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Factors affecting road mortality of the Barn Swallows *Hirundo rustica* in farmland

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Abstract. Ninety-nine road-killed Barn Swallows were found during three years of studies on a 48.8 km road network in an intensively farmed landscape in SW Poland. Nearly 88% of all road-kills were recorded in built-up areas and on road sections in their vicinity. The average number of road-kills per 1 km of roads was over twenty times higher in built-up areas than in open agricultural landscape (6.74 vs 0.33 road-kills/1 km). This paper investigates the influence of environmental factors (lines of trees along roads, number of livestock, volume of traffic, number of inhabitants) on the level of Barn Swallow mortality on the roads in question. During the breeding season the number of birds killed in built-up areas was related positively to the number of cattle reared, the overall number of livestock (including pigs) and the number of inhabitants. In the multiple regression model following stepwise forward selection, the number of cattle explained 41% of the variance in the size of the whole-year road mortality of swallows in the built-up area. During the autumn migration period the length of tree-lined road sections in the built-up area had an significant influence on road-kill frequency, explaining 36% of the variance in mortality. Mortality was high on tree-lined sections of road in adverse weather conditions.

Key words: Barn Swallow, *Hirundo rustica*, road kills, environmental factors, bird protection, landscape planning

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INTRODUCTION

Road mortality is currently one of the main issues in the protection of many groups of animals (see Clevenger 2000, Underhill & Angold 2000). Birds are highly affected by the negative impact of road traffic (e.g. Mumme et al. 2000, Fajardo 2001, see Erritzoe et al. 2003). In spite of the number of data accumulated over a long time (review in Clevenger 2000, Erritzoe et al. 2003), very little is known about the mechanisms, causes and environmental factors affecting mortality of particular bird species (Clevenger et al. 2003).

Nowadays, Barn Swallows *Hirundo rustica* are accidentally killed mainly on the roads of Eastern Europe (Poland, Ukraine, see Erritzoe et al. 2003), making up to 46% of all bird road-kills (Bereszyński 1980, Bartoszewicz 1997, reviewed in Erritzoe et al. 2003).

Over the last decade, the Barn Swallow abundance in Western Europe has decreased markedly (Turner 1994, Møller & Vansteenwegen 1997, Engen et al. 2001). In the early 1970s, the population of swallows in the Western Palearctic was estimated at 220 million individuals (Moreau 1972). According to some authors, ca. 50% of the northwest Europe population of swallows is subject to negative changes in abundance (Turner 1994, Møller & Vansteenwegen 1997). In England, despite high yearly fluctuations, the abundance between 1964–98 remained relatively constant (Robinson et al. 2003). In Denmark, the yearly drop in abundance is around 7.6% of the population, which may lead to extinction of the species within the next 22 years (Engen et al. 2001).

Changes in farming practices are usually given as the main cause of negative abundance trends in Europe. These changes include the abandonment of traditional cattle-rearing and disappearance of pastures (Møller 2001, Ambrosini et al. 2002), loss of unfarmed landscape elements (mainly hedgerows and treebelts) acting as potential feeding places (Evans et al. 2003a), and reduction of food supply due to massive use of pesticides and scarcity of suitable nesting sites in large industrial cattle farms (Turner 1994, Møller & Vansteenwegen 1997, Møller 2001). Climatic changes, including weather conditions on wintering grounds and migration routes, are equally important (van den Brink et al. 2000, Robinson et al. 2003).

A large proportion of swallows is probably killed on roads during the migration period, during sudden weather deterioration, which is confirmed by various data from the literature (Bruderer & Muff 1979, Wascher et al. 1988, Estrada & Riera 1995, Bartoszewicz 1997, Brown & Brown 1999).

In agricultural areas, the main factors determining the road mortality of swallows are probably the presence of roadside treebelts and hedgerows, as well as the density of livestock. Recent research carried out in Britain documented hedgerows as the main feeding places of swallows in farmland habitat. Hedgerows are mainly used by swallows during severe weather conditions (Evans et al. 2003a). In many regions hedgerows are located along the roads, increasing the risk of collisions with vehicles. During the breeding period, swallow abundance is closely correlated with the density of livestock and farm buildings used for their rearing, which provide nesting habitat for this species (Turner 1994, Møller 2001, Ambrosini et al. 2002).

The aim of the present paper was: 1) to determine the number of road-kills, 2) to characterize locations of collisions with vehicles, 3) to test for potential effects of some environmental factors (presence of roadside treebelts, livestock number, traffic volume, etc.) on the mortality level during the breeding and autumn migration period on selected road sections in areas with various traffic volumes and land use methods and 4) to suggest some ways of protection of the species against the negative impact of road traffic. In view of the growing interest in Barn Swallow conservation in Europe (e.g. Turner 1994, Evans et al. 2003a, b), formulation, and introduction, of an adequate strategy for this species protection, based on preventing from all possible threats resulting from human activity, is desirable.

