DEER-VEHICLE COLLISIONS IN LUBELSKIE REGION IN POLAND. SAFETY COEFFICIENTS

TAJCHMAN, K.[1*] – GAWRYLUK, A.[2] – DROZD, L.[1] – CZYŻOWSKI, P.[1] – KARPIŃSKI, M.[1] – GOLEMAN, M.[1]

[1]*University of Life Sciences in Lublin, Department of Companion and Wildlife Animals Akademicka 13, 20-950 Lublin, Poland*

[2]*University of Life Sciences in Lublin, Department of Grassland and Landscape Shaping Akademicka 13, 20-950 Lublin, Poland*

**Corresponding author*
e-mail: katarzyna.tajchman@up.lublin.pl; phone: +48-814-456-848

(Received 6th Feb 2017; accepted 28th Apr 2017)

Abstract. In the investigations, the number of collisions with red deer (*Cervus elaphus* Linnaeus, 1758), roe deer (*Capreolus capreolus* Linnaeus, 1758), and elks (*Alces alces* Linnaeus, 1758) registered on the roads of 18 districts of the Lubelskie region in Poland in 2011-2013 was analysed. The relationships between the number of wildlife-vehicle collisions and the abundance of the analysed animal species, forestation, road density, and the number of registered vehicles in the districts were examined. The trend towards changes in these factors was analysed and safety coefficients, i.e. the number of accidents per 1000 vehicles, the number of accidents per 1-km^2 area, the number of accidents per 1000 animals, accident density, and animal density per 1-km^2 area, were calculated. 1073 wildlife-vehicle collisions were recorded in the analysed period (2011-2013). Over half of the traffic incidents, i.e. 66%, were collisions with roe deer, collisions with red deer represented 27%, and accidents with elks accounted for 7%. The distribution of the wildlife-vehicle collisions was not uniform across the Lubelskie region. The greatest numbers were noted in Puławy (161), Lubartów (132), and Biała Podlaska (107) Districts, which was probably related to the substantial increase in the abundance of the analysed animal species and in the number of registered vehicles. The lowest number of incidents was noted in Janów (14), Opole (14), and Łęczna (18) Districts.
Keywords: *Cervidae, district area, forest area, road density, the number of vehicles*

Introduction

The once vast and continuous forested areas in Poland are currently fragmented and the parts are divided by crop fields, developments, and roads. As part of the intensive development of motorisation, transport routes are being continuously modernised and new expressways are being built. All these investments are undertaken to improve the comfort of travelling and enhance the efficiency of road transport. The developing road infrastructure interferes with the natural environment and fragmentation of biotopes by transport routes increases the risk of wildlife-vehicle collisions and accidents (Jędrzejewski et al., 2006, Ward et al., 2015, Russell at al., 2013).

Roads can become a barrier for migratory species, which will always lead to reduction of their population abundance (Soulé et al., 1998). The impact of roads as ecological barriers depends on traffic intensity as well as the structure and location of the roads. Traffic intensity influences the animal mortality rates in wildlife-vehicle collisions and the number of animals that do not attempt to cross the road out of fear (Jędrzejewski et al., 2006).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

Infrastructure that prevents fulfilling animal needs (feeding, reproduction, rearing offspring, and search for new living habitats) contributes to a decline in the number of individuals and the gene pool in the entire population, thereby leading to greater isolation of the group thus preventing the flow of outsiders. A decrease in the reproduction rate and a reduced gene pool is associated with drastic reduction in the chance of survival of such an isolated population (Borowska, 2010). Species characterised by considerable mobility, high space requirements, and long-range migration are most vulnerable to ecological barriers created by the road infrastructure. Such animals mainly include the wolf, lynx, bear, elk, bison, and red deer. This group is at special risk due to their high demand for living space and long-distance migrations. Since the species are strongly associated with the forest environment, any restrictions in movement between forest complexes can constitute a threat to these animals (Grabińska, 2006)

Therefore, analysis of animal traffic-related fatalities is becoming an increasingly important element of management of the natural space, which is essential for protection of fauna (Trombulak and Frissell, 2000).

Aim of the study

The aim of the study was to analyse the number of wildlife-vehicle collisions on the roads of 18 districts of the Lubelskie region in Poland in 2011–2013. We analysed the relationships between the number of wildlife-vehicle collisions and:

- the abundance of the selected animal species,
- forest area,
- road density,
- number of registered vehicles in the study area in the analysed period.

