Eur J Wildl Res (2008) 54:709–714
DOI 10.1007/s10344-008-0200-0

ORIGINAL PAPER

Mortality of vertebrates on a road crossing the Biebrza Valley (NE Poland)

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Received: 15 January 2008 / Revised: 12 May 2008 / Accepted: 19 May 2008 / Published online: 14 June 2008

Abstract Mortality of vertebrates was monitored on a local road running across Poland's Biebrza River Valley during 2 years (August 2005–July 2006). On the basis of distance from the river and surrounding habitats, the road (of total length 2,510 m) was divided into three stretches. The road was monitored on foot by two people every month, over a few consecutive days. A total of 1,892 road kills representing at least 47 species were found. Of these, 90.7% were amphibians, 4.2% mammals, 3.1% birds and 2.0% reptiles. Most (70%) of the amphibians were anurans, with the common toad, common frog and moor frog among them together accounting for 82% of the total. Mortality among amphibians differed between months, most anurans dying in May and August, while a majority of *Urodela* are lost in October. The peaks in mortality were connected with the migration of adult amphibians in spring and juveniles in summer and autumn. The number of amphibians killed was greatest on the (wettest) stretch adjacent to the river and decreased with distance from it. Mortality among birds was highest in July—probably in association with the dispersal of young individuals. Among recorded mammalian road kills, there was a prevalence of small rodents (mainly voles) and insectivores (mainly shrews). Medium-sized mammals were found only accidentally. Mortality in general was conditioned by the number of anurans killed.

Keywords Biebrza National Park · Road losses · Amphibians · Birds · Mammals

Communicated by H. Kierdorf

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Introduction

Traffic is now one of the most important factors impacting upon wildlife. Furthermore, as road infrastructure is developing steadily, its negative effect can only be expected to increase (Jędrzejewski et al. 2006). The first studies on animal casualties caused by vehicles were done at the end of the nineteenth and beginning of the twentieth centuries (i.e. Barbour 1895; Stoner 1925; Sutton 1927). The second part of the twentieth century brought a rapid development of transport infrastructure (e.g. motorways), especially in the highly developed countries of Western Europe and North America. In the light of this new situation, a number of scientific studies were carried out (as reviewed in: Spellerberg 1998; Trombulak and Frissell 2000; Erritzoe et al. 2003). According to some authors, counts of road traffic casualties can also represent a tool in wildlife censusing (Jahn 1959; Baker et al. 2004). For others, animals killed by vehicles are a source of material for *post mortem* examinations (Loughry and McDonough 1996; Hauer et al. 2000; Orłowski and Siembida 2005; Krone et al. 2007). In Poland, however, few studies have thus far been done, and most that have been carried out have been concerned with a single class of vertebrate, i.e. birds (Ptaszyk 1979; Bereszyński 1980; Oleś 1993; Goławski and Goławska 2002), mammals (Orłowski and Nowak 2006) or amphibians (Najbar et al. 2006), or even one order, i.e. bats (Lesiński 2007) or a particular species

(Bakowski and Kozakiewicz 1988; Orłowski and Nowak 2004; Ciesiołkiewicz et al. 2006; Orłowski 2005; Orłowski 2007). Just a few have extended to all classes of vertebrate (i.e. Wołk 1978; Bartoszewicz 1997).

The road infrastructure in Poland is relatively undeveloped, though the country's accession to the European Union has accelerated the process whereby new A-roads and motorways forming part of the Trans-European Networks are built. As is well-known, some of these are planned for areas counted among the most valuable in Europe, like the Rospuda Valley to be crossed by the *Via Baltica* road.

In the light of this, our study has aimed to assess mortality of vertebrates on a local road located in another of Poland's main ecological corridors, i.e. the world-famous Biebrza Valley.

Study area

The study was conducted within Poland's Biebrza (Biebrzański) National Park, which is located in the northeast of the country, in the unit of regional administration known as Podlaskie Voivodship. The National Park, which was established in 1993, is the Poland's largest (at nearly 600 km^2), offering protection to one of the largest and best-preserved marshes and peatlands in Europe. The site is thus protected under the Ramsar Convention, as well as being included within the *NATURA 2000* network. A detailed map of the area may be found on the websites http://www.biebrza.org.pl/graf/mapa.jpg and http://www.biebrza-sat.webpark.pl/12.jpg.

