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Bird casualties on European roads — a review

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Abstract. Road traffic affects the natural environment in numerous ways. The most striking of these is the death of wild animals and birds as a result of collisions with moving vehicles. In this paper the available data on bird mortality on roads are reviewed. Estimates of annual mortality for some European countries (350 000 to 27 million birds), the monthly distribution of casualties, their distribution among sex and age classes, as well as the methods used in the study of this problem are presented. The species composition of birds killed in this way is compared for several countries. In western Europe sparrows and Blackbirds are the species that most frequently die on the roads, but in Central and Eastern Europe not only sparrows but also corvids and Barn Swallows make up a high proportion of the victims. Analysis of the monthly distribution of casualties in 10 species shows this to differ between countries, probably because of the geographic variation of certain aspects of their biology (migration, breeding etc.). Several factors affecting the frequency of casualties are discussed, and some suggestions for the prevention of bird casualties are also given.

Key words: road casualties, road kills, learning abilities, sex ratio, road planning, conservation

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INTRODUCTION

Reviews of the impact of road systems and traffic on the landscape, surrounding environment and wildlife have thus far been published by Bennett (1991), Forman (1995), Forman & Alexander (1998), Trombulak & Frissell (2000), Underhill & Angold (2000) and Seiler (2001). The environmental impact of road traffic is greater than usually suspected. The discharge of toxic substances — oil, and other liquids, salt and waste — may lead to air, soil and water pollution and affect the population of both plants and animals throughout a large area (Williamson & Evans 1972, Przybylski 1979, van der Zande et al. 1980). The vicinity of roads significantly affects the biology of birds (e.g. Räty 1979, Reijnen & Foppen 1991, 1994, Reijnen et al. 1995, Ramsden 2003). Also, noise from vehicles is a stress factor (e.g. van der Zande et al. 1980, see also Reijnen et al. 1987). But above all, the many millions of birds killed each year as a result of collisions with cars is a serious problem.

The first report on bird traffic casualties was probably the work of Stoner (1925) in North America. Interest in this field was so great that by 1940 about 50 additional papers had been published. All of them, however, presented the results of counting carcasses on the road, narrative and lacked any analysis of the results. In Europe, the first report was a short paper from England (Barnes 1930 in Finnis 1960). In Germany, a similar work appeared in 1935 (Creutz 1935) and within the next two years another two appeared in England (Barnes 1936, Beadnell 1937). But since the 1960s, this problem has become a common theme in ornithological periodicals (e.g. Finnis 1960, Hodson 1960, Haas 1964, Hodson & Snow 1965). Hansen (1982) carried out the first thorough research.

Later, studies appeared in several countries on the impact of road traffic on animals with lists of numbers of killed species. Unfortunately, these works were based in most cases on different methods, and published in native languages in obscure publications or exist only as unpublished reports. Generally it is hard to find them and compare them to each other. As a result most studies are unavailable to the scientific community.

The aim of this review is to present the problem of bird collisions on European roads: gather some estimates of how many birds die each year, compare the most frequent species found dead on roads in particular countries, and describe the factors affecting the frequency of bird collisions. Also, the most frequently used methods in existing studies will be described and discussed, and proposals for more scientifically standardised methods presented. The present work only refers to European countries, except when general subjects are discussed. Of course, studies on road-killed birds have been conducted not only in Europe. Similar works are known from Australia, North America and other continents (e.g. Broekhuysen 1965, Brown et al. 1986, Dhindsa et al. 1988 and others). Readers with a worldwide interest can consult the following web site: <www.birdresearch.dk>.

We are aware that most results obtained in reviewed papers cannot be compared, though extremely rough estimates seem to be important in planning new research as well as for future bird protection. Estimates of road mortality and knowledge about the factors affecting the frequency of avian collisions with vehicles should result in projects reducing the negative influence of road traffic on birds and other animals.

UTILIZATION OF ROADS BY BIRDS

Roads and highways should be considered as ecological systems with a character of their own, as specific barriers that separate habitats of varied plant and animal communities (e.g. van der Zande et al. 1980, Forman 1995). Roads break the uniformity of farmland and offer a greater variety of food than can be found in the fields, e.g. garbage that has been thrown into the roads by car drivers or spilt grain after harvest (e.g. Bräutigam 1978, Slater 1994). Roads can also attract other animals that can become food for birds (e.g. Bourquin 1983). The heat of the road attracts many insects where many birds forage on them, mostly, perhaps, because they are much easier to find there (Bergmann 1974). After a heavy rain, some insects are washed onto roads or driven out of the soil (Zumeta & Holmes 1978). When bad weather occurs in the early spring, many early arriving forest birds are forced to forage on roads (Zumeta & Holmes 1978), and in winter these are the first places cleared of snow (Lindsdale 1929). Salt used to de-ice roads in winter attracts crossbills in great numbers (e.g. Meade 1942, Oeser 1977). The road also serves as a larder for scavengers (e.g. Hope Jones 1980, Mason & MacDonald 1995). The telephone and power lines, conspicuous features along most roads, should be considered as part of the road system (e.g. Robertson 1930). They provide birds of prey with fine observation posts from which they can hunt without expending a great amount of energy (Robertson 1930, Nero & Copland 1981, Bourquin 1983). In damp weather, there should be more earthworms because these come up to the surface (Tabor 1974). The hard surface of a road is commonly used as an anvil to smash snails or nuts by numerous bird species (such as Song Thrushes *Turdus philomelos* or corvids). Many birds, such as sparrows, drink from and bathe in puddles along the roads (Hodson 1962). Birds also collect grit for their gizzards on roads (Meinertzhagen 1954, Stanford 1954, Fetisov 1990), as well as mud for nest building (Finnis 1960). A road surface can absorb and store great quantities of solar heat. It was found that the average temperature on the road surface is 7°–10° warmer than the surrounding area. Birds that use this heat energy save many calories that would otherwise have to be used to maintain body temperature. A warm and wet road has more birds on it than a warm and dry one, but the number falls when the wind increases (Whitford 1985). Birds, similar to other groups of animals, can also use roads as a migration route (Forman 1995). So there are many reasons why birds use roads, where, however, they may risk colliding with a vehicle.

METHODS AND SOURCES OF ERRORS

The most important problem that arose in analysing the existing data is the difficulty of comparing the studies because of the different methods they used. They were conducted in various places and at various times. This could also lead to an erroneous interpretation of differing conclusions.

Surveying the roads

Among dozens of works on bird collisions with road traffic, it is possible to find several with frequent and careful surveys of the study plots and detailed descriptions of the birds found on roads (e.g. Bergmann 1974, Bereszyński 1980, Wäscher et al. 1988). Some checked the road every day (Hodson 1960, Kovalev 1998) or even several times each day (e.g. Göranson 1978, Bereszyński 1980, Korhonen & Nurminen 1987, Johnson 1989), while others once every second day (Wäscher et

al. 1988, Novak 1995, Zhumaniyazov & Fesenko 1995, Bartoszewicz 1997, Rohovyi 1998). In some studies, surveys were undertaken only at certain times in the season (e.g. Dunthorn & Errington 1964, Khokhlov & Khokhlov 1998, Bashta 1999). Other authors used a different frequency of surveys at different times of the year (e.g. Nankinov & Todorov 1983, Khokhlov & Khokhlov 1998, Bashta 1999) or portions of the study time (Havlin 1987). Sometimes work crews cleaned the road the day before the survey (Wołk 1978). Estimates made by some authors were based on material either collected or only seen on one particular route (e.g. Telegin & Ivleva 1983). Svensson (1998) took another approach. He recorded every bird killed by colliding with his car, and extrapolated the result to the total volume of traffic.