Research methods

The study involved analysis of the number of collisions with the selected *Cervidae* species (red deer (*Cervus elaphus* Linnaeus, 1758), roe deer (*Capreolus capreolus* Linnaeus, 1758), elk (*Alces alces* Linnaeus, 1758) that occurred on the roads of 18 districts of the Lubelskie region in 2011-2013 in Poland. Data on wildlife-vehicle collisions and animal abundance in 2011-2013 were part of the documentation of the Regional Directorate of State Forests (RDSF) in Lublin. Data on the district area, forest area, road density, and the number of vehicles registered in Poland were obtained from the Central Statistical Office (CSO). The number of wildlife-vehicle collisions was compared with the animal abundance and the number of vehicles registered in each district in the analysed period. The trend towards changes was analysed and the following coefficients were calculated:

1) number of accidents per 1000 vehicles (Wp_1)

$$Wp_1 = \frac{W * 10^3}{p} \quad \text{(Eq.1)}$$

where:
W- total number of accidents in the analysed period

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

p- number of registered vehicles

2) number of accidents per 1-km^2 area (Wp_2)

$$Wp_2 = \frac{W * 10^2}{P} \quad \text{(Eq.2)}$$

where:
W- total number of accidents in the analysed period
P- district area

3) number of accidents per 1000 animals (Wm)

$$Wm = \frac{W * 10^3}{z} \quad \text{(Eq.3)}$$

where:
W- total number of accidents in the analysed period
z- animal abundance

4) accident density (Dw)

$$Dw = \frac{W}{L} \quad \text{(Eq.4)}$$

where:
W- total number of accidents in the analysed period
L- length of the road network

5) animal density per 1-km^2 area (Zg)

$$Zg = \frac{z}{P} \quad \text{(Eq.5)}$$

where:
z- animal abundance
P- district area

The coefficients, which are presented in literature concerning road traffic safety, were adjusted to represent wildlife-vehicle collisions (Gaca et al., 2008).

The results were statistically evaluated with the analysis of variance method in the programme SAS v. 91. Multiple regression analysis of measurements performed during the three years was carried out with the irrelevant variable removal approach. The variables comprised the surface areas of the districts, traffic intensity, forestation, the number of vehicles, and the length of roads.

Statistical analyses were based on two-way analysis of variance models and Tukey's multiple t-tests at a significance level of $\alpha = 0.05$.

Tukey's multiple comparison t-tests facilitated detailed comparative analysis of the means by distinguishing statistically homogenous groups. The correlations between the analysed variables were tested with Pearson correlation coefficients. Correlation coefficients were calculated as well as the probabilities associated with the Student's t-

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

test functions used for assessment of the significance by comparison with the accepted significance level.

Results and discussion

According to the CSO data, the total length of public roads in the Lubelskie region in 2013 was 34 262.4 km (by 1% less than in 2011). Urban and non-urban roads accounted for approx. 3% and 97% of all the hard-surface public roads, respectively. The hard-surface public roads in the Lubelskie region covered 84.5 km per 100-km^2 area (mean value in Poland: 91.2 km), and improved-surface roads occupied 80.5 km (mean value in Poland: 84.0 km). In terms of the density of the hard-surface public road network, the Lubelskie region is in the eleventh place in the country (Statystyczne vademecum Samorządowca 2014) (*Table 1*).

Table 1. *Characteristics of the research area (Lublin province in Poland)*

district	area of the district (km^2) 2013	forest area (km^2) 2013	traffic 2010 DTA (daily traffic average)	total length of roads (km) 2013	number of vehicles 2013
bialski	2755	748	8856	1975	87291
parczewski	952	234	2599	643	28070
radzyński	965	204	1786	809	46878
włodawski	1256	500	3289	657	32578
biłgorajski	1681	657	6316	1123	70864
chełmski	1887	345	4051	1359	59307
hrubieszowski	1268	165	8519	1094	43162
krasnostawski	1031	156	9454	867	44161
tomaszowski	1489	324	17837	1321	58049
zamojski	1870	429	10405	1453	70904
lubartowski	1289	273	12408	999	59833
lubelski	1680	171	17350	1468	122477
łęczyński	637	87	10987	492	43363
świdnicki	468	53	17967	386	50363
janowski	875	354	12238	604	31682
kraśnicki	1005	211	10470	772	70664
opolski	810	184	3019	778	50668
puławski	934	228	12660	728	76007

The districts of the Lubelskie region exhibited significant differences in the length and density of roads. The highest road length coefficient in 2013 was noted for Biała

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

Podlaska (1 975 km), Lublin (1 468 km), and Zamość (1 453 km) Districts, and the lowest value was reported for Łęczna (492 km) and Świdnik Districts (385 km).

The highest coefficient of road density per 100 km^2 in the Lubelskie region in 2013 was noted in Ryki (104.3 km per 100 km^2) and Opole Districts (96.0 km per 100 km^2), whereas the lowest value was calculated for Włodawa District (52.3 km per 100 km^2).

The length of public roads situated in the forested areas of the Lubelskie region varied highly. The greatest length (density) of public roads was found in Biała Podlaska (536.57 km) and Biłgoraj (439.0 km) Districts, and the lowest value was reported from Łęczna (67.0 km) and Świdnik (43.4 km) Districts.