We monitored a local road running between the bridge over the river in Goniądz (53°29′ N, 22°43′ E)—a town of about 1,900 inhabitants—and the village of Wólka Piaseczna. This gave a total transect length of 2,510 m. The road cuts across the central—and narrowest—part of the Biebrza Valley. It was built on its embankment in the 1960s and, except for three culverts, is devoid of any crossing structures for animals. It is a 4-m wide asphalt road, without a hard shoulder and closed to vehicles (other than buses) weighing more than 10 tonnes. The embankment is overgrown along its length by shrubs and trees (mainly willows *Salix* spp. and common alder *Alnus glutinosa*).

On the basis of distance from the river and surrounding habitats, we divided the road into three stretches: 580, 1,230 and 700 m long, respectively. The first begins on the bridge and is illuminated by street lamps along its first 200 m. This stretch is surrounded by oxbow lakes, meadows and pastures flooded regularly at least once a year. The second stretch crosses open marshlands, meadows partially abandoned and covered by willow thickets and also an alder carr. The third stretch runs via open pastureland and ends at the foot of a dune on which the aforementioned destination village is situated.

The road is used by local inhabitants and seasonally by tourists, so traffic is not heavy, though it does differ in intensity from one time of the year to another (Kruskal–Wallis=20.09, $p<0.05$). The authors' counts (50 h of manual counts during various times between dawn and dusk) showed that daytime traffic is heaviest in spring (over 35 vehicles per hour), probably as a reflection of visits made to the Park by birdwatchers (Fig. 1). Three counts made in summer at nighttime revealed that traffic was much lighter after dusk, with almost no vehicles at all passing between 01.00 and 03.00. Among the 1,149 vehicles noted, 86.5% were passenger cars, 10.1% agricultural vehicles and 3.4% trucks. As the road is narrow and quite windy, a majority of cars do not travel at more than 60 km/h.

Materials and methods

The studies ran from August 2004 to July 2006 inclusive. Data were collected on 3 to 7 days each month in the period (51 checks made in total). The road was controlled between 08:00 and 10:00 in the morning. Two people walked simultaneously along the transect on a few consecutive days. Half of the road was first checked by one person, while the other looked for remnants on the roadside. On the way back, the same procedure was used on the other half of the road. All animals found were removed to avoid double counting on subsequent days. Nonetheless, a comparison of the numbers of animals obtained during the first check in a given month and on the consecutive day showed that these did not differ (t=1.96, p>0.05, t paired test for log-transformed data). Moreover, an experiment with a video camera run in eastern Poland (Najbar et al. 2006) shows that, even without removal, only a small fraction of remnants remain on a road for more than 24 h.

