Eur J Wildl Res (2016) 62:787–791
DOI 10.1007/s10344-016-1042-9

SHORT COMMUNICATION

Temporal patterns of wild boar-vehicle collisions in Estonia, at the northern limit of its range

Maris Kruuse[1] · **Sven-Erik Enno**[1] · **Tõnu Oja**[1]

Received: 26 July 2016 / Revised: 4 August 2016 / Accepted: 12 August 2016 / Published online: 19 August 2016

Abstract Collisions with large ungulates are considered to be a serious problem in many countries over the world. These incidents create a rising concern in traffic safety and cause extensive ecological and economical damage. In this paper, we investigate temporal distribution of wild boar-related traffic accidents—seasonal, weekday and diurnal patterns. We analysed 918 collision reports collected by Estonian environmental emergency hotline, police and insurance companies during 2004–2013. Notable increase in wild boar abundance and harvest numbers appeared during the study period, leading not only to higher road collision risk but also having been referred to African swine fever emergence in the area. Our results suggest that the highest risk for collision is in October, November and December. More wild boar-vehicle collisions (WBVCs) occur during weekends with a peak on Friday probably due to higher traffic volumes. Regarding diurnal patterns, most of WBVCs occur after sunset, and the frequency of collisions remains high until late night. Knowledge about temporal patterns of WBVCs is important, as it may help to improve suitable mitigation measures.

Keywords Road ecology · Wild boar-vehicle collisions · Temporal patterns · Traffic safety

Introduction

Wild boar (*Sus scrofa*) numbers have shown a continuous growth throughout Europe during the recent decades (Massei et al. 2014); hence, numerous studies have demonstrated increasing conflicts between wild boar populations and human activity, including research on wild boar-vehicle collisions (e.g. Balčiauskas and Balčiauskienė 2008; Lagos et al. 2012; Morelle et al. 2013; Rodríguez-Morales et al. 2013; Putzu et al. 2014). Although Estonia is situated close to the northern boundary of the species' range, the wild boar population has experienced notable increase during recent decades (Estonian Environment Agency 2014) mainly due to supplementary feeding by hunters (Oja et al. 2014).

Wild boar incidents represent only 7 % of the total number of the country's registered wildlife-vehicle collisions (WVCs) during the last decade; however, the increase of overall numbers of WBVCs in Estonia is alarming. In 1985–1990 on average, 79 WBVCs were registered each year (Mardiste 1992). In recent years, around 137 accidents with wild boar have been registered annually (Estonian Environmental Inspectorate, Estonian Police and Border Guard Board, unpublished data).

Therefore, proper knowledge about temporal and spatial patterns of WBVCs is essential to improve measures for reducing the collision numbers and collateral socio-economic and environmental damage. The aim of this study is to provide the first results of temporal patterns of wild boar-vehicle collisions for Estonia, using thoroughly reviewed data obtained from several authorities. We analysed seasonal, weekday and diurnal patterns of WBVCs.

Electronic supplementary material The online version of this article (doi:10.1007/s10344-016-1042-9) contains supplementary material, which is available to authorized users.

✉ Maris Kruuse
maris_kruuse@yahoo.com

1 Department of Geography, Institute of Ecology and Earth Sciences, University of Tartu, Vanemuise 46, 50410 Tartu, Estonia

Materials and methods

Study area

Our study area (45,227 km^2) covers the whole Estonia, including islands. It is located between 57° 30′–59° 30′ N and 21°–28° E (Online Resource 1). The landscape is mainly flat with the mean altitude of 50 masl. Approximately 50 % of the country is covered with forests (dominant tree species Scots Pine (*Pinus sylvestris*) 32 %, Silver Birch (*Betula pendula*) 31 % and Norway Spruce (*Picea abies*) 17 %), 30 % is agricultural land, 6 % internal waters and 5 % bogs (Estonian Environment Agency 2014). According to the 2011 census, Estonia has an average population density of 30 people per km^2 but the distribution is very uneven. Majority of the population (43 %) is concentrated to the capital Tallinn and surrounding Harju County whereas 55 % of Estonian territory is uninhabited (Statistics Estonia 2015). Road network consists of national (28 %), local (41 %) and private and forest roads (31 %) with total length of 58 787 km and an average road density of 1.3 km/km^2 (Estonian Road Administration 2014). National roads are divided to main (10 %, 1607 km), basic (15 %, 2406 km) and secondary (75 %, 12 476 km) roads. The speed limit on the national roads is usually 90 km/h all year round and 110 km/h in summer on some short four-lane road sections. Average traffic density was 812 vehicles per day on all the national roads and 4388 vehicles per day on the main roads in 2013 (Kaal et al. 2014). The number of motor vehicles in Estonia has increased from 571,000 in 2004 to 750,000 in 2013 (Statistics Estonia 2015).