The total number of vehicles and tractors registered in the Lubelskie region in 2013 was 1 124 720, which was by 44.7% higher than that reported in 2005. In 2013, the greatest number of registered vehicles was noted in Lublin (122 477), Biała Podlaska (87 291), and Puławy (76 007) Districts. In turn, the lowest number of vehicles was registered in Janów (31 682) and Parczew (28 070) Districts (*Table 1*).

The greatest number of cars and tractors per 100 km of roads was noted in Świdnik (13 058) and Puławy Districts (10 436), and the lowest value was reported from Tomaszów (4 395) and Hrubieszów (3 946) Districts.

In the analysed period (2011-2013), 1073 wildlife-vehicle collisions were reported. A vast majority, i.e. 66%, of the accidents were collisions with roe deer; collisions with red deer and elk accounted for 27% and 7%, respectively (*Fig. 1*). The highest number of incidents was noted in Puławy (161), Lubartów (132), and Białą Podlaska (107) Districts, whereas the number of wildlife-vehicle collisions was the lowest in Janów (14), Opole (14), and Łęczna (18) Districts (*Table 2*).

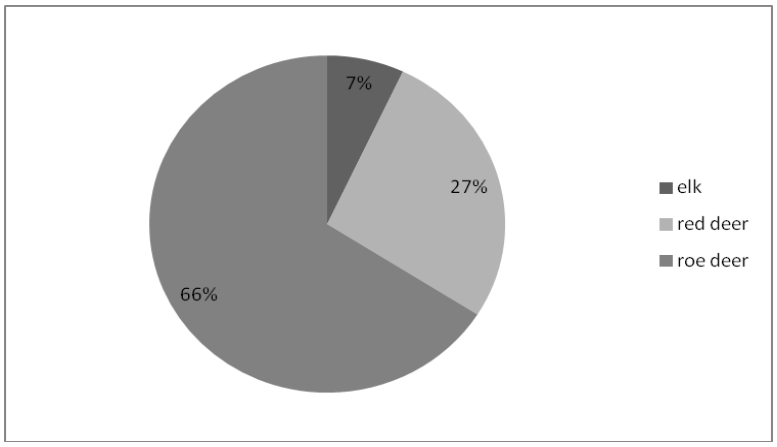

Figure 1. *Percentage proportion of wildlife species involved in road accidents in 2011-2013*

The problem of road accidents involving *Cervidae* species persists across Europe (Langbein and Putman, 2005, 2006). As shown by German statistics, 80% of all accidents are collisions with *Cervidae* species (red deer, roe deer, fallow deer, elk) and merely 10% of accidents involve wild boars (Groot Bruinderink and Hazebroek, 1996, Olson et al., 2015). Quite similar results were obtained in Lithuania and Estonia, where collisions with roe deer accounted for over 56%, with wild boars - 9.8%, elks - 6.0%, hare - 4.1%, and red deer - 1.3% (Balčiauskas, 2009). Similarly, roe deer is the main species involved in road collisions in Denmark (Madsen et al., 2002).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

Table 2. *Number of deer-vehicle collisions in 2011-2013 in different districts of the province of Lublin*

district	number of deer-vehicle collisions											
	2011				2012				2013			
	red deer	roe deer	elk	total	red deer	roe deer	elk	total	red deer	roe deer	elk	total
bialski	12	30	2	44	3	25	1	29	4	29	1	34
parczewski	2	4	0	6	1	5	1	6	5	0	0	7
radzyński	3	11	3	24	3	21	4	17	19	2	0	28
włodawski	5	11	7	38	5	16	8	23	24	5	0	29
biłgorajski	6	24	2	32	6	21	0	27	11	22	0	33
chełmski	4	10	2	16	2	8	6	16	3	6	1	10
hrubieszowski	1	12	0	13	1	5	1	7	2	10	0	12
krasnostawski	0	6	0	10	0	7	0	6	9	1	0	7
tomaszowski	0	15	1	18	0	31	0	16	17	0	0	31
zamojski	0	10	1	11	2	7	1	10	0	16	0	16
lubartowski	3	32	5	40	3	33	6	42	4	37	9	50
lubelski	4	23	3	27	4	21	3	30	22	2	0	28
łęczyński	1	5	1	6	1	4	0	7	4	1	0	5
świdnicki	2	11	1	14	2	11	2	15	2	10	2	14
janowski	2	2	0	4	1	5	0	6	1	2	0	4
kraśnicki	4	14	0	18	2	4	0	6	1	5	0	6
opolski	1	2	0	9	0	2	0	3	8	0	0	2
puławski	4	46	1	56	4	47	3	51	48	4	0	54
suma	54	268	29	386	40	273	36	317	184	152	13	370

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

Information collected from the country confirms the observation that roe deer and wild boar are most frequently involved in wildlife-vehicle collisions. The data from the country include red deer in this group (Czerniak and Tyburski, 2011). The results of the research carried out in the Lubelskie region show over 1000 wildlife-vehicle collisions reported annually, with approx. 75% of incidents involving roe deer (Tajchman et al., 2010). This is probably determined by two aspects. The first one is the dynamic growth of the population of this species, which was estimated at approx. 50% over the last decade (Budny et al., 2010). The other aspect is undoubtedly related to animals' behaviour associated with strong territoriality and hence, frequently distant migrations of young animals (Pielowski, 1999).

