in Europe', *Conservation Biology*, vol. 10, pp. 1059-1067, viewed 10 April 2021, <10.1046/j.1523-1739.1996.10041059.x>.
10. Canal, D, Martin, B, Lucas, M & Ferrer, M 2018, 'Dogs are the main species involved in animal-vehicle collisions in southern Spain: Daily, seasonal and spatial analyses of collisions', *PLoS ONE*, vol. 13, no 9, viewed 16 January 2021, <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0203693>.
11. Cahill, S, Llimona, F, & Gràcia, J 2003, 'Spacing and nocturnal activity of wild boar *Sus scrofa* in a Mediterranean metropolitan park', *Wildlife Biology*, vol. 9, pp. 3-13, viewed 19 January 2021, <https://doi.org/10.2981/wlb.2003.058>.
12. Creech, TG, Fairbank, ER, Clevenge, AP, Callahan, AR, & Ament, RJ 2019, 'Differences in Spatiotemporal Patterns of Vehicle Collisions with Wildlife and Livestock', *Environmental Management*, vol. 64, pp. 736–745, viewed 05 March 2021, <https://link.springer.com/article/10.1007/s00267-019-01221-3>.
13. Diaz-Varela, RM, Gonzalez, IV, Pérez, MFM, & López, CJA 2011, 'Assessing methods of mitigating wildlife–vehicle collisions by accident characterization and spatial analysis', *Transportation Research Part D: Transport and Environment*, vol. 16, no. 4, pp. 281-287, viewed 10 April 2021, < https://doi.org/10.1016/j.trd.2011.01.002>.
14. Dussault, C, Poulin, M, Courtois, R, & Ouellet, JP 2006, 'Temporal and spatial distribution of moose-vehicle accidents in the Laurentides wildlife reserve, Quebec, Canada', *Wildlife Biology*, vol. 12, no.4, pp. 415-425, viewed 10 April 2021, <https://doi.org/10.2981/0909-6396(2006)12[415:TASDOM]2.0.CO;2>.
15. Donaldson, B, & Lafon, N 2008, *Testing an Integrated PDA-GPS System to Collect Standardized Animal. Carcass Removal Data*, Virginia Transportation Research Center report nr. FHWA/VTRC 08-CR10, viewed 15 March 2021,<https://rosap.ntl.bts.gov/view/dot/19926>.
16. Huijser, MP, McGowen, P, Fuller, J, Hardy, A, Kociolek, A, Clevenger, AP, Smith, D & Ament, R 2008, *Wildlife-Vehicle Collision Reduction Study: Report to Congress'*, U.S. Department of Transportation, U.S.
17. Jakubas, D, Rys, M & Lazarus, M 2018, 'Factors affecting wildlife–vehicle collision on the expressway in a suburban area in northern Poland', *North-Western journal of zoology*, vol.14, no.1, pp. 107-116, viewed 17 January 2021, <https://biozoojournals.ro/nwjz/content/v14n1/nwjz_e171702_Jakubas.pdf>
18. Jägerbrand, AK, Antonson, H & Ahlström, C 2018, 'Speed reduction effects over distance of animal-vehicle collision countermeasures – a driving simulator study', *European Transport Research Review*, vol. 10, no. 40, viewed 15 January 2021, <https://etrr.springeropen.com/articles/10.1186/s12544-018-0314-8>.
19. Jägerbrand, AK, & Gren, IM 2018, 'Consequences of Increases in Wild Boar-Vehicle Accidents 2003–2016 in Sweden on Personal Injuries and Costs', *Safety*, vol. 4, no. 53, pp. 1-12, viewed 18 January 2021, < https://doi.org/10.3390/safety4040053>.

20. Jägerbrand, AK, & Sjöbergh, J 2016, 'Effects of weather conditions, light conditions, and road lighting on vehicle speed', *Springerplus*, vol. 5, no. 505, viewed 19 January 2021, <https://springerplus.springeropen.com/articles/10.1186/s40064-016-2124-6>.

