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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

Frekwencja, fenologia i czynniki ekologiczne kolizji saren (*Capreolus capreolus* Linnaeus, 1758) z pojazdami na obszarze powiatu lubelskiego (wschodnia Polska) w świetle danych policyjnych

Summary. Road roe deer – vehicle collisions (RVCs) remain a serious challenge to road traffic in Europe. The study covered 153 cases of roe deer-vehicle collisions reported to the police in the Lublin County (east Poland) in 2008–2011. The highest number of RVCs (65.3%) were reported in spring and autumn. According to the available data, the highest number of collisions took place in May and October. No significant differences in collision frequency were found between days of the week. The frequency of collisions resulting in roe deer getting killed reached its peak in May, and the largest number of cases in which roe deer individuals were killed was reported in time intervals connected with sunrise and sunset. Non-local drivers, unfamiliar with the Lublin County, collided with roe deer more frequently compared to local drivers, who knew the area they were driving in. An increase in the road network density favoured an increase in the frequency of roe deer-vehicle collisions.

Keywords: roe deer-vehicle collisions, road mortality, road traffic

INTRODUCTION

Road collisions with animals remain one of the most serious environmental challenges for road traffic in Europe and worldwide. Admittedly, they take different forms and not all of them constitute a threat to road traffic [Markolt *et al*. 2012, Covaciu-Marcov *et al*. 2012, Gunson *et al*. 2012]. Still, some of the collisions are extremely dangerous and end up in people getting killed or injured. According to Borowska's report [2010], 40 people were killed and over 1,500 were injured in wildlife-vehicle collisions in 2000–2009. Among vehicle-animal collisions, those that deserve special attention are collisions with different species of deer. Analysis of data from the late 1990s originated in West and Central Europe. Nearly half a million deer are estimated to be hit by vehicles yearly, resulting in approximately 300 human fatalities [Groot-Bruinderink and Hazebroek 1996]. Fresh data showed that the number of deer-vehicle collisions per year is estimated to exceed 140,000 in Germany, 55,000 in Sweden, 35,000 in Austria, 30,000 in Britain, and 10,000 in Switzerland [Langbein and Putman 2005].

A valuable source of data concerning wildlife-vehicle collisions can be police records [Skolving 1987, Hartwig 1991]. However, the limitation of this source of information may be the percentage of collisions that is actually reported to the Police. Skolving [1987] stated that only 50% of all wildlife accidents in Sweden were reported to the Police. In Southeast Michigan (USA), the corresponding figure was 46% [Marcoux and Riley 2010].

Among wildlife-vehicle collisions, those that deserve special attention are cases involving roe deer *Capreolus capreolus*, constituting the highest percentage of wildlife collisions in Europe [Madsen *et al*. 2002, Pokorny 2006, Balciauskas 2009, Markolt *et al*. 2012]. Comprehensive studies from Poland analysing the phenomenon of roe deer-vehicle collisions (RVCs) are scarce, even though these collisions are a considerable threat to road traffic safety, reduce the population of these mammals, and constitute a challenge for veterinary medicine [Czyżowski *et al*. 2011, Karpiński *et al.* 2012, Flis and Galicki 2013]. The aim of the present study was to carry out a comprehensive analysis of roe deer-vehicle collisions reported to the police from area of the Lublin County (East Poland) covering their frequency, phenology, and the determinants of their occurrence.

