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Bats as Victims of Vehicles on a Road Crossing a Mosaic of Habitats in South-Western Poland

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Abstract: A five-year study (2018-2022) conducted between April and October on a road in south-western Poland revealed 104 bats killed by vehicles. They represented at least 12 species. Bats of the genus *Pipistrellus* dominated in the collected samples. Relatively frequently recorded were: *Nyctalus noctula* and *Myotis nattereri* as well as small bats of *Myotis* (mostly not classified to species). *Eptesicus serotinus* and *Plecotus auritus* (common in Polish bat assemblages) occurred rarely. August and September were the periods with the highest number of bat casualties (ca. 2/3 records). More cases of bat casualties than expected were noted in places where a road crossed forests. The presence of embankment did not reduce the number of roadkills. This study confirms that bats are threatened by traffic, and species composition of bats killed by vehicles depends on landscape structure and local bat assemblages.

Key words: Chiroptera, mortality, *Pipistrellus,* road casualties, seasonal changes, traffic

Introduction

Many groups of animals are threatened by collisions with vehicles on roads (Hodson 1960, Fahrig & Rytwinski 2009, Hill et al. 2019) including various species of mammals (Hill et al. 2020, Moore et al. 2023). Previous studies on the threat posed to bats by vehicles showed that the phenomenon is characterised by diverse intensity and pertains to many species (Kiefer et al. 1994-1995, Lesiński 2007, 2008, Gaisler et al. 2009, Lesiński et al. 2011, Medinas et al. 2019). The number of bats as victims of collision with vehicles depends on the landscape structure around roads (Lesiński 2007, Medinas et al. 2013, 2019). Linear elements that concentrate bat movements (Limpens & Kapteyn 1991) increase the risk of collision with vehicles (Lesiński 2007, 2008, Russell et al. 2009). More bats are killed in places surrounded by habitats suitable for feeding such as water bodies (Bartoszewicz 1997, Medinas et al. 2013), forests and thickets (Lesiński 2007). Species flying low above ground or feeding near vegetation are more threatened (Lesiński 2007, Claireau et al. 2019) although not on all studied roads this relationship can be demonstrated. In central Europe, the

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long-eared bat *Plecotus auritus* (Linnaeus, 1758) is the frequent and regularly noted as a victim on roads (Lesiński et al. 2011), which flies low, usually near vegetation (Entwistle et al. 1996).

Apart from larger elaborations, there are several published local reports from Poland containing data on bats as victims of the road traffic (Bartoszewicz 1997, Lesiński & Gwardjan 2001, Gryz & Krauze 2008, Lesiński et al. 2009, Lesiński 2011). These reports confirmed regional variability of bat species and their share among road victims.

The studies on this phenomenon are not easy and that is why mortality of bats on roads has been documented on only a few road stretches. Data from monitored road stretches during a long time period are rare. The aim of studies undertaken in south-west Poland was to obtain such data from roads of intensive and around-the-clock traffic. We attempted to determine species composition of bats dying on the road and periods of the highest bat mortality.

Materials and Methods

Study area

Stretches of the highway S3 near Lubin in Lower Silesia in SW Poland were monitored (Fig. 1). Northern part was dominated by open agricultural lands, mainly arable lands and grasslands usually associated with watercourses. The area was mostly treeless, only along the short stretch the route ran along the edge of forest complex. The Scots pine in the age of about 60 years dominated in the habitat of mixed coniferous forest. Habitats were more diverse in the southern part of monitored route (Fig. 1). It included large grasslands (mainly meadows), interchange points cutting the route (linear woodlands, alleys, streams and small rivers), rural settlements and various types of tree stands. Most common were mixed coniferous forests dominated by the Scots pine. Broad-leaved forests – dry and riparian – and poplar thickets were present in some places. No area-based forms of nature protection were present along the road.

The road was surveyed along 45 short sections (from 2 to 688 m long, about 280 m/section) of a total length of 11.8 km. There were 12 sections between Gaworzyce and Polkowice of a total length of 3.6 km (58.3% of sections had protective screens and 41.7% of sections did not have screens). On the route between Lubin and Legnica there were 33 sections of a total length of 8.2 km (63.6% with screens and 36.4% without screens). Weighted mean for all sections was 61.9% for those with screens and 38.1% without screens. Regularly monitored road sections were situated mainly in a mosaic of habitats (56.8% i.e. 6.7 km), open agricultural lands (31.3% i.e. 3.7 km) and forests (11.9% i.e. 1.4 km).

