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Linear landscape elements and bat casualties on roads — an example

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A three-year (2004–2006) study on a 1-km road section near Warsaw (central Poland) indicated that road traffic may be an important cause of mortality in bats, at least locally. The total number of bat casualties was 52, mostly recorded on a short subsection (up to 9 individuals per 100 m of roadway and year). The bats were killed near two linear landscape elements — tree lanes, during the migration to mating and hibernation roosts. *Myotis nattereri* dominated the sample of dead individuals (over 70%).

Introduction

Transport routes (roads, railroads) causing the environmental fragmentation to many animals (Verbooom & van Apeldoorn 1990, Forman & Alexander 1998, Vos & Chardon 1998, Gerlach & Muslof 2000), also pose a threat to migrating bats (Kiefer *et al*. 1994/1995, Haensel & Rackow 1996, Lesiński 2007). Results of previous studies on bats do not provide much information regarding factors increasing the risk of vehicle-collision death. The collection of accidental data in Germany (Haensel & Rackow 1996) indicate that young individuals are more threatened than adults. The results of studies performed in Poland suggest that traffic threats to bats depend on the structure of the landscape and the foraging strategy of the species (Lesiński 2007). Nevertheless, we still do not possess estimates on the level of traffic threats to bats and the share of losses caused by this phenomenon in overall bat mortality.

The purpose of this work is to describe an example showing in what manner landscape structure and its use by bats (seasonal migration) could result in increased mortality of this group of animals.

Study area and methods

The study area was a 1-km-long section of a highway located in the northeast outskirts of Warsaw (central Poland). This road is a bidirectional asphalt road. Each direction comprises two lanes and a wide shoulder. On the right-hand side of the road (Fig. 1) there is a large complex of garden plots and suburban development. On the left-hand side from the north, the road is adjacent to several supermarkets and extensive parking areas. A significant section on this side is adjacent to a meadow and pasture; an average of three tree lanes connect the road with a forest complex of about 0.7 km^2. I do not possess data

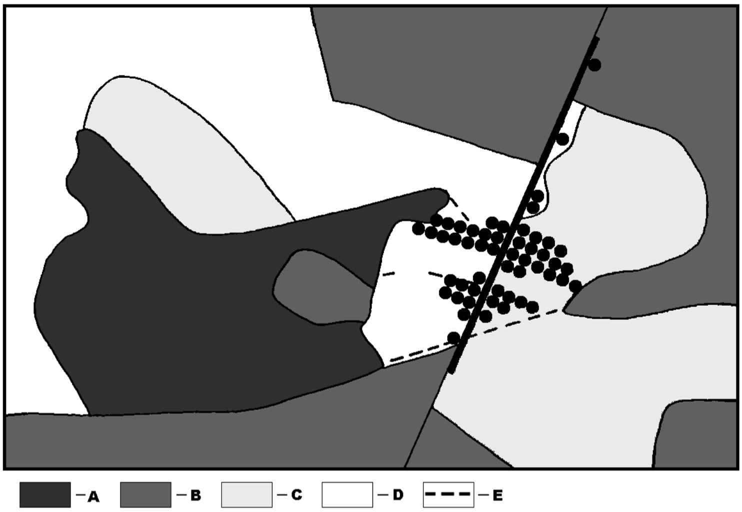

Fig. 1. Distribution of sites where dead bats were found on the road in 2004–2006. Thick line = road section under study, black dots = sites where dead individuals were collected. A: forest, B: built-up area, C: allotment gardens, D: open area, E: tree lane.

on vehicle traffic intensity on this road, but it can be considered heavy and round the clock, since the road handles traffic to countries situated to the east of Poland and connects two large cities, Warsaw and Białystok.

I conducted the studies from 2004 to 2006. In August and September of the first year, I had performed three preliminary inspections. In subsequent years in April–October I inspected the road on a regular basis with an average frequency of once per week. I recorded places where dead bats were found, taking into consideration the side of the road, and if possible the species and sex. Many specimens could not be sexed because of high level of destruction. In order to present seasonal changes in the number of dead bats found on the road, I divided every month in half (1–15 day, 16–30 or 31 day).