Over the three hunting seasons, the number of animals was noted to have increased by 3 313 roe deer (7%), 1 311 red deer (19%), and 395 elk (22%). There was a substantial increase in the number of large animals over the last 10 years (2004-2014), i.e. the population of elk has increased fourfold, red deer twofold, and roe deer approximately one and a half fold. The highest increase in the animal abundance was noted in Biała Podlaska, Chełm, and Biłgoraj Districts. The abundance of roe deer exhibited a remarkable increase in Krasnystaw and Świdnik Districts, while the elk population expanded in Sobibór District. Elks appeared in Kraśnik, Nowa Dęba, and Zwierzyniec Districts, where they had not been observed previously. The lowest rise in the abundance was noted in Gościeradów and Sobibór Districts for roe deer, in Józefów and Tomaszów Districts for red deer, and in Strzelce District for elk (*Table 3*).

Table 3. *Number of animals (elk, red deer and roe deer) in 2003 and 2011-2013 analyzed the districts of Lublin province*

district	number of animals (indiv.)			
	2003	**2011**	**2012**	**2013**
bialski	4545	7794	7692	8195
parczewski	1196	2061	2041	2281
radzyński	1324	2242	2285	2374
włodawski	2667	3522	3648	3699
biłgorajski	4312	7145	7159	6945
chełmski	2498	4383	4386	4989
hrubieszowski	2934	4459	4567	5128
krasnostawski	1686	2717	2993	3414
tomaszowski	2720	3608	3438	3534
zamojski	3600	5126	5256	5573
lubartowski	1004	2251	2487	2583
lubelski	1362	2307	1563	2651
łęczyński	644	1122	1128	1284
świdnicki	681	1154	1173	1325
janowski	1136	1584	1598	1627
kraśnicki	1332	1959	1973	2063
opolski	717	1326	1446	1629
puławski	2844	3907	3990	4392

The Wp_1 coefficient (number of accidents per 1000 vehicles) throughout the analysed period exhibited the highest value in Włodawa and Lubartów Districts and the lowest value in Kraśnik and Opole Districts, with the exception of 2011, when the lowest coefficient (0.13) was noted in Janów District (*Table 4*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

Table 4. *Safety coefficients in 2011-2013 in the data districts of the province of Lublin*

district	Wp1			Wp2			Wm			Dw			Zg		
	2011	2012	2013	2011	2012	22 013	2011	2012	2013	2011	2012	2013	2011	2012	2013
bialski	0.55	0.35	0.39	1.6	1.05	1.23	5.65	3.77	4.15	0.02	0.01	0.02	282.90	279.20	297.46
parczewski	0.23	0.22	0.25	0.63	0.63	0.74	2.91	2.94	3.07	0.01	0.01	0.01	216.49	214.39	239.60
radzyński	0.54	0.37	0.6	2.49	1.76	2.9	10.7	7.44	11.79	0.02	0.02	0.03	232.33	236.79	246.01
włodawski	1.29	0.73	0.89	3.03	1.83	2.31	10.79	6.3	7.84	0.05	0.04	0.04	280.41	290.45	294.51
biłgorajski	0.47	0.39	0.47	1.9	1.61	1.96	4.48	3.77	4.75	0.03	0.02	0.03	425.04	425.88	413.15
chełmski	0.29	0.28	0.17	0.85	0.85	0.53	3.65	3.65	2.0	0.01	0.01	0.01	232.27	232.43	264.39
hrubieszowski	0.32	0.17	0.28	1.03	0.55	0.95	2.92	1.53	2.34	0.01	0.01	0.01	351.66	360.17	404.42
krasnostawski	0.24	0.14	0.16	0.97	0.58	0.68	3.68	2.0	2.05	0.01	0.01	0.01	263.53	290.30	331.13
tomaszowski	0.33	0.28	0.53	1.21	1.07	2.08	4.99	4.65	8.77	0.01	0.01	0.02	242.31	230.89	237.34
zamojski	0.17	0.15	0.23	0.59	0.53	0.86	2.15	1.9	2.87	0.01	0.01	0.01	274.12	281.07	298.02
lubartowski	0.72	0.73	0.84	3.1	3.26	3.88	17.77	16.89	19.36	0.04	0.04	0.05	174.63	192.94	200.39
lubelski	0.24	0.26	0.23	1.61	1.79	1.67	11.7	19.19	10.56	0.02	0.02	0.19	137.32	93.04	157.80
łęczyński	0.15	0.17	0.12	0.94	1.1	0.78	5.35	6.21	3.89	0.01	0.01	0.01	176.14	177.08	201.57
świdnicki	0.29	0.31	0.28	2.99	3.21	2.99	12.13	12.79	10,57	0.03	0.04	0.04	246.58	250.64	283.12
janowski	0.13	0.2	0.13	0.46	0.69	0.46	2.53	3.75	2.46	0.01	0.01	0.01	181.03	182.63	185.94
kraśnicki	0.27	0.09	0.08	1.79	0.6	0.6	9.19	3.04	2.91	0.02	0.01	0.01	194.93	196.32	205.27
opolski	0.19	0.06	0.04	1.11	0.37	0.25	6.79	2.07	1.23	0.01	0.0	0.0	163.70	178.52	201.11
puławski	0.78	0.69	0.71	6.0	5.46	5.78	14.33	12.78	12.3	0.07	0.07	0.07	418.31	427.19	470.24