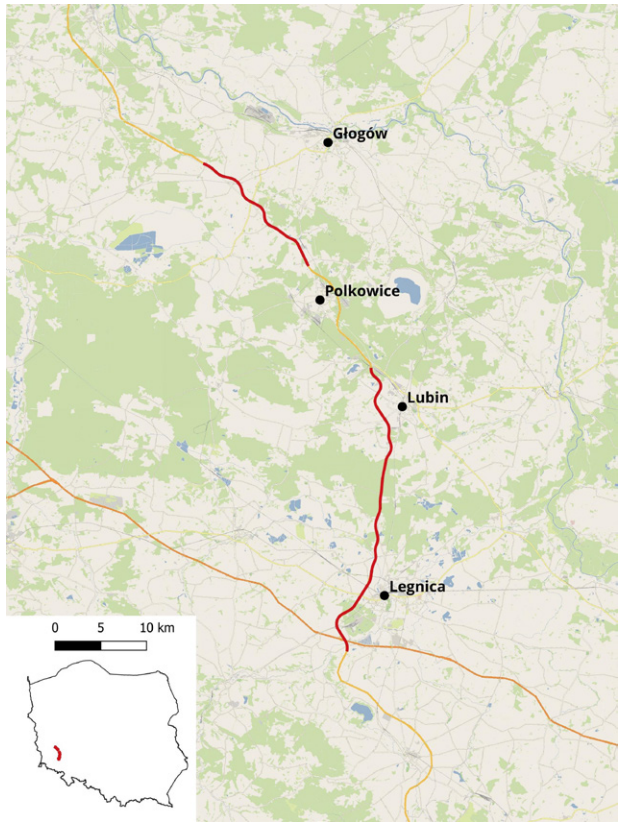

Fig. 1. Road sections (marked in red) in south-west Poland where bats killed by vehicles were searched for. Green – forests, blue – waters, white – open areas (fields and meadows). Most important towns near the road are marked. Base map: © authors OpenStreetMap, Open Database License.

Methods

Studies were carried out in the years 2018-2022 and took place in periods of the highest bat activity starting with emergence from hibernation (April-May). Both belts of the road and its roadside (up to appr. 3 m wide) were checked. Surveys were conducted from a slowly moving car or on foot. All found bats were removed from the road. Eight visits (including three along the whole length of the route in 2019) were made between July 1st and August 15th (6 visits) and in the autumn from September 1st to October 30th (eight visits). Time span between surveys was about 7 days.

In October 2018 three surveys covering the whole route were performed. Similarly, in spring 2019 the surveys covered the whole route (about 50 km long section between Gaworzyce and Leg-

nica). Based on obtained data, the target monitoring section for the years 2019-2022 was identified and selected.

In total 91 field surveys were performed. Three of them were made in the year 2018 and 22 surveys per year between 2019 and 2022:

2018 – 19 Oct, 24 Oct and 30 Oct,

2019 – 28 Mar, 5 Apr, 12 Apr, 20 Apr, 27 Apr, 5 May, 14 May, 21 May, 2 Jul, 11 Jul, 20 Jul, 29 Jul, 7 Aug, 15 Aug, 7 Sep, 14 Sep, 20 Sep, 26 Sep, 4 Oct, 12 Oct, 20 Oct and 30 Oct,

2020 – 7 Apr, 14 Apr, 21 Apr, 28 Apr, 4 May, 11 May, 17 May, 25 May, 5 Jul, 11 Jul, 19 Jul, 26 Jul, 5 Aug, 13 Aug, 7 Sep, 17 Sep, 24 Sep, 30 Sep, 7 Oct, 15 Oct, 20 Oct and 27 Oct,

2021 – 7 Apr, 11 Apr, 23 Apr, 30 Apr, 8 May, 11 May, 21 May, 25 May, 5 Jul, 11 Jul, 25 Jul, 30 Jul, 8 Aug, 25 Aug, 7 Sep, 16 Sep, 24 Sep, 27 Sep, 1 Oct, 15 Oct, 20 Oct and 27 Oct,

2022 – 5 Apr, 12 Apr, 23 Apr, 30 Apr, 10 May, 18 May, 24 May, 30 May, 9 Jul, 16 Jul, 24 Jul, 31 Jul, 8 Aug, 17 Aug, 6 Sep, 11 Sep, 19 Sep, 27 Sep, 7 Oct, 14 Oct, 21 Oct and 28 Oct.