STUDY AREA

The research was conducted on a 48.8 km road network (Table 1, Fig. 1), located in an intensively farmed part of the Wrocław Plain (south-west Poland). The study area covered ca. 56 km^2. In total, I established 22 road sections in built-up areas, passing through 20 settlements (17 villages and 3 peripheral parts of Wrocław city; Fig. 1, Table 1; more data in Orłowski & Nowak 2004). Two villages were crossed by roads with different traffic volumes and were treated as separate sections. Overall length of roads in built-up areas was 12.9 km (26.4% of total road length) (Table 1). Arable lands made up 92% of the total study area.

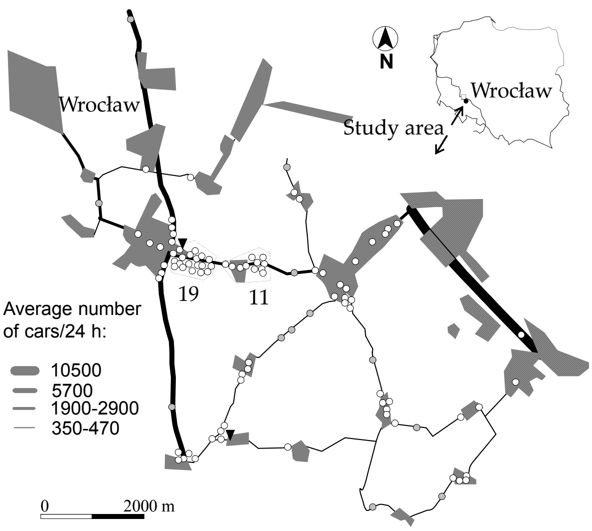

Fig. 1. Location of the Barn Swallow collision places within the studied road network; grey colour — built-up areas, white circles — victims in built-up areas and ≤ 400 m from them, grey circles — victims over 400 m from built-up areas, black triangles — larger cattle farms.

Table 1. Characteristic of the studied road sections and number of swallows killed.

Average daily traffic volume (number of vehicles/24 h)	Length of the studied roads		Length of roads in built-up areas (m)	Number of villages on the given road section	Total number of killed swallows
	m	%			
10500	3750	7.7	1600	2	1
5700	8350	17.1	1750	4	15
1900-2900	9600	19.6	4600	5	40
350-470	27100	55.6	4950	11	43
Total	48800	100	12900	20	99

Only 1.6% of the study area was covered by forests, one of the lowest percentages in Poland. The number of inhabitants in particular settlements crossed by the studied road sections ranged between 17 and 3921 (Table 1).

MATERIALS AND METHODS

The research was conducted from 24 June 2001 until 18 August 2003. The area was surveyed by car, driven at a speed of 20 to 50 km per hour. All roads were visited three times a week from the second half of March until the end of October. The length of a single visit depended on the number of road-kills and the weather conditions, and usually ranged from 1.5 to over 3 hours. The road-kill sites were marked on a map (1:25 000). To avoid repeated counting of the same road-kills, all dead birds were removed from the roads and their verges.

I categorized dead swallows as either found within villages or found in the open countryside — more than 400 m from the nearest buildings. It was found that during the breeding season swallows forage mainly within a 400 m radius of the nest (Ambrosini et al. 2002).

Road-kills found between 21 May (the earliest date) and 20 August were treated as local breeders. Due to the small percentage of broods commencing in the beginning of August (according to Wójcik 1985), and the simultaneous appearance of migrating flocks in the same month (Dyrcz et al. 1991), birds found after 20 August were treated as migrants. Age and sex of the birds were determined according to Busse (1990).

Due to the state of road-kill remains (in most cases only some body parts were found), my ability to determine age (67.7%) and sex (10.1%) was limited (the age determination based mainly on the head colour — the head was often the only body part available).

Characteristic of specified environmental variables

The values of variables were calculated for 22 road sections in the built-up areas of 20 settlements (Table 2). Traffic volume was determined using data from the General Management of Public Roads in Wrocław (sections of the national roads) and from Wrocław District Council (other roads). These data were obtained by traffic volume measurements conducted in 2000. I determined livestock numbers from the National Farm Census in 2002. The total number of animals was 2067 specimens (1101 cattle and 966 pigs). The length of roadside treebelts in the built-up area was calculated by direct field measurements and aerial photographs. The treebelts were a single row of trees (Pedunculate Oak *Quercus robur*, Small-leaved Lime *Tilia cordata*, maple *Acer* spp. and poplars *Populus* sp.), located on one or both sides of the road. The number of inhabitants in particular settlements was obtained from local authorities.

Statistical analysis

I used Statistica 5 software and Excel 2000 for all statistical analyses. Due to the lack or small number of road-kills on most road sections in the built-up areas (see Results) data were pooled for the whole study period. In order to normalize data, I transformed six variables (HIR, HIRBRE, HIRMIGR, COWS, LIVESTOCK, INHAB) based on the equation $f(x) = log(y + 1)$ (Table 2). Differences in the number of birds killed on particular road sections were tested using Chi-square (χ^2) goodness-of-fit analysis. Road length in the built-up areas and open farmland was used to calculate the expected values. Pearson's

Table 2. Environmental variables and swallows road-kill indices identified on 22 road sections within the built-up area of 20 settlements.