Collision data

We used three available data sets from the period of 2004–2013 in our study: (i) the list of environmental emergency hotline calls—the information received mostly from road users but also from hunters and police officers is gathered by the Environmental Inspectorate (EI). According to law, a driver who hits a big game animal species has to report to the EI or local hunters; (ii) data about WVCs resulting in human injuries collected by the police; (iii) data about WVCs resulting in property damage collected by the police and insurance companies. In this instance, only the cases when the vehicle had comprehensive insurance were notified, as the regular obligatory car insurance does not cover damage caused by wild animals. Accidents involving other species than wild boar were excluded from the analysis. Remaining entries were thoroughly reviewed. Duplications (the same WBVC was registered by both, the EI and the police) were removed. On the basis of the description of the case, reports were divided into three groups: (i) A—accurate (the accident had happened immediately prior to the notification), (ii) N—not sure (the accident could have happened immediately prior to the notification or slightly earlier), and (iii) I—inaccurate (the accident had happened earlier; for example, someone noticed an animal carcass in a road ditch). Only 'accurate' and 'not sure' entries were selected for further analysis, resulting in a data set of 918 WBVC reports.

Data analysis

Firstly, we analysed seasonal and weekday patterns of WBVCs. We set the hypothesis that the distribution of collisions would be different from the expected average for each of these timescales. The chi-square goodness-of-fit test was used to check the hypothesis (van Emden 2008). Statistical analysis was carried out using R version 3.1.2 (R Core Team 2014).

Secondly, diurnal patterns of WBVCs were examined. Before the analysis, all WBVC times were converted into Eastern European Time (UTC + 2 h), hereafter referred to as local time (LT). This step was necessary as summer incidents were originally registered in daylight saving time.

For all WBVCs, the following astronomical parameters were computed: time in seconds to sunrise and after sunset, altitude of the sun and the moon in degrees. *Ephem*, an astronomy module of *Python* programming language, was used for the calculations. A special script was developed on the basis of *Ephem*. The script inputs geographical coordinates and times of WBVCs and returns their astronomical parameters. The exact geographical coordinates of collisions are not registered; thus, the coordinates of the approximate centres of Estonian counties were used as accident locations. As Estonian counties are typically much less than 100 km across, the sunrise and sunset times do not differ by more than a few minutes within the counties. Similarly, the altitude of the sun and the moon can vary by no more than one degree. Thus, the use of the county centres is accurate enough considering that the data of the WBVCs is not free of a small timing errors in a range of a few minutes. The traditional definition of twilight is used in the present study. According to the definition, twilight is the time period when the altitude of the sun is between 0 and −18°. There are three subcategories of twilight: civil twilight (brightest, the sun is 0–6° below the horizon), nautical twilight (the sun is 6–12° below the horizon) and astronomical twilight (darkest, the sun is 12–18° below the horizon).

Results and discussion

The variation in numbers of registered WBVCs was noticeable during 2004–2013 (Fig. 1). The lowest number of collisions was registered in 2004 (16) and the largest number in 2013 (174).

