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# Wildlife-Vehicle Collisions in Croatia – A Hazard for Humans and Animals

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**A B S T R A C T**

*Wildlife-vehicle collisions (WVC) have increased and now there is a world-wide problem related to significant mortality of wildlife, habitat fragmentation, change in behavior and even disappearance of local endangered populations. Along with these deleterious effects on wildlife, WVC can also result in injuries and deaths of humans. During the three-year monitoring, a total of 7,495 wildlife-vehicle collisions were recorded, including mainly roe deer (73%), while other species were less frequently affected (wild boar – 9%; brown hare – 5%; and red deer and pheasant each with 4%). Incidence of wildlife-vehicle collisions were observed according to territorial distribution, seasonal and daily occurrence and type of road (total and per 1 km).*

***Key words**: wildlife-vehicle collisions, risk factors, mitigation measures*

## Introduction

Increasing human population has, among other, resulted in constant spread of communities throughout the world and subsequently in habitat fragmentation, which is now recognized as one of the most important factors that influence biodiversity and species conservation[1–3]. Besides many deleterious effects of habitat fragmentation, road network proliferation is also causing not only harmful and frequently lethal wildlife-vehicle collisions, but also exhibits other influence on wildlife, like changes in behavior and even disappearance of local populations[4–6]. Despite the fact that different measures to avoid/reduce wildlife-vehicle collisions have been applied such as green bridges, under-road tunnels and protective fences, the number of such accidents in the world have dramatically increased during the last fifteen years[7–10]. More than 500,000 road accidents that involve wildlife were reported each year in Europe[7]. The number has recently been even higher[11], posing serious problem for road planners and biologists concerned with traffic safety, species conservation and animal welfare. An overview of traffic collision involving ungulates in Europe is given by Langbein et al.[12]. However, according to certain authors these numbers could in fact represent only a part of accidents since cases of minor damages are not recorded and sometimes the animals are stolen before being registered by local police authorities or game wardens[7–13]. Along with these gloomy numbers, even more devastating is the fact that on average 30,000 humans have been injured in these accidents, of which 300 with lethal consequences each year in Europe[7].

Until recently there was no data on extent, distribution and frequency of wildlife-vehicle collisions in Croatia. Partially, this was presented by the Ministry of Internal Affairs which shows an increasing trend over the last ten years for more than 400 % (575 accidents in 1997; 2,764 in 2007), but in addition, the accidents involving livestock and companion animals were included. Police Department data were particularly useful since practically all damages were reimbursed by hunting associations, meaning that wastes of accidents were reported. Of the large carnivores, in the period up to 1995 (starting year depends on the species) a total of at least 73 brown bears (*Ursus arctos*) and 20 gray wolves (*Canis lupus*) as well as ten lynx (*Lynx lynx*) were killed on the roads[14–17]. The aim of this paper was: 1) to assess geographic distribution of wildlife-vehicle collisions in Croatia; 2) to determine its dynamics on the yearly and

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daily basis; and, 3) to identify key-risk factors that may help avoid such accidents. We focused on large wildlife species as they pose most significant threat to humans during collisions.

## Material and Methods

Data on game-vehicle collisions for the period of three years (2007, 2008, and 2009) were obtained from the Police Departments depending on their jurisdiction. Each accident was recorded and described by the date, hour, and location (including type of road) and game species. A total of 7,495 cases were recorded during the study period. The number represents only animals that were killed directly at the site or were injured and located by game wardens. The total length of public roads in Croatia is approximately 29,000 km, divided in four main categories: a) highways or high capacity roads – 4.25% of total roads, b) state roads or basic primary roads – 23.33%, c) county roads or complementary primary roads – 37.18%, and d) local roads or secondary roads – 35.23%. The data obtained were analyzed using Microsoft Office Excel 2007 (Windows XP). All registered accidents were classified according to game species, road type (calculated as total accidents and accidents per km of the road), month and time of the day (on a 1 hour based scale).

## Results

### *Species and territorial distribution of WVC*

During the three year survey a total number of 7,495 cases of GVC were recorded by Police Departments in Croatia. Distribution of WVC is presented in the Table 1. The majority of GVC was recorded in Istarska (1,168), Karlovačka (862) and Međimurska (573) County, which represents 34.73% of all recorded WVC in Croatia. Counties that were least affected with these events are located in the southern part of Croatia (Zadarska, Šibensko-kninska, Splitsko-dalmatinska and Dubrovačko-neretvanska). Table 2 presents WVC according to the species involved. Clearly, the most vulnerable species is roe deer (*Capreolus capreolus*; constituting 73% of accidents), followed by wild boar (*Sus scrofa*; 9%), European brown hare (*Lepus europaeus*; 5%), pheasant (*Phasianus* spp.; 4%) and red deer (*Cervus elaphus*; 4%). The ratio of recorded WVC in total car accidents in Croatia during this study is shown in the Table 3. The total number of car accidents in the period between 2007 and 2009 has decreased by 17.4%, while in the same time; the incidence of WVC has increased for almost 30%.