STUDY AREA AND METHODS

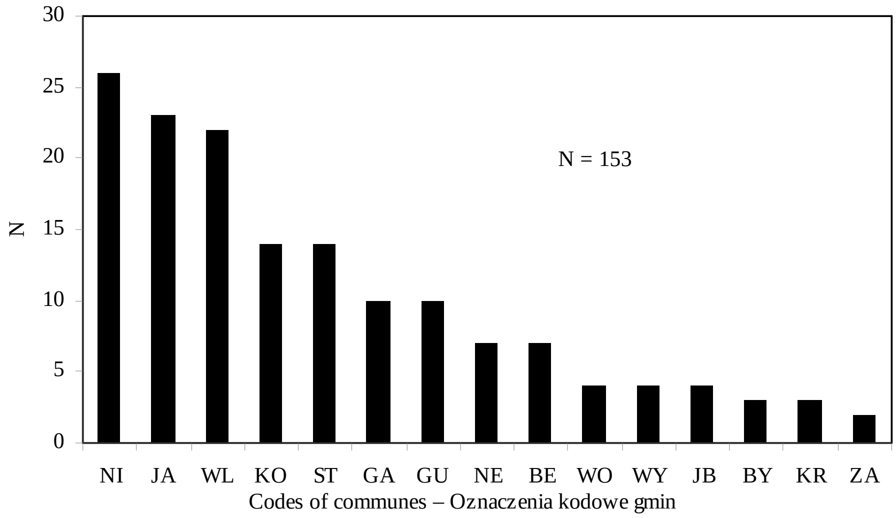
The analysed material comes from the Lublin County (East Poland), with an area of 1,678 km^2, which is about 0.5% of Poland's total area. Except for a small eastern part, the county is situated around the city of Lublin (150 km^2, about 400,000 residents). The area of the Lublin County comprises only two towns (Bełżyce, Bychawa) and 354 villages. Bełżyce has around 11,000 residents and Bychawa has approximately 5,300. The county (*powiat*) is divided into 15 smaller administrative units – communes (in Polish: *gmina*). Seven of these directly border on Lublin: Wólka, Niemce, Jastków, Konopnica, Niedrzwica Duża and Strzyżewice have a typically suburban character. The remaining communes are definitely more rural. The county is inhabited by nearly 144,000 people, which gives a population density of 86.4 individuals per km^2. The area is poor in water. Most water is collected by the River Bystrzyca and its tributaries, and then carried to the Wieprz River. The county has a typically agricultural character. Farmlands occupy as much as 76.3% of its area whereas forests take up a mere 9.7%. An important element of the county's environment is two landscape parks: the Krzczonowski Landscape Park and the Kozłowiecki Landscape Park, with large dense forest areas in them, particularly in the latter one.

The study analyses 153 cases of RVCs from 2008–2011 that police data report. Spring months were understood to mean the period from March to May, summer months were those from June to August, and autumn months – from September to November. December, January, and February were understood to be winter months. When analysing cases of collisions, local vehicles were understood as those with registration numbers of the Lublin County or the city of Lublin. Local drivers were assumed to be familiar with the area they were driving in. Non-local vehicles were understood as those whose registration numbers indicated that they came from outside the Lublin County or the city of Lublin. In their cases, it was highly probable that the familiarity of drivers with the area was much lower compared to that of local drivers. Data on road network density in particular communes of the Lublin County was used follow Statistical Yearbook of Lublin Voivodship [Urząd Statystyczny w Lublinie 2010]. Frequencies were compared using Chi-square and G-tests, and correlations were ascertained using Spearman's rank order coefficient (r_s) [Sokal and Rohlf 1981].

RESULTS

The number and spatial-temporal distribution of collisions

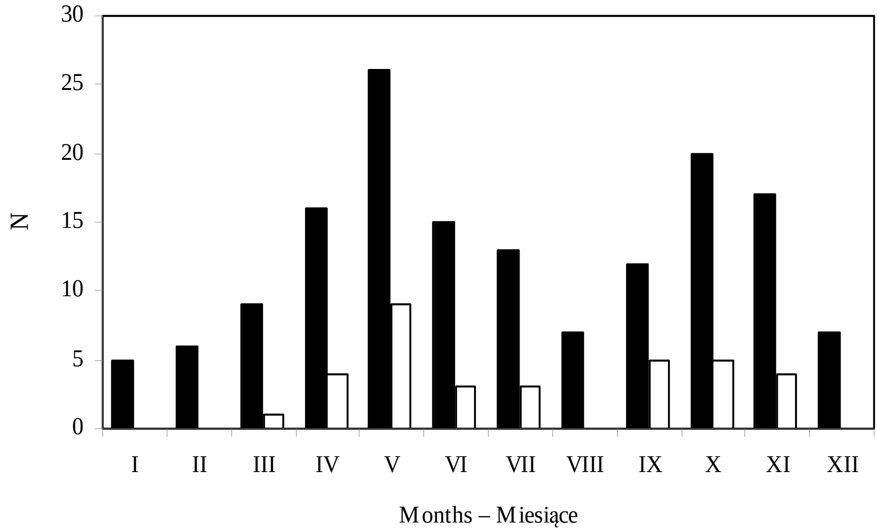
Out of 153 cases of RVCs, a decisive majority of collisions – as many as 116 (75.8%) – took place within the 7 communes directly bordering on Lublin. The largest number of collisions was reported in 3 communes bordering directly on the northern part of that city: Niemce, Jastków, and Wólka – 26, 23, and 22 cases, respectively (Fig. 1). They amounted to as much as 61.6% of all collisions recorded by the police within the county during the analysed period. In one commune – Borzechów – no collisions involving roe deer were reported in the analysed period.