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

The highest Wp_2 coefficient (number of accidents per 1-km^2 area), i.e. on average 5.8, was noted in Puławy District throughout the years. The lowest values were recorded in Janów District in 2011 (0.46) and in Opole District in 2012 (0.37) and 2013 (0.25). Values exceeding the average were recorded in Włodawa, Lubartów, and Świdnik Districts (*Table 4*).

The Wm coefficient (number of accidents per 1000 animals) in all the research years reached the highest value in Lubartów District, with the exception of 2012, when the highest value of the coefficient (19.19) was recorded in Lublin District. Low values of the Wm coefficient were obtained for Zamość District in 2011 and Hrubieszów District in 2012. In Opole District in 2013, the coefficient value was six fold lower and had a value of 1.23 (*Table 4*).

The Dw coefficient (accident density) was the highest in Puławy District in all the study years and reached a value of approx. 0.07. The lowest values throughout the study years were reported from Opole District (0.0) and in Chełm, Hrubieszów, and Krasnystaw Districts in 2011 (0.012) (*Table 4*).

Throughout the study years, the Zg coefficient (animal density per 1-km^2 area) had the highest value in Biłgoraj (mean value 421.35) and Puławy Districts (mean value 438.58) and the lowest value in Lublin District (mean value 129.38) (*Table 4*).

The results of the investigations of the number of wildlife-vehicle collisions in each district (irrespective of the year of the study) have revealed significant differences in the number of accidents only among Tomaszów, Radzyń, Lublin, Włodawa, Biłgoraj, Biała Podlaska, Lubartów, and Puławy Districts. These regions were characterised by a significantly higher number of collisions than Janów, Opole, Łęczna, Parczew, and Krasnystaw Districts. The number of wildlife-vehicle collisions in Lubartów and Puławy Districts was significantly higher than that noted in the other districts, except for Biała Podlaska District, where the number of accidents was similar (*Table 5*).

Table 5. *Number of wildlife-vehicle collisions in the analysed districts of the Lubelskie region (irrespective of the study years).* $^{a, b,c, d, e, f, g}$ *- homogeneous groups (a statistically homogeneous), no statistically significant difference*

district	number of deer-vehicle collisions
janowski	4.7^{a}
opolski	4.7^{a}
łęczyński	6.0^{a}
parczewski	6.3^{a}
krasnostawski	7.7^{a}
kraśnicki	10.0^{ab}
hrubieszowski	10.7^{abc}
zamojski	12.3^{abc}
chełmski	14.0^{abc}
świdnicki	14.3^{abc}
tomaszowski	21.7^{bcd}
radzyński	23.0^{cde}
lubelski	28.3^{de}
włodawski	30.0^{de}
biłgorajski	30.7^{de}
bialski	35.7^{ef}
lubartowski	44.0^{fg}
puławski	53.7^{g}

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

The significantly highest number of accidents was reported from Lubartów and Puławy Districts (44.0 and 53.7, respectively) and the significantly lowest value was noted in Janów, Opole, Łęczna, Parczew, and Krasnystaw Districts (4.7; 4.7; 6.0; 6.3; and 7.7, respectively) (*Table 5*).

Significant differences in the number of wildlife-vehicle collisions in the respective years of the analysed period were noted in the entire study area. The greatest number of accidents was reported in 2011 and the lowest number was noted in 2012 (statistically confirmed differences). The number of accidents did not differ statistically between 2012 and 2013 (*Table 6*).

Table 6. *Number of wildlife-vehicle collisions in the study years (irrespective of the districts).* [a, b,] *- homogeneous groups (a statistically homogeneous), no statistically significant difference*

year	number of deer-vehicle collisions
2012	17.6[a]
2013	20.6[ab]
2011	21.4[b]

A high positive correlation (R= 0.4682) was found between the number of wildlife-vehicle collisions and the total number of vehicles in 2011-2013. This indicates a significant increase in the number of these traffic incidents over the study years caused by the increase in the number of vehicles. The same relationship was noted between the number of wildlife-vehicle collisions and the total animal abundance (at R=0.3995) (*Table 7*).