In the years 2018-2019, bats were determined from photos while in the years 2020-2022 – from dried specimens. Therefore, in many cases some animals could not be identified to species, especially those of the genera *Myotis* and *Pipistrellus*. As some of features important to determine species from the group *Pipistrellus pipistrellus s.l.* [*P. pipistrellus* (Schreber, 1774) or *P. pygmaeus* (Leach, 1825)] in dead individuals were poorly visible, those bats were classified only to the genus level.

χ^2 test was used to assess: the similarity of shares of particular species or groups of species among bat victims on various roads, the similarity of proportion of the number of killed bats on roads of a given characteristics (crossing various habitats or the presence of screens) and the share of this characteristic on studied road (at significance level $p = 0.05$).

Results

One hundred and four individuals of bats belonging to at least 12 species were found killed by vehicles in the years 2018-2022 (Table 1). Many individuals of the genera *Pipistrellus* and *Myotis* were not identified to species. In the case of the second genus, apart from the Brandt's bat *Myotis brandtii* (Eversmann, 1845), the presence of species like the whiskered bat *M. mystacinus* (Kuhl, 1819) or the Alkatoe bat *M. alcathoe* Helversen et Heller, 2001 was possible.

Bats of the genus *Pipistrellus* definitely dominated among collected samples (more than 50% of individuals). Some features of dead individuals indicated that the common pipistrelle *P. pipistrellus* probably was more abundant than the soprano pipistrelle *P. pygmaeus*. Third species representing this genus – the Nathusius' pipistrelle *P. nathusii* (Keyserling et Blasius, 1839) was relatively rare. From other bats determined to species, the most often

Table 1. Species of bat victims found on the road in SW Poland and year of record.

Species	2018	2019	2020	2021	2022	Total (%)
Myotis bechsteinii	0	0	2	1	0	3 (2.9)
Myotis nattereri	0	2	1	2	1	6 (5.8)
Myotis daubentonii	0	1	1	0	1	3 (2.9)
Myotis brandtii	0	0	1	0	1	2 (1.9)
Myotis spp. (*mystacinus*/*alcathoe*/*brandtii)*	0	5	2	2	5	14 (13.5)
Eptesicus serotinus	1	0	0	0	0	1 (1.0)
Nyctalus leisleri	0	0	0	1	0	1 (1.0)
Nyctalus noctula	0	1	1	5	3	10 (9.6)
Pipistrellus pipistrellus or *Pipistrellus pygmaeus*	0	7	7	5	10	29 (27.9)
Pipistrellus nathusii	1	1	0	0	1	3 (2.9)
Pipistrellus spp.	0	7	4	4	10	25 (24.0)
Plecotus auritus	0	1	0	0	0	1 (1.0)
Barbastella barbastellus	0	0	1	0	0	1 (1.0)
Chiroptera spp.	0	3	1	1	0	5 (4.8)
Total	**2**	**28**	**21**	**21**	**32**	**104 (100.0)**