N – number reported collisions – liczba raportowanych kolizji.
Codes of communes – Oznaczenia kodowe gmin: NI – Niemce, JA – Jastków, WL – Wólka, KO – Konopnica, ST – Strzyżewice, GA – Garbów, GU – Głusk, NE – Niedrzwica Duża, BE – Bełżyce, WO – Wojciechów, WY – Wysokie, JB – Jabłonna, BY – Bychawa, KR – Krzczonów, ZA – Zakrzew.

Fig. 1. Frequency of reported roe deer-vehicle collisions at Lublin County
Ryc. 1. Frekwencja zgłoszonych kolizji drogowych saren z pojazdami na obszarze powiatu lubelskiego

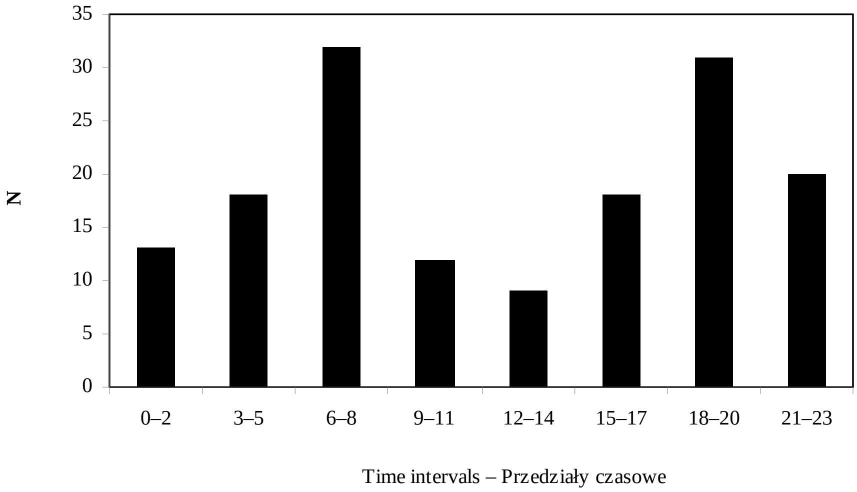
Cases of RVCs were also analysed in temporal context. The highest number of collisions were reported in spring – 51 (33.3%) – and in autumn: 49 (32.0%). In winter or summer months, there were only 18 (11.8%) and 35 (22.9 %) collisions, respectively. Differences between seasons in the frequency of reported collisions turned out to be significant (G-test: G = 20.26, $p < 0.001$). The months in which, in the light of the data available, the largest number of collisions happened were May and October, with 17.0% and 13.1% collisions reported, respectively (Fig. 2).



N – number reported collisions – liczba raportowanych kolizji.
Black columns: number of all collisions – Kolumny czarne: liczba wszystkich kolizji.
White columns: number of mortality cases – Kolumny białe: liczba przypadków zakończonych śmiercią saren.

Fig. 2. Monthly frequency of reported roe-deer vehicle collisions at Lublin County
Ryc. 2. Frekwencja zgłoszonych kolizji drogowych saren z pojazdami na obszarze powiatu lubelskiego w poszczególnych miesiącach roku

Frequencies of RVCs were also considered for different days of the week. The largest number of collisions (21.6%) took place on Wednesdays; fewer of them (17.6%) were reported on Mondays. The same number of RVCs were reported on Sundays and on Thursdays (13.7% in each case). Slightly fewer (13.1%) occurred on Tuesdays. The days with the lowest number of collisions turned out to be Fridays and Saturdays (9.8% and 10.5%, respectively). Differences between days of the week in the frequency of collisions were not significant, though: ($\chi^2 = 10.84$, df = 6, $p < 0.10$). However, when the joint frequency for the final three days of the week (Fridays, Saturdays and Sundays), with a total of 52 (34.0%) of cases, was compared with the predicted frequency assuming equal distribution of collisions between days (the figure being 66 cases for the last three days of the week just mentioned), differences turned out to be significant (G-test; G = 12.68, $p < 0.001$). In an hour-by-hour analysis of RVCs, day and night were divided into eight time bands. The frequency of all the collisions observed in specific time bands shows uneven frequency distribution diverging from predictions (χ^2 =26.19, df = 7, p < 0. 001) (Fig. 3).



N – number reported collisions – liczba raportowanych kolizji.