The results obtained may vary by several orders of magnitude depending on whether the survey was carried out by car, bicycle or walking (Slater 1994). The analysis of data from Hodson & Snow (1965) showed that the manner of surveying the road (car, bicycle or foot) significantly affected the number of casualties found (Kruskall-Wallis ANOVA, $H = 7.18$, $p < 0.028$, Fig. 1). Other authors also confirmed this (e.g. Havlin 1986). Road surveys in most studies were carried out from a car, where many birds are bound to be overlooked, especially the smaller ones. Therefore, these studies record a disproportionate number of larger birds (e.g. Telegin & Ivleva 1983, Korhonen & Nurminen 1987). It is often possible to check only one side of the highway while driving a vehicle (Haas 1964, Heinrich 1978). In order to ascertain the extent of error, Göransson et al. (1978) surveyed a road in Sweden every second hour for 25 days and nights. The result was that only about ⅓ of the small birds were found by the inspections

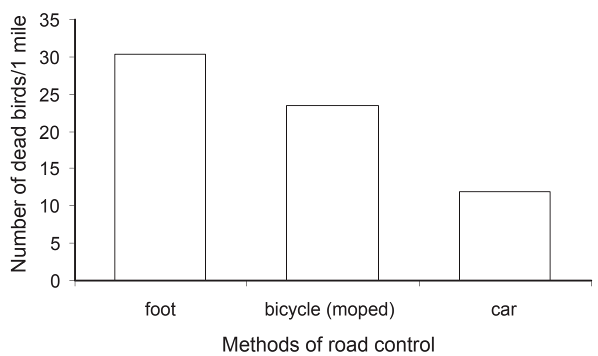

Fig.1. The number of dead birds found in relation to the way of the roads were surveyed. Data from Hodson & Snow (1965).

made perpendicular, against which, birds of the size of a thrush or larger were registered in about ½ of all cases. Havlin (1987) spotted only 1% from a car on highways compared with the result when surveying on foot, and Haas (1964) found only 26% by car compared with bicycle surveys.

In some papers there is no information at all about how the surveys were conducted (e.g. Novak 1995, Kovalev 1998, Bashta 1999). Some authors added reports of other people to their own collected data (Fetisov 1990). In studies on particular species or group of species (like owls) different methods were used — collecting reports made by those finding the road kill, ringing recoveries, not systematically collecting casualties more often than by personal inspections done by the researchers (e.g. Illner 1992, Ćwikowski 1997, Erritzøe 1999, Ramsden 2003).

Characteristics of roads

In the papers reviewed, surveys were made on various types of roads — from highways to rarely used dirt tracks. Only a few papers compare these various types during the same season and by using the same methods (e.g. Hansen 1982, Bashta 1999).

In the majority of cases, the authors did not measured traffic density, despite the fact that this could be a major factor affecting the probability of collision (Underhill & Angold 2000). Measurements of the mean speed of vehicles were also lacking. Authors generally made only rough estimates (e.g. monthly) of road utilisation and car speed (Brown et al. 1986, Johnson 1989, Novak 1995, Zhumaniyazov & Fesenko 1995, Rohovyi 1998). Detailed data (number of cars per day per month or year) are scarce (Ptaszyk 1979, Bereszyński 1980, Fuellhaas et al. 1989, Bruun-Schmidt 1994, Bartoszewicz 1997, Kovalev 1998). Estimates of traffic volume (light, moderate-heavy, heavy) are so vague that it is impossible to make reliable statements based on them (Hodson & Snow 1965). Long-term studies that compare changes in traffic density with frequencies of collisions are rare (e.g. Hansen 1982).

Although road width seems to be one of the predominant factors contributing to large numbers of road-related animal deaths (Underhill & Angold 2000), only a few studies have taken this variable into consideration. Nor are other characteristics considered (height of roadbed, placement on a plateau, etc.) as well as the type of roadsides (i.e. hedgerows).

Researchers surveyed roads of different lengths: from more than 8000 m (Beadnell 1937, Jones in Finnis 1960, Hansen 1982, Telegin & Ivleva 1983, Salnikov & Buslayev 1986) to less than 500 m (Kovalev 1998). This can be important in assessing the average frequency of collisions, because the longer the road distance, the more likely places are found with a higher incidence of collisions (Bashta 1999).

Seasonal timing of collecting carcasses

Authors collected dead birds from roads the whole year round (e.g. Govett 1960, Hodson 1960, Göranson et al. 1978, Blümel & Blümel 1980, Vignes 1984, Khokhlov & Khokhlov 1990, Bruun-Schmidt 1994, Müller 1995, Bartoszewicz 1997 and others), for almost a year (e.g. Hertz 1970) or only in summer, between April and July/September (e.g. Bereszyński 1980, Salnikov & Buslayev 1986, Kovalev 1998, Rohovyi 1998) or till October (e.g. Korhonen & Nurminen 1987, Goławski & Goławska 2002). Winter studies are rare. There were also some papers that did not indicate when collecting started or ended (e.g. Telegin & Ivleva 1983). Some authors showed the number of casualties found by each month (Göransson et al. 1978, Blümel & Blümel 1980, Johnson 1989, Müller 1995, Jensen 1996), some partially summarised the data (Hansen 1982) or presented only gathered data (e.g. Telegin & Ivleva 1983, Holisova & Obrtel 1986). In some studies, the authors characterised the time of collecting only as the breeding or migrating season (Bashta 1999). Finnis (1960) or Hodson & Snow (1965), on the other hand, showed a monthly distribution only for some chosen species. Fragmentation of the basic data makes it impossible to assess how many individuals of a particular species had been collected during particular months (e.g. Rettig 1965, Günther 1979, Vignes 1984, Straube 1988, Fuellhaas et al. 1989).

Sample size

The number of birds collected differs significantly among studies. In some, the number of total road casualties exceeded 1000 individuals (e.g. Beadnell 1937, Haas 1964, Hodson & Snow 1965, Hansen 1982, Müller 1995). In others, the number was less than 100 (Finnis 1960, Haas 1964, Johnson 1989, Svensson 1998). In one study, some thousands of victims were collected yearly by many helpers (Hodson & Snow 1965). Normally such a high number of birds was collected over several (3–9) years (e.g. Beadnell 1937, Telegin & Ivleva 1983, Quene & Grotenhuis 1994). In some studies, the analysis was based on less than 200 specimens collected over 10 years (Fetisov 1990). Sometimes the data came from different study plots and were then compiled (e.g. Hodson & Snow 1965, Hertz 1970, Jonkers & de Vries 1977, Jensen 1996).

Many papers lacked serious data on the characteristics of the carcasses — mostly only the age and sex of the birds. Sometimes there was no species list presented at all; authors characterised the road casualties only as small passerines, sometimes grouping together similar or closely related species in one group (Herz 1970, Hansen 1982, Quadrelli 1984, Holisova & Obrtel 1986).

Others sources of errors

In addition to the differences among the field studies mentioned above, research on avian road casualties can be affected by other than man-made factors. Cats *Felis domesticus*, Foxes *Vulpes vulpes*, Stoats *Mustela erminea*, Weasels *Mustela nivalis*, Hedgehogs *Erinaceus europaeus*, Rats *Rattus norvegicus* and small rodents, as well as gulls, Ravens *Corvus corax*, Magpies *Pica pica*, crows and many owls may forage on carrion and take many birds killed in traffic (e.g. Göransson et al. 1978, Blümel & Blümel 1980). Bergmann (1974) found a road-killed Hedgehog with a Robin *Erithacus rubecula* in its mouth. Cats are the most common scavengers both in towns and the country, and the Carrion Crow *Corvus corone* can fly away with carrion weighing up to approx. 150 g (Slater 1994). Road workers remove many of the larger birds (Hodson & Snow 1965). Humans can pick up dead game birds and waterfowl (like ducks or pheasants) (Herz 1970), or the birds can be caught on the radiators of cars (Bruun-Schmidt 1994). Haas (1964) tried to find several birds that had collided with his car, but without success (but see Svensson 1998). Death following collision some time after the road injury is most obvious in larger species such as Sparrowhawks *Accipiter nisus* and Tawny Owls *Strix aluco* (Slater 1994).