### *Seasonal and daily distribution of WVC*

Distribution of WVC according to months is presented in Figure 1. Peak of WVC occurs in April, with a higher risk of accidents during May, October and Novem-

**TABLE 1**
WILDLIFE-VEHICLE COLLISIONS PER EACH COUNTY DURING THE THREE-YEAR SURVEY

| County | Year | | | Total | Percentage (%) |
|---|---|---|---|---|---|
| | 2007 | 2008 | 2009 | | |
| Istarska | 408 | 358 | 402 | 1,168 | 15.58 |
| Karlovačka | 198 | 309 | 355 | 862 | 11.50 |
| Međimurska | 201 | 177 | 195 | 573 | 7.65 |
| Zagrebačka | 191 | 173 | 160 | 524 | 6.99 |
| Primorsko-goranska | 160 | 174 | 173 | 507 | 6.76 |
| Bjelovarsko-bilogorska | 147 | 157 | 200 | 504 | 6.72 |
| Osječko-baranjska | 141 | 132 | 200 | 473 | 6.31 |
| Varaždinska | 131 | 156 | 171 | 458 | 6.11 |
| Krapinsko-zagorska | 100 | 136 | 169 | 405 | 5.40 |
| Koprivničko-križevačka | 102 | 111 | 146 | 359 | 4.79 |
| Brodsko-posavska | 57 | 91 | 127 | 275 | 3.67 |
| Vukovarsko-srijemska | 77 | 71 | 119 | 267 | 3.56 |
| Sisačko-moslavačka | 86 | 65 | 107 | 258 | 3.44 |
| Ličko-senjska | 59 | 72 | 94 | 225 | 3.00 |
| Požeško-slavonska | 45 | 70 | 92 | 207 | 2.76 |
| Virovitičko-podravska | 47 | 62 | 78 | 187 | 2.49 |
| Zadarska | 24 | 40 | 37 | 101 | 1.35 |
| Šibensko-kninska | 23 | 22 | 25 | 70 | 0.93 |
| Splitsko-dalmatinska | 14 | 18 | 23 | 55 | 0.73 |
| Dubrovačko-neretvanska | 5 | 7 | 5 | 17 | 0.23 |
| Total | 2216 | 2401 | 2878 | 7495 | 100.00 |

**TABLE 2**
WVC ACCORDING TO SPECIES INVOLVED

| | Brodsko-posavska | Osjecko-baranjska | Bjelovarsko-bilogorska | Dubrovacko-neretvanska | Vukovarsko-srijemska | Medimurska | Varaždinska | Viroviticko-podravska | Karlovacka | Šibensko-kninska | Zadarska | Licko-senjska | Splitsko-dalmatinska | Sisacko-moslavačka | Istarska | Požeško-slavonka | Krapinsko-zagorska | Koprivničko-križevačka | Primorsko-goranska | Zagrebačka | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Roe deer | 139 | 303 | 437 | – | 175 | 460 | 297 | 116 | 746 | 1 | 13 | 126 | – | 177 | 877 | 165 | 354 | 282 | 409 | 409 | 5486 |
| Wild boar | 17 | 45 | 32 | 13 | 42 | 2 | 13 | 17 | 65 | 43 | 51 | 24 | 42 | 52 | 123 | 20 | 3 | 23 | 30 | 39 | 696 |
| Red deer | 3 | 43 | 10 | – | 1 | 9 | 1 | 32 | 1 | – | – | 6 | – | 1 | 2 | 4 | 1 | 8 | 32 | 5 | 159 |
| Fallow deer | – | – | 1 | – | – | – | – | – | – | – | – | 9 | – | – | – | – | – | – | – | – | 10 |
| Fox | 34 | 23 | 9 | – | 16 | 8 | 15 | 7 | 17 | 6 | 4 | 15 | 5 | 13 | 29 | 6 | 8 | 11 | 8 | 30 | 264 |
| Hare | 28 | 22 | 3 | 1 | 11 | 47 | 42 | 3 | 20 | 10 | 16 | 11 | 7 | 5 | 63 | 7 | 18 | 22 | 9 | 15 | 360 |
| Badger | 9 | 7 | 2 | 1 | 8 | 4 | – | 2 | 2 | – | – | 6 | – | 1 | 32 | 1 | – | 5 | 2 | 7 | 89 |
| Pheasant | 39 | 27 | 10 | – | 11 | 42 | 88 | 10 | 4 | – | 2 | – | – | 6 | 37 | 4 | 20 | 6 | – | 19 | 325 |
| Quail | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| Jackal | 2 | – | – | 2 | 1 | – | – | – | – | 3 | 7 | – | – | – | – | – | – | – | – | – | 15 |
| Wildcat | 4 | 2 | – | – | 2 | – | – | – | 5 | 1 | 2 | 6 | – | 3 | 1 | – | – | – | 1 | – | 27 |
| Grey partridge | – | – | – | – | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| Mallard | – | – | – | – | – | – | 1 | – | 1 | – | – | – | – | – | 2 | – | 1 | 2 | – | – | 7 |
| Gray wolf | – | – | – | – | – | – | – | – | 1 | 4 | 3 | 1 | 1 | – | – | – | – | – | – | – | 10 |
| Brown Bear | – | – | – | – | – | – | – | – | – | 2 | 2 | 17 | – | – | 1 | – | – | – | 16 | – | 38 |
| Mouflon | – | – | – | – | – | – | – | – | – | – | 1 | 3 | – | – | – | – | – | – | – | – | 4 |
| Martens | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | 1 | – | – | – | – | – | 2 |
| Total | 275 | 473 | 504 | 17 | 267 | 573 | 458 | 187 | 862 | 70 | 101 | 225 | 55 | 258 | 1168 | 207 | 405 | 359 | 507 | 524 | 7495 |

