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Wildlife tunnels and fauna bridges in Poland: past, present and future, 1997-2013

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Wildlife Tunnels and Fauna Bridges in Poland: Past, Present and Future, 1997-2013

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Abstract: In Poland the road and rail network crosses many sensitive areas, such as national parks, landscape parks, wildlife reserves, landscape protection areas and Natura 2000 sites, i.e., the protected area system of the European Union, because of road density, high landscape diversity, and its mosaic pattern. As a consequence of Poland joining the European Union in 2004, many changes have happened and are still happening all over the country, especially in building new roads and railway lines. The harmonization of the Polish legal system with the EU directives required the improvement of environmental legislation making the monitoring before and after the building of such constructions necessary together with the preparation of environmental assessment studies. The animal migration problem has become one of the most important barriers in the decision-making process on where to build new roads and improve others. According to the previous plans, most of the roads that should have become expressways or highways of national or international importance also bring higher traffic and driving speed in those areas. As a consequence, the risk of collisions became higher and many motorists died in fatal accidents. On average, on the 160-km A2 highway running from Nowy Tomyśl to Konin, 40 accidents with mammals were recorded in one month in 2003. The consciousness of the society grew enormously following these events, and it also urged the appropriate governmental institutions, as well as private companies, investors, and non-governmental organizations, to study animals along the roads all over the country, with special attention to their movement. As a first step toward solving this problem, the identification of animal migration routes became an important task. Besides large species that can cause the death of the driver when colliding with a car (such as elk, deer, wild boar), several smaller animals (such as fox, badger, amphibians or reptiles) with vulnerable populations in the surveyed area were also studied, and the building of passages and bridges for wildlife has become not only an obligation but also a necessity both at the constructor as well as at the social level. Since 1997 more than ten overpasses and one underpass were built for large mammals (elk, deer, wolf, wild boar) in Poland. They are located along the E65 international road, Katowice - Kraków and the Przylesie - Nowogowczyce sections of the A4 highway, Poznan - Nowy Tomyśl and Nowy Tomyśl - Konin sections of the A2 highway, Stryszek- Białe Błota section of the no. 10. national road, and Komorniki - Stęszewo section of the no. 5. national road. The decision about the exact location of the game bridges and the game passage was made after detailed interviews with national park officials and foresters, in addition to the results of field work. The monitoring of the effectiveness of these constructions revealed a lot of mistakes and often proved no use of the mitigation measures by the target animals. The main reasons for non-functioning were too-small dimensions, especially width in all of game bridges; lack of screens separating the animals from noise; vibration, light and visual disturbances, no or not enough vegetation on the bridges; lack of guiding structures leading the animals to the passages; and lack of fences along the road. As a consequence of such results, mitigation measures were improved and maintained better. For small mammals, amphibians, and reptiles, nine underpasses were built in 2004 along the Budzisko - Augustów section of the international road called Via Baltica, Jeleniów section of the local road next to the E67 international road, and Chabówka - Rdzawka section of the E 47 expressway. The decision about where to put tunnels was made on the basis of field research (day and night transects, the sound monitoring of amphibians, and amphibian breeding sides investigations) made by national park staff, private companies, and volunteers. The follow-up monitoring of these structures showed that the effectiveness of the tunnels with guiding structures is nearly 100 percent for amphibians and reptiles and 85 percent for small mammals. In the following nine years (2005-2013) several more wildlife passages will be built on Polish roads along the Łódź - Częstochowa section of the A1 highway, Przylesie - Prądy section of the A4 highway, Rosnówek section of the no. 5. national road, Zywiec - Zwardoń section of the S69 international road, Wyszków - Skuszew section of the no. 8. national road, and Poznań - Kórnik section of the no. 11. national road. From among these constructions the most important passages will be along the Zywiec – Zwardoń section of the S69 international road, as they will be aimed to protect wildlife of international importance (bears, lynx, and wolves).

Introduction

Poland (Rzeczpospolita Polska) is a country on the Baltic Sea in the middle of Europe with Warszawa as the capital (Encyklopedia PWN 2005). Its area is 312.685 km^2, and the population is 38.2 million. Poland has borders with Russia (210 km), Lithuania (103km), Belorussia (418 km), Ukraine (535 km), Slovakia (541 km), Czech Republic (790 km), and Germany (467 km). Because of its geographical location Poland is an important country, as its road network connects Western and Eastern Europe as well as Southern Europe with the Baltic countries. Poland is predominantly a lowland country; 91.3 percent of its area is under 300 m with an average height of 173 m above sea level. Its highest point is in the south of the country in the Tatra Mountains (Rysy Mountain – 2,499 m above sea level); its lowest point is in the north (Vistula Delta - 1,8 under sea level). In Poland there are 89 species of mammals (most of them are forest animals like European bisons, roe deer, reed deer, wild boar, wolf, and moose), 220 species of birds, 9 species of reptiles, more than 25,000 insects and around 1,400 spiders.

At the end of 2004 there were 379,500 km of public roads in Poland, 66 percent of which are hard; 34 percent are earth surface roads (Czarniecki 2005). The average road density of hard surface roads was 80.7 km per 100 km^2 at the end of 2004. Highways were 552 km in total (in 2003 their length was 405 km), and one- or two-lane express roads 233 km (in 2003 this figure was 226 km). At the moment, road cover takes three percent of the country. By comparison, the coverage of national parks is one percent.

The environmental effects of the road network (barrier effect, animal mortality) were studied at several sites in the past 20 years (Wolk 1987, Bartoszewicz 1999), but the need to build animal passages developed in last 10 years, in a period when building new, and modernizing existing, roads in order to have a modern road network was decided.

The aim of this paper is to summarize the status of the Polish road network development and mitigation measures and make recommendations for the future.

Road Network Development in Poland

The highway network of Poland

A key to understanding the necessity of building wildlife tunnels and fauna bridges developed with building the road network. Highway building started in the 1980s in Poland. The development of the Polish highways is presented in table 1.

Table 1. Length and construction period of Polish highways through 2002 (Szczepaniak M. 2004)

Code	Highway section	Length (km)	Time of building
A1	Piotrkow Trybunalski- Tuszyn	18	1980s
A2	Wrzesnia- Konin	48	1980s
A4	Zgorzelec- Krzyzowa	2	1992-1993
A4	Krzyzowa- Wroclaw	109	before World War II
A4	Wroclaw- Nogawczyce	126	1997-2001
A4	Chorzow- Krakow	4	2000-2001
A4	Katowice- Krakow	65	1980s
A4	ring road around Krakow	16	1990-1994
A6	ring road around Szczecin	6	1998-1999
	TOTAL	394	

By comparison, Western European countries of similar size to Poland, such as Italy and Germany, had 6,473 and 11,515 km of highways, respectively. Even much smaller countries, such as the Netherlands or Belgium, had a longer highway network, at 2,200 and 1,702 km, respectively (International Road Traffic and Accident Database OECD 2000).