Table 7. *Correlations between analysed features.* [*] *- the severity of α = 0.01,* [**] *- the severity of α = 0.05, p - probability distribution*

	number of animals	number of vehicles	total length of roads	forest area (km^2)	traffic DTA (daily traffic average)	area of the county (km^2)
number of deer-vehicle collisions	0.3995 p=.003	0.4682 p=.000	0.2924 p=.032	0.3649 p=.007	0.1770 p=.200	0.3396 p=.012
number of animals		0.3434 p=.011	0.7293 p=.000	0.8227 p=.000	-0.1692 p=.221	0.8285 p=.000
number of vehicles			0.6438 p=.000	0.2040 p=.139	0.4360 p=.001	0.5515 p=.000
total length of roads				0.5994 p=.000	0.0746 p=.592	0.9524 p=0.00
forest area (km^2)					-0.2529 p=.065	0.7785 p=.000
traffic DTA (daily traffic average)						-0.0509 p=.715

The correlations between forestation and the number of wildlife-vehicle collisions as well as the district surface area and the number of wildlife-vehicle collisions exhibit a

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

slightly lower positive value (i.e. R= 0.3649 and R= 0.3396, respectively). This implies that the district surface area and forestation exert a lesser effect on the increase in the number of collisions with roe deer, red deer, and elk. The total length of the roads has even a lower impact (R= 0.2924) on this parameter (*Table 7*).

Obviously, the animal abundance is higher in districts with a greater total surface area and forestation. The statistical calculations showed a very strong positive correlation (R= 0.8227 and R= 0.8285) between the surface areas and animal abundance (*Table 7*).

Summary and conclusions

The distribution of the number of wildlife-vehicle collisions is not uniform in the entire study area (Lubelskie region). The greatest number of this type of incidents were reported from Puławy (161), Lubartów (132), and Biała Podlaska (107) Districts, which was probably associated with the substantial increase in the abundance of the analysed animal species and the rise in the number of registered vehicles. Lublin District was characterised by lower accident rates. Probably, the vicinity of the main city of the study area does not provide animals with a large number of refuges; hence, the animal migration rate in this area is lower than in the other above-mentioned districts, where roads often intersect large forest areas.

The statistical analyses also confirm the significant positive correlation between the number of accidents and animal abundance, number of vehicles, and the length of roads in the area. Puławy and Lubartów Districts are characterised by relatively high forestation, i.e. ca. 24.3%. It should be noted, however, that in Włodawa, Biłgoraj, and Tomaszów Districts, where the forestation exhibits a higher level of ca. 39-40%, no proportionally higher number of accidents was noted due to the lower traffic intensity and a lower increase in the number of vehicles. Notably, the animal abundance declined in Tomaszów and Biłgoraj Districts. These areas are located close to the low-anthropopressure silence zone of the Roztoczański and Poleski National Parks and the borders of the Lubelskie region, where there are no voivodeship and trunk roads.

The trends observed in the wildlife-vehicle collisions were confirmed by the calculated coefficients. Their highest values were obtained in the case of Lubartów and Puławy Districts.

Wildlife-vehicle collisions are among the most dangerous road incidents (Saeki and Macdonald, 2004). Their proportion in the total number of accidents is growing steadily, which is related to the increased wild animal abundance in forests, greater traffic intensity, and expansion of the road network. The total number of cars and tractors registered in the Lubelskie region in 2013 was 1 124 720, which was by 44.7% higher than that reported in 2005. In turn, during the three hunting seasons, the number of elks, red deer, and roe deer increased by 22%, 19%, and 7%, respectively. A substantial increase in the number of large animals can be observed. Over the last 10 years (2004-2014), the population of elks has increased fourfold, red deer twofold, and roe deer approximately one and a half fold.

There was no effect of increased forestation in the analysed districts on the increase in the number of wildlife-vehicle collisions. This proves a strong influence of other factors on the number of collisions, e.g. traffic intensity, road density, and animal abundance.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

Wildlife-vehicle collisions are associated with financial consequences. In Poland, the cost of one collision with an animal was estimated at ca. 8 153 PLN; the cost of an accident resulting in human body injury is 28 976 PLN, and an accident with human casualties reaches 10 237 196 PLN. The mean cost of the accidents in 2001-2010 was 173 602 989 PLN. In Utah, the USA, the total cost of wildlife-vehicle collisions for the period of 1992-2001 was estimated at 470 million dollars (Tyburski and Czerniak, 2013, Page, 2007).

