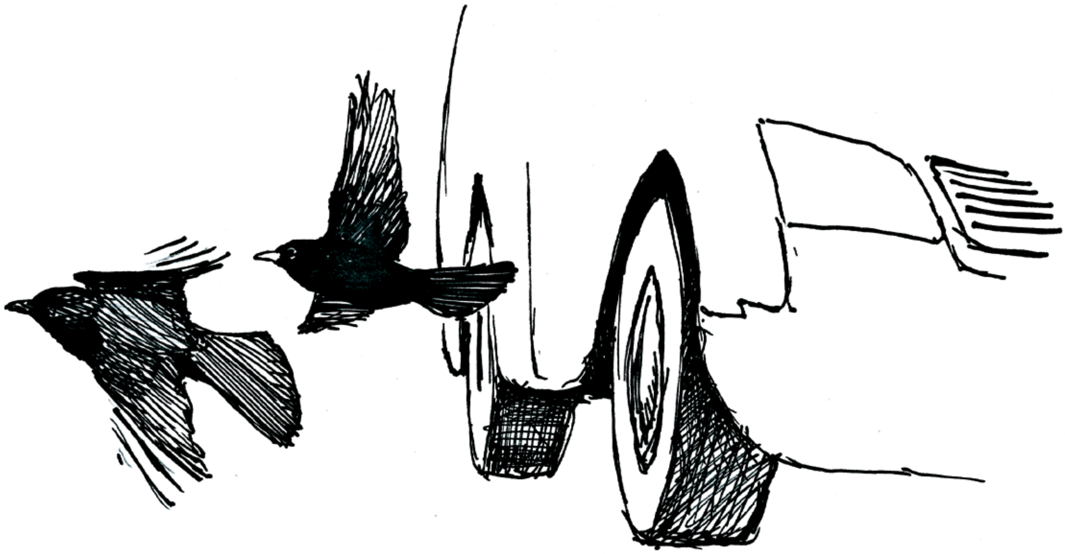
Birds killed on roads in Southern Jutland, Denmark, 2001-2008

Johannes Erritzøe, Helga Erritzøe & Marius Nørgaard



(Med et dansk resumé: Trafikdræbte fugle i sydjyske landdistrikter 2001-08)

Abstract Seven and a half years of monitoring bird traffic casualties by walking and cycling an accumulated 14 750 km of road in a small village and surrounding arable land in the south of Jutland produced a total of 612 roadkilled birds belonging to 42 species. The black spots in our study were houses with gardens situated on both sides of the roads. There were more males than females of the two most frequently killed species, House Sparrow *Passer domesticus* and Eurasian Blackbird *Turdus merula*, with the difference more pronounced in Blackbird. Whereas juvenile House Sparrows were in the majority among the roadkill, the opposite was the case for Blackbird, reflecting the different post-fledging behaviour of the two species. During the study period, a 50% decline in recorded roadkill was noted. Compared with another study conducted on Lolland-Falster in southern Denmark between 1957 and 1981, we found about 76% fewer birds per unit of road. Among potential reasons for the decline, we suggest the most likely to be decreasing bird populations, increased predator populations continuously 'cleaning' the roads, and birds learning to avoid vehicles. Our numbers of roadkill differ to some degree from studies in other countries, supporting the possibility that some populations (e.g. corvids and swallows) have learned to be more cautious of moving cars than others or that even natural selection may have been at work.

Introduction

Studies of traffic casualties among birds have been conducted since 1925 when the first paper appeared in Iowa, USA (Stoner 1925). Up to 1958, however, all studies derived only from records of carcasses found on roads, mostly conducted from a car on a single trip. The first long-term systematic study globally was carried out by a Dane, Lindhard Hansen, between 1957 and 1981 on farmland roads in Lolland-Falster, southern Denmark. A total of 7316 birds were found on an accumulated 23 299 km of road examined by moped in three periods, which as a grand total for the whole of Denmark was calculated to correspond to 1.3 million birds killed yearly in 1957-1958, 3.5 million in 1964-1965, and 3.3 million in 1979-1981 (Hansen 1982). During 1992-1993, roads on farmland in the middle of Jutland, Denmark, were studied from a car that covered 5952 km which produced 273 roadkilled birds, and the yearly number of roadkilled birds in the whole of Denmark was then estimated at 1.1 million (Bruun-Schmidt 1994). Two more studies on traffic casualties have been conducted in Denmark (Jensen 1996, Thomsen 1996), but none of them are comparable with those mentioned above and our work.

The enormous magnitude of the toll of birds on roads due to traffic in other countries is best illustrated by the following: Hodson & Snow (1965) calculated the yearly toll of birds killed by vehicles in the USA to be 57 million; another estimate from the USA extracted from 13 studies gave a result of 200 million birds annually (Loss *et al.* 2014); similar estimates from other countries include Great Britain 27 million birds/year (Errington 1971) and Bulgaria with more than seven million birds/year (Nankinov & Todorov 1983). Therefore a global estimate decades ago and reviewed by Møller *et al.* (2011) was set at at least hundreds of millions per year, or 5-10% of the overall bird mortality.

Roads are attractive to many bird species because they are easy larders: there is spilt grain after harvest, garbage thrown on roads by car drivers, insects attracted by the heat of the asphalt, corpses from roadkill, earthworms that come up to the surface after rain, and in severe winters roads are the first places cleared of snow. Roads are also used by birds to find grit, to smash snails, to bath in puddles, or as migration routes, etc. (Oeser 1977, Forman 1995, Erritzøe *et al.* 2003). Furthermore, predators such as Eurasian Sparrowhawks *Accipiter nisus* are not common by roads (Nankinow & Todorov 1983, own obs.). However, roads also have adverse effects: noise from the vehicles and the danger of being killed by a vehicle are stress factors, and in Dutch studies it was shown that a zone of 300 m on both sides of a road was secondary breeding habitat due to traffic noise (Reijnen & Foppen 1991, Foppen & Reijnen 1994, Forman & Deblinger 2000).

Description of roads and methods

Our study was conducted between 1 January 2001 and 22 August 2008 in an open, intensively farmed agricultural region with fragmented groves and woods surrounding a small village, Taps (55° 24′ N, 09° 29′ E), which has about 340 inhabitants and is situated in the south of Jutland, Denmark. During this period we travelled a total of 14 750 km on five 1 km long routes, which we examined almost every second day either by walking (HE) or by bicycle (JE) (Fig. 1). Route 5 in a southerly direction to an inn, called Den Gamle Grænsekro, was added only from 2003. The road on routes 1 and 2 was a secondary 4 m wide road, while routes 3, 4 and 5 were on a 8 m wide main road; all roads were paved with asphalt and had a verge width ranging from 1 to 3 m on each side. Only about 300 m of route 1 had a narrow hedgerow on both sides of the road, made up mainly by scrub, small bushes and a few trees.