The rate at which vehicles totally demolish a carcass on the road is astonishing. In one of the earliest works (Flint 1926), this problem was given serious mention. Stewart (1971) placed 50 dead sparrows on a heavily used highway. After 90 minutes, only the remains of five were still recognisable and 30 minutes later these were also gone. On another highway with volume of 9000 vehicles every day and night, small birds were gone after 1.2 days ± 0.4 while larger birds after 2.1 ± 0.7 (Korhonen & Nurminen 1987). Bruun-Schmidt (1994) in Denmark obtained nearly the same result: 50% of small birds were gone after 9 hours, averaging 1.2 days for small birds, and 2.1 days for larger birds. On average, a road kill could be identified for 2.2–4 days (Scott 1938, McClure 1951), and even longer in cool weather (Seibert & Conover 1991).

Car speed is also important — carcasses can be thrown into fields by high-speed vehicles, making them unavailable for collecting (Wołk 1978). At high speeds 5% of the birds were thrown into a ditch, while at low speed only 0.5% were thus thrown (Nankinov & Todorov 1983).

Some studies indicated other factors that could affect study results: bad light, low sun overhead, resulting in overlooked birds (Hansen 1982).

CHARACTERISTICS OF ROAD CASUALTIES

Only papers with the following criteria were used in this paper's analysis: studies that lasted at least one year, with regular and frequent surveys, with information about the months when casualties were collected, and based on a sample of at least 100 dead birds. Authors who used other methods are also included, but this is mentioned in the text or tables.

Numerical estimate of the phenomenon

An estimate of the size of the phenomenon can be made based on the number of carcasses collected on the roads. Significant differences in casualty numbers per 1 km of road were found due to the season, traffic density and methods used (review in Finnis 1960). For instance, a total of 128 dead birds were found along 1 km of a frequently used road during 4–5 surveys made each day during July (Bereszyński 1980), resulting in an average of 3 birds per 1 km/day. Hansen (1969) obtained similar results. Svensson (1998), using his original method, assessed that the number of birds killed was 3.22 per year per car or 1 per 10 000 km per car. It must be remembered however, that differences between main roads, highways and country roads were also observed (Hansen 1969, Goławski & Goławska 2002). In India, for instance, 219 birds were found in a year on a 5 km stretch of a road near Bharatpur (Sharma 1988), and in New South Wales, Australia 1095 traffic casualties were found on a 301 km road between Canberra and Lake Cowal during a three-year study (Vestjens 1973). These two examples (44 birds per year/km and 1.2 birds per year/km, respectively) should be enough to demonstrate how many birds are victims of traffic annually.

In most cases, the number of dead birds found on roads was used to further analyse this phenomenon on a larger scale. Most authors agree that the number of birds killed on roads is high — several million individuals according to some studies (Table 1).

Unfortunately, most of the studies estimating the yearly number of avian road casualties were conducted decades ago. It was not possible to find newer data, but cars — their forms and shapes, speed, noise level and the quality of road have changed greatly since that time. Therefore, the number of bird casualties on roads in the 21st century could differ from those presented in the papers reviewed. On the other hand, bird populations in Europe have also changed dramatically. For this reason, new studies are needed.

Species most frequently found on roads

The frequency of finding a particular species as a road casualty could be connected with its population density in neighbouring areas, the habitat characteristics, etc. The list of species found as road casualties varies in different countries (Table 2 and 3). There are significant differences across Europe — from west to east and from

Table 1. Estimate of the number of birds killed annually on roads in several of European countries.

Country	Years	Birds killed/year	Source
England	early 1960s	4 000 000	Hodson 1966
	1960-61	2 500 000	Hodson & Snow 1965
		27 000 000	Errington 1971
Netherlands:	1973-76	653 000	Jonkers & de Vries 1977
Germany	1987-88	ca 9 400 000	Fuellhaas et al. 1989
Denmark	1957-58	ca 1 370 000	Hansen 1982
	1964-65	ca 3 521 000	Hansen 1982
	1979-81	ca 3 273 000	Hansen 1982
		350 000	Thomsen 1992
	1992-93	1 100 000	Bruun-Schmidt 1994
Sweden	1977	500 000–1 000 000	Göransson et al. 1978
	1989-98	8 500 000	Svenson 1998
Bulgaria	1979-80	> 7 000 000	Nankinov & Todorov 1983

north to central (Table 2 and 3). Presumably, this is closely related to the different species composition of these countries as well as habitat composition (forestation, the agricultural policies). The most frequently killed birds on most western European roads are the House Sparrow *Passer domesticus* and Blackbird *Turdus merula* (Table 2). Meanwhile, Barn Swallows *Hirundo rustica* and corvids join House Sparrows as the predominant avian road casualties in eastern Europe (Table 3). Only one study reported a dominance of chickens *Gallus domesticus* (Hertz 1970).

Proportion of road casualties by sex and age

It is not possible to determine the gender of all the carcasses found on the roads. This could be one reason for the differing results obtained by different authors. For some of the most common road casualty species, the sex ratio is identical or insignificantly biased toward males and does not differ generally from parity (Table 4). A summary of the data from many papers shows the Blackbird as the only species where male casualties predominated (χ^2 test, $\chi^2 = 4.61$ $p < 0.05$). But one cannot exclude the possibility of a biased gender proportion as a possible cause of this result.

Determining the age of many road casualties is possible in birds almost exclusively during or just after the breeding season. At this time, young birds appear in great numbers and differ significantly in plumage from the adults. Later

Table 2. Bird species that represent more than 75% of all casualties on roads in Western Europe (data from studies that found at least 100 birds and were conducted for at least one, entire year). Source of data: England (GB) — summarised: Finnis 1960, Govett 1960, Hodson 1960, Dunthorn & Errington 1964, Hodson & Snow 1965; France (F) — summarised: Vignes 1984, Bersuder & Caspar 1986; Netherlands (NL) — Jonkers & de Vries 1977; Germany (DE) — summarised: Martens 1962, Bergmann 1974, Blümel & Blümel 1980, Smettan 1988, Wascher et al. 1988, Müller 1995; Denmark (DK) — summarised: Hansen 1982, Bruun-Schmidt 1994; Sweden (SE) — Göransson et al. 1978.

Species	GB	F	NL	DE	DK	SE
Passer domesticus	40.4	51.3	15.6	23.9	30.4	29.0
Turdus merula	13.2	3.9	19.1	17.4	14.6	7.9
Phasianus colchicus	3.4		3.4		2.1	12.9
Turdus philomelos	8.9			2.6	4.0	
Passer montanus				5.5	6.5	4.9
Erithacus rubecula	2.7	14.4		2.2		
Hirundo rustica				4.4	6.2	7.7
Sturnus vulgaris			11.8		2.1	4.4
Fringilla coelebs	3.9			4.9	5.8	
Larus ridibundus			8.6			4.7
Emberiza citrinella				3.2	3.0	
Parus caeruleus				2.2		
Parus major				2.9		
Alauda arvensis						4.6
Carduelis chloris				4.0		
Anas platyrhynchos			6.5			
Gallinula chloropus			3.6			
Columba palumbus			3.5			
Fulica atra			2.5			
Ficedula hypoleuca		4.8				
Prunella modularis	2.5					
Motacilla alba				1.6		
Ind. analized	7946	749	12618	3364	7145	680
Species found		47	126	> 88	> 59	52
Papers analysed	6	2	1	6	3	1

Table 3. Bird species that represent more than 75% of all casualties on roads in Central, Eastern and Southern Europe (information from all available papers that contain quantitative data). * — data presented for *Passer* sp.
Source of data: Finland (FI) — Korhonen & Nurminen 1987; Russia (RU) — summarised: Fetisov 1990, Khokhlov 1991; Poland (PL) — summarised: Wołk 1978, Ptaszyk 1979, Bereszyński 1980, Bartoszewicz 1997, Goławski & Goławska 2002; Ukraine (UA) — Novak 1995, Kovalev 1998, Rohovyi 1998, Bashta 1999, Czech Republik + Slovakia (CZ + SL) — Herz 1970, Holisova & Obrtel 1986, Havlin 1987; Bulgaria (BL) — Nankinov & Todorov 1983; Italy (IT) —Quadrelli 1984.