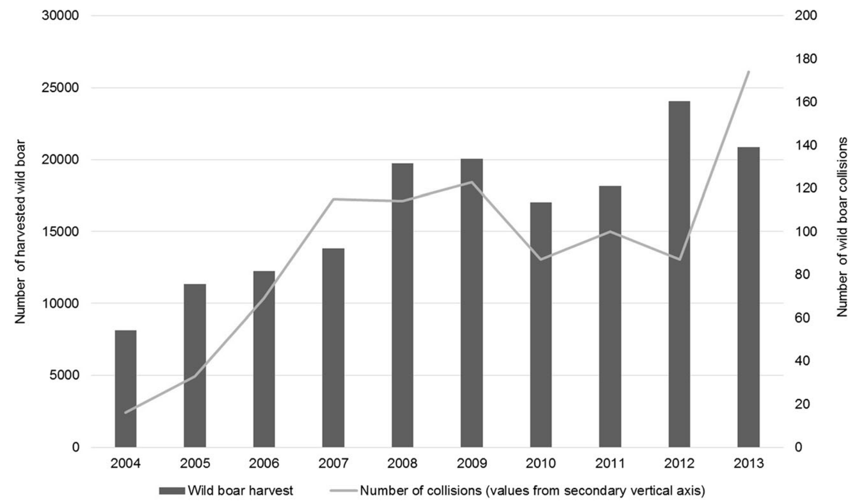

Fig. 1 Wild boar harvest and collision numbers in Estonia, 2004–2013 (Estonian Environment Agency 2014; Estonian Environmental Inspectorate, Estonian Police and Border Guard Board)

Supposedly, the dramatic increase in accident reports during 2004–2007 was due to several reasons. As there was no wildlife-vehicle collision reporting system in Estonia before 2000, one reason was probably rising awareness of road users, who started to report the collisions more often. Secondly, the occurrence of ungulate collisions increases with higher traffic volume but this relationship is not linear (Romin and Bissonette 1996; Zuberogoitia et al. 2014; Valero et al. 2015). According to Thurfjell et al. (2015) the collision risk related to wild boar is highest at intermediate traffic levels. Average traffic density on main roads increased from 3520 vehicles per day in 2004 to 4740 vehicles per day in 2007.

Furthermore, the number of wild boar has risen from 17,000 in 2004 to 22,320 in 2013 with a peak of 23,450 in 2009 (Estonian Environment Agency 2014). This is likely a result of extensive supplementary feeding primarily in the wintertime (Oja et al. 2014) and avoidance of hunting adult females, which both have been common management practise in Estonia during the 2000s (Veeroja and Männil 2014). Such high density of wild boar population has also been associated to proliferation of African swine fever virus (ASFV). As several occasions of ASFV were diagnosed in Latvia, Lithuania and Poland earlier in 2014, the first outbreak in Estonia, near Latvian border, was recorded in September 2014. Supposedly, the infection spread to South Estonia from Latvia by free-roaming wild boar (Nurmoja 2016; Oļševskis et al. 2016). However, outbreaks in northeastern part of the country have been linked to human activity—through infected meat and food waste (Nurmoja 2016).

In monthly distribution, we noticed statistically significant deviation from the expected average. WBVCs ($\chi^2 = 455.7$, df = 11, $p < 0.001$, $n = 918$) peak in September–December with the highest frequency in October and are the least frequent in February, April and May (Fig. 2a). This pattern is similar to Lithuania (Balčiauskas and Balčiauskienė 2008), Wallonia in southern Belgium (Morelle et al. 2013) and also Italy (Putzu et al. 2014). In Galicia (Spain) and southern Sweden, the peak occurs 1 month later from October to January (Lagos et al. 2012; Rodríguez-Morales et al. 2013; Thurfjell et al. 2015). As suggested by Thurfjell et al. (2015), wild boar-vehicle collisions happen when traffic is at intermediate levels and female wild boars are active. These two factors probably meet during the long and dark late fall/winter nights. Poor light and road surface conditions (e.g. rain, snow, ice) may also increase the collision risk (Neumann et al. 2012).

The WBVCs were not uniformly distributed between days of the week (Fig. 2b). More incidents occur at weekends with a notable peak on Friday, and the difference from the expected average is statistically significant ($\chi^2 = 17.0$, df = 6, $p < 0.01$, $n = 918$). The lowest collision risk was observed on Thursday. High collision risk at weekends is presumably related to traffic volume as no biological, ecological or behavioural factors depending on weekdays are known (Steiner et al. 2014; Hothorn et al. 2015). We did not manage to obtain detailed traffic data for all roads but traffic count studies carried out in 2006 and 2007 on one of the main roads (E263 Tallinn-Tartu-Võru-Luhamaa) suggested that traffic volume increases sharply on Friday afternoon (Koonik 2008; see also Järv et al. 2012). This is in compliance with other studies that relate the weekend ungulate-vehicle collision peaks to increased traffic (Dussault et al. 2006) and the drivers' habits (Lagos et al. 2012). In Estonia, numerous city dwellers drive to their country houses for the weekend. On Friday, people also drive to the parties at night and return early in the morning like discussed by Lagos et al. (2012).