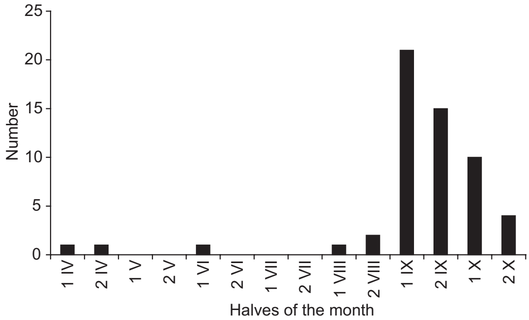

Fig. 2. Phenology of bat road casualties between April and October in years 2005 and 2006.

Differences between observed and expected frequencies were statistically tested using the χ^2-test (significance level $P = 0.05$). The Yates correction was used if at least one value was smaller than 10.

Results

The distribution of 52 sites where I found dead bats was clearly uneven (Fig. 1). The majority of individuals died near two points where the tree lanes were nearly perpendicular to the road on one side. No significant differences were noted in the proportion of bat species between the study years ($\chi^2 = 2.03$, d.f. = 2, $P = 0.36$). Neither the proportion of numbers of bat casualties on both sides of the road (24:28), nor the sex ratio (9 males:15 females) differed statistically from 1:1 ($\chi^2 = 0.04$, d.f. = 1, $P > 0.05$, and $\chi^2 = 0.3$, d.f. = 1, $P > 0.05$, respectively).

I recorded most bat road casualties in late summer and at the beginning of autumn with a peak (21) in the first half of September (Fig. 2). I noticed more cases in 2005 (28) than in 2006 (19). Most individuals killed by vehicles in 2005 (27) were found on a short 300-m-long subsection of the road, resulting in a high concentration of 9 individuals per 100 m.

Natterer's bat (*Myotis nattereri*) clearly dominated (over 70%) the sample of bats killed by vehicles on the road section under study. This corresponds with the frequency of *Myotis nattereri* in urban bat hibernacula of Warsaw (Table 1); no statistical difference between the incidence on the road and in winter roosts was found (χ^2 = 0.5, d.f. = 1, $P > 0.05$). Among other species, only the brown long-eared bat (*Plecotus auritus*) was killed relatively frequently (near 13%).

Table 1. The proportion of *Myotis nattereri* to other bat species on the studied road section (in 2005 and 2006) and in the Warsaw underground hibernacula (from Lesiński *et al.* 2001).

Species	Road (%)	Hibernacula (%)
Myotis nattereri	37 (78.7)	3146 (73.8)
Other species	10 (21.3)	1118 (26.2)

Discussion

The linear elements of the landscape comprise important places along which many bat species migrate when feeding and pass over during longer migrations between summer and winter roosts (Limpens & Kapteyn 1991, Verboom 1998). In locations where such linear elements (e.g. tree lanes) run perpendicular to the road they might indirectly contribute to bat mortalities, as suggested in this example. Similar concentrations of bat road casualties were described in France on the road section close to a bat hibernation site (Capo *et al*. 2006).

Being killed by vehicles on the studied road section is probably a significant cause of mortality, at least for *Myotis nattereri,* although exact calculations are not possible, since we do not possess data on the population size of this species, or numbers of individuals attempting to fly over the road. It should be remembered that the number of casualties found is smaller than the actual number of bats killed by vehicles: some individuals cannot be found while others are taken by carrion-eating animals (Slater 2002). Road traffic within the study area definitely poses a greater threat to bats than was documented. *Myotis nattereri* is a species that collects its prey from the surfaces of plants and is characterized by flying at rather low altitudes (Arlettaz 1996, Siemers & Schnitzler 2000). Thus, when flying to the road along tree lanes it is highly exposed to collisions with vehicles.

Within the studied road section, bats most likely migrate to places where mating and hibernation take place. Many bat species mate near their hibernation roosts (Parsons & Jones 2003, Parsons *et al*. 2003). Řehák *et al*. (1994) and Rivers *et al*. (2006) determined that *Myotis nattereri* shows the largest swarming intensity in the very period (September–mid-October) when large numbers of this species were killed on the road under study. The similarly expressed dominance of *Myotis nattereri* in winter roosts of Warsaw (73.8%, Table 1) also supports the contention that some heretofore unknown winter roost of bats could be found nearby the road.

The spatial difference in the threat levels to bats near roads described in this work, especially the concentration of prey near linear elements of the landscape, could be important in undertaking conservation measures. In places where intensive bat flights were found, such as in the study area, high fences or other structures should be tested that could reduce the number of bats killed by vehicles.

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