Variable	Explanation	Values		
		min.	max.	mean ± SD
HIR	Total number of killed swallows/1 km of road	0	59.9	9.0 ± 14.8
HIRBRE	Number of swallows killed in breeding period/1 km of road	0	36.0	4.9 ± 8.5
HIRMIGR	Number of swallows killed during migration/1 km of road	0	30.0	3.6 ± 6.6
ROAD	Length of road section (m)	100	2500	606.8 ± 535.2
TREE	% of road section with trees	0	100	40.5 ± 21.6
TRAFFIC	Traffic volume (number of vehicles/24 h)	350	10500	2673 ± 3218
COWS	Number of cows	0	750	88.6 ± 215.3
PIGS	Number of pigs	0	109	40.7 ± 42.8
LIFESTOCK	Number of cows + number of pigs	0	765	134.5 ± 213.5
INHAB	Number of inhabitants	17	3921	577.8 ± 900.6

correlations coefficients were applied to identify the relation between the number of road-killed swallows and the environmental variables on road sections in built-up areas. I used 0.05 significance level for all statistical analyses. The multiple regression model of the number of road-killed swallows on the 22 road sections within 20 settlements during the whole study period (2001–2003) was calculated with the use of stepwise regression with forward selection. In all models variables were introduced and removed from the equation separately in each step of the regression procedure. The final, best fit models are constructed after including one of four highly intercorrelated independent variables (COWS or LIVESTOCK or PIGS or INHAB, range of Pearson's correlations coefficients between this variables: $r = 0.54–0.98$, $p < 0.05$), introduced separately to a particular regression model. Transformed variables were introduced to all models.

RESULTS

Temporal and spatial distribution of swallow collisions with vehicles

A total of 99 killed swallows were recorded during the whole study period (11.5% of all 862 bird found road-killed. In consecutive years (2001–2003) 36, 43 and 20 road-kills were found respectively, and the average number of road-kills per 1 km of road in a year was 0.73, 0.88 and 0.41 (data for complete year were gathered only for 2002). Nearly 88% of all road-kills were found in village areas and road sections situated in their immediate vicinity (Fig. 1). The rest (12%) were recorded outside the built-up areas. The difference was statistically significant (87 road-kills in built-up areas vs 12 in open landscape; $\chi^2 = 193.4$, df = 1, $p < 0.0001$). I recorded from 0 to 2 road-kills on 12 out of 22 sections on built-up areas. On other road sections were recorded from 4 to 19 victims. The highest number of road-kills (n = 19) was noted near a big cattle farm (Fig. 1). Four times, during prolonged hot weather, dead birds were found near puddles. During the whole study period the average number of road-kills per 1 km of roads in the built-up areas was over 20 times higher compared to the open landscape (6.74 vs 0.33 road-kills/1 km of road). Statistically significant differences in the number of road-kills between built-up and open areas were found both for the breeding (55 vs 4 road-kills; $\chi^2 = 143.1$, df = 1, $p < 0.0001$), as well as for the autumn migration period (32 vs 8 road-kills; $\chi^2 = 78.4$, df = 1, $p < 0.0001$).

Two peaks in road-kill numbers were clearly visible within a year: between 1st and 19th of July, and on the turn of August (Fig. 2). Among 67 birds with known age, 44 (65.7%) were young individuals, and in the group of adults (n = 23) the sex was established only in 10 specimens (5 males and 5 females) (Fig. 2). In the periods following the first findings of young road-killed birds (5 July, 29 and 27 June in consecutive years), juveniles were more often killed com-pared to adults. The overall ratio of juveniles to adults was 2.59:1 (44 young vs 17 adults).