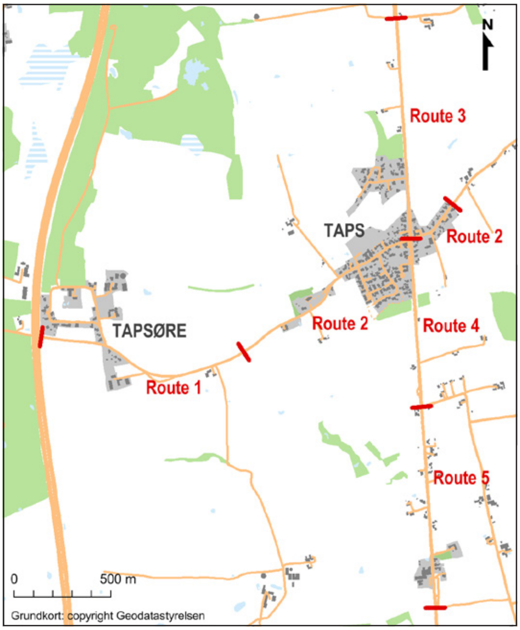


Fig. 1. Map of the study area at Taps indicating the road sections examined.
Kort over undersøgelsesområdet ved Taps med angivelse af de undersøgte vejstrækninger.

The number of vehicles on the secondary road (routes 1 and 2) was between 0 and 45 per hour with an average of 375 in 24 hours; on the main road from Taps and north (route 3) between 15 and 525/h and in 24 hours an average of 6875; from Taps and south between 15 and 575/h and an average of 5325 in 24 hours (E. Harbo, Kolding Kommune, pers. comm.).

About 65% of the surroundings of the routes consisted of open areas (arable fields and meadows), 33% was residential areas, and 2% was woods. The rural land was mostly cultivated with cereals, and there were only three small meadows, where cows periodically grazed, along the routes. The examinations were mostly conducted during the second half of the day, e.g. in 2003 only 23.7% of the censuses were made between 8 and 12 a.m., the rest in the afternoons.

For comparison, the roads around Sommersted (55° 18′ N, 9° 20′ E) c. 15 km from Taps were inspected by car between 1993 and 2008 by MN while travelling to and from his workplace in Haderslev (55° 16′ N, 9° 30′ E) and on other small trips within a radius of about 30 km from Sommersted. The route to Haderslev was a main road called Sommerstedvej, which continued as Moltrup Landevej. Both roads were paved with asphalt, rather similar to our routes 3, 4 and 5, were 8 m wide and had a verge width ranging from 1 to 3 m on each side. Most of the 15 km stretch ran through farmland, rather similar to the Taps area, and a small village called Moltrup and three hamlets called Kastved, Simmersted and Bramdrup. There were four small groves near the road and two groves directly by the road.

The following were entered into a database for the Taps area: the number of the route in question, date, time of day, weather conditions, walking or cycling. For each bird found, the scientific name, sex and age were recorded when possible, and the exact place where the bird was found was plotted on a 1:25 000 map with the database number. The visibility of the dead bird to the observer, its condition and mass were also recorded. In addition, live birds on the road and both low (< 2 m) and high flying (< 10 m) birds were counted from 2002 by (JE), but only if they crossed the road and landed on the other side or some meters away from the road, or when they flew at a height of not more than 10 m along the road. Only birds easy to identify without binoculars were recorded to species; unidentified sparrows, warblers or other songbirds were entered as such. Live birds were not registered each day; i.e. on average, live birds were not registered on 35% of the trips and, specifically, only 1% were examined in 2002, 16% in 2003, 48% in 2004, 41% in 2005, 31% in 2006, 52% in 2007, and 56% in 2008.

All dead birds found were either taken home for closer examination or, if too damaged, removed to avoid double recording. Post mortem external and internal examinations were carried out and skins, or if too damaged, only feathers were kept. In the area around Sommersted birds that were not too damaged only, were collected by MN, and notes were taken on date, locality and cause of death and kept with the bird in a plastic bag in a freezer.

From the beginning of our study we made an appointment with the road workers not to remove bird cadavers on the five routes around Taps.

Differences between numbers of roadkilled females and males or between adults and juveniles were tested by an exact binomial test with the zero hypothesis of equal distribution. T-tests were applied to test of difference between the numbers of roadkilled birds per km between different surrounding land types and between working days and Sundays/public holidays. Trends in numbers of roadkilled birds during the study period were tested by linear regression.

Birds stated as killed in built-up areas were defined as birds found where one or more houses with or without gardens were situated within 50 m of the bird, regardless of whether the houses were on one or both sides of the road or further down the road from the dead bird.

Owls are often caught in the headlights of cars at night. Here, a Barn Owl was struck and killed. Photo: Erik Thomsen.
Ugler indfanges ofte af bilernes lygter on natten. Her har en Slørugle måtte lade livet

Results

Species distribution among roadkilled birds

In total, 612 roadkilled birds were found. House Sparrow *Passer domesticus* was the species most frequently killed, but compared with the number of live House Sparrows using the roads, the road killed birds were very few; i.e. 2.8% relative to live birds seen (Tab. 1). The second most common bird found in our study was Eurasian Blackbird *Turdus merula*, at 26.3% killed relative to live birds seen. Third were Eurasian Tree Sparrow *Passer montanus* at 19.0%, Common Chaffinch *Fringilla coelebs* at 19.0%, and Yellowhammer *Emberiza citrinella* at 39.3% (Tab. 1). Besides House Sparrow, among the other species with more than 50 live birds seen on the roads around Taps during the seven years, the following four species were found with less than 3% killed relative to live birds seen: Barn Swallow *Hirundo rustica*, Northern House Martin *Delichon urbica*, White Wagtail *Motacilla alba* and Rook *Corvus frugilegus* (Appendix 1).

Contrary to expectations, the percentage of insect

Tab. 1. The number of the most common roadkilled birds for the years 2001-2007 compared to live birds 2002-2007 seen on or close to the road. - = Less than 10 birds seen.
Antallet af de mest almindelige trafikdræbte fugle i årene 2001-07 sammenlignet med levende fugle set på eller nær vejen i årene 2002-07. - = mindre end 10 fugle er set.