Highway development in Poland

Joining the European Union in 2002 forced Poland not only to improve its transport infrastructure (both roads and railways) faster but also to take environmental needs into consideration. While accessing the EU the Polish government created a special program called Infrastructure-key of development (Infrastrukrura- klucz do rorwoju) in 2002. One of the purposes of this program is road network planning through 2013. A political decision was made to radically speed up road construction: the capacity should increase to reach the ability of 250 km highway (at present it is a maximum of 60 km), 60 km expressway (at present it is a maximum of 20 km), and the rate of modernizing roads should be 500 km per year (at present it is 200 km). As of 2005 the following highway and express way sections have been put in use:

- 122 km of highways (the 103-km Konin - Strykow section of A2, the 19-km Kleszczow - Sosnica section of A4),
- 41 km of expressways (the 11-km Bielsko Biala - Jasiennica, the 7-km Skoczow - Cieszyn section and the 5-km ring road around Skoczow of S1, the 6-km ring road around Jedrzejowo in S7, the 12-km ring road around Torun of S10).

An additional 338 km of highways will begin construction by the end of 2005 (the 91-km Gdansk - Nowe Marzy and the 27-km Swierklany - Gorzyczki section of A1, the 50-km Zgorzelec - Krzyzowa section of A4, while on the Wroclaw - Krzywa section of the same highway 92 km will be modernized: the 8-km Klucz - Kijewo section of A6, the 70-km Olszyna - Golnice section of A18).

An additional 231 km of expressways will begin construction by the end of 2005 (the 11-km Pyrzowice - Podwarpie section and the 5-km ring road around Grodzisk Slaski of S1, the 3-km ring road around Miedzyzdroje, the 10-km ring road around Gorzow Wielkopolski, the 6-km ring road around Miedzyrzecze and the 15-km ring road around Nowa Sol of S3, the 5-km ring road around Szubin of S5, the 16-km Myslenice - Lubien section and the 8-km ring road around Grojec of S7, the 12-km ring road around Olesnica, the 13-km ring road around Wyszkow, the 17-km Radzymin - Wyszkow section and the 11-km Konotopa - Powazkowska section of S8, the 10-km Motaniec - Lipnik section of S10, the 13-km ring road around Gawrwolin of S17, the 51-km Elblag - Grzechotki section of S22, the 25-km Zywiec - Zwardon section of S69). As an additional measure, 180 km of existing country roads will also be modernized in 2005.

Table 2. Highways under construction as of June 2005 (after Szczepaniak 2004)

Code	Section	Total length (km)	Finished (km)	Percentage (%)
A1	Gdansk - Gorzyczki (border)	582	17	3
A2	Swiecko (border) - Kukuryki (border)	610	150	25
A4	Jedrychowice (border) - Korczowa (border)	670	342	51
A6	Kolbaskowo (border) - Szczecin- Kijewo	21	14	67
A8	ring road of Wroclaw	27	0	0
A18	Olszyna (border) - Krzyzowa	70	17	24

The current realization of these impressive plans, however, is still not enough if we take into consideration that most roads need to be renovated. Some roads, for example Via Baltica, expressway 8, connecting Wroclaw, Lodz and Warszawa agglomerations with Lithuania and farther to the Kowno direction and Riga, are still in the planning stage, mostly because of environmental assessment problems and arguments/protests connected to the selection of the new route. Still today, no final decision has been made. One version goes from the border at Budzisko through Suwalki, Augustow, Bialystok and further to Warszawa/ Lody and Krakow crossing many areas of the Natura 2000 network, which should be avoided from an ecological point of view. The other variant gets to the border of Warszawa through Lomza and Ostroleka, which not only avoids Natura 2000 network sites, but it is also more than 20 km shorter. Even if the second variant should be selected, from both an ecological and an economical point of view (as it is cheaper both because it is shorter, the additional cost of building mitigation measures is much smaller, and the other variant needs special constructions like estacades), media-supported ecological protest was needed; otherwise, the worst route would have been chosen, which also crosses the Biebrza valley, a unique, natural riverine ecosystem unprecedented in Europe.

Nowadays, infrastructure development or modernization does not follow the increase of numbers of cars in Poland. In 2004 the number of cars was 6.5 percent higher than in 2003, almost 12 million vehicles, which translates to 314 cars per 1,000 citizens (in 2003 it was 294 cars per 1,000 citizens). In 2004 the number of trucks was 2.3 million, which is a 3.2-percent increase, making 59 lorries per 1,000 citizens.

Figure 1. Highway and expressway network of Poland in 2004 (after Szczepaniak 2004).

Future highway network development in Poland
In the next years the following highway lengths are planned to be constructed:

- 170 km in 2006, another 323 km will be under construction
- 735 km between 2007 and 2010 (average of 184 km)
- 508 km between 20011 and 2013 (average of 169 km).

In total, the Polish road network should include 2,085 km of highways by 2013. Figure 2 presents the plans for highway development. Existing roads are marked by black.

Figure 2. Planned highway development in Poland through 2013 (after Ministerstwo Infrastruktury, Generalna Dryrekcja Drog Krajowych i Autostrad, 2005). Different colors represent years of construction planned (black: existing highways; red: 2005; orange: 2006; light brown: 2007; blue: 2008; violet: 2009-2011; green: 2011-2013)

The figures for expressways are the following:

- 156 km in 2006, another 268 km will be under construction
- 1,668 km between 2007 and 2010 (average of 417 km)
- 1,200 km between 20011 and 2013 (average of 400 km
- An additional 3,050 km to be built after 2013

Figure 3 presents the plans for highway development. Existing roads are marked by black.