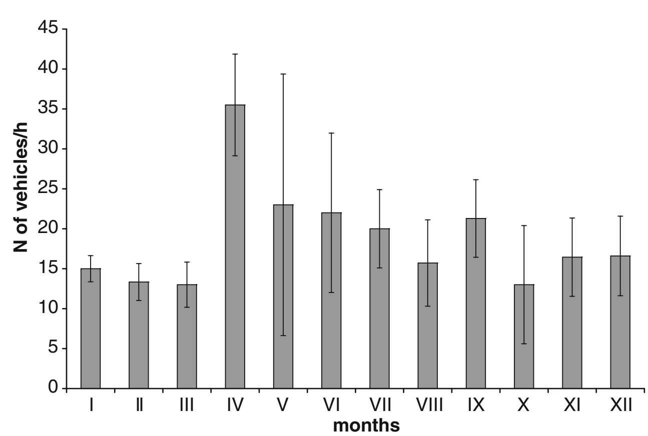

Fig. 1 Average traffic intensity between dawn and dusk

Table 1 Percentage shares of all casualties accounted for by particular species

Animal species	Number of individuals	% share
Bufo bufo	501	26.5
Bufo viridis	1	0.1
Bufo spp.	15	0.8
Rana spp.	528	27.9
Bombina bombina	1	0.1
Anura unidentified	212	11.2
Anura total	1,258	66.5
Triturus vulgaris	449	23.7
Triturus spp.	9	0.5
Urodeles total	558	24.2
Amphibians total	1,716	90.7
Lacerta agilis	11	0.6
Lacerta vivipara	1	0.1
Lacerta spp.	14	0.7
Natrix natrix	12	0.6
Reptiles total	38	2.0
Ciconia ciconia	1	0.1
Columba livia f. *domestica*	1	0.1
Asio otus	1	0.1
Jynx torquilla	1	0.1
Hirundo rustica	7	0.4
Motacilla alba	3	0.2
Luscinia sp.	2	0.1
Saxicola ruberta	1	0.1
Turdus merula	1	0.1
Turdus pilaris	1	0.1
Turdus sp.	1	0.1
Sylvia communis	2	0.1
Sylvia sp.	1	0.1
Phylloscopus sp.	1	0.1
Ficedula sp.	1	0.1
Lanius collurio	1	0.1
Garrulus glandarius	1	0.1
Sturnus vulgaris	4	0.2
Passer montanus	1	0.1
Passer sp.	1	0.1
Fringilla coelebs	6	0.3
Emberiza citrinella	2	0.1
Emberiza schoeniclus	2	0.1
Pyrrhula pyrrhula	1	0.1
Aves unidentified	14	0.7
Birds total	58	3.1
Vespertilionidae unidentified	1	0.1
Erinaceus europaeus	2	0.1
Talpa europea	5	0.3
Sorex araneus	9	0.5
Sorex minutus	1	0.1
Sorex spp.	12	0.6
Apodemus flavicollis	2	0.1
Apodemus agrarius	1	0.1
Apodemus spp.	8	0.4
Microtus oeconomus	9	0.5
Microtus agrestis	2	0.1
Microtus spp.	13	0.7
Ondatra zibethicus	1	0.1
Rodentia unidentified	6	0.3
Lepus europaeus	1	0.1
Canis familiaris	1	0.1
Nyctereutes procyonoides	1	0.1
Mustela vison	1	0.1
Mustela nivalis	1	0.1
Mustela sp.	1	0.1
Martes foina	1	0.1
Felis catus	1	0.1
Mammals total	80	4.2
Total	1,892	100.0

Whenever possible, the road victims were identified to species level and included into two categories (juvenile and adult). If the corpses' disintegration made species identification impossible, they were pooled into higher taxa (i.e. newts, toads, anurans).

Results

Altogether, the study period as a whole yielded 1,892 separate remains representing at least 47 species. Of the items, 90.7% were of amphibian origin, while mammals accounted for 4.2%, birds for 3.1% and reptiles for 2.0% of all casualties (Table 1). Anurans accounted for 73% (among which common toads *Bufo bufo* accounted for 40%, moor frogs *Rana arvalis* and common frogs *Rana temporaria* together for 42% of all the amphibians). Juvenile individuals accounted for 24.8% of all the anurans (42% of frogs, 13% of toads, 10.4% of unidentified anurans). Of identified urodeles (newts), 96% were juveniles.

The number of road-kills was highest along the first stretch and was lower on the stretches more distant from the

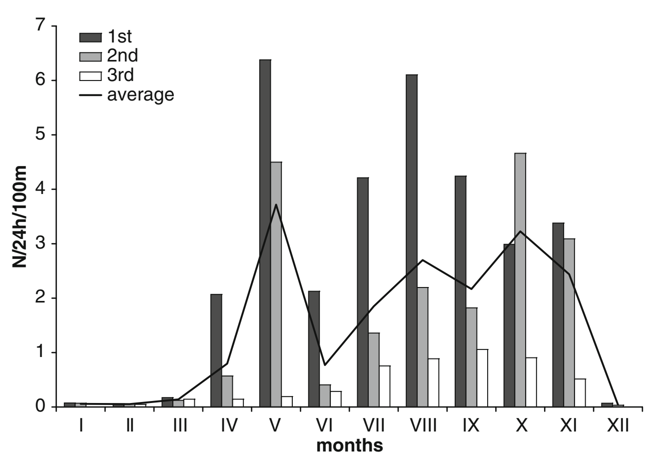

Fig. 2 Mortality rate of vertebrates (all taxa) on the three stretches

river (Fig. 2). The average figure obtained for the first stretch was higher than that for the second (t=2.41, p<0.05, t paired test) and the third (t=3.84, p<0.01, t paired test). Equally, the average mortality rate along the second stretch was higher than on the third (t=2.65, p<0.05, t paired test). On all stretches, the number of road-killed anurans in each month was positively correlated with total mortality (r=0.94, p<0.01; r=0.63, p<0.05; r=0.92, p<0.01 for stretches 1, 2 and 3, respectively).

Road mortality of anurans was double-peaked (in May and August). The number of casualties was highest on the stretch adjacent to the river and lowest on the last stretch (Fig. 3). The number of road-kills was dependent on both the month (df=11, F=9.86, p=0.000) and the stretch [df=2, F=5.08, p<0.001, two-factor analysis of variance (ANOVA)]. On average, 61% of the anurans found dead in August were juveniles.