21. Kitowski, I, Letowski, J, & Kepowicz, M 2014, 'Frequency, phenology and ecological factors in roe deer (Capreolus capreolus Linnaeus, 1758) – vehicle collisions in the Lublin County (East Poland) in the light of the police data', Annales Universitatis Mariae Curie-Skłodowska, Sectio EE: Zootechnica, vol. 32, pp: 9-17, viewed 18 January 2021, <https://czasopisma.up.lublin.pl/index.php/jasbb/article/view/1105>

22. Lagos, L, Picos, J, & Valero, E 2012, 'Temporal pattern of wild ungulate-related traffic accidents in northwest Spain', *European Journal of Wildlife Research*, vol.58, pp. 661-668, viewed 17 January 2021, <https://link.springer.com/article/10.1007/s10344-012-0614-6>.

23. Laurance, WF, Clements, GR, Sloan, S, Connell, CSO, Mueller, ND, Goosem, M, Venter, C, Edwards, DP, Phalan, B, Balmford, A, Ree, RVD, & Arrea, IB 2014, 'A global strategy for road building', *Nature*, vol. 513, pp. 229–232, viewed 28 March 2021, <https://www.nature.com/articles/nature13717>.

24. Langbein, J, Putman, RJ, & Pokorny, B 2011, 'Road traffic accidents involving ungulates and available measures for mitigation. In: Ungulate Management in Europe: Problems and Practices', 215-259. Cambridge University Press, Cambridge, UK viewed 18 January 2021, <https://www.researchgate.net/publication/284890667_Traffic_Collisions_involving_deer_and_other_ungulates_in_Europe>.

25. Langley, RL, Higgins, AS & Herrin, KB 2006, 'Risk factors Associated with Fatal Animal-Vehicle Collisions in the United States, 1995-2004', *Wilderness and Enviromental Medicine*, vol.17, no.4, pp. 229-239, viewed 16 January 2021, <https://pubmed.ncbi.nlm.nih.gov/17219786/>.

26. Lietuvos draudimas, viewed 10 March 2021, <https://www.ld.lt/>.

27. Malo, JE, Suarez, F & Diez, A 2004, 'Can we mitigate animal–vehicle accidents using predictive models? ',*Journal of Applied Ecology*, vol. 41, pp.701-710, viewed 16 January 2021, <https://besjournals.onlinelibrary.wiley.com/doi/10.1111/j.0021-8901.2004.00929.x>

28. Malin, F, Norros, I & Innamaa, S 2019, 'Accident risk of road and weather conditions on different road types', *Accident Analysis & Prevention*, vol. 122, pp. 181-188, viewed 16 January 2021, <https://www.sciencedirect.com/science/article/pii/S0001457518308455>.

29. Mainguy, J, & Côté, SD 2008, 'Age and state dependent reproductive effort in male mountain goats, Oreamnos americanus', *Behavioral Ecology and Sociobiology*, vol. 62, pp. 935–943, viewed 10 April 2021, <https://link.springer.com/article/10.1007/s00265-007-0517-9>.

30. María, AS, & Tellería, JL 2015, 'Wildlife-vehicle collisions in Spain', *European Journal of Wildlife Research*, vol. 61, no.3, pp. 339–406, viewed 16 January 2021, <https://www.researchgate.net/publication/273758330_Wildlife-vehicle_collisions_in_Spain>.

31. Meijer, JR, Huijbregts, MAJ, Schotten, KCGJ, & Schipper, AM 2018, 'Global patterns of current and future road infrastructure', *Environmental Research Letters*, vol. 13, no. 6, pp. 1-10, viewed 19 January 2021, <https://iopscience.iop.org/article/10.1088/1748-9326/aabd42>.

32. Morelle, K, Lehaire, F, & Lejeune, P 2013, 'Spatio-temporal patterns of wildlife-vehicle collisions in a region with a high-density road network', *Nature conservation*, vol. 5, pp. 53-73, viewed 19 January 2021, <https://natureconservation.pensoft.net/articles.php?id=1345>.