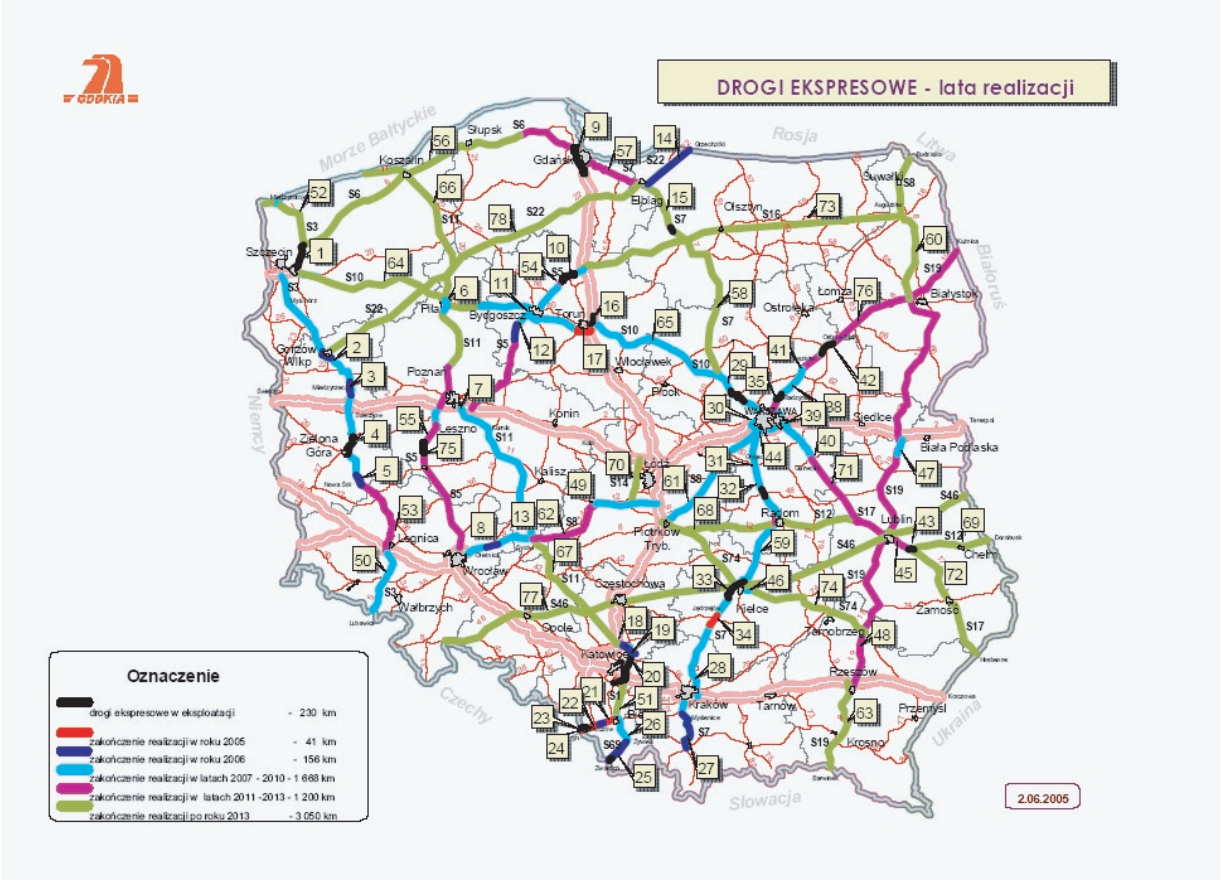

Figure 3. Planned expressway development in Poland through 2013 (after Ministerstwo Infrastruktury, Generalna Dryrekcja drog Krajowych i Autostrad, 2005). Different colors represent years of construction planned (black: existing highways; red: 2005; orange: 2006; light brown: 2007; blue: 2008; violet: 2009-2011; green: 2011-2013)

Ecological Effect of Roads

Background of Polish studies

From an economical point of view infrastructure development has strong positive sides, and the whole country can benefit due to easier access and better transport conditions, which attracts, e.g., large companies to move their regional headquarters into those areas. From an ecological point of view, however, this vision is rather negative. There are several reasons why concern is growing in Poland regarding road-related environmental issues. Legal regulations concerning building mitigation measures for wildlife along the roads are not strong enough; the lack of qualified staff as well as the lack of experience in this field seems to make the situation even worse. Only a very low number of studies were conducted in Poland, which I summarize below.

Animal mortality on roads

According to Jedrzejewski W. (2004) in Austria 34,706 red deer, 428 roe deer, 1,552 foxes, and 36,243 rabbits were killed on the roads in 1997. In Germany these numbers are smaller: 14,906 red deer, 3,901 foxes, and 2,333 rabbits died under car wheels in 2000. In Poland, unlike other countries there are no official national statistics about road accidents with animals. The description of spectacular and fatal accidents is getting into different papers, and local police headquarters have sporadic data, but there is no country-wide overview on this topic. It is known, for example, that on the 160-km A2 highway running from Nowy Tomy?l to Konin, 40 accidents with large mammals were recorded in a month in 2003. Such figures indicate that road kill is quite common due to the lack of protective measures (e.g., fences) and the relatively high density of animals.

What might be considered even more significant from an ecological point of view is that rare species, e.g., lynx or wolves, also die in accidents. Another factor is the importance of local roads in road kills, that Jedrzejewski (2004) proved for a lot of animals, especially for amphibians, reptiles, and small mammals. One reason for this fact is the extent of the road system, but behavioral effects also play a role in the case of mammals. A road with a 6-10,000 cars per day traffic density is less often approached. Another factor is the local decline of populations near these roads, which lowers the probability of road kills on busy roads in comparison to local roads. According to Jedrzejewski (2004),

highways with a traffic density higher than 10,000 cars per day are practically complete barriers for animals, and they mostly come on the road when they are in a stress situation, e.g., frightened by hunters or predators.

Some statistics on different animal groups exist for Poland. On amphibians the most detailed investigation during spring migration was made by Baldy (2003) in the Gory Stolowe National Park. Within a 200-m section of road along a lake, several thousand of common frogs and common toads were migrating (figure 4). As a result of the attention of the local national park as well as the media and local people, it became the site of the first permanent amphibian mitigation measure in 2003. Rybacki (1995) worked on amphibian road mortality in the Pieniny National Park, where he, similar to Baldy (2003), also proved a seasonal migration pattern of amphibians, but it varied according to the species.

Less information is available on other animal groups from longer-term data. Wolk (1978) studied road mortality in the Bielowieza forest, while Bartosewicz (1997) worked in the Slonsk Nature Reserve for a year. The ratio of reptile, bird, and mammal species and individual numbers can be seen in figure 5 and figure 6. The ratio of species found on the road was quite similar in both investigations, though relatively more reptiles were found in the more open, and probably warmer, road in Slonsk Nature Reserve. The individual number at that site, however, was more mammal dominated, and the number of birds was lower than in the other investigation.