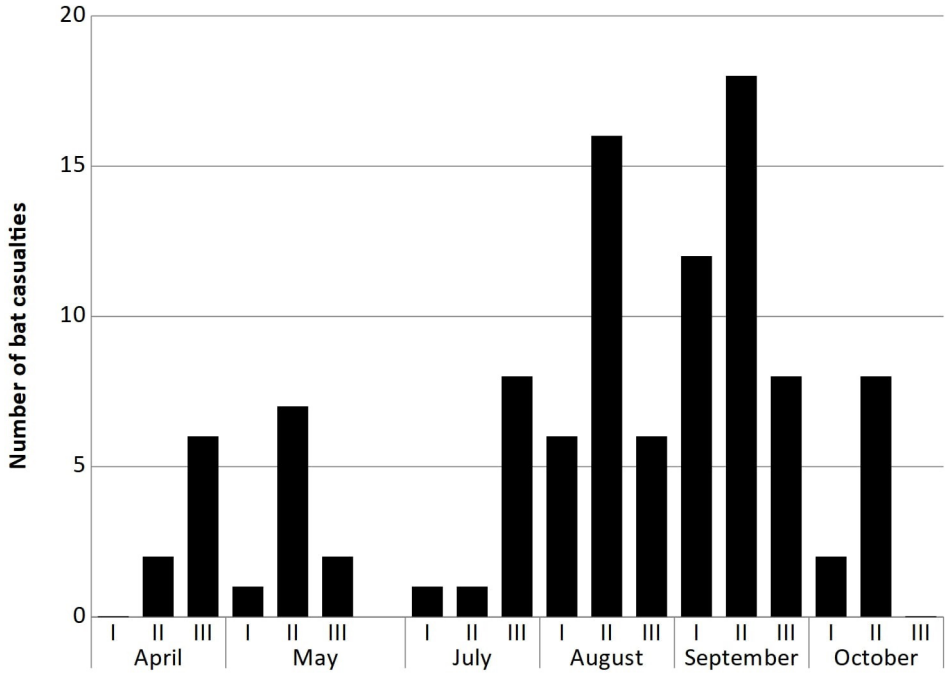

Fig. 2. The number of bat individuals killed on the road in various decades of months in the years 2019-2022.

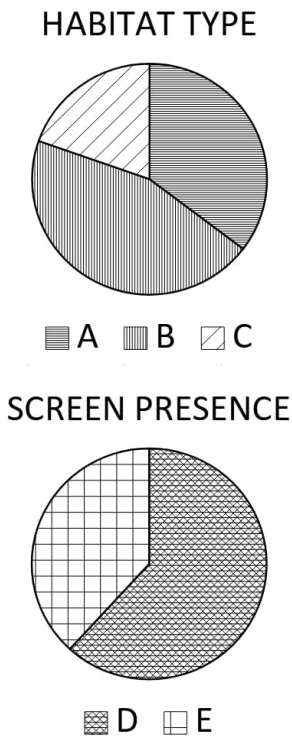

Fig. 3. Percent of dead bats (N = 104) found in various types of habitats in the years 2019-2022: A – forest, B – mosaic of habitats, C – open areas, and in relation to the presence of screens by the road: D – with screen, E – without screen.

killed were: the common noctule *Nyctalus noctula* (Schreber, 1774) and the Natterer's bat *Myotis nattereri* (Kuhl, 1818). Noteworthy was the presence of species like: the Bechstein's bat *Myotis bechsteinii* (Kuhl, 1818), the lesser noctule *Nyctalus leisleri* (Kuhl, 1818) and the common barbastelle *Barbastella barbastellus* (Schreber, 1774). The serotine bat *Eptesicus serotinus* (Schreber, 1774) and the brown long-eared bat *P. auritus* were represented only by single individuals (Table 1).

Most bats killed by vehicles were noted in August and September when about 2/3 of all casualties were recorded (Fig. 2). In September, the mean number of findings was 10 per study year.

The effect of selected road characteristics on the number of killed bats was tested (Fig. 3). Among various types of habitats, dead bats were most often found in places where the road crossed forests or a mosaic of habitats while the least number of collisions was noted in open areas. Comparison of proportions of habitats crossed by the road showed that individuals died on forested sections significantly more often than one would expect ($\chi^2 = 14.41$, $p < 0.001$). No significant differences were found on open road sections ($\chi^2 = 2.61$, $p = 0.11$) and on a mosaic of habitats ($\chi^2 = 2.37$, $p = 0.12$). The presence of screens did not affect the frequency of killing bats – the proportion of the number of found bats was nearly identical on road sections with and without screens.

