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Bat road casualties and factors determining their number

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Abstract

This paper examines 167 records of 14 bat species killed on roads in Poland. Regional differences in the species composition of road traffic accident records resulted from differences in the structure of local bat faunas. Young-of-the-year individuals (ind.) were killed significantly more often than adults. The highest mortality occurred in August and in the first half of September during intense dispersal of young bats. The highest incidence of road casualties was noted in places where roads crossed bat flyways, especially at junctions with forest edges and tree alleys. The rate of mortality depended on the habitat. It was highest where roads approached tree stands (up to 6.8 ind./km/year) or crossed a forest (2.7 ind./km/year) and lowest within densely built-up areas of Warsaw (0.3 ind./km/year). The mean was 1.5 ind./km/year in an 8-km section of a road near Warsaw. Road mortality depended on the hunting strategy of bats, in particular on the height of their flight. Road casualties were frequent for the low-flying gleaner, *Myotis daubentonii* (39.5% of the records), but rare for the high-flying aerial hawker, *Nyctalus noctula* (1.9%).

Keywords: bat protection; Chiroptera; landscape; mortality; roadkill ecology; threats; traffic casualties.

Introduction

Studies conducted to date on animal mortality on roads have shown that bats are not frequently killed by motor vehicles (Hodson 1960, Seibert and Conover 1991, Ashley and Robinson 1996, Bartoszewicz 1997, Smith and Dodd Jr. 2003). This is primarily because of their low densities compared to high densities of species killed more often (e.g., small birds, amphibians, rodents). Only a few studies have analysed bat road casualties. Records of bat mortality on roads in Germany (mainly car accidents) show that most bat species are vulnerable (Kiefer et al. 1994/1995, Haensel and Rackow 1996). Some data has also been published as short notes (e.g., Lesiński and Gwardjan 2001, Dikiy and Srebrodolska 2006). Recently, a 4-year study on a road close to a bat hibernation site was described as a special threat case (Capo et al. 2006). However, little is known on the rate of bat mortality on different roads, and also on the effects of population and habitat factors, especially the landscape structure. Therefore, the aim of this study was to focus on these issues.

Materials and methods

Two methods were used for collecting data on bats killed on roads: (1) in the period from May to October of 1994–2000, an 8-km section of a two-lane highway with heavy traffic near Warsaw was surveyed at regular intervals (on average one survey of both roadsides per week), and irregular surveys were carried out between 1992 and 1993, and 2001 and 2004 (Figure 1); and (2) records of bats found by chance on different roads across Poland (by author and other people – surveyed by a questionnaire) in the period 1993–2001. Also, published data from Poland were used (Bartoszewicz 1997, Lesiński and Gwardjan 2001).

The bat casualty records consisted of date, species, sex and age (of the first year or older), and were established based on not completely ossified bones in joints of the digits. External characters (especially forearm length, ear shape, foot, calcar length, presence of post-calcarial lobe) were used to identify the bat species. Sometimes the skulls were examined. To compare differences in proportion of species (in tables 2×2), the χ^2-test with Yates' correction was used.

Results

In total, 167 records of bat road casualties are known in Poland (Table 1). They represented 14 species of which *Myotis daubentonii*, *Plecotus auritus* and *Eptesicus serotinus* were most frequently killed (39.5%, 24.2% and 9.6% of the records, respectively). *M. daubentonii* clearly dominated on the 8-km road section near Warsaw. In other parts of Poland, the proportion of *E. serotinus* was higher, while *M. daubentonii* was lower. On roads near Kielce (central Poland), *Myotis mystacinus* or *Myotis brandtii* were the most frequent casualties (over 50% of the records). Records of *Rhinolophus hipposideros* occurred only in south Poland.

Young-of-the-year individuals were killed significantly more frequently than expected. The expectation was one young per two adult individuals (for most species only one young is born; for three species, representing approximately 4% of records, two young are regularly born; some females have no reproduction). Sex ratio did not significantly differ from 1:1 (Table 2).