Species Art	2001	2002	2003	2004	2005	2006	2007	Total	2002-07	Per cent
Passer domesticus Gråspurv	15	42	56	25	12	34	19	203	188	2.8
Seen alive *Set levende*		2277	2681	946	526	884	215		7314	
Turdus merula Solsort	9	9	19	21	21	18	22	119	110	26.3
Seen alive *Set levende*		145	119	41	34	36	44		419	
Passer montanus Skovspurv	5	9	11	2	2	13	6	48	43	19.0
Seen alive *Set levende*		143	43	7	0	22	11		226	
Passer sp. Spurv sp.	1	8	5	4	0	1	1	20	19	10.4
Seen alive *Set levende*		65	43	24	25	12	13		182	
Fringilla coelebs Bogfinke	4	0	4	3	0	1	3	15	11	19.0
Seen alive *Set levende*		12	31	2	4	5	4		58	
Emberiza citrinella Gulspurv	1	1	5	0	1	0	4	12	11	39.3
Seen alive *Set levende*		2	10	3	2	4	7		28	
Cyanistes caeruleus Blåmejse	1	1	2	0	0	1	3	8	7	-
Seen alive *Set levende*		0	0	0	0	2	0		2	
Curruca communis Tornsanger	0	0	2	1	1	1	2	7	7	-
Seen alive *Set levende*		0	0	0	0	0	0		0	
Hirundo rustica Landsvale	4	3	0	2	0	0	0	9	5	1.0
Seen alive *Set levende*		158	120	54	42	81	24		479	
Parus major Musvit	0	1	2	0	1	0	1	5	5	41.7
Seen alive *Set levende*		1	4	2	1	3	1		12	
Curruca curruca Gærdesanger	1	1	1	1	0	2	0	6	5	-
Seen alive *Set levende*		0	0	0	0	1	0		1	
Erithacus rubecula Rødhals	2	0	2	0	1	0	1	6	4	-
Seen alive *Set levende*		1	0	0	0	0	0		1	
Linaria cannabina Tornirisk	2	0	0	0	2	2	0	6	4	-
Seen alive *Set levende*		0	4	0	0	1	0		5	
Columba palumbus Ringdue	2	0	0	2	1	0	0	5	3	-
Seen alive *Set levende*		2	3	0	0	1	0		6	

feeding passerines (warblers) was rather constant over the seven years, and made up on average 4.8% of the total number of roadkilled birds (Appendix 1). The roadkilled Sylviidae and Phylloscopidae warblers were also evenly distributed in the summer months with no concentration in migration periods.

Sex, age and moult differences

There was little difference in mortality between the sexes of both adults and juveniles in House Sparrow, with 53 males and 44 females killed. But many more juveniles than adults were killed, as was indicated by the 125 juveniles found (including un-sexed individuals) compared to 44 adults (exact binomial test: $p < 0.01$). The situation was quite different in Blackbird, where many more males were killed compared to females (70 males, 33 females; exact binomial test: $p < 0.01$), but surprisingly only 19 young birds (including unsexed birds); exact binomial test: $p < 0.01$). The difference in age composi-

Tab. 2. Live birds seen on the road or flying at a height of up to 2 m over the road, and birds flying at a height of 2-10 m over the roads 2002-2007.
Levende fugle set på vejen eller flyvende < 2 m over denne, og i højre kolonne flyvende 2-10 m over denne 2002-07.

Year *År*	On road or < 2 m over *På vejen eller < 2 m over*	2-10 m over road *2-10 m over vejen*
2002	2733	333
2003	3172	320
2004	1138	233
2005	661	39
2006	1070	87
2007	298	58

Tab. 3. Numbers of roadkilled birds found in each month in the years 2001-2007 compared to kilometres walked and cycled for each bird found.
Antal af trafikdræbte fugle for hver måned 2001-07 sammenlignet med antallet af km gået og cyklet og km for hver fugl fundet.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Km	Km per bird
2001	3	2	1	2	7	13	1	9	9	6	0	0	53	716	13.5
2002	0	0	0	0	1	1	30	26	13	6	3	2	82	1398	17.0
2003	0	2	1	11	7	17	17	43	17	6	0	1	123	2156	17.5
2004	1	0	7	5	9	13	3	17	9	3	2	2	71	2176	30.6
2005	1	2	0	2	6	10	5	14	2	0	1	5	48	1710	35.6
2006	2	0	1	7	5	14	15	31	10	3	1	0	89	2776	31.2
2007	6	1	3	8	7	9	16	14	2	5	2	1	74	2366	32.0
Total	13	7	13	35	42	77	87	156	62	29	9	11	514	13298	25.9

tion between the two species was also statistically significant (exact binomial test: $p < 0.01$). Among the rest of the sex determined species, there were 45 males and 33 females but no statistical significance.

Only one adult bird – a female Blackbird found in 2005 – with wing and tail feathers in moult was roadkilled, but many juveniles, especially of House Sparrow, were found with growing body feathers, short wings and stumpy tails.

Where, when and under what conditions were most birds killed?

About ten times as many birds were found per kilometer where there were houses and gardens along the roads (t-test, $t = 2.30$, $p = 0.03$). Taken together, an average of 0.106 birds were killed per km in built-up areas, as compared to 0.013 in farmland areas. This was so despite the fact that there was a speed limit of 50 km/h in the village of Taps. On route 5, where a large inn, three houses and a farm were situated along a stretch of less than 200 m, the speed limit was 80 km/h, and over six years 83 roadkilled birds were found there, or on average 0,343 birds killed per km. This is more than three times as many as in Taps (0.103 birds per km; t-test: $t = 8.62$, $p < 0.01$).

Our recordings of birds flying low i.e. below 2 m compared to at a height of 2-10 m did not show any tendency toward an increase in flight height in the seven years of study (Tab. 2).

The months with the most roadkilled birds were not surprisingly June to September, with a peak of 30% of the annual kill in August, while November to February were the months with fewest killed birds, i.e. an accumulated total of 8% (Tab. 3). This is in accordance with other studies from Northern Europe (Hodson & Snow 1965, Bergmann 1974, Göransson & Karlsson 1978).

The pattern of traffic intensity was different on weekdays compared to holidays and we therefore also checked for effects of this. In 2002 and 2003 we had to cycle or walk 18.8 km on weekdays for each bird found, but only 14.7 km on Saturdays, Sundays and holidays (t-test: $t = 11.1$, $p < 0.01$).

The decline

There has been a steady decline in the number of roadkilled birds in the years of the study at Taps (linear regression: $F = 18.2$, $p < 0.01$, $R^2 = 0.78$, slope $= -0.008$). Hence the number of kilometres cycled or walked for each roadkill found increased from 12.5 km in 2001 to more than 30 km from 2004 onwards, with an overall average of 24.1 km for the years 2001-2007 (Fig. 2). Similarly, there was a comparable decline in not too damaged roadkilled birds found around Sommersted to that of Taps (Appendix 2; linear regression: $F = 29.0$, $p < 0.01$, $R^2 = 0.69$, slope $= -0.001$). As a comparison, there was a clear decline in live birds registered on or close to the roads at Taps that was comparable with that of the roadkilled birds found (Tab. 2, Appendix 3; linear regression: $F = 47.3$, $p < 0.01$, $R^2 = 0.92$, slope $= -0.482$).