Habitat fragmentation

More significant than road mortality, but certainly less visible - as there are no visible victims, caused by building new transport infrastructure is habitat fragmentation (Forman 1998, Iuell 2003). It is caused by several mechanisms, such as habitat loss and the barrier effect, and the isolation of particular populations can cause the extinction of all sub-populations.

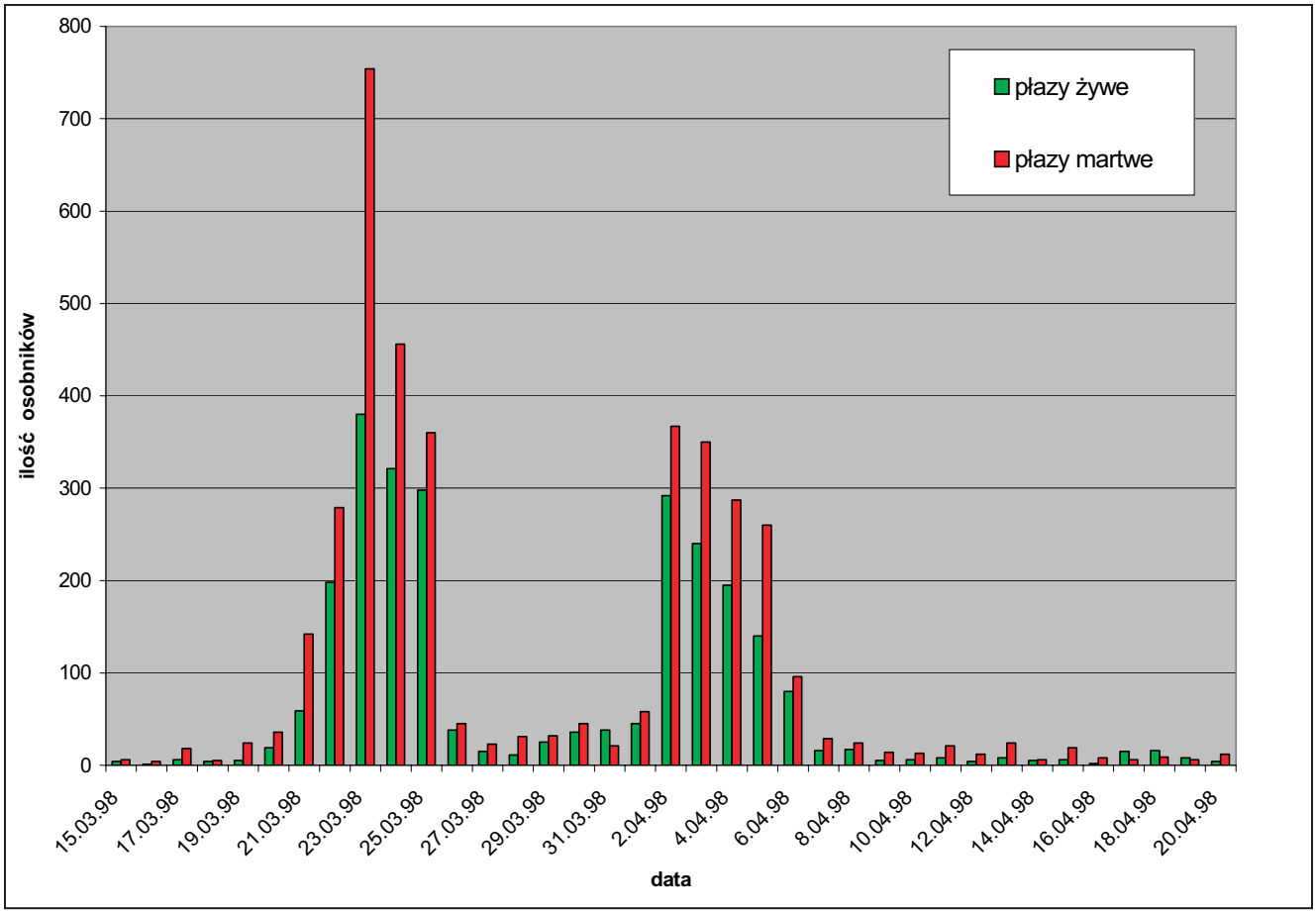

Figure 4. Death rate of amphibians on the road of local importance in Jeleniów near Kudowa Zdroj (after Baldy 2003).

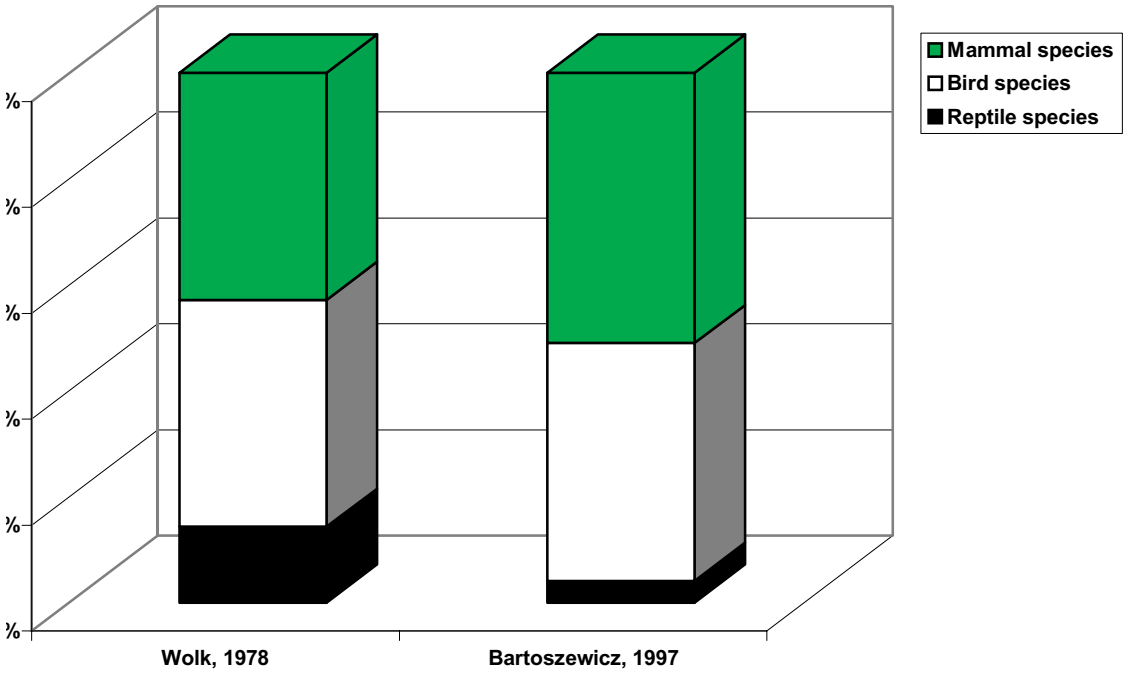

Figure 5. Species number of road-killed reptiles, birds, and mammals in two Polish studies (Bartoszewicz 1997, Wolk 1978).