The number of killed urodeles (newts) was low even throughout spring and summer, only to rocket in autumn. In this case, the largest number of casualties was noted on the second stretch and the smallest on the third (Fig. 4). Mortality was dependent on month (df=11, F=5.08, p=0.0000) as well as stretch (df=2, F=4.24, p<0.05, two-factor ANOVA). All the individuals found in autumn were juveniles.

Mortality among birds differed from month to month (Kruskal–Wallis=33.4, p<0.001), being highest in July (52% of all the casualties). Mortality among mammals also varied between months (Kruskal–Wallis=21.7, p<0.05). A moderately strong relationship was obtained between traffic intensity and the number of mammalian road-kills (r=0.52, df=11, p=0.0856). There was, however, no correlation between numbers of vehicles and the mortality rates in any other group.

Our assessment, based on a calculation of the average number of road-kills in each month and the number of days in a month, is that around 14,000 vertebrates are killed on the road every year.

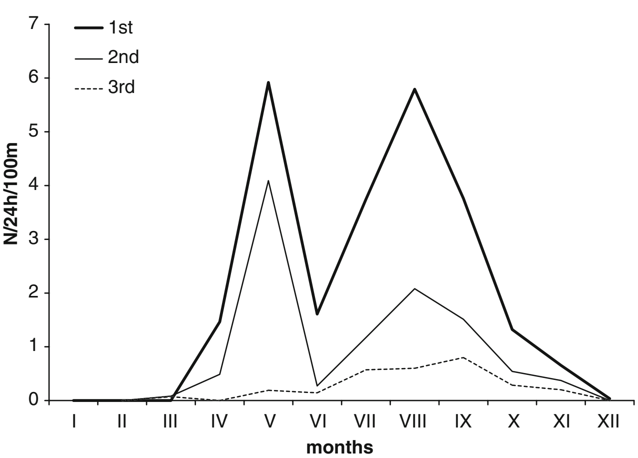

Fig. 3 Mortality rates among anurans (toads and brown frogs) on the three stretches

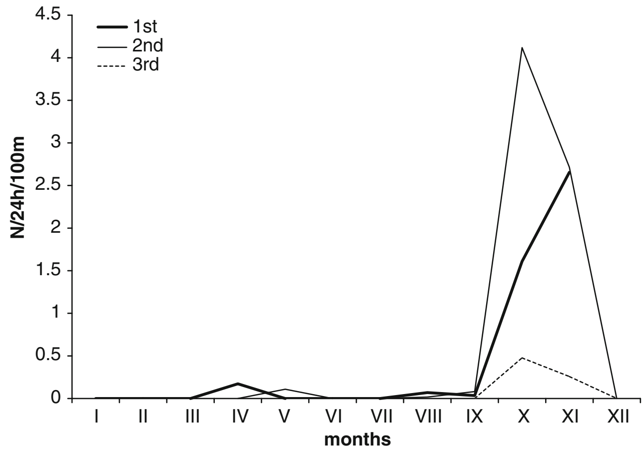

Fig. 4 Mortality rate among *Urodela* (newts) on the three stretches

Discussion

Overall mortality was shaped by the number of road-kills of anurans, the mortality in other groups playing a far less important role. The high mortality of amphibians on a relatively quiet road can be explained by three factors: characteristics of the surrounding habitats providing numerous breeding sites, migration patterns of amphibians demanding regular crossing of the road and the fact that individuals are slow-moving and inconspicuous (Trombulak and Frissel 2000).

Road-side topography may be critical where mortality of small vertebrates is concerned, and more wetland habitats adjacent to a road can result in more amphibians being killed by cars (Clevenger et al. 2003). Orłowski (2007) obtained a positive correlation between the number of road-killed toads and the overall area of water bodies around the road. In our study, too, closer approaches by the road to the river were associated with greater humidity of the surrounding area, and hence a higher mortality rate for anurans.

Many studies have shown that even light traffic can exert a critical influence on the survival of amphibians. Thus Kuhn (1987) calculated that four cars per hour could kill 10% of the entire population of common toads in an area, while 60 cars per hour resulted in 75% mortality in the population. According to Hels and Buchwald (2001), traffic reaching 4,000 vehicles per 24 h equates to ca. 100% common toad mortality among individuals crossing the road, and the probability of an individual being killed by a car depends on the traffic intensity and the velocity of the species. Contrary to amphibians, birds and mammals may be fast enough to avoid being hit by a vehicle.