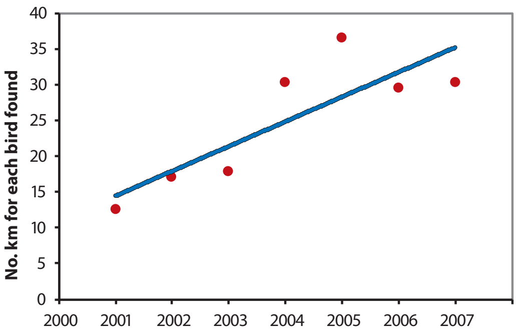


Fig. 2. Number of km walked or cycled for each roadkilled bird found during 2001-2007 in the Taps area (linear regression $F = 18.2$, $p < 0.01$, $R^2 = 0.78$, slope $= -0.008$).
Antal km gået og cyklet for hver trafikdræbt fugl fundet fra 2001 til '07 ved Taps.

Discussion

An estimate of the total number of roadkilled birds per year in Denmark

In a study like this there are many possible sources of error. Here only the most important are mentioned: many roadkilled birds are taken by corvids, raptors, cats, foxes, hedgehogs, humans etc., or are thrown into fields by high-speed vehicles, where they are difficult to find. Low sun or otherwise poor visibility can also make finding the corpses problematic. Killed birds on roads with fast moving vehicles are worn away in a few hours to a few days depending on traffic intensity (Göransson *et al.* 1978, Hansen 1982). More birds are overlooked when inspection is conducted from a car than by moped or bicycle, while most bird corpses are found by walking; in fact, only a third of bird corpses were found by car compared with a walking participant in a British study (Hodson & Snow 1965). Nearly the same was demonstrated in Sweden where only a third of the small birds and about half the larger birds were found by car (Göransson *et al.* 1978). A cautious guess at the real number killed in our area was probably twice as many as the 612 roadkilled birds we found when all sources of error mentioned above and in the description of roads and methods are taken into consideration.

Denmark has a dense network of paved roads, i.e. about 72 000 km (1619 km highway, 9702 km main road and 60 894 km secondary road in 2005), and also had about two million cars in 2005 (A.D. Bracht, Statistics Denmark, *in litt.*). However, it is difficult to extrapolate from our study to the total number of roadkilled birds in all parts of Denmark per year because we conducted our study by walking or cycling only, and therefore had no opportunity to include highways. Instead, based on our findings on main road routes 3, 4 and 5, which are likely to be the most representative, and the ratio between the kill rate on highways (0.355 birds per km per day), main roads (0.204) and secondary roads (0.085) given by Hansen (1982), a very rough estimate would be 665 000 birds killed per year in Denmark. If the above mentioned estimate that twice as many birds are actually killed than are found is correct, we reach a figure of between one and one and a half million kills.

The most commonly roadkilled birds compared to the number of live birds seen at Taps

The recorded roadkilled and observed live birds reflect quite well the occurrence of breeding bird species in the Taps area, except for a few species which are rather common in our area but were never seen on the roads, namely Mallard *Anas platyrhynchos*, Great Spotted Woodpecker *Dendrocopus major* and Eurasian Nuthatch *Sitta europaea*. Because there were no severe winters between 2001 and 2007, no Eurasian Buzzards *Buteo buteo* were found among the roadkilled birds, while the opposite was the case in, for instance, the severe winter of 1996-1997, where 14 roadkilled Buzzards from our area were brought to us by members of the public. The same applied to owls (Erritzøe 1999).

The three most common roadkilled species in the material from Taps were not surprisingly the most urbanized species: House Sparrows made up 38%, Blackbirds 22% and Tree Sparrows 9% of the total number of roadkilled birds. More surprising was the Yellowhammer with 39.3% roadkilled birds compared with the live birds seen, which may indicate that this species is vulnerable to traffic because only 28 live birds were seen on the roads in the full seven years of study, while 12 were found as roadkill (Tab. 1).

The 503 Rooks seen alive on the roads in our area compared with only two roadkilled birds (0.4%) is also surprising, considering their frequency and fearlessness. A big rookery was situated in Christiansfeld, and Rooks were therefore a common sight on the fields and roads, often several hundred at a time. Compared to the c. 3% roadkilled House Sparrow and White Wagtails *Motacilla alba* in relation to live birds seen, the 26.3% roadkilled Blackbirds are remarkable and probably a result of Blackbirds normally crossing roads at a low flight height (Appendix 3). The relatively constant number of insect-eating birds among the roadkill was also surprising considering the disastrous decline in flying insects we now experience (Hallmann *et al.* 2017).

A comparison between Taps and Sommersted

Our results from Taps were confirmed by the findings around Sommersted between 1993 and 2008 in a similar rural area (Appendix 2). The most important result here was the rather constant numbers recorded per year in the first eight years in the Sommersted data, i.e. in the years prior to the study at Taps, 1993-2000, compared with the continuous decline in the number of birds found between 2001 and 2008. The most common bird species killed at Sommersted was House Sparrow at 13, followed by 12 Blackbirds, 10 Yellowhammers, nine Tree Sparrows and eight Chaffinches.

To make a comparison of the number of roadkills from Sommersted with Taps realistic, the percentage of damaged roadkilled birds that were not collected and recorded must be estimated. In the Taps study, 2003 was the year with most roadkill. In that year, the proportion of birds in good condition versus damaged birds was as follows: 21 undamaged birds, 15 slightly damaged, 26 severely damaged, 45 flat corpses and 11 with only a few remains. Hence, only 44% were undamaged or slightly damaged. Therefore, to compare the Taps results with

MN's contribution, about 127% must be added to MN's numbers to obtain a reasonable comparison between the two areas.

Morning versus evening search and traffic intensity

Many studies state that most birds are killed in the morning, and scavenging of carrion on roads by corvids in particular is well known. Accordingly, most searches are done in the early mornings (Jones 1980). Therefore our study is likely to have had a bias because more than half of the work was conducted in the afternoon. However, many of the birds killed in the morning were still found in the afternoon when additional birds could have been added to the toll. Most live corvids found on our routes were Rooks, which often forage on the roads but rarely take carrion (Cramp & Perrins 1994, own obs.). Routes 4 and 5 were nearest Christiansfeld, which as already mentioned had a large rookery and most Rooks were therefore found there. In spite of this, these two routes had the highest amount of roadkill recorded in our study, i.e. 54% of the corpses on our five routes. A check of our morning searches in 2003 showed that 15 birds were found on 588 km (= 39.2 km for each bird found) of road compared to 109 birds on 1570 km (= 14.4 km for each bird found) of road in the second half of the day, which contradicts the above.