Regarding diurnal patterns, the frequency of wild boar collisions increases suddenly if the sun is more than 6–7° below the horizon and remains high even in the complete darkness when the sun is more than 18° below the horizon (Fig. 2a). As mostly the main activity of ungulates is related to

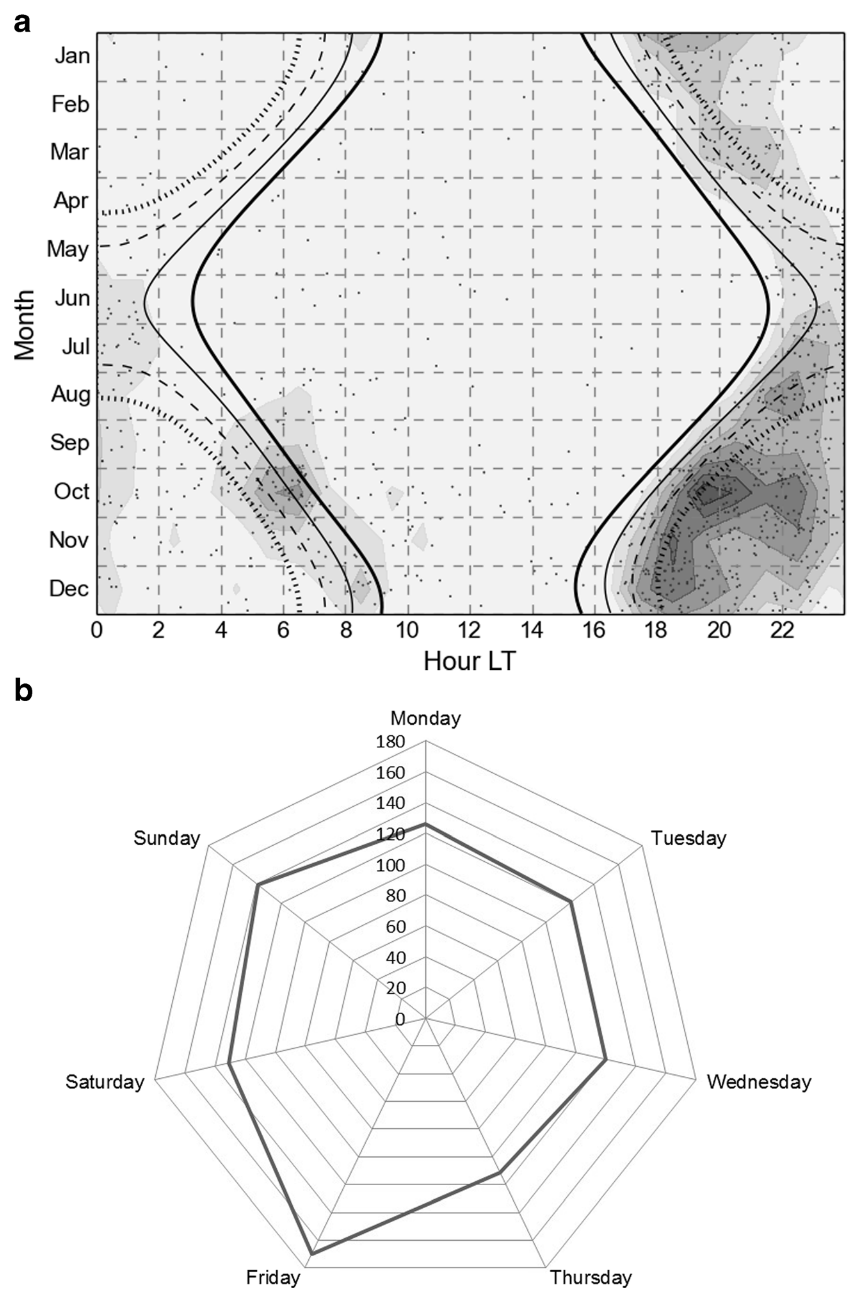

Fig. 2 **a** Annual course of diurnal distribution of WBVCs with a daily step. Individual WBVCs are represented as *dots* and *darker background shading* indicates higher frequency of WBVCs. *Thick lines* show the sunrise and sunset times. Civil, nautical and astronomical twilight times are bounded by *thin*, *dashed* and *dotted lines*, respectively. **b** Weekday distribution of WBVCs

sunrise and sunset, wild boars are generally known as nocturnal animals (Boitani et al. 1994; Thurfjell et al. 2015). This is in line with our finding that the majority of collisions related to this species occurred in nighttime.

Conclusion

Collisions with large free-ranging animals are an increasing problem all over the world. Significant temporal variations in wildlife collisions occur in different regions (Groot Bruinderink and Hazebroek 1996). Thus, it is important to identify the local patterns. Both spatial and temporal data are necessary for choosing suitable mitigation measures. We investigated seasonal, weekday and diurnal patterns of traffic accidents related to wild boar. Accurate temporal data enables to warn road users about periods of high collision risk by using temporary electronic warning signs, mobile apps or road safety campaigns, for example.

Acknowledgments This research was supported by the project IUT2-16 'Global Warming and Material Cycling in Landscapes. Global Warming- and Human-Induced Changes of Landscape Structure and Functions: Modelling and Ecotechnological Regulation of Material Fluxes in Landscapes', financed by the Estonian Research Council.