Fig. 3. Twenty four hour frequency of reported roe deer – vehicle collisions based on three hour intervals at Lublin County
Ryc. 3. Dobowa frekwencja zgłoszonych kolizji drogowych saren z pojazdami na obszarze powiatu lubelskiego w oparciu o trzygodzinne przedziały czasowe

It turned out that the largest number of accidents in which roe deer individuals were killed was reported in time bands connected with sunrise and sunset: 03:00–06:00, 06:00–09:00, and 18:00–21:00, when 18 (6), 32 (10), and 31 (5) of accidents happened, respectively. This amounts to 81 collisions in total (52.9% of all collisions) and 21 collisions resulting in at least one roe deer individual killed (61.8% of all such collisions).

The fate of roe deer after collisions

During a majority of RVCs – as many as 97 (63.4%) – roe deer were seen to leave the collision site. During the remaining 22 RVCs (14.4 %), roe deer individuals remained at the collision site, which suggested various degrees of injury and required taking them to veterinary clinics. In 34 other cases (22.2%), roe deer were killed on the spot. Collisions resulting in fatalities took place only during 8 months in the year, none having been reported in winter (the December–February period) or in August. The frequency of collisions resulting in roe deer getting killed reached its peak in May. A high frequency of roe deer getting killed in collisions with vehicles was also reported in September and in October **(**Fig 2.).

Such cases were reported within 9 of the county's communes, but as many as 73.5% of fatalities were reported in the communes of Niemce, Jastków, Wólka, Konopnica, and

Strzyżewice. There were differences between seasons in the frequency of collisions fatal to roe deer ($\chi^2 = 16.35$, df = 3, p < 0. 001). However, the difference between the frequencies of collisions observed in particular seasons and the frequencies predicted (assumed) on the basis of the total number of collisions turned out not to be significant: ($\chi^2 = 6.14$, df = 3, p = 0.17).

Vehicle origin

Out of the 153 vehicles colliding with roe deer, registration numbers were established for 99 (64.7%). Among the vehicles with known registration numbers, 56 came from Lublin district and the nearby city of Lublin. Consequently, they were classified as local vehicles – meaning those whose drivers may have been familiar with the area they were driving in. The remaining 43 vehicles came from outside this area and were accordingly classified as non-local. Local as well as non-local vehicles most often hit roe deer at night and at dusk: in 32 (57.1%) and 30 (69.8%) cases, respectively. For local vehicles, the frequency of collisions with roe deer reported to have happened at night and during the daytime did not diverge from predictions: ($\chi^2 = 1.14$, df =1, p = 0.285). By contrast, a highly significant difference was found for non-local vehicles: ($\chi^2 = 6.72$, df = 1, p = 0.009). It was also observed that an increase in road network density in particular communes of the Lublin County was accompanied by an increase in their percentage share in the total number of collisions considered in the study (r = 0.635, n = 15, p = 0.039).

DISCUSSION

When starting to analyse the factors that determine the frequency of roe deer-vehicle collisions in the studied area, it is necessary to point to the very large local increase in the population size of these mammals as their main cause. It reflects, locally, the unprecedented development of the population of these mammals that has been registered in Europe [Andersen *et. al.* 1998, Apollonio 2004, Battersby 2005, Burbaite and Csányi 2009, Kamieniarz and Panek 2008, Prentovic *et al*. 2012].

A strict relation is observed between roe deer population size and the frequency of road collisions involving roe deer. Balciauskas [2009] reports that extremely high correlation (r = 0.98, p < 0.001) was found between roe deer population numbers in the country and roe deer-vehicle accidents. Seiler [2004] showed strong correlations between the densities of vehicle collisions with roe deer and the average annual harvests of this species in 22 Swedish counties as well as in moose hunting districts within those counties.

Within the studied area, the largest number of roe deer-vehicle collisions took place in spring (particularly in May) and in autumn (in October). A study concerning the nearby city of Lublin [Czyżowski *et al*. 2011] confirms the existence of a very pronounced peak of collisions involving roe deer in May, when one fifth of the reported RVCs took place. In October, though, the frequency of collisions was found to be considerably lower. Yet, their percentage was much higher in the November–February period – 31.8%, compared to only 12.4% in our study concerning an area dominated by agricultural landscape. In Slovenia [Pokorny 2006] the risk for RVC varies over the year – the majority of crashes occurred in April and May; nevertheless, the risk is high during the summer and autumn as well. However, for the cases analysed there, temporal distribution of red deer-vehicle collisions has a pronounced peak in early autumn, which coincides fairly well with the rut period [Pokorny 2006]. Pintur *et al*. [2012] report from central Croatia that there are two equal peaks of RVCs there: April – May and October – November. Hungarian data collected on one of the most important motorways in Hungary in 2002 – 2009 showed that the peak of RVCs was in April and May, when 18.7% and 42.9% of N = 91 collisions took place, respectively. The smallest percentage of collisions (1.1%) was reported in December [Markolt *et al.* 2012]. Other researchers [Peris and Morales 2004] observe that the peak of roe deer mortality, found to be in May, seems to concern not only road accidents. They also point to the highest number of roe deer drawn into a deep concrete canal in May. This supports the opinion that roe deer are expressly vulnerable in the period of territorial fights [Pielowski 1988]. This corresponds with observations from Lithuania. In Lithuania, seasonally, roe deer were most frequently killed on roads from April to July and then from October to January [Balciauskas 2009].