33. Niemi, N, Rolandsen, CM, Neymann, W, Kukko, T, Tiilikainen, R, Pusenius, J, Solberg, EJ & Ericsson, G 2017, 'Temporal patterns of moose-vehicle collisions with and without personal injuries ',*Accident Analysis & Prevention*, vol. 98, pp. 167-173, viewed 16 January 2021, <https://www.sciencedirect.com/science/article/pii/S0001457516303542>.

34. Pépin, D, Morellet, N, & Goulard, M 2009, 'Seasonal and daily walking activity patterns of free-ranging adult red deer (*Cervus elaphus*) atthe individual level', *European Journal of Wildlife Research*, vol. 55, no.5, pp. 479–486, viewed 10 April 2021, <DOI:10.1007/s10344-009-0267-2>.

35. Putzu, N, Bonetto, D, Civallero, V, Fenoglio, S, Meneguz, PG, Preacco, N, & Tizzani, P 2014, 'Temporal patterns of ungulate-vehicle collisions in a subalpine Italian region', *Italian Journal of Zoology*, vol. 81, pp. 463-470, viewed 17 January 2021, <https://www.tandfonline.com/doi/full/10.1080/11250003.2014.945974>.

36. Richard, JH, White, KS, & Côté, SD 2014, 'Mating effort and space use of an alpine ungulate during the rut', *Behavioral Ecology and Sociobiology*, vol. 68, pp. 1639–1648, viewed 10 April 2021, <10.1007/s00265-014-1772-1>.

37. Sáenz, SMA, & Tellería, JL 2015, 'Wildlife-vehicle collisions in Spain', *European Journal of Wildlife Research*, vol. 61, pp. 399–406, viewed 18 January 2021, <https://link.springer.com/article/10.1007/s10344-015-0907-7>.

38. Stott, J, Stephenson, M, & Hanford, K 2018, *Effects of movement and activity behavior in a pasture system compared to time*, Nebraska Beef Cattle report no. 955, pp. 72–74, Lincoln, Nebraska.

39. Sullvian, JM 2011, 'Trends and characteristics of animal-vehicle collisions in the United States'. *Journal of Safety Research*, vol.42, no.1, pp. 9-16, viewed 18 January 2021, <https://www.sciencedirect.com/science/article/pii/S0022437510001234>.

40. Torsten, H, Jörg, M, Leonhard, H, Lisa, M, & Atle, M 2015, 'Temporal patterns of deer–vehicle collisions consistent with deer activity pattern and density increase but not general accident risk', *Accident Analysis and Prevention*, vol. 81, pp. 143-152, viewed 19 January 2021, <https://doi.org/10.1016/j.aap.2015.04.037>.

41. Van, RH, & Hutson, G 1983, The behaviour of free-ranging cattle on an alpine range in Australia, *Journal of Range Management*, vol. 36, no. 6, pp.740–743.

42. Vazquez, C, Rowcliffe, MJ, Spoelstra, K, & Jansen, PA 2019, 'Comparing diel activity patterns of wildlife across latitudes and seasons: Time transformations using day length', *Methods in Ecology and Evolution*, vol. 10, no. 12, pp. 2057-2066, viewed 19 January 2021, <https://doi.org/10.1111/2041-210X.13290>.

43. Wilkins, CD, Kockelman, KM, & Jiang, N 2019, 'Animal-vehicle collisions in Texas: How to protect travelers and animals on roadways', *Accident Analysis & Prevention*, vol. 131, pp. 157-170, viewed 19 January 2021, <https://doi.org/10.1016/j.aap.2019.05.030>.

44. Willisch, CS, & Ingold, P 2007, 'Feeding or resting? The strategy of ruttingmale Alpine chamois', *Ethology*, vol. 113, pp. 97–104, viewed 10 April 2021, <https://doi.org/10.1111/j.1439-0310.2006.01301.x>.

ABBREVIATIONS

AVCs – Animal-vehicle collisions

UVCs – ungulate – vehicle collisions

WVCs – wildlife-vehicle collisions

DVCs – domestic-vehicle collisions

MVCs – moose vehicle collisions