Species	FI	RU	PL	UA	CZ + SL	BL	IT
Passer montanus		13	4.2	40.8	41.9*	50.3	81.4*
Passer domesticus	7.8	23.1	29.6	15.3		36.4	
Hirundo rustica		2.6	27.1	10.6			
Fringilla coellebs		6.8	3.9	5.5			
Parus major		2.9	3.4	2.4			
Emberiza citrinella	12.1		3.4				
Corvus corone cornix	39.7	3.4					
Pica pica	17.2	6					
Columba livia domestica		2.9			5.8		
Sturnus vulgaris				2			
Carduelis carduelis			2.8				
Erithacus rubecula			2.5				
Corvus frugilegus		15.8					
Phasianus colchicus					21.2		
Perdix perdix					8.8		
Ind. analized	116	385	358	251	396	594	129
Species found	10	44	44	35	32	17	13
Papers analysed	1	2	5	4	3	1	1

Table 4. Sex ratio (%) of several species of birds killed on roads. M — males, F — females.

Species	M	F	N	Summarised data
Passer domesticus	44	56	317	Finnis 1960, Govett 1960, Hodson 1962
Turdus merula	62	38	167	Govett 1960, Finnis 1960, Beckmann 1961, Hodson 1962, Smettan 1988
Fringilla coelebs	56	44	36	Govett 1960, Hodson 1962
Carduelis chloris	48	52	25	Govett 1960, Hodson 1962

Table 5. Distribution by age group (% of adults and young) of birds killed on roads during the summer, when young birds could be identified). Ad — adults, Y – young.

Species	Ad	Y	N	Months	Source
Passer domesticus	76	24	99	May-September	Finnis 1960
	39	61	387	May-September	Dunthorn & Errington 1964
Turdus merula	63	37	32	April-August	Finnis 1960
	60	40	88	April August	Dunthorn & Errington 1964
	39	61	44	May-September	Bergmann 1974
Turdus philomelos	84	16	31	April-September	Finnis 1960
	62	38	94	April-September	Dunthorn & Errington 1964
Emberiza citrinella	58	42	38	May-September	Bergmann 1974
Carduelis cannabina	62	38	53	June-September	Dunthorn & Errington 1964
Hirundo rustica	0	100	19	July-September	Bergmann 1974

in the season, during the late autumn and winter, after the moulting period, it is not possible to distinguish between birds in their first year of life and adults for many species without an internal inspection of the gonads. It is quite obvious from all the research that more young birds are killed in the summer, as they do not yet have their full flight power and lack the experience of adults (Barnes 1936). In Denmark 5% of the road casualties found in May were young birds, in June this proportion reached 43%, in July — 72% and in August — 82% (Hansen 1969, 1982). In Russia Salnikov & Buslayev (1986), Fetisov (1990) stated that juvenile birds represented about 50%–90% among all birds killed on roads between April and October. With the Barn Owl *Tyto alba*, Massemin et al. (1998) found that mostly immature females were killed on roads in autumn, while the proportion of adults increased later in winter when the proportion of sexes was equal.

Several papers reported a significantly different proportion of adult vs. juvenile road-killed birds belonging to various species (e.g. Bergman 1974, Braütigam 1978, Fetisov 1990). This could be related to the number of young fledged and number of clutches laid per year. But the most important factor affecting these results seems to be the time data was collected and the way it was analysed. When the ratio of a particular age class of dead birds is studied in a particular month or period, it is easy to find that most road casualties are adult birds. Only a few studies showed different results (Table 5).

The condition of birds killed on roads

In most cases, the condition of the body of the birds killed by vehicles was not described. This is difficult to do and avoided by most authors. Most of the data concerning this topic can be found in American papers. There are reports from the USA of Lapland Longspurs *Calcarius lapponicus* suffering massive road killings in cold winters, where most of these birds were extremely fat and had crops filled with seeds gathered along the road side (Gollob & Pulich 1978). In Pennsylvania, 82 Screech Owls *Otus asio* were killed on the road in 1924. Only a "few" of them were lean. The rest had a normal body mass and many even had plenty of food in their stomachs (Sutton 1927). In Europe, a more detailed study on the condition of road casualty carcasses was done for the Barn Owl by Massemin et al. (1998). It was found that the birds were in good condition before they were killed and the condition parameters were similar to those individuals fed ad libitum in captivity, with the only exception being adult females.

It is unlikely that poor body condition and therefore lower activity or poorer concentration could be a reason for collisions with vehicles. On the other hand, young road killed Chaffinches *Fringilla coelebs* were found to be more infested by blood parasites than birds caught in nets (Valkiunas 1998). This demonstrates that future studies should also consider this factor, and comparisons between road casualties and living wild birds could be useful.

Monthly distribution of road casualties

Most birds are killed on roads between April and September. Sometimes two peaks of mortality are observed: the first in April–May and the second in July–September (Fig. 2 and 3). The former is connected with breeding activities and therefore with reduced attention, the latter is due to the dispersal of young and the inexperience of young birds (Hansen 1969, Bräutigam 1978, Günther 1979, Korhonen & Nurminen 1987, Smettan 1988, Fetisov 1990). The harvest in summer must also be mentioned with regard to this, where many cereal seeds are wasted on the roads, and seed-eating birds collide with cars (Hodson 1960, Berezovikov 1995). On the other hand, traffic density increases during the holidays and can result in higher avian mortality on roads. In winter (November to January), after migration, only resident species are present and the total number of birds killed is significantly lower. The fewest individuals are killed in the winter months partly because there is less traffic, the cars are not moving so fast (Hodson & Snow 1965), and because of the shorter length of daylight (Hodson 1960).

The House Sparrow and its relative, the Tree Sparrow *Passer montanus*, are species most frequently killed on roads and their number significantly affects the monthly distribution of the total number of road casualties (Fig. 2 and 3).

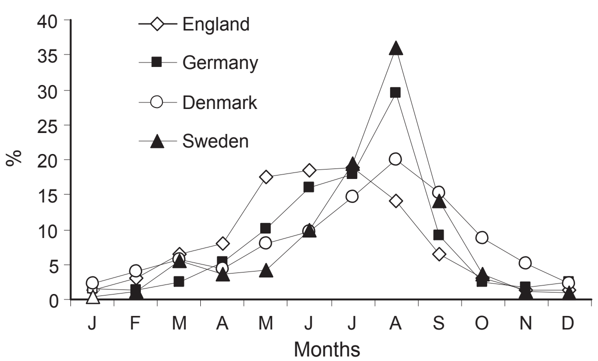

Fig 2. Monthly distribution of road casualties — all bird species. Source of data: England — summarised: Dunthorn & Errington 1964, Hodson & Snow 1965 (N = 5960); Germany: summarised — Blümel & Blümel 1980, Müller 1995, Wäscher at al. 1988 (N = 2511); Denmark: summarised — Hansen 1969, Bruun-Schmidt 1994 (N = 2673); Sweden: Göransson et al. 1978 (N = 739).