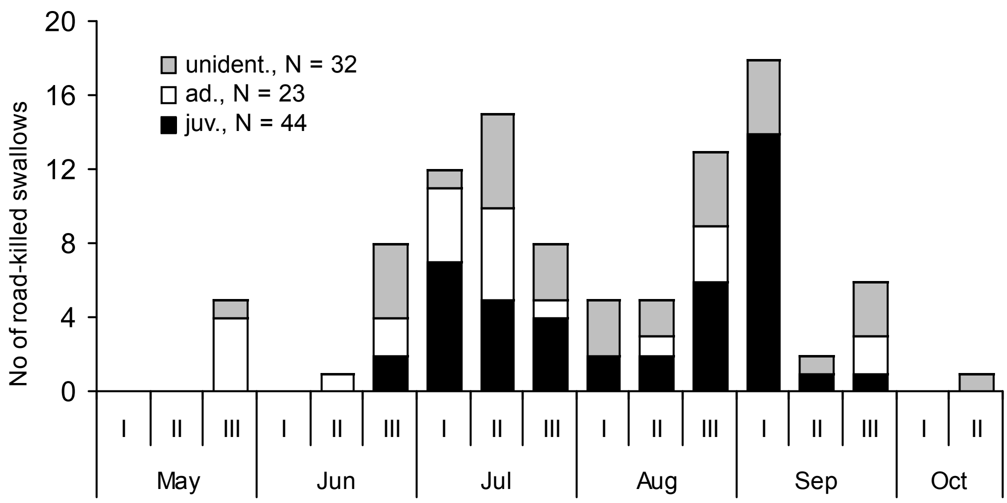

Fig. 2. The distribution of Barn Swallow numbers killed (N = 99) in particular months in 10-day intervals.

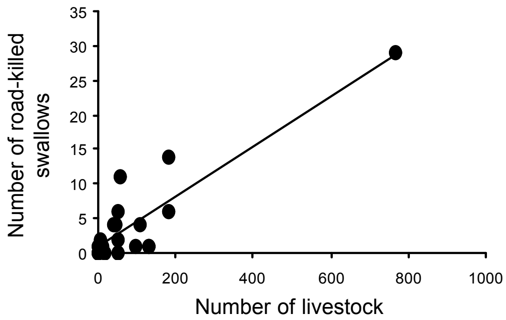

Fig. 3. The relationship between the total number of killed swallows and the livestock (cows and pigs) number in 20 villages; y = 0.037x + 0.823.

The collision locations, both in the breeding period and during the autumn migration, were concentrated mainly along well developed tree-belts (avenues) growing within built-up areas. In total, 47 road-kills were counted on tree-lined road sections passing through the area of six settlements, with an overall length of 1450 m. The average road-kill frequency on these sections was 32.4/1 km of road, and was almost five times higher than the average for all roads in built-up areas (32.4 vs 6.7 road-kills/1 km of roads).

Influence of environmental factors

In 20 villages, crossed by the studied roads, the level of Swallow mortality was closely related to the overall number of cattle and pigs ($r = 0.89$, $p = 0.000$; Fig. 3), and the number of cows ($r = 0.69$, $p = 0.001$). In the case of pigs this relationship was not statistically significant ($r = 0.12$, $p = 0.61$).

During the breeding period the number of killed swallows/1 km of road in built-up areas was positively related to five out of seven environmental variables (Table 3). However, only three of these correlations were significant: number of reared cattle, total number of livestock and number of inhabitants (Table 3). In the autumn migration period the number of road-kills per 1 km of road was positively related only to the percentage of tree-lined road sections (Table 3). In total, for both periods of the year, statistically significant correlation coefficients were found in the case of four analysed variables (Table 3).

Table 4. Results of multiple regression analysis of the number of killed Swallows (N = 87) on 22 road sections in built-up areas during the whole study period (2001–2003) and the identified environmental variables.

Variable	B	SE	T	p
		Breeding period		
LIFESTOCK	0.595	0.182	3.268	0.004
ROAD	-0.0007	0.0004	-1.645	0.116
Constant	-0.942	0.705	-1.336	0.197
$F_{2,19} = 5.34$, $p < 0.014$, $R^2 = 0.36$				
		Migration		
TREE	0.184	0.055	3.343	0.003
Constant	-3.898	2.515	-1.549	0.137
$F_{1,20} = 11.18$, $p < 0.003$, $R^2 = 0.36$				
		Total for breeding and migration period		
COWS	0.296	0.109	2.712	0.014
TREE	0.017	0.010	1.691	0.107
Constant	0.071	0.483	0.147	0.884
$F_{2,19} = 6.72$, $p < 0.006$, $R^2 = 0.41$				

For the breeding season data, two (LIVESTOCK and ROAD) out of four simultaneously analysed environmental variables were used in the final, best fitted multiple regression model after stepwise forward selection. They explained 36% of the variance in whole-year road mortality on 22 road sections in built-up areas (Table 4). After the introduction of the interchangeably used variable, COWS, in the final model of regression two variables appeared — COWS ($p = 0.008$) and TREE ($p = 0.224$). They explained 32% of the variance in size of mortality (result of regression analysis: $F_{2,19} = 4.39$, $p < 0.027$).

During the autumn migration period, only TREE turned out significant in the multiple regression model (both after application of variable COWS or LIVESTOCK), and, as in the breeding season model, explained 36% of the variance in mortality (Table 4).

The multiple regression model for both seasons combined explained 41% of the variance in mortality, with two variables being included in the model: COWS and TREE (Table 4). After the

Table 3. Pearson's correlation coefficients between the number of swallows killed per 1 km of road and the identified environmental variables on 22 road sections passing through built-up areas of 20 settlements. * — $p < 0.05$, ** — $p < 0.02$, *** — $p < 0.006$.