Bat road mortality records were most frequent in late summer and early autumn (in August and at the beginning of September). In the periods preceding parturition, i.e., in June, few bat road accidents were recorded. *M. daubentonii* road mortality was highest over August, whereas *P. auritus* road mortality was highest in the second half of August and in the first half of September.

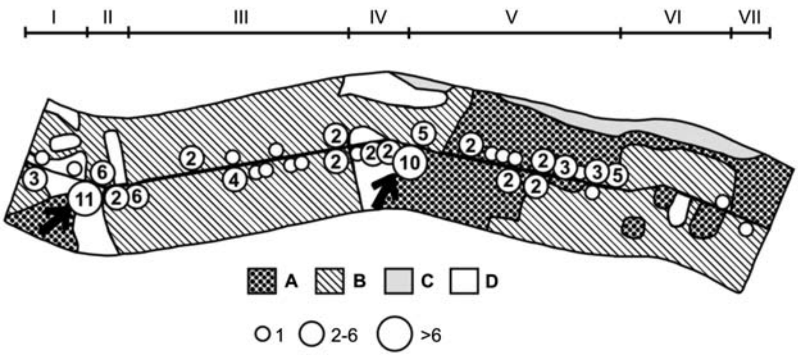

Figure 1 The distribution of bat road casualty records on a highway near Warsaw in relation to habitat structure at a distance of 0.7 km on each side. A, woods and forests; B, built-up areas; C, waters; D, open habitats. I–VII, road sections. Circles, bat records (empty circles, single individuals; numbers indicate more than one individual in the same place). Arrows indicate probable main routes of bat dispersal flyways.

Table 1 The number of bat road casualties near Warsaw and in other parts of Poland.

Species	Warsaw surroundings (n=112)	Other parts of Poland (n=55)
Rhinolophus hipposideros	0	2
Myotis myotis	0	1
Myotis nattereri	10	2
Myotis mystacinus	4	5
Myotis brandtii	4	2
Myotis dasycneme	2	0
Myotis daubentonii[a]	53	9
Eptesicus serotinus[b]	3	12
Pipistrellus nathusii	2	1
Nyctalus noctula	2	1
Nyctalus leisleri	1	0
Plecotus auritus	25	13
Plecotus austriacus	1	0
Barbastella barbastellus	0	2
Myotis spp. (*mystacinus/brandtii*)	3	5
Not determined	2	0

Significant differences in species by region (d.f.=1): [a]$\chi^2=5.93$ ($p<0.05$), [b]$\chi^2=11.79$ ($p<0.001$).

Table 2 Age and sex structure of bats killed on roads by motor vehicles.

Category of individuals	Number of observed casualties	Number of expected casualties	Significance of differences (d.f.=1)	
			χ^2	p
Females	30	30.5		
Males	31	30.5	0.02	>0.5
Adults	29	56.7		
Juveniles	56	28.3	40.65	<0.001

Peak road mortality of *P. auritus* occurred approximately 2 weeks later than that of *M. daubentonii*. The distribution of the number of casualty records for other species was similar to that of *M. daubentonii* (Figure 2).

The mean density of bat road casualties near Warsaw between 1994 and 2000 was 1.5 ind./km/year, and it was highest at 6.8 ind./km/year where a narrow forest stretch adjoined the road (section II in Figure 1), or where the road crossed a forest at 2.7 ind./km/year (section V in Figure 1). It was low where the road crossed open areas (sections I and IV in Figure 1) and suburban residential areas (sections III and VI in Figure 1) at 0.9 and 0.7 ind./km/year, respectively, and especially in densely built-up areas of the city (section VII in Figure 1) at 0.3 ind./km/year.

Road mortality of different bat species depends not only on their abundance but also on their hunting strategy, especially on the height of their flight above the ground level. *M. daubentonii*, gleaning species that fly very low and belonging to the most common bats, is most frequently killed by motor vehicles in Poland. *E. serotinus*, abundant species but flying higher and belonging to aerial hawkers, is clearly less frequently killed. *Nyctalus noctula*, flying in open spaces and highest of all the bat species, is least frequently killed by vehicles, although this is one of the dominant species in bordering areas. *M. mystacinus* and *M. brandtii*, fly relatively low, are rather frequent road casualties although they are rare species (Table 3).