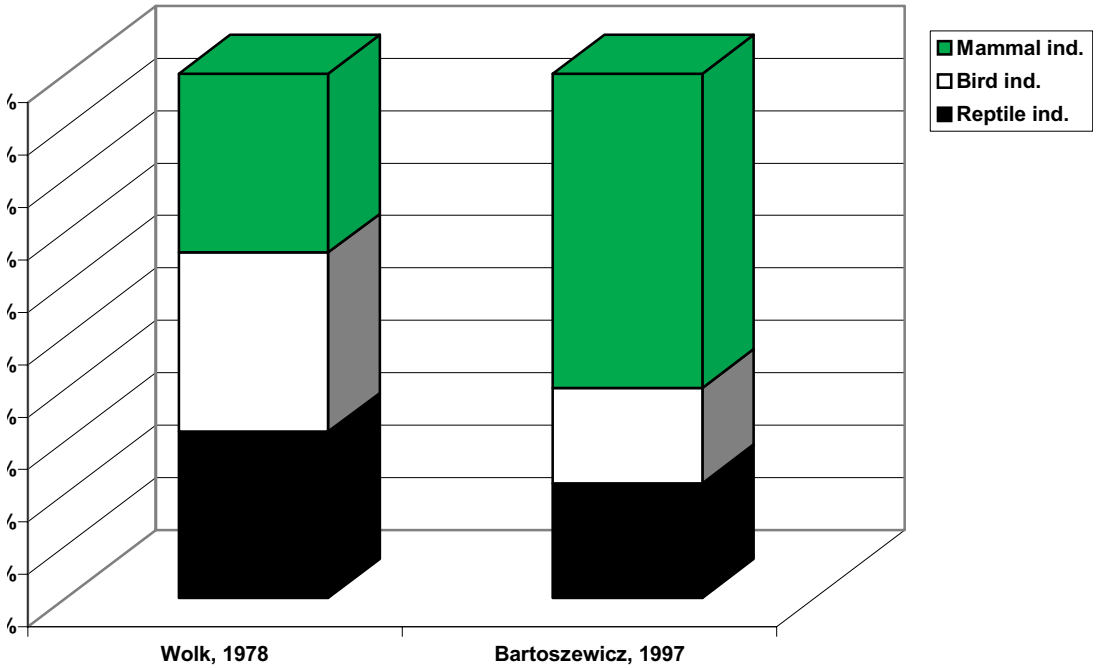

Figure 6. Individual number of road-killed reptiles, birds, and mammals in two Polish studies (Bartoszewicz 1997, Wolk 1978).

The barrier effect can be analyzed at the local or the regional scale. At a local scale it divides natural habitats, for example, an old forest, for two different patches and often causes isolation of both parts and the inability of inidviduals that live in one of the patches to move from one part to the other. Often this permanently separates breeding sites from feeding grounds, which is particularly important for amphibians and some reptiles. For terrestrial species, roads are usually a barrier that makes it impossible to get all habitat patches within their own territories. Wolves, lynx, and bears are very important indicators of negative road impacts. High area demands of those species, for which usually 100 km2 is not enough to keep one territory, are factors that limit the number of areas large enough for those animals. However, highway and expressway system planning nowadays divides large forest complexes in which these animals live for smaller-sized patches in Poland. At a regional scale, roads make animals unable to migrate. As a result of this, healthy, DNA-exchanging populations are scattered and become smaller and isolated sub-populations. In such cases, the extinction of all local populations can happen without the possibility for natural regeneration through immigration. The barrier effect depends on many factors, e.g., the additional facilities along the roads, such as screens, fences, drainage systems, and traffic density (noise, pollution, light disturbance). The analysis of these factors is not the aim of this article, although habitat fragmentation is of growing importance. Because of the lack of financial resources no such studies have been conducted in Poland so far. However, it is important to note those areas, which were recognized by a higher, European Union level, as the most valuable habitats in Poland, as their protection from fragmentation must be safeguarded.

Table 3. List of most important sites in Poland, where habitat fragmentation should be avoided participating in the NATURA 2000 network