Variable	ROAD	TRAFFIC	COWS	PIGS	LIFESTOCK	TREE	INHAB
HIRBRE	-0.015	0.001	0.509**	0.294	0.518**	0.341	0.515**
HIRMIGR	-0.192	0.025	0.209	-0.045	0.091	0.600***	0.127
HIR	-0.019	-0.201	0.571***	0.288	0.509**	0.433*	0.529**

application of another independent variable (LIVESTOCK), the variance remained similar (multiple regression: $F_{2,19} = 6.20$, $p < 0.008$, $R^2 = 0.40$), and two variables came out in the final regression model (as in the breeding period): LIVESTOCK ($p = 0.019$) and TREE ($p = 0.053$).

DISCUSSION

In spite of the lack of quantitative data about breeding swallow population in the study area, the results of the present work suggest the essential role of cattle rearing as the main factor stimulating the species abundance in farmland, which was found by earlier studies conducted all over Europe, e.g. in Denmark (Møller 2001), Italy (Ambrosini et al. 2002) and England (Robinson et al. 2003). The livestock numbers are closely associated with the presence of farm buildings (cowsheds, piggeries) that provide the majority of nesting sites for Swallow in rural Europe. Research carried out in Denmark showed a decline in cattle-rearing restricted insect biomass, mainly flying Diptera, that constitute the staple diet of swallows, by an average of 52% (Møller 2001).

The analysis of the multiple regression models shows that the main factor increasing swallow mortality on roads during breeding season was the number of livestock. Another important factor influencing mortality, both throughout the whole year as well as during the autumn migration, was the length of tree-lined road sections in the built-up areas. The appearance of swallows in the vicinity of roads was associated with foraging activity in roadside treebelts by breeding birds from nearby farm buildings. Although not nesting places for swallows, the belts and hedgerows play an essential role in foraging. Both within them as well as in field margins overgrown with herbaceous vegetation, a higher abundance of insects was recorded, compared to the inner parts of the fields (Ryszkowski & Karg 1991, Karg 1994, Evans et al. 2003a). In agricultural landscapes roads with accompanying vegetation play a role as ecological corridors and ecotones separating different crops and facilitating movements and feeding along their borders. The insect density in a wheat field in a belt up to 10 m away from treebelts was ca. 2.5 times higher than 50 m away, and large Diptera were among the most numerous insects (Ryszkowski & Karg 1991, Karg 1994). According to Evans et al. (2003a) limited wind speed and locally higher temperatures are the main factors resulting in the abundance of flying insects in the immediate vicinity of hedgerows.

Unfavourable weather conditions also result in increased Barn Swallow mortality. Twenty-eight birds died during intensive rainfall at the end of August and the beginning of September 2001. During the same period in 2002, but during much calmer weather, only three birds were killed. Studies of swallows foraging habits in England showed stronger preference of hedgerows during poor weather conditions (Evans et al. 2003a). Also, the highest number of road-kills during a one-day visit was recorded on road sections with well developed treebelts, during strong rainfall and winds (maximum number was 8 killed swallows in a day). According to Evans et al. (2003a), the increased Barn Swallow appearance around the hedgerows during inclement weather may be a way of cutting down the amount of energy spent on flight. A similar explanation may apply to the more frequent appearance of swallows near treebelts within built-up areas in autumn, which was associated with searching for suitable feeding areas and reducing the energetic cost of flight. Severe weather conditions forced birds to stay in places sheltered by buildings and trees and to fly low above the ground, where the wind speed is smallest (Elkins 1988, Evans et al. 2003a), which in turn increased the risk of collisions with vehicles. Probably swallows sometimes also take advantage of the traffic by catching insects flushed from the road by approaching cars, as well as picking dead ones from the road surface, especially during rainy weather and sudden drops of temperature (Finnis 1960, Hobson & Sealy 1987).

The high number of juvenile swallows killed in the first twenty days of July corresponded with the peak of the fledging period in the Milicz fish ponds area, when ca. 30% of all chicks were leaving nests (Wójcik 1985). It may indicate that the road-kills in this period originated mainly from the local breeding population. The second peak of mortality of young swallows on the turn of August, mainly during sudden weather deteriorations may suggests the lower survival rate of juveniles hatched later in the season. One of the reasons for increased juvenile mortality in bad weather is their different morphology, especially in the outer tail feathers, which are much shorter than in adults. It was proved that females (having shorter tails than juveniles but of similar shape), that survived six days of severe weather deterioration in Nebraska im May 1996, had longer outer tail feathers and were heavier than those that collapsed (Brown & Brown 1999). In bad weather the hunting efficiency of young birds (like that of females with shorter tails, Brown & Brown 1999), can be much lower, leading to exhaustion and thus higher risk of collision.