Differences in sex and age composition etc. among common roadkilled species

The sex ratio among Blackbirds found in this study (69 males, 33 females) corresponds well with five other roadkill works that report 62% males (n = 167) (Finnis 1960, Govett 1960, Beckmann 1961, Hodson 1962, Smettan 1988), but three of the mentioned authors found 56% female House Sparrows (n = 317). Large-scale poisoning of House Sparrows (n = 30 319) in different parts of Germany showed that there was a slight majority of males, ranging from 50.3% in Württemburg to 54.7% in North Rhine-Westphalia (Summers-Smith 1963). As already stated, we found 53 male House Sparrows and 44 females in our study. Bruun-Schmidt (1994) found that 68% of all roadkill of all species which could be sex determined (n = 98) were males and suggested that the reason is that males are more active, including territorial disputes, while females are more sedentary.

Far more adult than juvenile Blackbirds in their first plumage were killed in our study, and the same was the case in a study in mid-Jutland where only two out of a

House Sparrows are common on roads when spilled grain represents easily available food, and they were the most common traffic victims in this study. Photo: Erik Thomsen.
Gråspurven er en hyppig gæst på vejene, når der er masser af spildkorn, og de var de hyppigste trafikofre i nærværende undersøgelse.

total of 21 Blackbirds were juveniles (Bruun-Schmidt 1994). The high number of newly fledged House Sparrows with a stumpy tail that were roadkilled in our study (73%) compared to newly fledged Blackbirds (17%) suggest that this is due to differences in post-fledging behaviour in the two species. Snow (1958) wrote: "As soon as the young Blackbird leaves the nest, barely able to fly and with only a stump of a tail, it seeks cover, usually a little above the ground, and spends most of its time sitting motionless" … "after about ten days they begin to move farther afield." We have not found a description of House Sparrow behaviour at this age, but according to our results they must move around soon after they have left their nests. In contrast to our results, a study from Great Britain found relatively many roadkilled young Blackbirds (42%) between April and August (Finnis 1960), and Dunthorn & Errington (1964) found 10 adult and 17 juvenile Blackbirds from all months of the year in Wiltshire, UK, during 1957-1960. In a study from Poland, 59.5% were young birds among the 508 roadkilled birds of all reported species of known age (Orlowski 2008).

Storage of fat increases body mass and consequently alters flight performance such as take-off abilities. Foraging in scrub is therefore safer for fat birds because it only requires a short flight to find cover if an aerial predator arrives (Cimprich & Moore 2006). In contrast, birds accept greater predation risks as their risk of starvation increases (Lima & Dill 1990, cited in Cimprich & Moore 2006). However, several papers document a large number of fat roadkilled birds, but no papers we know of mention lean birds (Sutton 1927, Gollob & Pulich 1978, Massemin & Handrich 1997, Massemin *et al.* 1998). In severe winters, however, lean birds like Buzzards mentioned above and owls are commonly killed (own obs.).

Flight performance may be reduced during moulting of flight feathers, and intensively moulting birds have higher flight costs than slowly moulting birds because their wing loading is higher (Bergmann 1974). Against this background it is remarkable that only one moulting adult bird was found in our study, a female Blackbird in 2005. It is likely that this is a result of the more secretive behaviour of birds during the moult. However, among the less experienced young birds, individuals with growing feathers were frequently found among roadkill.

On which part of the roads are most birds killed?

Although not statistically significant, it was not surprising that most roadkill was found near human settlements. Another Danish study (Bruun-Schmidt 1994) together with many foreign studies (e.g. Bräutigam 1978, Smettan 1988) have also arrived at a similar result. In a Swedish study, the traffic death toll was greatest near farms and large gardens and in a cleft with deciduous trees on both sides (Göransson *et al.* 1978).

We compared roadkill in Taps village and along the road where an inn was situated on route 5. In the first mentioned area the speed limit was 50 km/h and in the second it was 80 km/h. Three times fewer birds were killed along the stretch of road with the lower speed limit, a result also found by Bruun-Schmidt (1994), Blumstein (2003) and DeVault *et al.* (2015), but see also Legagneux & Ducatez (2013). It is difficult to say at what speed moving cars start to be dangerous to birds. A Song Thrush *Turdus philomelos* was killed at a speed of only 32 km/h (Govett 1960), and many birds are killed in towns where the speed limits are mostly 50 km/h (Bruun-Schmidt 1994). In a German study, Illner (1992) found that owls were 21 times more frequently killed when the speed of cars was more than 80 km/h, and Haas (1964), who travelled 46 400 km on bicycle and by car, found more traffic casualties on roads with high speed limits even if the traffic density was low. Besides the difficulty a bird has in estimating the speed of a car, there must also be stronger turbulence around a car moving at high speed, which can throw a small bird into the path of an oncoming vehicle or down onto the road surface (Göransson *et al.* 1978).

In an earlier study documenting interspecific variation in the traffic casualties among bird species, which used data from between 2001 and 2006 from the present study, the conclusion which explained 42% of the variance was that the frequency of roadkilled birds increased significantly and linearly with abundance (Møller *et al.* 2011). Birds with short flight initiation distance when approached by humans, and solitary birds were killed disproportionately often by vehicles (Møller 2008), and birds had a significantly higher flight initiation distance on road sections with higher speed limits (Legagneux & Ducatez 2013).

How much influence do weather and weekdays have on roadkilled birds?

Our data did not allow a proper analysis, but both Hodson (1960) and Bergmann (1974) found more bird corpses on overcast and sultry days and fewest in rainy and stormy weather when birds exhibited a more hidden behaviour. In contrast to this, Common Swifts *Apus apus* and swallows fly closer to the ground in moist, cold and rainy weather and under such conditions are killed by the vehicles (Bräutigam 1978, Harding 1979, Wascher *et al.* 1988). After a heavy snowstorm, an estimated 9000 Lapland Buntings *Calcarius lapponicus* were killed by vehicles in Texas because they foraged on the snow-free part of the highway (Gollop & Pulich 1978).