Patterns of avian mortality by monthly distribution often differ from country to country. This reflects a geographic variation in their biology, such as breeding phenology, terms of fledging, migration pattern, etc. Therefore, road mortalities for specific species from various countries were totally different when compared (Fig. 3).

The daily distribution of road casualties

It is difficult to say at what time of the day most birds are killed. Human activity, as well as the daily activity of birds, affects this variable. This is the main reason why results presented in numerous papers differ. In the former German Democratic Republic (Lüpke 1983) and Czechoslovakia (Havlin 1987), most birds were killed in the early morning hours. The peak in Sweden was found to be at seven in the morning and 17 in the evening, with most in the morning, and Saturday-Sunday in the middle of the day (Göransson et al. 1978). However, House Sparrow, Tree Sparrow and Barn Swallow collisions peaked at about 12:00 both on holidays and weekdays. In the New England region of the USA, most casualties occurred in the evenings between 15:30 and 21:00 (Zumeta & Holmes 1978).

The distribution of road casualties during the week

Most road kills occurred on Saturday and Sunday; Wednesday and Thursday had the fewest (Schoenemann 1977, Göransson et al. 1978) In Finland, the peak of bird collisions happened on Mondays. However, we could not be sure that the birds were not killed the day before or even earlier because of the methodology used (Korhonen & Nurminen 1987). Without a doubt, there is a clear connection between the frequency of collisions occurring on weekends and holidays. The reason for this could be that traffic on these days does not peak at a regular morning and evening time.

FACTORS AFFECTING THE FREQUENCY OF CASUALTIES

Traffic density

It seems that the density of traffic strongly affects bird collisions with vehicles. Many researchers suggest such a relationship and recommend more detailed studies (Joselyn et al. 1969). But it is impossible to make any reliable comparisons due to the lack of detailed studies (Hodson 1960,

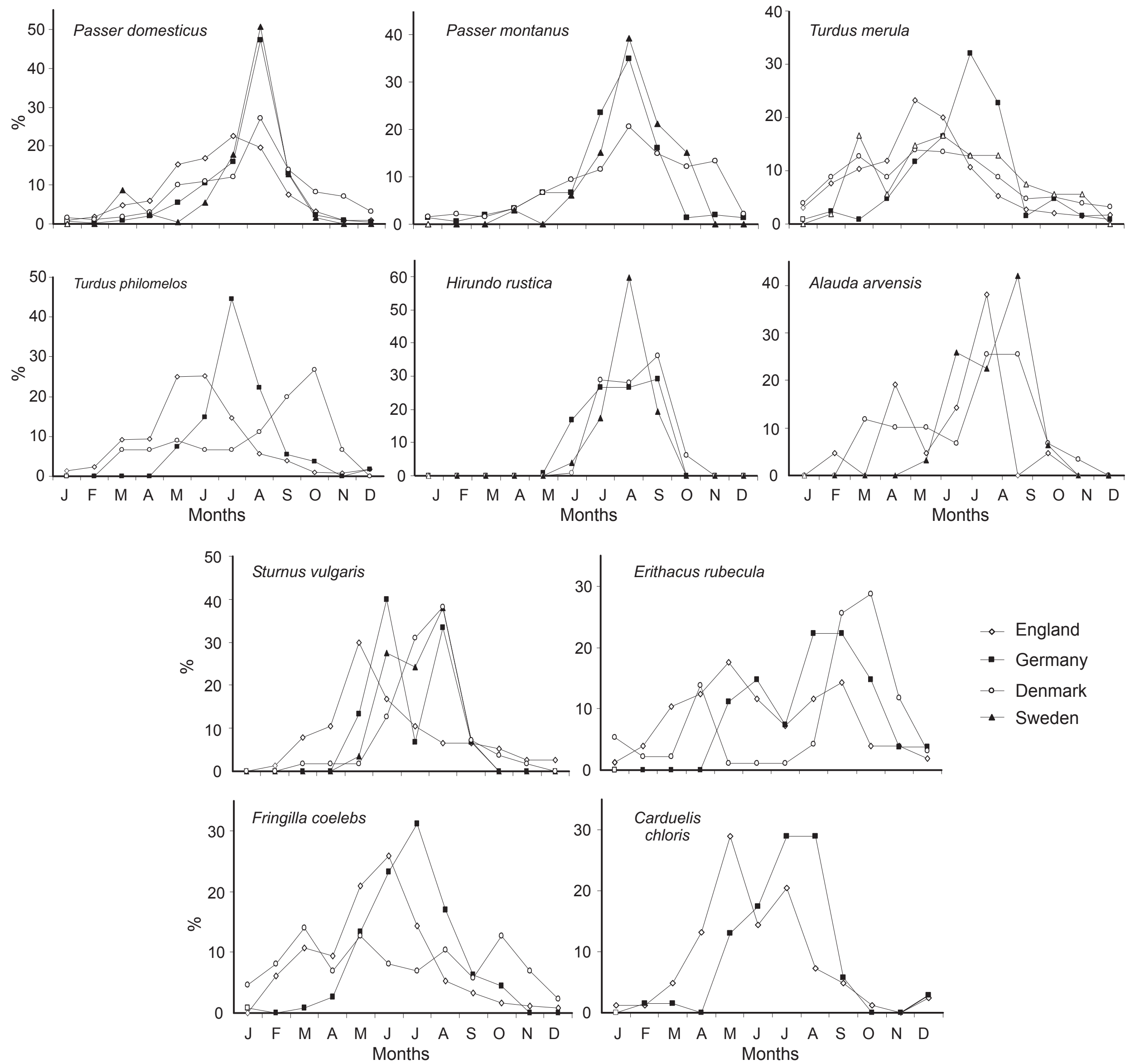

Fig. 3. Monthly distribution of road casualties by selected species.
Source of data: House Sparrow — England: Finnis 1960, Dunthorn & Errington 1964, Hodson & Snow 1965 (N = 2789); Germany: Blümel & Blümel 1980, Müller 1995 (N = 616); Denmark: Hansen 1969 (N = 735), Sweden: Göransson et al. 1978 (N = 197); Tree Sparrow — Germany: Blümel & Blümel 1980, Müller 1995 (N = 146); Denmark: Hansen 1969 (N = 180), Sweden: Göransson et al. 1978 (N = 33); Blackbird — England: Finnis 1960, Dunthorn & Errington 1964, Hodson & Snow 1965 (N = 924); Germany: Blümel & Blümel 1980, Müller 1995 (N = 128); Denmark: Hansen 1969, Bruun-Schmidt 1994 (N = 252), Sweden: Göransson et al. 1978 (N = 54); Song Trush — England: Dunthorn & Errington 1964, Hodson & Snow 1965 (N = 570); Germany: Müller 1995 (N = 54); Denmark: Hansen 1969 (N = 45), Barn Swallow — Germany: Blümel & Blümel 1980, Müller 1995 (N = 113); Denmark: Hansen 1969 (N = 208), Sweden: Göransson et al. 1978 (N = 52); Skylark — England: Dunthorn & Errington 1964 (N = 21); Denmark: Hansen 1969, Bruun-Schmidt 1994 (N = 59), Sweden: Göransson et al. 1978 (N = 31); Starling — England: Hodson & Snow 1965 (N = 77); Germany: Müller 1995 (N = 15); Denmark: Hansen 1969 (N = 55); Sweden: Göransson et al. 1978 (N = 29); Robin — England: Dunthorn & Errington 1964, Hodson & Snow 1965 (N = 154); Germany: Müller 1995 (N = 27); Denmark: Hansen 1969 (N = 94); Chaffinch — England: Dunthorn & Errington 1964, Hodson & Snow 1965 (N = 243); Germany: Blümel & Blümel 1980, Müller 1995 (N = 112); Denmark: Hansen 1969, Bruun-Schmidt 1994 (N = 86), Greenfinch — England: Dunthorn & Errington 1964, Hodson & Snow 1965 (N = 83); Germany: Blümel & Blümel 1980, Müller 1995 (N = 69); Denmark: Hansen 1969 (N = 12), Sweden: Göransson et al. 1978 (N = 11).