Debinskie mokradla
Lachy Valley
Stolowe Mountains
- minors in Zloty Stok
- Karkonosze Mountains
- Church in Konradow
- Skaly Pieninskie
- Devil Valley near Polanica
- Rudawy Janowickie
- Skaly Stoleckie
- Torfowisko pod Zielencem
- Wrzosowisko Przemkowskie
- Sztolnie w Lesniej
- Kamionki
- Forty w Toruniu
- Torfowiska Chelmskie
- Dolina Srodkowego Wiepsza
- Goscieradow
- Jeziora usciwerskie
- Katy
- Krowie Bagno
- Ostoja Poleska
- Roztocze Srodkowe
- Sztolnie w Senderkach
- Torfowisko Sobowice
- Torfowisko Weglanowice Sniatycze
- Zurawce
- Hubale
- Popowka
- Dolina Krasnej
- Ostoja Nidzianska
- Ostoja Przedborska
- Dolina Drwecy
- Gierloz
- Jezioro Druzno
- Jezioro Karas
- Mamerki
- Puszcza Romnicka
- Rzeka Pasleka
- Zalew wislany and Mierzeja Wislana
- Biedrusko
- Dabrowy Obrzyckie
- Dabrowy Krotoszynskie
- Ostoja Nadwarcianska
- Fortyfikacje w Poznaniu
- Jezioro Kubek
- Jezioro Zgierzynieckie
- Kopanki
- Dolina Noteci
- Puszcza Beniszewska
- Rogalinska Dolina Warty
- Sierakow
- Ostoja Wielkopolska
- Pustynia Bledowska
- Diable Skaly
- Kostrza
- Na Policy
- Waly
- Streczow- Scianka
- Tatry
- Torfowiska Orawsko-Nowotarskie
- Lipowka
- Bagno Calowanie
- Baranie Gory
- Dabrowa Radziejowska
- Dabrowy Seroczynskie
- Ostoja Nadbuzanska
- Dolina Wkry
- Dolina Zwolenki
- Legi Czarnej Strugi
- Olszyny Rumockie
- Puszcza Kampinowska
- Sikorz
- Wydmy Lucynowsko- Mostowieckie
- Kantor Stany
- Krogulec
- Forty Nyskie
- Gora Sw. Anny
- Bieszczady
- Ostoja Magurska
- Dolina Biebrzy
- Dolina Gornej Narwi
- Nawianskie Bagna
- Przelomowa Dolina Narwi
- Puszcza Bialowieska
- Ostoja Suwalska
- Ostoja Wigierska
- Jeleniewo
- Bagna Izbickie
- Biale Bloto
- Bialogora
- Dolina Gornej Leby
- Dolina Klodawy
- Dolina Reknicy
- Zachodnie Pojezierze Krzywinskie
- Bobolickie Jeziora Lobeliowe
- Brzeznicka Wegorza
- Dolina Grabowej
- Dolina Iny kolo Recza
- Dolina Krapieli
- Dolina ploni and Jezioro Miedwie
- Dorzecze Parsety
- Janiewskie Bagno
- Jeziora Szczecineckie
- Jezioro Kozie
- Jezioro Wielki Bytyn
- Kemy Rymanskie
- Pojezierze Mysliborskie
- Police- Kanaly
- Ostoja Goleniowska
- Slowinskie Bloto
- Ujscie Odry and Zalew Szczecinski
- Trzebiatowsko- Kolobrzeski Pas Nadmorski
- Wolin and Uznam
- Wzgorza Bukowe
- Dolinki Jurajskie
- Jaroszowiec
- Kalina- Lisieniec
- Kolo Grobli
- Dolina Pradnika
- Pienieny
- Dolina Srodkowej Wietcisy
- Jar Rzeki Raduni
- Jeziorka Chosnickie
- Jezioro Piasek
- Kurze Grzedy
- Mawra- Bagno Biala
- Mechowiska Sulenczynskie
- Mierzeja Sarbska
- Orle
- Pelcznica
- Piasnickie Laki
- Plywajace Wyspy pod Rekowem
- Przymorskie Blota
- Sandr Brdy
- Pobrzerze Slowinskie
- Staniszewskie Bloto
- Studzienickie Torfowiska
- Trzy Mlyny
- Zatoka Pucka i Polwysep Helski
- Twierdza Wisloujscie
- Bor Chrobotkowy
- Hopowo
- Lubnia
- Przywidz
- Wacmierz
- Bytowskie Jeziora Lobeliowe
- Cieszynskie Zrodla Tufowe
- Podziemia Tarnogorsko- Bytomskie
- Szachownica
- Modohora

Measures Used to Minimize the Negative Effect of Roads on Animals

In Poland, most roads were built before people became aware of the environmental problems they pose. Obvious consequences, such as collisions, however, helped people recognize the importance of counter-balancing the negative effects of roads on wildlife. Naturally, the best solution is avoidance, i.e., checking animals' migration routes in a planning stage and avoiding collisions or fragmentation by either planning to build the road in a different area (mostly used in cases where nationally endangered species exist) or building wildlife tunnels and fauna bridges with additional structures, such as fences, guiding structures, and screens.

A perfect road design (Iuell 2003) respects existing landforms, requires the fewest large earthworks, minimalizes the extent of habitat loss, avoids sites of nature conservation interest, and, where possible, protects non-renewable resources and seeks to maintain connectivity through the use of structures that carry the landscape over the infrastructure or permit the landscape to flow under the infrastructure. Naturally, the need to build highways and expressways in Poland preceded that of protecting animals from collisions by fauna bridges or underpasses. Also, the first bridges were more like an experimental design than structures linking divided territories.

Fauna bridges and wildlife passages constructed through 2005

The first Polish fauna bridges were created after building the Wroclaw - Gliwice section of the A4 highway (see fig.7), an important trans-European road linking Ostende in Belgium through Köln and Drezden in Germany, Wroclaw and Krakow in Poland to Kijev in Ukraine, in 2001. When these bridges where built the legal background as well as experience were missing. That is the main reason why they were (and are) not effective wildlife bridges. Five bridges over the highway with a width between 10-12 m for newly built bridges and 9 m for those that were just modified for animal use (people also use them) were created (see fig.7). Five passages under the highway with a width of 6 m and a height from 2.2-4 m depending on local landscape conditions were also created along that highway stretch. On the Nogowczyce - Sosnica highway section, which was designed later, after negotiations and the consequent higher budget, two additonal fauna bridges with a width of 30 m were created. However, follow-up studies showed that only one fauna bridge from the first five was used by animals, although they are present around all structures, and they also did not use one of the new, wide bridges (Gazeta Wyborcza 2003, 2004, 2005). The main reason for this failure was that no data were available about animal migration routes in the area, except survey results made in the building stage on the basis of interviews with forestry workers. Two other very important factors in the failure of the first set of bridges are the narrow design and their common use by people. Also, lack of noise and light screens, guiding structures, and poor quality fences most probably contributed to the problem.

On the A2 highway(see fig.7), which connects Western Europe with Belorussia and Russia crossing central Poland, additional game bridges were put into operation in the Konin - Wrzesnia section in 2004 and 2005. Their monitoring showed that several species, such as reed deer, foxes, and rabbits, used those mitigation measures. This result is considered to be a success and a great step in the progress of building such structures in Poland, especially because the width of these passages is below 33 m. The study also proved that good guiding structures and correctly chosen vegetation planted on both sides of the bridges, joining to the pine forests at both side of the bridges, as well as on the bridges and walls also make animals accept the bridges as crossing points, and they are not afraid to use them. In comparison with the A4 bridges, a lot of development, correct vegetation, guiding structures, noise and light screens were implemented, but still, some elements of these mitigation structures can also be improved upon. Fences in many places do not reach the ground, or it is easy for an animal to dig under them, and then animals can easily get on the road. At those sections, regular collisions with cars was observed, and more than 40 people died in a month in 2004.

Fauna bridges were also built on a former country road that was improved to expressway no. 3. (see fig.7) leading to Swinoujscie port. This road crosses the forested areas of Wolinski National Park. Two fauna bridges and 13 pipe tunnels for small animals were constructed there. The monitoring of the use of the fauna bridges proved high efficiency. At present, they are the best fauna bridges for medium and big mammals in Poland. Besides the proper construction of the mitigation measures, their success is also the result of efficient cooperation of national park staff, designers, and the building company.