**TABLE 3**
WVC IN RELATION TO TOTAL CAR ACCIDENTS

| Year | Total number of car accidents | Car accidents involving wild animal species | Percentage (%) |
|---|---|---|---|
| 2007 | 61,020 | 2,216 | 3.63 |
| 2008 | 53,496 | 2,401 | 4.49 |
| 2009 | 50,388 | 2,878 | 5.71 |
| Total | 164,904 | 7,495 | 4.45 |

ber. On a daily basis, the highest incidence of WVC occurs between 06.00–07.00 a.m., and 09.00–10.00 p.m., exhibiting a strong bimodal pattern (Fig. 2). In fact, the early morning and late evening hours constitute 19.5% and 44.0%, respectively, of all WVC. On the other hand, period between 09.00 a.m. and 16.00 p.m. is characterized as period of minimum risk for WVC.

### *Type of road and WVC*

Table 4 shows the average number of WVC according to the road length and year. The results obtained in this

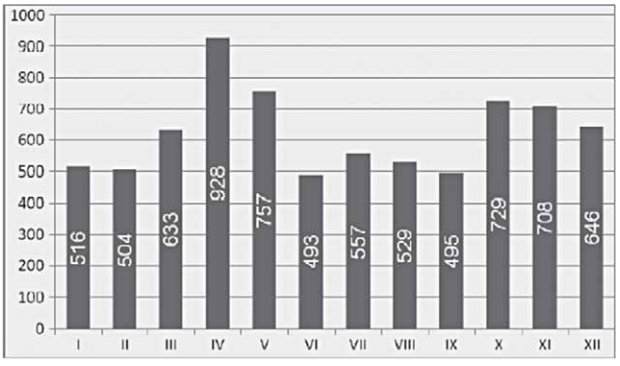


*Fig. 1. Monthly distribution of WVC.*

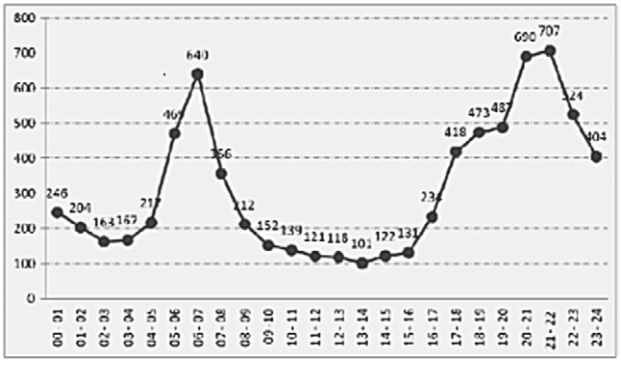


*Fig. 2. Daily distribution of WVC.*

**TABLE 4**
WVC ACCORDING TO TYPE OF THE ROAD, INCLUDING OBSERVATIONS PER 1 KM OF ROAD

| Road type | Road length (km) | Road ratio (%) | Total WVC during 2007, 2008 and 2009 | Average number of WVC/km/year |
|---|---|---|---|---|
| Highways | 1,243.6 | 4.26 | 573 | 0.15 |
| State roads | 6,819.7 | 23.33 | 3,639 | 0.18 |
| County roads | 10,867.4 | 37.18 | 2,649 | 0.08 |
| Local roads | 10,297.2 | 35.23 | 637 | 0.02 |
| Total | 29,227.9 | 100.00 | 7,495 | 0.09 |

study shows that highest incidence of WVC per km of road was recorded on the major roads (highways and state roads). If WVC are observed according to the type of road it is evident that majority of accidents occurs on state roads (48.6 %) and county roads (35.3 %), followed by local roads (8.5 %) and highways (7.6 %).