Discussion

Among natural factors of bat mortality, the predation of owls is cited as an important factor (Ruprecht 1979, Speakman 1991). Large aggregations of bats (winter and nursery colonies) sometimes cause opportunistic behaviour of avian and mammalian raptors, significantly increasing the proportion of bats in their diet (Bauer 1956, Kowalski and Lesiński 1990, Tryjanowski 1999). Environmental pollution is believed to be the most important anthropogenic factor (Jefferies 1972, Geluso et al. 1976, Stebbings 1988). The results of this study also show that roads with fast, 24-h traffic could considerably increase the mortality of bats. Exact estimation of the role of this factor seems to be impossible as we have no data on bat densities. Moreover, simple counts of corpses found on roads are an underestimate of the actual road casualty rate (Slater 2002). But locally, at a high density

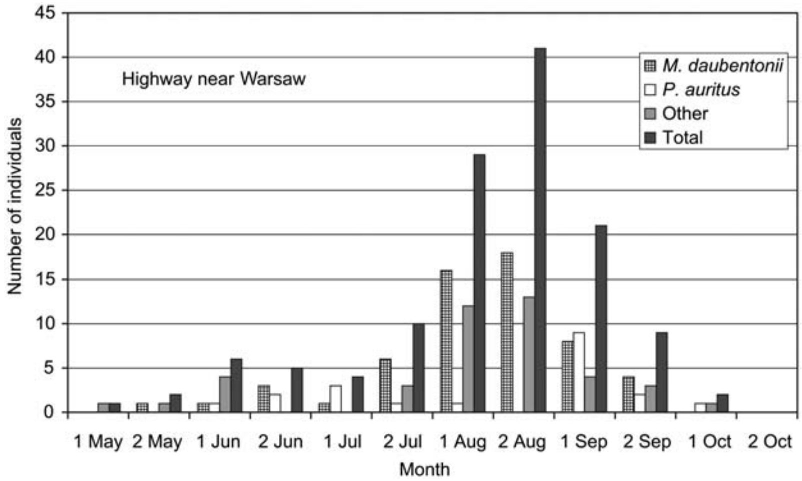

Figure 2 Phenological changes in the frequency of bat road casualties. 1, days 1–15 of a month; 2, days 16–30 (31) of a month.

Table 3 The impact of hunting strategy and position in dominance structure of selected species in the bat assemblage on the frequency of bats killed by motor vehicles on roads (data for central Poland).

Species	% of bats killed by cars (n=135)	Height of flight, prey catching	% of bats netted (mostly over waters)[a] (n=750)	Relative frequency among bats recorded using other methods[b]
Myotis daubentonii	39.3	Very low, gleaner	15.7	Very frequent
Plecotus auritus	23.7	Middle high/low, gleaner	12.0	Very frequent
Myotis mystacinus/brandtii	14.1	Low/middle high, aerial hawker	2.5	Rare
Eptesicus serotinus	9.6	Middle high, aerial hawker	9.9	Very frequent
Myotis nattereri	7.4	Middle high, gleaner	3.7	Frequent
Myotis dasycneme	1.5	Low, gleaner	0	Rare
Nyctalus noctula	1.5	High, aerial hawker	32.3	Very frequent

[a]Data from Kowalski and Lesiński 1995, Kowalski et al. 1996, Kowalski and Lesiński, unpublished data. [b]Data from Kowalski and Lesiński 1995, Kowalski et al. 1996, Lesiński et al. 2000.

of the road network, this may be an important anthropogenic source of bat mortality.

The timing of peak bat road casualties and also the fact that young bats are more vulnerable than adults (similar results to Haensel and Rackow 1996) indicate that the period of dispersal of young bats and migration to swarming and winter roosts are most dangerous. The incidence of bat road casualties is increased when roads cross habitats with high abundance of these animals. Auditory examinations with the use of ultrasound detectors in central Poland in the vicinity of an 8-km section of the road in this study showed that the highest densities of foraging bats were in forests, followed by suburban residential areas, open areas, and densely built-up urban areas (Lesiński et al. 2000); this correlates with the results of the present study.