Research on vertebrate road mortality shows that vehicle speed and traffic volume are important factors influencing mortality (see reviews: Trombulak and Frissell 2000, Erritzoe et al. 2003). The results of a detailed analysis of the distribution of hedgehog *Erinaceus* spp. road-kills on the same 22 road sections in the built-up areas described here, showed that 90% of the variance in road mortality was explained by the level of daily traffic volume and the length of roads in built-up areas (Orłowski & Nowak 2004). However, in the case of swallows these factors were not important, while environmental conditions (presence of treebelts and livestock numbers) were of crucial importance. Clevenger et al. (2003) suggested that the bird mortality on roads mainly results from environmental factors, such as the presence of ecotones between forests and open areas. In studies of bird mortality on railways in an agricultural landscape of western Poland, the highest losses were observed in places where railway tracks intersected hedgerows and treebelts at a right angle (Lorek & Stankowski 1991). The lack of significant correlation between traffic volume and swallows mortality in the present study, was most likely the reflection of local habitat conditions, especially the lack of livestock in villages situated along the busiest roads. In the study area farm animals were kept mainly in villages crossed by roads with small or medium traffic volume. The negative impact of roads and the noise they generate on breeding bird fauna is much more prominent around high traffic volume roads (e.g. Reijnen et al. 1996, Forman et al. 2002). In the case of Barn Swallows and other species, such roads can act as a repelling factor, and may be avoided by foraging birds. On the other hand, it can not be ruled out that on the busiest roads some road-kills can remain undetected (e.g. after being thrown beyond the road during the accident or quickly crushed and destroyed by passing vehicles; see e.g. Eritzoe et al. 2003).

IMPLICATIONS FOR CONSERVATION

According to some authors losses suffered by birds as a result of road traffic are not an important factor at the population level (Reijnen et al. 1995). However, in the case of species with negative abundance trends it seems desirable to investigate and identify all potential threats. On the basis of this study it may be estimated, that each year on Polish roads die up to 180 000 swallows. The base for these calculations was the average road-kill number in the study area — 0.88 indi-vidual per 1 km of road (in 2002), multiplied by the length of non-urban roads in Poland, that amounted to 201 135 km in 2000 (Central Statistical Office 2001). The obtained number may seem tremendous compared with the Barn Swallow abundance in some western European countries (see Turner 1994). Although our data come from a very small area, it can be assumed that on the European scale the road mortality level of swallows exceeds one million specimens per year.

Linear woodlots (treebelts and hedgerows) are used by swallows as foraging places, mainly during bad weather conditions and their location along roads puts the birds at risk of collision with vehicles. The proper landscape management, including road verges, aimed at the reduction of bird losses is one way of limiting the mortality of swallows and other species associated with woodlots and hedgerows in the farmed landscape. In light of our results we do not recommended planting roadside hedgerows and treebelts in the built-up areas or near farm buildings. Instead, new networks of treebelts and hedgerows should be created further away from transportation routes, where birds will not be at risk of accident. In places of particularly high bird mortality (like outskirts of built-up areas), the erection of tall vertical barriers that would force birds to fly higher, seems to be a better solution (Pons 2000).

Our field experience gathered while collecting material for this study suggests that the use of car horns by drivers can be an efficient way of avoiding accidents with birds flying by or sitting on the road surface. The swallows, often foraging above the road surface and flying very close to the passing vehicles, reacted to the blaring with a sudden change in flight direction, consequently avoiding collision.

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REFERENCES

Ambrosini R., Bolzern A., Canova L., Arieni S., Møller A. P., Saino N. 2002. The distribution and colony size of barn swallow in relation to agricultural land use. J. Appl. Ecol. 39: 524–534.

Bartoszewicz M. 1997. [Mortality of vertebrates on the highway bordering on the Słońsk Reserve, western Poland]. Parki Narodowe i Rezerwaty Przyrody 16: 59–69.

Bereszyński A. 1980. [Studies on mortality of birds killed on public roads]. Roczniki Akademii Rolniczej w Poznaniu 72: 4–10.

van den Brink B., Bijlsma R., van der Have T. 2000. European Swallows *Hirundo rustica* in Botswana during three non-breeding seasons: the effects of rainfall on moult. Ostrich 71: 198–204.

Brown C. R., Brown M. 1999. Natural selection on tail and bill morphology in Barn Swallows *Hirundo rustica* during severe weather. Ibis 141: 652–659.

Bruderer B., Muff J. 1979. [Abundance fluctuations of Barn Swallow and House Martin in Switzerland, with special attention to the population breakdown in autumn 1974]. Ornithol. Beob. 76: 229–234.

Busse P. 1990. [The guide to sex and age determination of European passerines]. Notatki Ornitol. 31: 1–368.

Central Statistical Office. 2001. Statistical Yearbook of the Republic of Poland. Central Statistical Office, Warsaw.

Clevenger A. P. 2000. Effects of highways and other linear developments on wildlife populations. A literature collection. Banf National Park, Canada. (available: http://www.cmiae.org/biblio.html)

Clevenger A. P., Chruszcz B., Gunson K. 2003. Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. Biol. Conserv. 109: 15–26.

Dyrcz A., Grabiński W., Stawarczyk T., Witkowski J. 1991. [Birds of Silesia]. Univ. Wrocław, Wrocław.