Although traffic intensity is often perceived to be the most important factor increasing road mortality (review in Trombulak and Frissell 2000), it does not necessarily apply to amphibians. Thus, in the study by Orłowski (2007), mortality among common toads was higher on less-busy roads and was not correlated with traffic intensity. According to that study, the main factor affecting road mortality of common toad was the local abundance of the species. As it is said in Mallic et al. (1998) if some species is found often killed on the road, it may be the reflection of its large and thriving population. On the other hand, long-lasting impact of road-traffic may lead to population decimation or even local extinction due to increased mortality and lowered colonization rate (Vos and Chardon 1998). Therefore, low mortality on relatively busy roads may indicate that the local population has been already affected.

According to Trombulak and Frissell (2000), the fact that amphibians' life history includes migration leaves them extremely vulnerable to traffic. This is in line with our findings, inasmuch as that two-peaked mortality was observable for anurans, compared with single-peaked mortality in the case of urodeles. This connects clearly with the respective migration patterns. Orłowski (2007) registered only one peak for mortality among common toads, though in his study it was mainly adults that were killed. In our study, the first (spring) peak in mortality can be explained by reference to adults' migration to their breeding sites. The second peak, on the other hand, was shaped substantially by mortality among juveniles. It is possible that our study, carried out in very favourable conditions (very low traffic allowing for detailed observation and two observers walking along the same section of the road twice), resulted in very high detection rates of killed individuals. What is more, we conducted surveys by walking only, while the data in Orłowski (2007) derives partly from driving surveys, a method that could have resulted in underestimation of the density of road mortality (Langen et al. 2007) and does not make it possible to register juvenile amphibian victims. Hels and Buchwald (2001) highlighted just how relatively unreliable uncorrected road kill estimates might be, showing that up to 93% of certain amphibian road victims (*Triturus vulgaris* and *Triturus cristatus*) could be missed where a road is patrolled on foot once a day. They disappear eaten by scavengers or being run over by cars repeatedly. However, as our counts were done on a road with the traffic intensity at least four times lower and the density of scavengers such as corvids (Dyrcz et al. 1984) and foxes (Jędrzejewski and Kowalczyk 2005) in the area was moderate, we believe that our underestimation was not so great. Nevertheless, it must be taken into account that the overall (especially amphibian) mortality is greater than the number of dead individuals found.

Bird mortality was highest in summer, rocketing in July and plummeting to almost zero in winter. Such a pattern to avian mortality may reflect the dispersal of young and inexperienced birds (review in Erritzoe et al. 2003). Hell et al. (2005) also observed a marked seasonal variation in bird road kills, recording highest mortality in summer and lowest in winter.

According to Orłowski and Nowak (2006), the decisive factor affecting the level of mortality among small mammals is the daily traffic volume, with the majority of casualties recorded between May and October. Our study also obtained most (70%) mammalian road kills during this period. In the study by Hell et al. (2005)—performed mostly on first-class busy roads—medium-sized animals such as hamsters (*Cricetus cricetus*), brown hares (*Lepus europaeus*) and hedgehogs (*Erinaceus europaeus*) accounted for a considerable portion of the mammals killed. In our study, however, most of the mammals killed were small rodents (mainly voles *Microtus* spp.) and insectivores (mainly shrews *Sorex* spp.), larger mammals being nothing more than accidental road victims. Such results resemble those of Orłowski and Nowak (2006), wherein small rodents dominated (accounting for 40% of mammal kills), followed by insectivores (32%). However, the insectivores in that study were predominantly hedgehogs, a species recorded only twice in our study. Overall, then, there is no evidence that the volume of traffic recorded along our road poses a serious threat to medium-sized mammals. Neither does it influence large mammals such as ungulates. For mammals such as hedgehogs and hares, the probability of being killed at such a low traffic intensity is close to 0 (Hels and Buchwald 2001) as they move fast enough to avoid being run over. During winter checks, we often recorded tracks of moose *Alces alces*, roe deer *Capreolus capreolus* or wild boar *Sus scrofa* passing across the road, but we never found these animals killed.

Acknowledgments We would like to express our gratitude do Dr. M. Keller and Dr. P. Rowiński for their help in identifying the remains of birds. We would also like to thank Profs. Jacek Goszczyński and Michał Wasilewski for their comments on the manuscript and their help with the performing of statistical analyses. The text was revised by James Richards.

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