In two studies, most birds were killed on Saturdays

Tab. 4. Numbers of roadkilled birds in Lindhard Hansen's (LH) study compared to our results from Taps given both as actual numbers and in km covered for each bird found. Hansen drove 23 299 km; we cycled and walked 14 750 km.
Antal trafikdræbte fugle i Lindhard Hansens (LH) undersøgelse sammenlignet med vores angivet både som faktiske antal og som dækkede km pr. fundet fugl. Hansen kørte 23 299 km; vi cyklede og gik 14 750 km.

Species in LH's study ***Arter i LH's studie***	**LH 1957-1981**	**Km/bird** ***Km/fugl***	**Taps 2001-2007**	**Km/bird** ***Km/fugl***	**Taps in % of LH**
Passer domesticus Gråspurv	2168	11	229	64	16.7
Turdus merula Solsort	1009	23	134	110	21.0
Hirundinidae *Svaler*	462	50	10	1475	3.4
Passer montanus Skovspurv	457	51	52	284	18.0
Fringilla coelebs Bogfinke	395	59	17	868	6.8
Turdus philomelos Sangdrossel	284	82	3	4917	1.7
Emberiza citrinella Gulspurv	208	112	12	1229	9.1
Sylvidae & Phylloscopidae *Sangere*	199	117	35	421	27.8
Sturnus vulgaris Stær	149	156	1	14750	1.1
Phasianus colchicus Fasan	139	168	4	3688	4.5
Erithacus rubecula Rødhals	132	177	7	2107	8.4
Chroicocephalus ridibundus Hættemåge	131	178	0	0	0.0
Parus major Musvit	109	214	6	2458	8.7
Carduelis chloris Grønirisk	98	238	4	3688	6.4
Alauda arvensis Sanglærke	91	256	0	0	0.0
Linaria cannabina Tornirisk	84	277	5	2950	9.4
Prunella modularis Jernspurv	54	431	5	2950	14.6
Vanellus vanellus Vibe	45	518	0	0	0.0
Other birds *Andre fugle*	658	35	58	254	13.9
Unindentified birds *Ubestemte fugle*	444	52	30	492	10.7
Total	7316	3	612	24	13.2

and Sundays (Schoenemann 1977, Göransson *et al.* 1978), maybe due to a different traffic pattern on these days, which introduces an element of surprise. As already described, our study supported this statement.

Geographical variation in roadkilled species

Corvids are worldwide frequent guests on roads, but are rarely reported as roadkill in most places. On a 46 400 km journey between 1956 and 1963 encompassing nine different trips through many countries in Europe together with Turkey and Morocco, only six Eurasian Crows *Corvus corone*, one Rook, nine Eurasian Jackdaws *Curvus monedula,* nine Eurasian Magpies *Pica pica* and two Eurasian Jays *Garrulus glandarius* were found, or 1.5% of all birds found (Haas 1964). Hansen (1982) mentions no corvids in his study, but they are maybe among his 658 individuals of "other species". Jensen (1996) found only 10 Rooks and seven Magpies in a 252 000 km road study in Denmark between 1972 and 1983 despite stating that Crows were often seen on and near the roads, and Bruun-Schmidt (1994) found only four corvids in his Danish study. Our study gave only three roadkilled Crows, two Rooks and one Magpie even though corvids often frequent the roads (see Appendix 1). In Schleswig-Holstein no crows were found killed on a 43 km long road which was driven regularly between 1975 and 1976, despite the presence of three rookeries nearby and that Rooks from there often were seen foraging on the roadside (Heinrich 1978). In South Africa, where there are three native members of the crow family that all often frequent roads, only one Pied Crow *Corvus albus* was found roadkilled among 585 casualties (Broekhuysen 1965).

In Finland, Sweden and Czechoslovakia (now the Czech Republic), the situation is quite different. In the Finnish study conducted in the snow free period April-October 1982-84 Crows and Magpies accounted for 20% of all roadkill. This result confirms an earlier Finnish work, according to which 23% were Crows (Moilanen 1978, cited in Korhonen & Nurminen 1987). In Sweden, the proportion of roadkill was 0.9-1.6% for Magpies and 0.8-1.2% for Crows, but 10-11% for Rooks (Göransson *et al.* 1978 p. 97). In Central and Eastern Europe corvids made up a high proportion of the victims (see compilation by Erritzøe *et al.* 2003), e.g. in the Czech Republic 8% of roadkilled birds were Rooks (Havlin 1987). None of the above cited studies made any mention of Crows or Magpies breeding in trees along roads or close to roads, which otherwise could explain the high death toll.

The roadkilled Barn Swallows in Bruun-Schmidt's (1994) study made up 4.4% of all roadkilled birds found, while in our study Barn Swallows amounted to only 1.7% (Appendix 1), but in Poland 27.1% were found as traffic accidents between 1978 and 2002 and in Ukraine 10.6% between 1995 and 1999 (see compilation by Erritzoe *et al.* 2003). Though different traffic intensities in the mentioned countries were not taken into consideration, the above examples of increased frequency of roadkilled corvids and Barn Swallows are remarkable.

What is the reason for decreasing numbers of roadkilled birds?

A comparison of Hansen's (1982) work from 1957 to 1981 with our study is difficult (Tab. 4). Through contact to Hansen's heir we learned that all his notes on his traffic study had been destroyed (L. Clausen *in litt.*), so it was not possible to check his records about e.g. the 658 individuals of "other species", which makes many comparisons impossible. In the last two studies (1964-65 and 1979-81) Hansen did not search the roads in the winter months, but estimated numbers from his first study. This gives some uncertainty in a comparison with our results, but because the winter months are the months when fewest birds are found (Tab. 3), this may be of less importance. If a stretch of road is only examined every second day or less, there will be more birds found per trip than if the study is conducted every day, because there will be more birds left from previous days. Hansen left at least one week between each of his examinations of a road (i.e. he made mostly only 2-3 trips per month), while we examined the roads about 60% of all days. To obtain an idea of the significance of this problem, we examined data from 2003 for the first day after a period without inspection of the routes. The result was that after the roads had not been examined for three or more days, only eight birds were found out of a total of 123 roadkilled birds that year. We suppose the reason for this low number is that most dead birds are quickly found and eaten by scavengers, and therefore the difference in Hansen's and our study may be of less importance.

As was the case in our work there were no severe winters during Hansen's study (B. Evers-Jahnsen, Danish Meteorological Institute, pers. comm.). However, a very coarse comparison of his results of about three decades ago with ours shows a 76% reduction in roadkilled birds found. Hence, Hansen (1982) found 0.204 birds per km main road per day, while we found 0.048 on road sections 3, 4 and 5, which probably are the most comparable stretches. This interpretation is based on the assumption that the birds in both studies represent kills during comparable periods (see above).