Fencing the roads integrated with animal migration routes seems to be the most effective way to prevent this type of accidents; however, this method is relatively seldom used in Poland, as only 0.64% of all roads are fenced. A commonly used method, although little effective, is installation of warning signs (A-18b "wild animals"), which allow road administrators to avoid liability for the consequences of accidents (Szczęsny and Orlicz-Szczęsna, 2014). It is therefore necessary to undertake mitigation measures during construction of new roads or modernisation of existing ones. An important element in reduction of the number of wildlife-vehicle collisions is appropriate education and awareness-raising actions. Adequate information about animals' behaviour on the roads provided to drivers may contribute to reduction of the number of such traffic incidents. This practice has become a standard in many countries (Ford et al., 2011, Malo at al., 2004, Bright at al., 2015).

Researchers agree that, although an increase in the number of ungulates-vehicle collisions has been reported in Europe and the United States, there are no reports of a possible threat of extinction of animal species killed in such traffic incidents. This is associated with the high rate of reproduction in ungulates and their great ability to recolonise habitats in which a population was extinct (Forman and Alexander, 1998, Seiler, 2003).

Nevertheless, wildlife-vehicle collisions lead to severe consequences. Investigations conducted by Spanish researchers have shown that wild boars (*Sus scrofa*) and roe deer (*Capreolus capreolus*), i.e. the two most abundant species of cloven-hoofed animals whose populations have spread across Spain over the last few decades, were involved in 79% of wildlife-vehicle collisions. Accidents with these species yielded the highest economic losses and, in the case of wild boars, the greatest number of human injuries. It should also be noted that these species together with the red deer, were the most often hunted ungulates in Spain (Saenz-de-Santa-Maria and Telleria, 2015). Wild boars and roe deer accounted for 43.6% and 31% of economic losses, respectively, but differed in the number of resulting human injuries. Wild boars caused substantial damage, i.e. 47% of car crashes, 43% of the total number of injuries, and 47% of fatal injuries. Roe deer were involved in 32.3% of car crashes, 8.6% of the total number of injuries people, and 8.3% of fatal injuries. The costs associated with ungulates-vehicle collisions increased by 72%, with a mean annual increase of 8%. The costs generated by collisions with wild boars increased by 41.43%, and by 92.24% and 131% in the case of accidents with red deer and roe deer, respectively (Saenz-de-Santa-Maria and Telleria, 2015).

REFERENCES

[1] Balčiauskas, L. (2009): Distribution of species-specific wildlifevehicle accidents on Lithuanian roads, 2002-2007.- Estonian J Ecol [in English]

[2] Borowska, S. (2010): Raport „Śmiertelność zwierząt na drogach w Polsce".- Raport przygotowany w ramach projektu „Ochrona gatunkowa rysia, wilka i niedźwiedzia w

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

Polsce" realizowanego przez WWF Polska przy dofinansowaniu z środków Norweskiego Mechanizmu Finansowego i Mechanizmu Finansowego EOG s. 1-25 [The report, "Mortality of animals on the roads in Poland." -The report prepared within the project "Protection of species of lynx, wolf and bear in Poland", implemented by WWF Poland with funding from the Norwegian Financial Mechanism and the Financial Mechanism EOG] [in Polish]

[3] Bright, P. W., Balmforth, Z., Macpherson, J. L. (2015): The effect of changes in traffic flow on mammal road kill counts.- Applied Ecology And Environmental Research 13(1): 171-179. [in English]

[4] Budny, M., Panek, M., Bresiński, W., Kamieniarz, R., Kolanoś, B., Mąka, H. (2010): Sytuacja zwierząt łownych w Polsce w latach 2009–2010.- Biuletyn Stacji Badawczej w Czempiniu 7: 24-26. [The situation of game animals in Poland in 2009-2010.- Newsletter Research Station in Czempiń] [in Polish]

[5] Czerniak, A., Tyburski, Ł. (2011): Zdarzenia drogowe z udziałem zwierzyny.- Infrastruktura i Ekologia Terenów Wiejskich Nr 2/2011 Polska Akademia Nauk, Oddział w Krakowie 275-283 Komisja Technicznej Infrastruktury Wsi [Traffic incidents involving animals. - Infrastructure and Environment Rural No. 2/2011 Polish Academy of Sciences Branch in Krakow. Commission Technical Rural Infrastructure 275-283] [in Polish]

[6] Ford, A. T., Clevenger, A. P., Huijser, M. P., Dibb, A. (2011): Planning and prioritization strategies for phased highway mitigation using wildlife-vehicle collision data. - Wildl Biol 17: 253-265. [in English]

[7] Forman, R. T., Alexander, L. E. (1998): Roads and their major ecological effects. - Annu Rev Ecol Syst 29: 207-231. [in English]

[8] Gaca, S., Suchorzewski, W., Tracz, M. (2008): Inżynieria ruchu drogowego. - Teoria i praktyka, Wydawnictwa Komunikacji i Łączności, Warszawa [Traffic engineering. - Theory and practice. Publishing and Communications and Communications Warsaw] [in Polish]