The general situation of medium and large mammals using wildlife passages, however, is much worse. Most of the passages are too narrow, and the main target of building them was to provide access to the other side of the road for local people, like local and forestry transport and pedestrians. As a result of human presence that frightens most animals, these passages are not often used by wildlife. On the other hand, the crossing for mammals along streams or rivers improved considerably. In each case, when building or modernizing highways or expressways needed the building or restructuring of a bridge under which water flows, wildlife passages were made according to the needs of mammals (for example, bridges in Sleza Olawa). In most cases, they provide dry passage along the banks to help animals avoid swimming to cross under the road that make possible crossing it by animals that are not swimming.

Wildlife tunnels for amphibians and small mammals constructed through 2005

The protection of migrating amphibians over roads has been the most successful conservation element of the mitigation of road effects in Poland so far. In 1990 a national project called "Amphibians Protection Project" started. A survey was launched in different parts of Poland (mountains, lowlands, seaside) at the same time. Special fences (Wisniewski 2002) were put out along many roads (see fig.8), often even longer than for 300 m, in a way that

prevented amphibians from getting on the road in order to protect animals from being killed on the roads. Volunteers (schoolchildren, university students, etc.), national park staff, non-governmental organizations, and private companies started to build temporary measures, including fences and buckets, and amphibians were taken to the other side of the street by volunteers. At the peak of the migration, buckets (see fig.8) with amphibians had to be taken to the other side of the road even 30 times, for example, on a road in Jeleniow (Baldy 2003). However, amphibians research did not finish by only counting amphibians and taking them to the other side of the road. The survey of particular species was also made along the routes of new roads to support decision-making about finding the best alternative. Breeding sides were usually checked by day transects in small groups, and the results were also confirmed by night sound monitoring.

Figure 7. Game bridges and wildlife passages in Poland (*top left*: Multifunction (animals, agriculture) fauna bridge on A4; *top right*: Multifunction (animals forestry) fauna bridge on A4; middle left: Guiding lines of fauna bridge on A2; *middle right*: Fauna ridge on A2; *bottom left*: underpass for Lutra lutra (Kampinos National Park); *bottom right*: Underpass for big and medium mammals on expressway no. 3).

Amphibian road mortality was checked while slowly driving and stopping every 100-500 m and counting dead animals (Bartoszewicz 1997) and also by cycling or walking along the road (Wolk 1978) in different parts of Poland. The aim of such activities was not only to save amphibians, but also to educate people living near those localities where amphibians migrate. Local and country television stations helped spread information and recruit motivated people to save amphibians. In 2003, as a result of successful cooperation of the local national park, NGOs, and private organizations, the first three rectangular concrete tunnels (see fig. 8) were built on a local road in Jeleniow (Baldy 2003). Later, two more were built on the Chrabowka- Rdzawaka section of S7 (Dziennik Polski 2004), and four more, on the international Szypliszki- Budzisko section of S8 (see fig.7). On expressway S3, 15 pipes were improved for small mammal use in 2003, two more on the Bodzecin-Redestowo local road, and also those on the A2 and A4 highways in 2005.

Figure 8. Mitigation measures for amphibians in Poland (*top left*: detail of a temporary mitigation measure at Via Balitica S8. Note that the bucket was dug in farther away from the fence and amphibians can pass it. Also, the pole should have been fixed on the other side of the fence not to disturb amphibian movement. *top right*: Frog King type of amphibian fence; *middle left*: tunnel entrance with guiding structure; *middle right*: concrete amphibian fence element from above built in where a small side road joins the main road; *bottom left*: entrance of an amphibian tunnel at Jeleniow; *bottom right*: concrete fence element at Jeleniow)

Building tunnels for amphibians on local roads is very important because usually these are the roads where amphibians die in large numbers (Jedrzejewski 2004). However, getting financial support for such purpose is much more difficult than building mitigation measures along highways or expressways where it is regulated by law. However, experience shows that tunnels on local roads have been made very carefully, and they also involve many students, local people, and organizations in such projects. The monitoring of toad tunnels (see fig.8) in the Jeleniow section of the local road (Baldy 2002) and those in Via Baltica showed almost 100 percent efficiency. The efficiency of A4 tunnels is currently being monitored. From these three sites, tunnels built on Via Baltica are particularly important because they help *Bombina bombina* (a species from Annex II. of the Habitat Directive of the European Union) to get from their breeding sites to terrestrial areas. The continuous monitoring between 1995 and 2000 (Adrados et al. 2002) showed that it is probably the biggest known metapopulation of this amphibian in Europe.

Wildlife tunnel and fauna bridge construction through 2013

It was quickly recognized in Poland that building wildlife passages is not a “strange idea” of ecologists, but a real need. For an average driver, these passages can ensure his/her own safety and can protect health or even life. As a consequence, the most important factor of why to build passages for wildlife in the country remains lethal collisions with animals (Gazeta Wyborcza 2003, 2004, 2005). As large animals, like moose, still cross roads, it is easy to see that the chances of a motorist surviving a frontal collision with such a large animal are quite small, and measures should be taken to avoid such collisions. Accidents with moose are especially common between Biebrza National Park, Pusza

Augusttowska, and Knyszynska, which resulted in people urging governmental organizations responsible for road safety to build mitigation structures providing migration corridors (if it is not possible to solve the problem in any other way) for moose in the conflict points of S8.

The General Road and Highway Authority (Generalna Dyrekcja Drog Krajowych and Autostrad) quickly realized the advantage of conducting accurate surveys and choosing the best places for these constructions, as the continuous adaptation of incorrect fauna bridges costs three times more than the cost of building one on the right spot in the right way. General Road and Highway Authority (Generalna Dyrekcja Drog Krajowych and Autostrad) fines put on road construction companies pushed road constructors to get highly dedicated to finding the best solutions (Ministerstwo Infrastruktury, Generalna Dryrekcja drog Krajowych i Ministerstwo Infrastruktury, Generalna Dryrekcja drog Krajowych I Autostrad, 2005 Autostrad, 2005). Still, lack of experience and well-qualified staff remain an existing problem. In addition, many years will pass before all constructors change their minds and think of the environment as something not only to use but also to protect. Another key issue is to get the right information in the planning stage. However, it is only possible if the migration corridors are known. Students, researchers, university teachers, national and landscape park staff, and members of non-governmental organizations all can and should participate in such data collection before the final decisions are made.