## Discussion

Wildlife-vehicle collisions are in direct correlation with type and length of roads, habitat characteristics, size of game population and of course, volume and density of traffic. Beside obvious factors like road density, volume and speed of traffic[18–21], landscape fragmentation with long forest edge, particularly where forest is attached directly to the road edge are considered as areas of high risk for WVC[9,10,22–25]. These findings are in strong correlation to habitat occupancy and in-line visibility, especially when grass areas as buffer zone between roads and surrounding habitat are not applied. In the case when buffer zones are present, it is proved that they need to be properly designed and maintained. In example, Ramp et al.[20] found that hotspots of wildlife-vehicle collisions coincided with abundant forage and protective cover along the road edge. The feed compound was further supported by Barrientos and Bolonio[26] who found that European polecat (*Mustela putorius*) collisions correlate with abundant rabbit burrows along the road-side. From the perspective of road type, it is expected that minor roads are regularly crossed by animals, while major roads represent more decisive type of border and are expected to be passed less frequently, except during the mating season or migration of the subadults (quest for a territory). High participation of highways (per km of road) is probably related to speed limits and traffic volume, and consequent possibility of both, drivers and animals to avoid collision. Similar effect of better road visibility at higher driving speeds (feeling safer) and increased risk of WVC was proposed by Borkovcová et al.[21]. Similarly to our results, Diaz-Varela et al[27] reported that 60% of wildlife-vehicles collisions in the province of Lugo, Northwest Spain occurred on primary basic roads, which corresponds to state roads in our study.

Similar to other studies, WVC in Croatia exhibits a clear relationship to season and time of the day. Despite the fact that temporal and seasonal risks of WVC in this study are made upon total collisions, they mainly reflect patterns of roe deer-vehicle collisions, since roe deer participates in 73% of accidents. As in other countries a highest risk on a daily basis coincides with sunset and sunrise, two periods with decreased visibility and increased activity of wildlife[12,27]. Within that, risk of collisions showed to be higher at sunset, when 44% of all WVC were recorded. In the case of wild boar, Diaz-Varela et al.[27] reported that the majority of accidents occurred 1–4 hours after sunset, while in the case of roe deer they are evenly distributed between sunset and sunrise. On the seasonal basis, peak of WVC coincides with April and May, a time when roe deer are trying to establish their territories[10,28], to satisfy their increased food demands or even to find the remains of salt near the roads. A second increase in WVC incidence occurs in October, November and December, probably due to the increased activity of offspring and maize harvesting[12]. Collective wild boar hunting and the subsequent increased disturbance can also contribute to the occurrence of WVC in that period. Similarly, Diaz Varela et al.[27] reported that majority of accidents involving wild boar occurred in the autumn and winter. Finally, frequent rainfalls and fogs decrease the visibility of drivers. According to species, it is interesting that despite a relatively large population, wild boar participated in only 9% of WVC. This is probably a result of their predominantly nocturnal way of life (parallel with decreased traffic volume during the night) and larger hunting pressure resulting in more discreet behavior. Finally, the presented number of WVC probably reflects only part of real accidents, since minor accidents or collisions involving drivers that were drunk or were driving too fast are not reported to the police departments.

In the case of WVC hot spots, it is possible to apply certain chemical or acoustic deterrents, but their effectiveness is usually short-term as animals adapt to them rapidly. Since the majority of mitigation measures are limited to roads and their immediate surroundings, the education of drivers and more frequent warnings emphasizing most critical periods of the day and year should be applied. Finally, as concluded by Gunson et al[29], this problem requires multidisciplinary approach on a local basis, which should also include game managers providing data on the estimated numbers of game species and traditionally used migration corridors.

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## NALETI VOZILA NA DIVLJE ŽIVOTINJE U HRVATSKOJ – RIZIK ZA LJUDE I ŽIVOTINJE

## SAŽETAK

U posljednje vrijeme je broj naleta vozila na divlje životinje u porastu te danas predstavlja problem na svjetskoj razini glede stradavanja divljih životinja, fragmentacije staništa, promjena u ponašanju pa čak i izumiranja lokalno ugroženih populacija. Pored navedenoga, naleti vozila na divlje životinje također mogu uzrokovati ozljede i smrt ljudi. Tijekom trogodišnjeg praćenja utvrđeno je ukupno 7495 naleta vozila na divlje životinje, uključujući poglavito srnu običnu (73%), dočim su ostale vrste bile znatno rjeđe zahvaćene (divlje svinje – 9%; zec obični – 5%; jelen obični i fazan svaki sa 4%). Učestalost naleta vozila na divlje životinje promatran je na razini teritorijalne rasprostranjenosti, sezonske i dnevne pojavnosti te tipa prometnice (ukupno i prema 1 km).