Dunthorn & Errington 1964, Hansen 1969, Smettan 1988, Wäscher et al. 1988, Lodé 2000, but see also below).

On small, secondary roads, Hansen (1969) found 0.10 birds/km/day, on larger secondary roads — 0.24, on main roads — 0.79, and on highways — 3.16. However, in a study done 14 years later, the same author found that the number of road-killed animals had not risen despite an increase in the number of cars on the roads. A reasonable explanation of this could be that the bird population had decreased in the intervening period (Hansen 1982). Another Danish study showed that 43 birds were killed in a year on a 10 km secondary road with 332 vehicles/24h, and 96 birds were killed in a year on a 10 km main road with 2823 vehicles/24 h, both roads situated in towns (Bruun-Schmidt 1994). The work carried out in Germany did not support this result. 320 road casualties were found in a year on a secondary road with 780 vehicles/24h and only 154 birds were found on a main road with 2650 vehicles/24h (Fuellhaas et al. 1989). But errors could be enhanced by unfound or decomposed corpses. The methods used to survey the roads were also different (Denmark by car, Germany by walking) so such results are not fully comparable. Odzuck (1975) noted that smaller roads presented a greater danger to birds, because the birds there were not familiar with traffic, while roads with denser traffic gave birds "Lehrneffect", a learning effect. Other authors arrived at the same conclusion — birds quite simply learn to cross the roads at a greater height (Martens 1962, Bergman 1974, Case 1978). This is supported by a Czech study on three different highways leading in different directions from Brno. 14.7 birds were found for every 100 km on the oldest and almost completely stabilised highway, on another highway finished later the result was 16.3, and on a newly completed section — 28.8. This suggests that new motorways may have the highest percentage of traffic casualties (Havlín 1987), though, such results could be explained not only by birds' learning ability, but also by the disappearance of birds from the close vicinity of highways. Nevertheless, it was stated that the increase in the number of cars in France and Germany does not influence the number of owl and raptor traffic casualties, but the 3–4 year cycle of mice does (Bourquin 1983, Illner 1992).

Speed of the vehicles

The speed of cars has a substantial influence upon collisions of birds with road vehicles (e.g. Hodson 1960, Dunthorn & Errington 1964, Hansen 1969, Yoselyn et al. 1969, Case 1978, Smettan 1988). It is difficult to state which car speed is lethal to birds during a collision. Collisions were rare at speeds below 40 km/h, and road kills started at a speed of 56 km/h (Dickerson 1939, Wascher et al. 1988). However, in cities where the speed limit is mostly 50 km, many bird traffic casualties still occurred (Bruun-Schmidt 1994). Are the few which drive faster here the culprits? Nevertheless, even a lower speed can be fatal: a car hit a Song Thrush at 32 km/h, and the bird was immediately killed (Govett 1960).

In a study of the Little Owl *Athene noctua* in Spain, 74.4% of the road-killed victims were found on very curved roads and therefore killed at a relatively low speed (Hernandez 1988). Haas (1964) who travelled 46 000 km on bicycle and car, found more traffic casualties on roads with high speed limits even if the traffic density was low. Martens (1962) stated that traffic density has no importance, but the few very fast cars kill the birds. High speed also makes turbulence stronger, which will throw a small bird over to an oncoming car (Göransson et al. 1978). However, when the speed level is higher it is more difficult to find a killed bird — a significant part of road casualties will be throw far from the road or become unrecognisable by being run over by the traffic from behind (see Methods).

The factor of weather

Weather affects not only birds – especially in feeding, but also drivers — who must modify their speed, decide whether or not to drive, etc. Only a few papers discussed the influence of weather on bird casualties. In storms and rainy weather, bird collisions with cars are much fewer than in good weather, whereas on hot and humid July days the number of killed birds can be extremely high (Hodson 1960, Bergmann 1974). Swifts and swallows fly close to the ground in damp, cold and rainy weather and are killed (Bräutigam 1978, Harding 1979, Wäscher et al. 1988). Birds prefer to fly against the wind when they take off, or they lose valuable time if they have to change direction (Göransson et al. 1978). Therefore, the aspect of weather should be considered in new studies.

The habitat surrounding the road and road characteristics

Many authors state that the habitat surrounding the road plays an important role in frequency of bird collisions. Many traffic casualties occur where the road runs through forests, small streams, wood edges and other marked changes of one type of vegetation to another, in wet areas, outskirts, and stretches with hedges on both sides of the road (Göransson et al. 1978, Brown et al. 1986, Wäscher et al. 1988, Bosch 1989, Johnson 1989). For instance, only 6.5–7.4 birds per km/year were found on roads of farmland habitat, while 16.5–19.6 birds km/year were found on roads running through areas with much vegetation, fruit trees or on roads which run through villages, fields, meadows, forests and lakes (Bergmann 1974, Bräutigam 1978, Lüpke 1983). The most numerous road kills occur on the outskirts of towns with gardens, because the densest populations of birds can be found here (Bräutigam 1978, Smettan 1988). For example, 23.8 birds km/year were found in a garden suburb near Stuttgart, compared with 19.8 birds km/year on roads in farmland (Smettan 1988). In a study done by Holisova & Obrtel (1986) the greatest number of collisions occurred on roads crossing fields and villages.

In a Swedish study, the traffic death toll was greatest near farms and large gardens and in a valley with deciduous trees on both sides (Göransson et al. 1978). Most "danger zones" are found where there are gaps and openings for birds to attempt to fly from one side of the road to the other (Hodson 1960, 1962, Dunthorn & Errington 1964). Several authors have found the greatest number of both living birds and traffic casualties at traffic centres maybe because these areas are more spacious, with more vegetation than the normal highway (Hodson 1962, Günther 1979, Havlín 1987, Bruun-Schmidt 1994).

Road characteristics can also affect the number of casualties. If the road is at the same level or higher than the surrounding area, birds crossing the road will fly low and more will be killed than on roads where the surroundings are higher (Wäscher et al. 1988, Bruun-Schmidt 1994). In a study in France, most road kills occurred on embanked road sections (Lodgé 2000). Many birds are killed where the road curves, even though cars have to slow down here (Bergmann 1974, Hernandez 1988). On a road in Bulgaria, 68.9% of the birds were killed by cars going downhill because vehicles could move faster there (Nankinov & Todorov 1983).

The behaviour of birds

Hansen (1969) suggested that bird behaviour determines whether a species is more likely to be killed on roads. The behaviours of the different bird species seem to be of great importance. For example, some birds fly lower or slower than others and are therefore more exposed to collisions. Other birds make diving manoeuvres or sharp turns, which may be a good strategy to avoid attack by a raptor, but catastrophic in the case of an approaching car (Govett 1960, Dunthorn & Errington 1964). The headlights of cars seem to be of great importance for collisions after dark with nocturnal birds. It was demonstrated that presumably the headlights of a car are able to totally stun a chicken only during darkness (Schoenemann 1977). The headlights of cars can stun wild birds, especially owls and nightjars. Therefore many species of these families are mentioned in the literature as traffic casualties (Harrison 1954, Benson 1955, Haverschmidt 1955, Uhlenhaut 1976, Aronson 1979, Brouwer 1992, Barlow & Gale 1999, Erritzøe 1999).