[9] Grabińska, B. (2006): Wykorzystanie programu komputerowego Aviso (GIS) do oceny rozmieszczenia ssaków Polski. - Przegląd Geograficzny 78: 413-423. [Use of a computer program Aviso (GIS) to evaluate the distribution Polish mammals. - Geographical Overview 78: 413-423.] [in Polish]

[10] Groot Bruinderink, G. W. T. A., Hazebroek, E. (1996): Ungulate traffic collisions in Europe. - Conservation Biology 10: 1059-1067. [in English]

[11] Jędrzejewski, W., Nowak, S., Kurek, R. (2006): „Zwierzęta a drogi. Metody ograniczania negatywnego wpływu dróg populacje dziko żyjących zwierząt" - wyd. Zakład Badania Ssaków PAN, Białowieża [Animals and roads. Methods of reducing the negative impact of roads populations of wild animals ed.: Mammal Research Institute PAS Bialowieza] [in Polish]

[12] Langbein, J., Putman, R. J. (2005): Deer collisions – a nationwide issue. In Practice (Bulletin of the Institute of Ecology and Environmental Management) 47: 1-7. [in English]

[13] Langbein, J., Putman, R. J. (2006): Collision cause. - J Brit Deer Soc 13: 19-23. [in English]

[14] Madsen, A. B., Strandgaard, H., Prang, A. (2002): Factors causing traffic killings of roe deer Capreolus capreolus in Denmark. - Wildl Biol 8: 55-61. [in English]

[15] Malo, J. E., Suárez, F., Díez, A. (2004): Can we mitigate animal-vehicle accidents using predictive models? - Journal of Applied Ecology 41: 701-710. [in English]

[16] Olson, D. D., Bissonette, J. A., Cramerr, P. C., Bunnell, K. B., Coster, D. C., Jackson, P. J. (2015): How does variation in winter weather affect deer-vehicle collision rates? - Wildl Biol 21: 80-87. [in English]

[17] Page, M. A. (2007): A Toolkit for Reducing Wildlife and Domestic Animal-Vehicle Collision in Utah. - Utah Department of Transportation Salt Lake City [in English]

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498

[18] Pielowski, Z. (1999): Sarna. - Wydawnictwo Świat, Warszawa [Roe deer. - Publishing World Warsaw] [in Polish]
[19] Russell, T. C., Herbert, C. A., Kohen, J. L., Cooper, D. (2013): The incidence of road-killed possums in the Ku-ring-gai area of Sydney. - Australian Journal of Zoology 61: 87-94. [in English]
[20] Saeki, M., Macdonald, D. W. (2004): The effects of traffic on the raccoon dog (*Nyctereutes procynoides viverrinus*) and other mammals in Japan. - Biological Conservation 118: 559-571. [in English]
[21] Saenz-de-Santa-Maria, A., Telleria, J. L. (2015): Wildlife-vehicle collisions in Spain. - Eur J Wildl Res 61: 399-406. [in English]
[22] Seiler, A. (2003): The toll of the automobile: Wildlife and roads in Sweden. - Doctoral thesis, Department of Conservation Biology, Swedish University of Agricultural Sciences Uppsala Szwecja [in English]
[23] Soulé, M. E., Bolger, D. T., Alberts, A. C., Sauvajot, R. M., Wright, J., Sorice, M., Hill, S. (1998): Reconstructed dynamics of rapid extinction of chaparral requiring birds in urban habitat islands. - Conserv Biol 2: 75-92. [in English]
[24] Statystyczne Vademecum Samorządowca (2014) Województwo Lubelskie [Statistical Vademecum Local Government, Lublin Voivodeship] [in Polish]
[25] Szczęsny, P., Orlicz-Szczęsna, G. (2014): Identyfikacja wypadków drogowych z udziałemzwierząt na terenie Polski. - Logistyka -nauka 6: 10289-10298. [Identification of road accidents involving animals on Polish territory. - Logistics - the science 6: 10289-10298.] [in Polish]
[26] Tajchman, K., Gawryluk, A., Drozd, L. (2010): Effects of roads on populations of wild game in the Lublin region. - Teka Kom Ochr Kszt Środ Przyr 7: 420-427. [in English]
[27] Trombulak, S. C., Frissell, C. (2000): Review of ecological effects of Road on terrestrial and aquatic communities. - Conserv Biol 14: 18-30. [in English]
[28] Tyburski, Ł., Czerniak, A. (2013): Koszty zdarzeń drogowych z udziałem zwierzyny. - Studia i Materiały CEPL w Rogowie R.15. zeszyt 36/3/2013 [The costs of road accidents involving animals. - Study Materials and CEPL in Rogow R.15. notebook 36/3/2013] [in Polish]
[29] Ward, A. I., Dendy, J., Cowan, D. P. (2015): Mitigating impacts of roads on wildlife: an agenda for the conservation of priority European protected species in Great Britain. - Eur J Wildl Res 61: 199-211. [in English]

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1503_14851498