Analysis of the collected material from East Poland in the context of the daily pattern of RVCs revealed that there are two temporal peaks of collisions, connected with dawn and dusk. The same holds for collisions resulting in roe deer getting killed. The daily distribution of roe deer-vehicle collisions in the Lublin County confirms that the risk of collisions is higher in the dark part of the day and is particularly high soon after sunset as well as early in the morning. The results obtained by other authors analysing roe deer collisions were similar. Discussing collisions taking place in Slovenia, Pokorny [2006] reports that the daily pattern of RVCs has a pronounced bimodal distribution with peaks at dawn (5 a.m. – 7 a.m.) and dusk (6 p.m. – 10 p.m.). Also data supplied by Diaz-Varela *et al*. [2011] from northwest Spain show that roe deer collisions apparently concentrated in the hours immediately after both sunrise and sunset.

Analysis of roe deer-vehicle collisions from the vicinity of Lublin demonstrated that an increase in the density of roads in particular communes correlated with an increase in their share in the total of all reported collisions. Likewise, analyses from Slovenia showed that the density of roads can determine the number of roe deer-vehicle collisions [Pokorny 2006].

Analyses of this material revealed the peak of fatal collision frequency to be in May, and no fatalities were found in winter. Pokorny [2006] presents very similar results from Slovenia, observing that the frequency of roe deer fatalities was the highest in April and May. Much like in our analyses: although there were cases of fatal collisions reported in winter, it was in February and March that the fewest of them occurred. Pokorny [2006] points to the connection between high frequency of fatal cases and the period of establishing territories.

Differences in collision frequency between days of the week turned out not to be significant to the cases we analysed. Marcoux and Riley [2010] found no pronounced difference in the frequency of white-tailed deer *Odocoileus virginanus* – vehicle collisions in southern Michigan between days of the week, either. Analysis of material from the vicinity of Lublin showed that drivers from outside the county tended to collide with roe deer more often at night, which undoubtedly resulted from failure to adjust speed to the conditions in unfamiliar area. Other authors also point to the high speed of vehicles as a significant factor conducive to deer-vehicle collisions [Skolving 1987, Groot-Bruinderink and Hazebroek 1996, Marcoux and Riley 2010].

CONCLUSIONS

1. The highest number of collisions was reported in spring and autumn.
2. An increase in road network density favoured an increase in the frequency of roe deer-vehicle collisions.
3. At night, non-local drivers, unfamiliar with the area they were driving in, hit roe deer more often compared to local drivers knowing the area better.
4. Analyses of roe deer-vehicle collisions should be continued due to the importance of this problem to road traffic safety.

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Streszczenie. Zderzenia pojazdów z sarnami pozostają poważnym wyzwaniem ruchu drogowego w Europie. Analizami objęto 153 przypadków kolizji z sarnami zgłoszonych policji na obszarze powiatu lubelskiego (wschodnia Polska) w latach 2008–2011. Największą liczbę kolizji (w sumie 65,3%) zgłoszono wiosną i jesienią. W świetle posiadanych danych najwięcej kolizji było w maju i październiku. Szczyt frekwencji kolizji prowadzących do śmierci saren przypadł na maj, a najwięcej przypadków zderzeń, podczas których sarny zostały zabite, zanotowano w przedziałach czasowych związanych ze wschodem lub zachodem słońca. Kierowcy obcy, nieznający terenu powiatu lubelskiego, częściej zderzali się nocą z sarnami niż kierowcy miejscowi, znający teren, po którym się przemieszczali. Wzrost zagęszczenia sieci drogowej sprzyjał wzrostowi frekwencji kolizji pojazdów z sarnami.

Słowa kluczowe: kolizje pojazdów z sarnami, śmiertelność drogowa, ruch drogowy