Elkins N. 1988. Weather and bird behavior. Second edition. T. & A.D. Poyser, Calton.

Engen S., Sæther B., Møller A. P. 2001. Stochastic population dynamic and time to extinction of a declining population of barn swallow. J. Anim. Ecol. 70: 789–797.

Erritzoe J., Mazgajski T. D., Rejt Ł. 2003. Bird casualties on European roads — a review. Acta Ornithol. 38: 77–93.

Estrada H., Riera G. 1995. High mortality of *Hirundinidae* on roads in and around the Ebro Delta in spring 1992. Bull. Grup Catalá d'Anellam 12: 17–22.

Evans K. L., Bradbury R. B., Wilson J. D. 2003a. Selection of hedgerows by Swallows *Hirundo rustica* foraging on farmland: the influence of local habitat and weather. Bird Study 50: 8–14.

Evans K. L., Wilson J. D., Bradbury R. B. 2003b. Swallows *Hirundo rustica* population trends in England: data from repeated historical surveys. Bird Study 50: 178–181.

Fajardo I. 2001. Monitoring non-natural mortality in the barn owl (*Tyto alba*), as an indicator of land use and social awareness in Spain. Biol. Conserv. 97: 143–149.

Finnis G. 1960. Road casualties among birds. Bird Study 7: 21–32.

Forman R. T., Reineking B., Hesperger A. 2002. Road traffic and nearby grassland bird patterns in suburbanizing landscape. Environ. Manage. 29: 782–800.

Hobson K. A., Sealy S. 1987. Foraging, scavenging and other behaviour of swallows on the ground. Wilson Bull. 99: 111–116.

Karg J. 1994. Insect community response to the shelterbelt-field ecotone. In: Ryszkowski L., Bałazy S. (eds). Functional Appraisal of Agricultural Landscape in Europe. Research Center for Agricultural and Forest Environment, Pol. Acad. Sci., Poznań.

Lorek G., Stankowski A. 1991. [Mortality of birds on the railway tracks in Poland]. Notatki Ornitol. 32: 5–26.

Moreau R. E. 1972. The Palearctic-African Bird Migration System. Academic Press, London and New York.

Møller A. P. 2001. The effect of dairy farming on barn swallow *Hirundo rustica* abundance, distribution and reproduction. J. Appl. Ecol. 38: 378–389.

Møller A. P., Vansteenwegen C. 1997. Barn Swallow *Hirundo rustica*. In: Hagemeijer W. J., Blair M. (eds). The EBCC Atlas of European Breeding Birds. T. & A.D. Poyser, London, pp. 478–479.

Mumme R. L., Schoech S., Woolfenden G., Fitzpatrick J. 2000. Life and death in the fast lane: demographic consequences of road mortality in the Florida Scrub-Jay. Conserv. Biol. 14: 501–512.

Orłowski G., Nowak L. 2004. Road mortality of hedgehogs *Erinaceus* spp. in farmland in Lower Silesia (south-western Poland). Pol. J. Ecol. 52: 377–382.

Pons P. 2000. Height of the road embankment affects probability of traffic collision by birds. Bird Study 47: 122–125.

Reijnen R., Foppen R., Ter-Braak C., Thissen J. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. J. Appl. Ecol. 32: 187–202.

Robinson R. A., Crick H., Peach W. 2003. Population trends of Swallows *Hirundo rustica* breeding in Britain. Bird Study 50: 1–7.

Ryszkowski L., Karg J. 1991. The effect of the structure of agricultural landscape on biomass of insect of the above-ground fauna. Ekol. pol. 39: 171–179.

Turner A. 1994. Swallow *Hirundo rustica*. In: Tucker G. M., Heath M. (eds). Birds in Europe: Their Conservation Status. BirdLife International. Cambrigde, pp. 370–371.

Underhill J. E., Angold P. 2000. Effects of roads on wildlife in an intensively modified landscape. Environ. Rev. 8: 21–39.

Wascher S., Janisch A., Sattler M. 1988: [Bird mortality on communication routes]. Luscinia 46: 41–55.

Winkler H., Christie D. 2002. The Red-headed Woodpecker *Melanerpes erythrocephalus*. In: del Hoyo, J., A. Elliott & Sargatal. J. (eds). Handbook of the Birds of the World. Vol. VII. Picidae. Lynx Edicions, Barcelona.

Wójcik M. 1985. [Selected aspects of breeding biology of the Barn Swallow (*Hirundo rustica*)]. MSc Thesis, Univ. of Wrocław.