We are grateful to the Estonian Environmental Inspectorate and Estonian Road Administration for providing the collision data. Special thanks to Villu Lükk and Sirje Lilleorg from the Estonian Road Administration for their useful comments about the data, and the anonymous reviewers for constructive criticism on an earlier draft of this manuscript. We would also like to thank all road users, hunters and police officers who have reported collisions or animal carcasses on the road.

References

Balčiauskas L, Balčiauskienė L (2008) Wildlife–vehicle accidents in Lithuania, 2002–2007. Acta biol univ Daugavpil 8(1):89–94

Boitani L, Mattei L, Nonis D, Corsi F (1994) Spatial and activity patterns of wild boars in Tuscany, Italy. J Mammal 75:600–612

Dussault C, Poulin M, Courtois R, Ouellet J-P (2006) Temporal and spatial distribution of moose-vehicle accidents in the Laurentides Wildlife Reserve, Quebec, Canada. Wildl Biol 12(4):415–425

Estonian Environment Agency (2014) Aastaraamat Mets 2013. (Yearbook Forest 2013. In Estonian). Available at http://www.keskkonnainfo.ee/failid/Mets_2013.pdf. Accessed 22 December 2015

Estonian Road Administration (2014) Aastaraamat 2014. (Yearbook 2014. In Estonian). Available at https://issuu.com/maanteeamet/docs/aastaraamat_2014. Accessed 22 December 2015

Groot Bruinderink GWTA, Hazebroek E (1996) Ungulate traffic collisions in Europe. Conserv Biol 10:1059–1067

Hothorn T, Müller J, Held L, Möst L, Mysterud A (2015) Temporal patterns of deer-vehicle collisions consistent with deer activity pattern and density increase but not general accident risk. Accid Anal Prev 81:143–152

Järv O, Ahas R, Saluveer E, Derudder B, Witlox F (2012) Mobile phones in a traffic flow: a geographical perspective to evening rush hour traffic analysis using call detail records. PLoS ONE 7(11):e49171. doi:10.1371/journal.pone.0049171

Kaal L, Metlitski S, Jentson M, Teder A (2014) Liiklusloenduse tulemused 2013. aastal. (Results of traffic counts in 2013. In Estonian). AS Teede Tehnokeskus, Tallinn