The frequency of bat road casualties strongly depends on the structure of their local assemblages, as evidenced by differences noted in various parts of Poland (Table 1), and by comparing the species composition and frequency of road mortality between Poland and Germany (Haensel and Rackow 1996) (Table 4). The greatest difference was noted in the proportion of *Pipistrellus pipistrellus s.l.* (*P. pipistrellus* or *P. pygmaeus*) casualties, which was high in Germany but absent in Poland. This probably indicates that German populations of these species are more numerous. Road casualties of *Myotis myotis*, *Myotis bechsteinii* and *Plecotus austriacus*, the species at the boundary of their ranges in Poland (Pucek and Raczyński 1983) were markedly rarer in Poland, whereas those of *M. daubentonii* and *P. auritus* were more frequent.

The 2-week shift in the occurrence of peak numbers of *P. auritus* road casualties compared with that of *M. daubentonii* (Figure 2) implies differences in the timing of migration to swarming and winter roosts between these two species. In central Poland, *M. daubentonii* begins to occupy transient underground roosts in late August and early September (Lesiński 1990), whereas *P. auritus* occupy summer roosts throughout September and even later (Lesiński and Blicharski 2002).

Most bats are killed probably in a situation when a road crosses their migration flyways. It cannot be excluded that after rain some young, inexperienced bats take smooth road surface for water surface. This could explain frequent *M. daubentonii* casualties as this species forages mostly above water bodies.

This paper confirms the importance of linear landscape components for bat movements (Limpens and Kapteyn 1991). The greatest concentrations of bat road casualties were noted at the junctions with forest edges and tree alleys leading to forests. This fact has important impli-

Table 4 Comparison of the frequency of bat species road casualty records in Poland (this study) and Germany (Haensel and Rackow 1996).

Species	Poland, n=167 (%)[a]	Germany, n=307 (%)[a]
Rhinolophus hipposideros	2 (1.3)	3 (1.1)
Rhinolophus ferrumequinum	0 (0)	1 (0.4)
Myotis myotis[b]	1 (0.6)	22 (7.8)
Myotis bechsteinii	0 (0)	5 (1.8)
Myotis nattereri	12 (7.6)	7 (2.5)
Myotis mystacinus	9 (5.7)	14 (5.0)
Myotis brandtii[c]	6 (3.8)	1 (0.4)
Myotis dasycneme	2 (1.3)	0 (0)
Myotis daubentonii[d]	62 (39.5)	17 (6.0)
Miniopterus schreibersi	0 (0)	1 (0.4)
Vespertilio murinus	0 (0)	3 (1.1)
Eptesicus nilssonii	0 (0)	3 (1.1)
Eptesicus serotinus	15 (9.6)	35 (12.5)
Pipistrellus pipistrellus s.l.[e]	0 (0)	83 (29.5)
Pipistrellus nathusii	3 (1.9)	2 (0.7)
Nyctalus noctula[f]	3 (1.9)	39 (13.9)
Nyctalus leisleri	1 (0.6)	5 (1.8)
Plecotus auritus[g]	38 (24.2)	25 (8.9)
Plecotus austriacus	1 (0.6)	11 (3.9)
Barbastella barbastellus	2 (1.3)	4 (1.4)
Myotis spp.	8	3
Plecotus spp.	0	4
Not determined	2	19

[a]Excluding not determined bats. Significant differences between Poland and Germany by species (d.f.=1): [b]χ^2=8.28 ($p<0.05$), [c]χ^2=5.39 ($p<0.05$), [d]χ^2=48.10 ($p<0.001$), [e]χ^2=40.90 ($p<0.001$), [f]χ^2=12.95 ($p<0.001$), [g]χ^2=12.87 ($p<0.001$).

cations for bat protection against road mortality. Appropriate designs of these high-risk areas for bats would optimize the effectiveness of their protection at the lowest costs.

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