Furthermore, in our study there was a nearly 50% decline in roadkill during the seven full years of study (Fig. 2) in spite of a 9% increase in the traffic in Denmark during the same period (A.D. Bracht, Statistics Denmark, *in litt.*). Hansen (1982) came to the same conclusion that the number of birds killed in traffic did not rise in step with the increase in traffic. This decline has apparently continued up to now; even though we have stopped the systematic study, we have continued our almost daily walks on the same roads around Taps (routes 2, 4 and 5). Furthermore, when we now undertake longer trips by car we see the same trend; for example in September 2017 we drove from our home in Taps to Viborg, a total distance of 260 km without seeing a single bird corpse. This would have been quite unthinkable only 15 years ago.

Bruun-Schmidt (1994) conducted a careful study in 1992-1993 on three roads in mid-Jutland, about 120 km north of Taps. The study was conducted in only one year and from a slowly moving car (30 km/h) on five consecutive days each month. In total, 273 roadkilled birds were registered on 5952 km of road, or 21.8 km for each bird found. Our study gave 25.9 km on average for the seven years (Tab. 3), i.e. a marked decline in rural roadkilled birds. Here it is worth mentioning that in our study, 281 roadkilled birds were found outside the asphalted portion of the road and were therefore difficult to recognise from a car compared to the 250 found on the asphalted road itself (Tab. 5).

A further contributing reason for the decline in amount of roadkill found may be a significant increase in corvid numbers since the 1970s, by as much as 50-100% for some species (Moshøj *et al.* 2017). However, in our area the crows have not increased in the years the study has been conducted (Appendix 1), and most of the na-

Tab. 5. Numbers of roadkilled birds found on the road itself versus those found outside of the asphalted area 2001-2007.
Antallet af trafikdræbte fugle fundet på selve vejen versus udenfor det asfalterede område 2001-2007.

Year *År*	**On road *På vejen***	**Outside road Udenfor vejen**
2001	20	30
2002	44	38
2003	59	61
2004	30	40
2005	20	28
2006	43	46
2007	34	38
Total	250	281

tional increase has levelled out over the last 15-20 years.

In spite of these biases, a marked decline in actual bird numbers is evident. More than 60% of the land area of Denmark is intensively farmed land, and according to national indices several bird populations have suffered severe declines is this habitat (Heldbjerg & Fox 2016). This decline corresponds well with our study, except for the Barn Swallow for which Heldbjerg and Fox state a small increase whereas we found a decline both among the roadkilled birds and the live birds around Taps (Appendix 3).

The House Sparrow has undergone a marked decline in Europe since the 1970s (EBCC *et al.* 2015, Moshøj *et al.* 2017). In 1992, the percentage of House Sparrows was only 1.5% of all birds found in mid-Jutland (Bruun-Schmidt 1994) against 38% in our study, suggesting that the populations in different parts of Denmark vary in abundance. However, in the seven and half years study at Taps there has been a large decline in the House Sparrow population (Tab. 1; linear regression: $F = 8.47$, $p = 0.03$, $R^2 = 0.63$, slope = -0.003).

It is striking to see the nearly total lack of open country species both among the roadkills and among the live birds seen, such as Northern Lapwing *Vanellus vanellus*, Eurasian Skylark *Alauda arvensis* and Corn Bunting *Milaria calandra*, where the two first mentioned were quite common in Taps in the 1970s (own obs.).

One may ask what the reason for the decline of the bird populations around Taps in recent years may be, if the number of roadkilled birds provides a reasonable indication of a serious decline. That mortality on the roads cannot solely be blamed is obvious: for example, such mortality would only involve death of 13% of the House Sparrow population in Great Britain each year, which for a species with a high breeding potential should be of minor significance (Hodson & Snow 1965). The only predator of significance in our area is the Sparrowhawk, but it is rarely observed (Appendix 1). For example, in our bird-rich garden we find only 1-2 corpses each year taken by a predator. Heldbjerg & Fox (2016) stated that the increasing agricultural intensification has put bird populations in Danish farmland under great stress, and

According to a rough estimate, in the order of 1-1½ million birds are killed annually in Denmark. Photo: Hanne Petra Katballe, Feral Pigeon.
Tallene fra denne undersøgelser tyder på, at i størrelsesordenen en til halvanden million fugle bliver dræbt hvert år i trafikken, hvilket er langt mindre end for 30-40 år siden.

the use of insecticides is likely to depress the breeding success of many bird species by reducing the availability of food for the chicks (BirdLife International 2004). As mentioned above, the decrease in roadkill has continued even after 2008 in the Taps and Sommersted areas. However, we suggest there are more explanations for the fall in roadkilled birds.

Have birds adapted to road traffic?
A literature search of other studies which show drastic decline in birds killed by vehicles gave only one result: a study on American Cliff Swallows *Petrochelidon pyrrhonota* conducted in Nebraska between 1983 and 2012 by daily inspection by car, where the nests of the swallows under bridges and culverts along the road examined in this period rose from 11 000 to 25 000. In spite of this increase, and no increase in avian scavengers, the roadkill declined in a sharp curve from 20 to two per year, and the authors supposed that risk-taking birds had been selectively removed (Brown & Brown 2013).

In the Taps area the opposite has occurred. The populations of most species have declined and so has the roadkill tally. But this cannot be the sole explanation for the drastic drop in roadkilled birds in Taps. For example, the House and Tree Sparrow populations in Taps according to our best estimates have declined by only about half as already mentioned. A similar decline in House Sparrows has been documented nationally since the 1970s, whereas Tree Sparrows have doubled in number during the same period (Moshøj *et al.* 2017). With regard to the other three most commonly roadkilled species, a halving of the national indices has been documented in Yellowhammer, while the populations of Blackbird and Chaffinch have predominantly been stable – again since the 1970s (Moshøj *et al.* 2017). This points to other causes for decline in roadkill than decreasing bird populations alone.

Birds have been shown to adapt to the direction of traffic and lane use, and this apparently reduced the risk of roadkill (Brown & Brown 2013). Suggestions that individual birds that are not killed in traffic should have larger brains for their body size made this a promising possibility to study. An analysis of the link between being killed by traffic and relative brain mass in 3521 birds belonging to 251 species brought to JE showed that birds that were killed in traffic did indeed have relatively smaller brains, while there was no similar difference for liver mass, heart mass or lung mass. These findings suggest that birds can learn the behaviour of cars, and that smart birds have been able to adjust their behaviour in relation to these fast moving objects (Møller & Erritzøe 2017). This study suggests that natural selection acting over few decades may even have been involved.