Discussion

Data presented in this study confirm a great variability of species composition and proportion between the species of bats killed by vehicles on various sections of roads. The domination of bats of the genus *Pipistrellus* found in this study is similar to that re-

Table 2. Comparison of the share of selected species of bats as victims of road traffic in SW Poland (this study) with that in Germany (Kiefer et al. 1994-1995) and in central Poland (Lesiński 2007, 2011, Lesiński et al. 2011). The number of individuals of particular species is presented in relation to the number of the remaining bats. Statistically significant differences are given in bold.

Species	SW Poland (I) N = 104	Germany (II) N = 164	Central Poland (III) N = 197	I vs. II χ^2, p	I vs. III χ^2, p
Myotis bechsteinii	3 : 101	4 : 160	0 : 197	0.03, 0.86	3.19, 0.07
Myotis nattereri	6 : 98	6 : 158	19 : 178	0.26, 0.61	0.88, 0.35
Myotis mystacinus/ alcathoe/brandtii	16 : 88	14 : 150	11 : 188	2.354, 0.13	**7.01, 0.01**
Myotis daubentonii	3 : 101	9 : 155	69 : 128	0.49, 0.48	**36.89, <0.001**
Eptesicus serotinus	1 : 103	21 : 143	8 : 189	**10.33, 0.00**	1.31, 0.25
Nyctalus noctula	10 : 94	24 : 140	20 : 177	1.03, 0.31	0.00, 0.96
Pipistrellus spp.	58 : 46	51 : 113	7 : 190	**15.05, <0.001**	**40.71, <0.001**
Plecotus auritus	1 : 103	12 : 152	45 : 152	**4.28, 0.04**	**23.51, <0.001**

corded in Germany and different from that noted on roads in central Poland (Table 2). In Czechia (Gaisler et al. 2009) and in Portugal (Medinas et al. 2013) a more frequent presence of species of the genus *Pipistrellus* was also noted. On the other hand, *P. auritus* regularly recorded victim on many European roads (Lesiński et al. 2011) was rare on the road under study (Table 1) and less frequent than in Germany and in SW Poland (Table 2). Noteworthy, it was also not found on the road in Czechia (Gaisler et al. 2009). *E. serotinus* represented by one individual only was also rare (Table 1), although it belongs to most common and numerous bats in Poland (Sachanowicz et al. 2006). Rare presence of the two species is hard to explain. Possibly, locally low densities are at stake. *Myotis daubentonii* (Kuhl, 1819) was markedly more often on roads in central Poland than that in our study area (Table 2).

Bats of the group *Myotis mystacinus*/*alcathoe*/*brandtii* were relatively often killed by vehicles on the road in SW Poland (about 15% of bat victims). Similarly, and even more often, they were found on one of the roads in central Poland (Lesiński & Gwardjan 2001). Locally, these species are seriously threatened by road traffic.

From among bats noted in the study area remarkable are those associated with forests of a great share of broad-leaved tree stands: *M. bechsteinii*, *N. leisleri* and *B. barbastellus* (Dietz et al. 2007). Such tree stands are present in forests cut by the study road.

With respect to periods when most bats were killed by vehicles, our study area was similar to the road near Brno in SE Czechia (Gaisler et al. 2009) and to the road in Portugal (Medinas et al. 2013). In Germany (Kiefer 1994-1995) and near Warsaw (Lesiński 2007, Lesiński et al. 2011), most victims were noted earlier (August and especially its first half). On a short road section on the periphery of Warsaw, most bats died in September (Lesiński 2008) but the sample was dominated there by individuals of *M. nattereri* which probably commuted to places of swarming and wintering.

It was confirmed on the road in SW Poland that more bats die in habitats visited for feeding (forested areas) than in areas rarely visited by bats (open areas) (Lesiński 2007). Our study did not statistically confirm that in open areas fewer bats die than one would expect from their share. This was probably a result of a small sample of victims. Noteworthy, screens by the roads did not decrease the risk for bats caused by road traffic. Species of weak sonar do not rise after passing the screen but decrease their flight to keep contact with the substratum.

Obtained data do not allow for assessment of the effect of the studied road on mortality of particular species. The number of bats found as victims of the traffic is many times lower than the real scale of the phenomenon (Slater 2002). Moreover, we do not know the sizes of local bat populations. One may only expect that for species of the genus *Pipistrellus* and for small species of the genus *Myotis*, the road traffic may be an important source of mortality.

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