At the moment, this process seems to be moving more quickly in southern Poland, where members of a nature conservation association, called "Wolf," are trying to negotiate all parties for the correct location of wildlife bridges for wolves and lynx on the Bielko Biala - Zywiec - Zwardon (border) section of the S68 expressway (Nowak S. 2004). Members of this association made long-term migration surveys and proved that the initial fauna bridge locations that road engineers selected are at the wrong places, and they should be re-situated in other areas. Ecological organizations as well as private companies challenged governmental offices, and the same also happened at other localities. If the present plans will not be changed, international wolf migration corridors will be broken. The participation of ecological organizations, however, involved not only protesting, but also developing proposals to help with designing guiding structures that would be monitored in each stage during construction and afterwards.

In general, wildlife tunnels and fauna bridges must be built for highways and expressways where surveys show that the migration routes of endangered species (according to Polish regulations or EU directives) cross planned or improved highways or expressways, and where moving the road is not advised in the environmental assessment survey. By 2005 such measures will definitely be applied in the following sections:

- Lodz - Czestochowa section of the A1 highway
- Dabie - Emilia and Ciosny section of the A2 highway
- Krakow - Tarnow and Przylesie - Prady section of the A4 highway
- Szubina ring road of the S5 expressway
- Bydgoszcz - Strystek- Biale-Blota section of the S5 expressway
- Radzymin Wyszkow, Wyszkow - Skuszew and Wroclaw - Lodz section of the S8 expressway
- Bielsko Biala - Zywiec - Zwardon section of the S69 expressway
- Rosnowek section of the no. 5. national road
- Poznan - Kurnic section of the no. 11. national road

Future needs

On the basis of the above overview of the Polish mitigation measures over roads, the following areas should be mentioned where further development is urging to protect wildlife effectively:

- More detailed environmental assessments should be carried out that consider more thoroughly the reduction or avoidance of fragmentation.
- Migration corridors should be defined on a local, regional, and national scale.
- Conflict points between road development and wildlife should be identified and mapped.
- Special attention should be given to Natura2000 sites and strictly protected species under European Union or/and Polish regulations.
- National databases including all available data should be built.
- Multi-disciplinary approach should be used to increase efficiency and also to make passages for multiple species.
- Monitoring during all construction stages should be carried out, and the results should be used if changes are necessary.
- The efficiency of mitigation measures are to be monitored.
- The maintenance of all existing and new mitigation measures have to be realized.
- Existing structures should be improved.
- Education programs should be expanded to include a wide range of target groups, e.g., young children.

References

Adrados, L. C., Briggs, L., de Vries, W., Elmeros, M. & Madsen, A. B. (2002): VIA BALTICA - Rozwiazywanie konfliktów na styku plazy, ssaki i drogi. Raport techniczny no. 9. VIA BALTICA - Solving conflicts at sections where amphibians and cross the road. Technical Report no 9.). AmphiConsult. pp. 27.

Baldy, K. (2003): Plazy Gór Stolowych i ich ochrona w latach 1998-2001 (Amphibian conservation in Gory Stolowe 10 1998-2001). Manuscript. pp. 8.

Bartoszewicz, M. (1997): Smiertelnosc kregowców na szosie graniczacej z rezerwatem przyrody Slonsk (Mortality of vertebrates on the highway bordering the Slonsk Reserve, Western Poland). *Parki Narodowe i Reserwaty Przyrody, Bialowieza* 16(4): 59-69.

Czarniecki S.2005 www.egospodarka.pl.

Denac K., 2003: Mortalialiteta vretencarjev na cestah Ljunljanskaega arja, Univerza v Lubljani, Biotehniska fakulteta, Oddelek za biologio.

Dziennik Polski 2004: Kolumna Slask- Wniosek o budowe przejscia dla zwierza na zakopiance.

Evink G. L. Garnet P., Zeiejler D. Breey J., 1996: *Trends in addressing Transportation Related Wildlife Mortality, Department of Transportation*, Tallahassee, Florida.

Encyklopedia PWN 2004: Wydawnictwo Naukowe PWN SA, Warszawa.

Forman R. T.T. Alexander L.E.,1998: *Roads and their major ecological effects*. Harvard University, Cambridge, Massachusetts.

Gazeta Wyborcza 2003, 2004, 2005 www.wiadomosci.gazeta.pl.

International Road Trafic and Accident Database OECD 2000: www.oecd.com

Iuell, B., Bekker, G. J., Cuperus, R., Dufek, J., Fry, G., Hicks, C., Hlavác, V., Keller, V. B., Rosell, C., Sangwine, T., Torslov, N. and Wandall, B. le Maire (eds) (2003): *Wildlife and traffic: A European handbook for identifying conflicts and designing solutions*. KNNV Publishers.

Jedrzejewski W. 2004: Zwierzeta a drogi (Animals contra roads), Zaklad Badania Ssakow, Bialowieza.

Ministerstwo Infrastruktury, Generalna Dryrekcja drog Krajowych I Autostrad, 2005: Harmonogram budowy autostrad i drog ekspresowych na lata 2007-2013, Zalacznik do Narodowego Planu Rozwoju.

Mleczko-Król, M. (2003): The issue of animal passages in the construction of the A4 motorway, section Wroclaw - Gliwice (length of the section 163 km). Manuscript.

Nowak S. 2004: Stanowisko Stowarzyszenia dla natury WILK w sprawie realizacji projektu budowy drogi expresowej S69- Bielko Biala- Zywiec- Zwardon (granica panstwa) na odcinku Laliki- Zwardon (granica Panstwa)(Opinion Association for nature “Wolf” in making road S69 on Bielsko Biala- Zywiec- Zwardon(border) section on Laliki – Zwardon section (Border)), Stowarzyszenie dla natury Wilk.

Rada Ministrow 2002: Strategia Gospodarcza Rzadu SLD-UP-PSL Przedsiebiorczosc- Rozwoj- Praca, czesc 7 - Infrastuktura- klucz do rozwoju.

Szczepaniak M. 2004: Drogi do autostrad technologie, infrastruktura (Roads to highway, technology, infrastructure), Warszawa.

Wisniewski, A. (2001): Zapora typu “King Frog” chroniaca male zwierzeta w obszarach graniczacych z siecia dróg (“King Frog” type barrier protecting small animals in areas along road systems). Planpol-1, Starachowice, Poland. pp. 16.

Wolk, K. (1978): Zabijanie zwierzat przez pojazdy samochodowe w Rezerwacie Krajobrazowym Puszczy Bialowieskiej (Road-killed animals in the Bialowieza Nature Reserve). *Chronmy Przyrode Ojczysta* 34: 20-29.