STRESZCZENIE

[Czynniki wpływające na śmiertelność dymówki na drogach w krajobrazie rolniczym]

Pomimo stosunkowo dużej liczby danych o ptakach zabijanych na drogach, pochodzących z długiego okresu czasu (patrz przegląd

w Clevenger 2000, Erritzoe et al. 2003) niewiele jest wiadomo na temat mechanizmów, przyczyn i czynników środowiskowych wpływających na śmiertelność poszczególnych gatunków. Dymówka należy do najczęstszych ofiar kolizji z pojazdami samochodowymi na drogach środkowej i wschodniej Europy, stanowiąc do 46% wszystkich zabijanych ptaków (Erritzoe et al. 2003). Podczas trzyletnich badań na drogach w krajobrazie rolniczym okolic Wrocławia w grupie 862 zabitych ptaków, dymówka stanowiła 11.5% wszystkich ofiar (G. Orłowski — dane niepubl.).

W pracy przeanalizowano wpływ czynników środowiskowych (obecność zadrzewień liniowych, liczba zwierząt gospodarskich, natężenie ruchu drogowego, liczba mieszkańców wsi) na wysokość strat dymówki na liczącej łącznie 48.8 km sieci dróg, zlokalizowanej w intensywnie użytkowanym rolniczo obszarze południowo-zachodniej Polski (Fig. 1, Tab. 1 i 2), przebiegającej przez obszar 20 miejscowości (22 odcinki dróg w terenie zabudowanym charakteryzujące się zróżnicowanym natężeniem ruchu drogowego).

Ogółem podczas trzyletnich badań stwierdzono 99 zabitych dymówek. Blisko 88% wszystkich ofiar stwierdzono na terenach zabudowanych i odcinkach dróg położonych bezpośrednio w ich sąsiedztwie (Fig. 1). W ciągu całego okresu badań średnia liczba ofiar na 1 km dróg położonych w obrębie terenów zabudowanych była ponad dwudziestokrotnie wyższa w porównaniu z otwartym krajobrazem rolniczym (6.74 vs 0.33 ofiary/1 km drogi), a w 2002 roku (kiedy zebrano pełne dane) wyniosła 0.88 ofiary/1 km drogi. W ciągu roku zarysowywały się dwa szczyty liczby ofiar, w pierwszej i drugiej dekadzie lipca oraz na przełomie sierpnia i września (Fig. 2). Spośród 67 ptaków, u których oznaczono wiek, 44 (65.7%) było osobnikami młodymi, a w grupie ptaków dorosłych (n = 23) płeć oznaczono zaledwie u 10 osobników (5 samców i 5 samic) (Fig. 2). W okresie od momentu stwierdzenia pierwszych młodych zabitych ptaków (w kolejnych latach było to 5 lipca, 29 i 27 czerwca) osobniki młodociane częściej były ofiarami kolizji w porównaniu z dorosłymi (44 młodych vs 17 dorosłych; $\chi^2 = 16.7$, df = 1, $p < 0.001$).

Na obszarze 20 wsi, przez które przebiegały badane drogi, wysokość strat dymówki była wysoko skorelowana z łączną liczbą hodowanego bydła i świń ($r = 0.89$, $p = 0.000$; Fig. 3) oraz liczbą krów ($r = 0.69$, $p = 0.001$). W okresie lęgowym liczba zabitych dymówek / 1 km dróg położonych w obszarze zabudowanym była statystycznie istotnie skorelowana z liczbą hodowanych krów, łączną liczba krów i świń oraz liczbą mieszkańców (Tab. 3).

W modelu regresji krokowej postępującej dwie zmienne środowiskowe — liczba bydła i świń (LIFESTOCK) oraz długość odcinka drogi (ROAD), w 36% określały poziom zmienności wysokości strat dymówki w okresie lęgowym w terenie zabudowanym. Podczas przelotu jesiennego istotny wpływ na liczbę zabitych ptaków miała zmienna TREE (% zadrzewionego odcinka drogi w obszarze zabudowanym), która określała 36% zmienności wysokości strat. Ogólna, całoroczna zmienność strat dymówki na drogach w obszarze zabudowanym w 41% określona była przez zmienną — liczba krów (LIFESTOCK) (Tab. 4).

Zadrzewienia liniowe wykorzystywane są przez dymówki jako żerowiska, głównie podczas złych warunków pogodowych, a ich lokalizacja wzdłuż dróg naraża ptaki na kolizję z pojazdami. Sposobem ograniczenia śmiertelności na drogach dymówki i innych gatunków ptaków, których występowanie na obszarach rolniczych wiąże się z obecnością zadrzewień, jest właściwe kształtowanie krajobrazu, w tym poboczy dróg pod kątem minimalizacji strat w awifaunie. W świetle przedstawionych wyników nie jest wskazane wprowadzanie pasów drzew i krzewów wzdłuż dróg w pobliżu wsi i zabudowań gospodarskich, lecz tworzenie nowych sieci zadrzewień z dala od szlaków komunikacyjnych, przy których żerowanie nie będzie związane z ryzykiem kolizji. Własne doświadczenia wskazują także, że sposobem zmniejszenia strat u ptaków może być rozpowszechnienie wśród kierowców zwyczaju używania klaksonu, szczególnie w przypadku osobników nadlatujących czy siedzących na drodze.