Koonik V (2008) Tallinn-Tartu-Võru-Luhamaa põhimaanteel üle 12 m pikkuste sõidukite ja autorongide liikluse reedeti kella 13.00-st kuni kella 20.00-ni kehtinud piirangu (eksperimendi) analüüs. (Analysis of experimental road usage restriction for vehicles over a length of 12 m and road trains on Fridays from 13:00 to 20:00. In Estonian). Estonian Road Administration. Available at http://www.mnt.ee/?id=15956. Accessed 22 December 2015

Lagos L, Picos J, Valero E (2012) Temporal pattern of wild ungulate-related traffic accidents in northwest Spain. Eur J Wildl Res 58:661–668

Mardiste M (1992) Liiklusõnnetused metsloomadega. (Traffic accidents related to wild animals. In Estonian). Eesti Loodus 5:290–295

Massei G, Kindberg J, Licoppe A, Gačić D, Šprem N, Kamler J, Baubet E, Hohmann U, Monaco A, Ozolinš J, Cellina S, Podgórski T, Fonseca C, Markov N, Pokorny B, Rosell C, Náhlik A (2014) Wild boar populations up, numbers of hunters down? A review of trends and implications for Europe. Pest Manag Sci 71:492–500

Morelle K, Lehaire F, Lejeune P (2013) Spatio-temporal patterns of wildlife-vehicle collisions in a region with a high-density road network. Nat Conserv 5:53–73

Neumann W, Ericsson G, Dettki H, Bunnefeld N, Keuler NS, Helmers DP, Radeloff VC (2012) Difference in spatiotemporal patterns of wildlife road-crossings and wildlife-vehicle collisions. Biol Conserv 145:70–78

Nurmoja I (2016) Sigade Aafrika katk—uuringutest ja tulemustest. (African swine fever—research and results. Presentation for hunters. In Estonian). Estonian Veterinary and Food Laboratory. Available at http://www.ejs.ee/wp-content/uploads/2016/03/SAK-uuringutest-VTL_-Imbi-Nurmoja.pdf. Accessed 17 June 2016

Oja R, Kaasik A, Valdmann H (2014) Winter severity or supplementary feeding – which matters more for wild boar? Acta Theriol 59:553–559

Oļševskis E, Guberti V, Seržants M, Westergaard J, Gallardo C, Rodze I, Depner K (2016) African swine fever virus introduction into the EU in 2014: experience of Latvia. Res Vet Sci 105:28–30

Putzu N, Bonetto D, Civallero V, Fenoglio S, Meneguz PG, Preacco N, Tizziani P (2014) Temporal patterns of ungulate-vehicle collisions in a subalpine Italian region. Ital J Zool 81:463–470

R Core Team (2014) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, http://www.R-project.org/

Rodríguez-Morales B, Díaz-Varela ER, Marey-Pérez MF (2013) Spatiotemporal analysis of vehicle collisions involving wild boar and roe deer in NW Spain. Accid Anal Prev 60:121–133

Romin LA, Bissonette JA (1996) Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildl Soc Bull 24:276–283

Statistics Estonia (2015) Statistical database. Available at http://pub.stat.ee/px-web.2001/Dialog/statfile1.asp. Accessed 22 December 2015

Steiner W, Leisch F, Hackländer K (2014) A review on the temporal pattern of deer-vehicle accidents: impact of seasonal, diurnal and lunar effects in cervids. Accid Anal Prev 66:168–181

Thurfjell H, Spong G, Olsson M, Ericsson G (2015) Avoidance of high traffic levels results in lower risk of wild boar-vehicle accidents. Landsc Urban Plan 133:98–104

Valero E, Picos J, Álvarez X (2015) Road and traffic factors correlated to wildlife-vehicle collisions in Galicia (Spain). Wildl Res 42:25–34

van Emden HF (2008) Statistics for terrified biologists. Blackwell Publishing Ltd, UK

Veeroja R, Männil P (2014) Population development and reproduction of wild boar (*Sus scrofa*) in Estonia. Wildl Biol Pract 10(3):17–21

Zuberogoitia I, del Real J, Torres JJ, Rodríguez L, Alonso M, Zabala J (2014) Ungulate vehicle collisions in a peri-urban environment: consequences of transportation infrastructures planned assuming the absence of ungulates. PLoS ONE 9(9):e107713. doi:10.1371/journal.pone.0107713