Many bird species like the Common Buzzard *Buteo buteo*, Red Kite *Milvus milvus* and gulls are also known to be scavengers. They are often seen on road carcasses and are often themselves victims (Feindt & Göttgens 1967, Coleman 1968, Göransson et al. 1978, Masson & MacDonald 1995). Scavengers are killed and in turn eaten by cats, foxes and corvids (Slater 1994). Bosch (1989) states that most birds of prey are killed not by colliding with a car itself but with in collision with the car's antenna.

The House Sparrow is without a doubt the most often found road-killed bird worldwide (Table 2 and 3). Its preferred habitat is human settlements, such as gardens with thick hedges and bushes, and it is often found on farms. From here it flies to the nearest cornfield on the other side of the road, often in flocks. Every time the flock is alarmed it must cross the road to reach safety — and the risk of colliding with a vehicle is great. Sparrows forage on corn spilled on the road sides, they sunbathe directly on the road and very often young can be seen being fed by their parents there (Göransson et al. 1978). Finally, sparrows are not shy and thus may react less when a car appears (Heinrich 1978).

The Blackbird has a visible peak in traffic accidents in March, when territory and pair building takes place, and many birds are chasing each other. Still more important, Blackbirds very often cross a road just above the ground (Göransson et al. 1978, Heinrich 1978). Birds that fly with a dipping motion often collide with vehicles (Slater 1994). Other birds that fly low over the ground are Song Thrushes, Whitethroats *Sylvia communis*, European Robins and Wrens *Troglodytes troglodytes*. Many birds dive to gain speed instead of flying away from a car, or they suddenly turn around to come back to their starting point, a manoeuvre which can cause them to lose speed. An Australian study showed that the Western Rosella *Platycercus icterotis* typically crosses the road and collides with an oncoming car, whereas another frequent visitor of the roads, the Common Bronzewing *Phaps chalcoptera* is very seldom hit because it has a very quick take-off and flies parallel to the road (Brown et al. 1986). Owls are attracted to roads by the abundance of prey, and can be killed by vehicles when they fly from one perch to another (Nero & Copland 1981). However, owl mortality is lower on roads with a higher availability of perch sites (Hernandez 1988).

Take-off distance for flight is also of great importance. Large birds need a greater distance to take off than smaller birds (Dhindsa et al. 1988).

The next important question is whether there are different abilities that need to be learned in order to cope with the danger of traffic in different con-specific populations. This review gives some hints, which look promising for future research. In his study done in Denmark, Bruun-Schmidt (1994) wrote that some species were apparently better adapted to life along roads. For instance, the Starling *Sturnus vulgaris*, the Hooded Crow, the Jay *Garrulus glandarius*, and the White Wagtail *Motacilla alba* are all often seen along roads, but only the Hooded Crow is, in a few cases, found traffic-killed. In many populations, corvids seem to have learned how to use roads without being killed, e. g. in Germany on a 43 km long stretch with three Rook colonies and many Rooks foraging on the road, none were found killed by vehicles (Heinrich 1978). Conversely in Switzerland, Sweden and Finland where, for example, a Finnish study concluded that 23% of all traffic fatalities were Hooded Crows and 17% Magpies (Moilanen 1978, cited in Korhonen & Nurminen 1987, Table 3).

In Osnabrück, Germany, no White Wagtails were found killed in vehicular collisions, even though they were commonly seen on the roads. The author wrote that their reactions were very effective, and often when the car had passed, the birds came back at once to the road (Fuellhaas et al. 1989). Also in Czechoslovakia, White Wagtails were seen frequently on the roads, but none were found dead (Havlin 1987). In a Swedish study done during 1973–76, no Wagtails were mentioned among the casualties (Göransson et al. 1978). In other studies however, White Wagtails comprised up to 3% (Bergmann 1974, Vignes 1984).

Can the bird population be monitored using the number of traffic casualties?

In England, 13% of the House Sparrow population was killed by traffic (Hodson & Snow 1965). Dunthorn & Errington (1964) found that 3% to 12% of young Song Thrushes, Blackbirds, Linnets *Carduelis cannabina* and House Sparrows were killed. Approximately 5% of the total population of House Sparrows were within the risk zone of becoming road casualties. By contrast, Hansen (1982) found that nearly all House Sparrow young in the Danish population were traffic-killed at a highway near Copenhagen. A German study undertaken during 1973–1976 found that about 5% of the House Sparrow population was killed on the roads. For Blackbirds and Greenfinches *Carduelis chloris* this proportion reached 8% and 4% respectively. In Sweden only 1–4% of most species are killed by vehicular traffic, but for some species it rises up to even 10%. Pheasants, *Phasianus colchicus*, Partridges *Perdix perdix*, hawks, Rooks and owls are those species most exposed (Göransson et al. 1978). According to the most recent reports, the proportion of recorded deaths of Britain's Barn Owl population attributed to road traffic increased from 6% in 1910–1954 to 50% in 1991–1996 (Ramsden 2003). This species suffered a substantial decline throughout of the 20th century. For some species (like the Little Owl) vehicular collision is the primary cause of non-natural death and perhaps responsible for its general decline to a certain extent (Hernandez 1988, Illner 1992, Fajardo et al. 1998).

The percentage of birds killed on roads is not the same by a far margin for species with similar population densities (Sargeant & Forbes 1973), but it is logical that population density is an important factor for many species. All small passerines with territories within 150–200 m from the road are in a risk zone (Göransson et al. 1978). A study undertaken in Nebraska in the early 1940s showed that the number of traffic accidents in each year depended on the number of live animals, i.e. the success of the breeding season (McClure 1951).

Only common species that are often road victims can be monitored. Casualties among the rarer species are more or less accidental and therefore cannot be used in any analysis. Counting traffic casualties of those species with a high population density and many traffic accidents could show the range of different populations and the local variation in density of the general yearly population cycle (Bruun-Schmidt 1994).

COMMENTS AND PROPOSALS

The chief question one must pose after reading this survey must be whether natural selection will sharpen the evolution of birds' road behaviour or, in other words, make some species develop an "antimortality strategy." The above mentioned examples of crows and White Wagtails could hint a confirmation of this thesis. The great number of young birds killed in summer and early autumn is not surprising in view of the greater number of juveniles at that time, their lack of experience, and the adults' more reclusive behaviour during the moulting period. However, the question of whether natural selection has modified bird behaviour along roads is impossible to answer until long-term studies on the same sites are conducted. These studies should not only count traffic-killed birds, but also monitor the populations living along the roads by point counts or transects, and consider any changes in population size, density of traffic and the maximum speed of cars.

Much has already been done in many countries to prevent road kills of mammals and reptiles, but birds' ability to fly renders nearly all these safeguards superfluous for them. Many papers present proposals of how to prevent collisions of birds with vehicles. They can be grouped as follows:

Road and roadside planning. It seems that roads should not run as a border between habitats or through valuable habitats (Wäscher et al. 1981). Dense thorny bushes planted along the roads can force birds to fly over the roads (Ramsden 2003). Continuous hedges and/or lines of closely spaced trees (>3 m high) can obstruct low-level flight across carriageways. Wherever possible, these should be created adjacent to the barriers along both sides of major roads. This is especially important where roads are level with or raised above the adjacent terrain (Ramsden 2003). The artificial elevation of roads and vegetation in close proximity to the road should be avoided — especially where highway networks meet (Madsen et al. 1998).

Presence of hedges. This is a controversial proposal (Finns 1960, Lüpke 1983, Slater 1994, Lodge 2000). Any vegetation can attract birds to roads — for nesting, feeding or resting. High, thorny hedges on both sides of the road may force birds to fly higher. However, such trees or bushes should not bear fruit or berries that could serve as a source of food for birds.

Awareness of drivers. This is one of the most important factors that can lower the frequency of collisions. Reducing speed, preventing the spillage of grain, etc. can result in less birds being killed on roads (Havlin 1987, Günther 1979, Fuellhaas et al. 1989).

Some proposals were developed exclusively for a particular bird species (for instance constructing speed bumps through forests in national parks with rare owl species, Bencke & Bencke 1999). Some proposals are contradictory. For example, there is no agreement on the issue of lighting: some authors postulated that roads should be lit, others rejected this because light attracts invertebrates, a common food for many birds (e. g. Hernandez 1988). In reports on the mortality of Barn Owls from vehicular collisions, the authors recommend that rough grass not be planted near roads without installing continuous screens, that permanent ground cover such as dense bramble or gorse be maintained across the entire width of both verges, and even that no new major roads be built without screens in rural areas where owls reside within 25 km of the proposed route (Ramsden 2003).

Local conditions related to both traffic as well as to the birds should be considered in any activities undertaken to prevent avian casualties of vehicular collisions.

Proposals for conducting future studies of bird collisions with vehicles

It is important that future research on road casualties becomes more standardised to enable a statistical analysis of different studies. If the main aim of a study is to assess the frequency of collisions, chosen roads should be surveyed at least 2–3 times a day. In most cases, however, this will be unrealistic. One daily or eventually weekly survey may be useful if a careful study of all possible errors were conducted and a formula developed from the result which includes different habitats, time of the year, traffic density and speed, number of human settlements on the surveyed stretch, composition of bird population and abundance determined by point counting.

Typical road stretches in the study area should be chosen, as well as different types of roads — secondary road, main road, highway — and each stretch should be of an even length, 1 km, 10 km etc. to allow for easier analysis and comparison later. It is important to collect all possible information on factors which could prove important in data interpretation in future studies — such as date, time of day, description of the weather, the taxon of birds found, sex, age, where found (countryside, village), description of where the collision occurred (houses both sides, houses on one side, field on the other, field on both sides, etc.), existing speed restrictions, description of the road (straight, curved, etc.), where the bird was found on the road (road edge, ditch etc.), visible at distance or not, time of death, condition of the bird, amount of fat (normal or lean), survey methods (by car, bicycle or foot), day of the week (whether a holiday or weekday), time needed to check the route, how many vehicles counted during that time, etc.

The place where each bird casualty is found should be noted individually on a map of the surveyed study area. A new map should be used for each new year. After several years, good information will be available about the "danger zones" on the routes. To review which bird use the roads year round, the birds living along the roads should also be counted. Point counts of the birds living in the vicinity of the studied roads would also be of great value.

Dead animals could be used as a source of data for studies on species biology (activity, food, etc.) and ethology, some aspects of geographical variation, contamination, etc. (e.g. Jefferies 1975, Uhlenhaut 1976, Massemin & Handrich 1997, Dale 2001). Also, this would be a way of increasing museum collections without killing any animals directly.

A glance into the future

In the event of specific environmental changes that stretch the carrying capacity of the natural environment beyond the possible (for example, still more roads, cleaner, quieter cars, more human settlements, and fewer, more fragmented natural habitats), a genetic basis for a rapid and diverse micro-evolutionary development affecting patterns of future road use may begin to work as more and more bird species are forced to forage on roads. With increased traffic density and traffic jams, more and more garbage will be left on the roads. With high traffic density, natural selection will presumably work faster, because the birds will learn about the danger on the roads and fewer birds will become victims. Global warming can result in a situation similar to that currently being seen in the Mediterranean region, where new ecological niches are being created for a greater and greater number of formerly migratory, but now resident, birds. The scenario will be still worse as the desertification of the Sahel in Africa continues. This will result in still more migrants forced to find new winter sites in the Mediterranean countries. All these circumstances may work towards more use of our roads by an increasing number of bird species. Roads may also serve as corridors between small, fragmented habitats for weaker flying species in the future.

If this image of the future is realistic, the demand for more research about how we can make our roads more "user-friendly" for the avian fauna is even greater. Presumably, the advantages for birds of using roads will outweigh the disadvantages — they will be using our roads in increasing numbers, with or without our acceptance.

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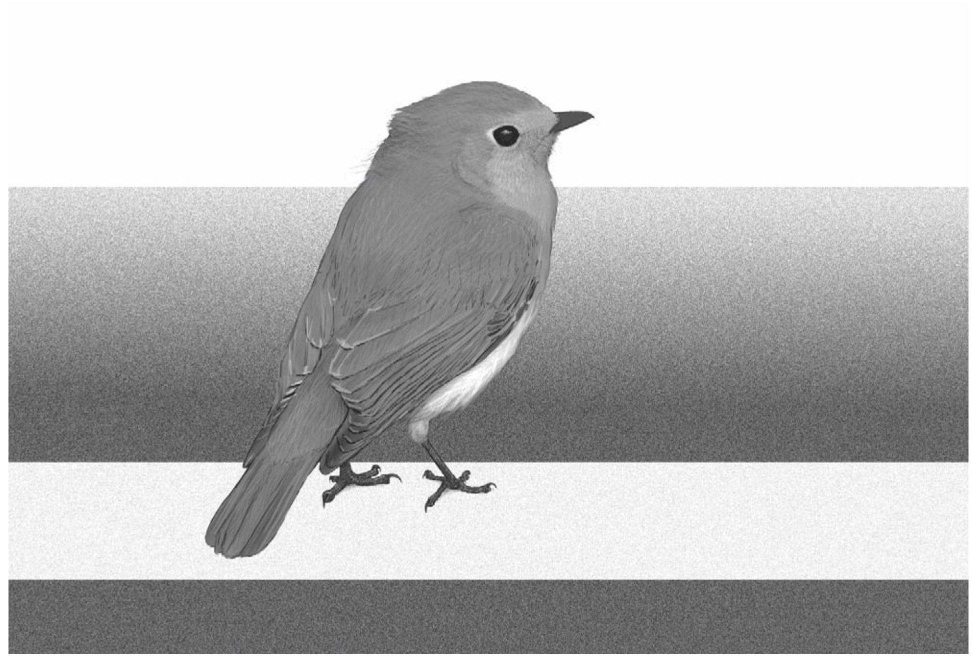
STRESZCZENIE

[Śmiertelność ptaków na drogach Europy]

Drogi wpływają na ptaki na wiele sposobów. Jednym z najbardziej znaczących jest śmiertelność w wyniku kolizji z pojazdami. W prezentowanej pracy zebrano europejskie dane dotyczące tego zagadnienia — szacunki śmiertelności ptaków w skali roku (Tab. 1), zróżnicowanie miesięczne (Fig. 2), rozkład płci i wieku ofiar (Tab. 4 i 5), stosowane metodyki badań. Dla szeregu państw przeprowadzono porównania składu gatunkowego ofiar kolizji. Zgromadzone dane wskazują, że w Europie Zachodniej wśród ptaków najczęściej ginących na drogach dominują wróble domowe i kosy (Tab. 2), natomiast w państwach Europy Centralnej i Wschodniej, oprócz wróbli, ofiarami kolizji padają także ptaki krukowate i dymówki (Tab. 2). Wśród 10 gatunków ptaków, dla których przeprowadzono analizę całoroczną śmiertelności na drogach, wykazano znaczne różnice między krajami, z których pochodziły analizowane dane (Fig. 2). W pracy omówiono także niektóre czynniki wpływające na częstość kolizji ptaków z pojazdami, jak również propozycje działań zmierzających do zmniejszenia negatywnego wpływu ruchu drogowego na ptaki.



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