Closing words
The decline in bird populations on rural areas at Taps and Sommersted, where farmland specialists like Grey Partridge *Perdix perdix*, Lapwing and Corn Bunting have now virtually disappeared, is a major cause of declining roadkill. But we suggest that a learning ability (habituation), possibly even aided by natural selection in the decades since Hansen's study, have also been at work by eliminating individuals which showed risky behaviour. We presume this for three reasons, all described in this paper: 1) because some populations of the same species in Europe, especially corvids, seems to be more susceptible to roadkill than other populations; 2) the study of the Cliff Swallow in USA where roadkill decreased by 90% despite a population increase of more than 150% in the same period; and 3) a new study of 3521 birds killed on roads or by flying into windows has shown that roadkilled birds have smaller brains than conspecifics killed in other ways. Roadkill in Denmark will therefore presumably soon be of lower importance in conservation issues than birds killed by collisions with windows, towers, windmills, electrocution, oil disasters and other man-made causes.

Acknowledgements

We want to thank Birgitte Reitz from the Danish Road Directorate for useful information, Bettina Evers-Jahnsen from the Danish Meteorological Institute for help with meteorological questions, Erik Harbo from Kolding Municipality for information about traffic density, Anna Dorthe Bracht from Statistics Denmark for other traffic data and the road workers for not removing the dead birds on our study road stretches. Hans Meltofte has helped a lot with improvements to the manuscript and provided much inspiration. Frank Rigét conducted all the statistical tests, Nick Quist Nathaniels improved our English, and Britta Slott, COWI, produced the map for Fig. 1. Niels Linneberg has been a great help with database management. Lastly we thank two anonymous reviewers for many constructive suggestions for improvements.

Resumé

Trafikdræbte fugle i sydjyske landdistrikter 2001-08
Lindhard Hansens undersøgelse mellem 1957 og 1981 var det første systematiske studie af trafikdræbte dyr i verden, hvor han undersøgte, hvor mange fugle, pattedyr, krybdyr og padder, der blev dræbt af trafikken på Lolland-Falster. Han nåede frem til, at der årligt i Danmark blev dræbt 1,3 mio. fugle i 1957-58, 3,5 mio. i 1964-65 og 3,3 mio. i 1979-81 (Hansen 1982). En undersøgelse af det samme foretaget i 1992 af Jesper Bruun-Schmidt (1994) i Midtjylland og foreliggende undersøgelse fra 2001-08 omkring Taps i Sydjylland i et typisk landbrugsområde med en lille landsby og ellers spredt bebyggelse (Fig. 1) viser, at der nu ved en grov sammenligning findes omkring 76 % færre trafikdræbte fugle sammenlignet med Hansens samlede resultat for alle hans tre undersøgelsesperioder. Desuden er der i de blot 7½ år, vores undersøgelsen fandt sted, sket en halvering af an-

tallet af trafikdræbte fugle trods en 9 % stigning i trafikken i den samme periode (Fig. 2). Denne artikel omhandler, hvad denne nedgang kan skyldes.

I det foreliggende arbejde blev 612 fugle fundet trafikdræbte. I Tab. 1 er antallet af dræbte fugle af de talrigeste arter vist for de syv fulde undersøgelsesår. Desuden er antallet af levende fugle set på vejen, krydsende denne eller flyvende i indtil 10 m højde over vejen registreret (Tab. 2). De trafikdræbte fugle viste sig at være i stor overensstemmelse med et nærliggende område (Sommersted), hvor trafikdræbte fugle blev indsamlet mellem 1993 og 2008 (Appendiks 2), idet en tilsvarende nedgang i antallet af fundne trafikdræbte fugle var sammenfaldende med Taps-området.

De hyppigst dræbte fugle er Gråspurv *Passer domesticus*, Solsort *Turdus merula* og Skovspurv *Passer montanus*, hvilket stemmer overens med de faktiske antal fugle i Tapsområdet. Kun én fældende voksen fugl, en Solsort, blev fundet, hvorimod mange ungfugle, der stadig ikke havde udvoksede fjer, blev trafikkens ofre. De fleste dræbte fugle blev fundet i forbindelse med menneskelig bebyggelse, men det må her påpeges, at der ikke forekom strenge vintre i undersøgelsesperioden. Desuden blev flest dræbte fugle fundet på lørdage, søndage og helligdage, sikkert på grund af det anderledes trafikmønster på disse dage. De relativt konstante antal insektædende fugle i vores undersøgelse var en overraskelse, den katastrofale nedgang blandt flyvende insekter i de senere år taget i betragtning (Hallmann *et al.* 2017).

Hovedårsagerne til faldet i antal trafikdræbte fugle siden Hansens undersøgelser er antagelig en kombination af reducerede fuglebestande især i landbrugslandet (Heldbjerg & Fox 2016), øgede antal kragefugle (Moshøj *et al.* 2017), der fjernede trafikdræbte fugle inden vi nåede frem, metodiske forskelle på de to undersøgelser, og tillæring blandt fuglene. Den væsentligste metodiske forskel i forhold til Hansens undersøgelse var, at vi gennemgik de udvalgte vejstrækninger hyppigere, hvilket alt andet lige betyder, at man finder færre fugle pr. vejstrækning pr. tur, end hvis fugle fra længere perioder 'hober sig op' på vejene.

Især det lave antal trafikdræbte kragefugle vagte vores forundring, fordi de er så hyppige gæster på veje, hvor de indsamler alskens spiseligt, ikke bare herhjemme, men mange steder i verden. På trods af dette er det meget forskelligt, hvor mange trafikdræbte kragefugle, der bliver registreret i mange undersøgelser. Under 1 % af trafikdræbte fugle i vores undersøgelse var kragefugle. Tilsvarende fandt Jensen (1996) kun syv Husskader *Pica pica* og 10 Råger *Corvus frugilegus* mellem 1972 og 1983 i Ringstedområdet, hvor trafikdræbte fugle blev indsamlet fra bil langs 252 000 km vej. Går vi til udlandet er billedet det samme mange steder, men i Finland udgjorde kragefugle 20 % af alle trafikdræbte fugle (Moilanen 1978, citeret i Korhonen & Nurminen 1987) i Sverige var 10 % af trafikdrabene Råger (Göransson *et al.* 1978) og i Tjekkiet 8 % (Havlin 1987).

Dette kunne tyde på varierende indlæring af ny adfærd i forskellige populationer af den samme art. I en undersøgelse af Stensvaler *Petrochelidon pyrrhonota* fra Nebraska 1983-2012, hvor ynglebestanden i samme periode var steget fra 11 000 til 25 000 par, faldt antallet af årligt fundne trafikdræbte svaler fra 20 til to. Da der ikke var sket nogen forøgelse af kragefuglebestandene, som kunne have opsamlet de trafikdræbte svaler før optællerne, konkluderede forfatterne, at fuglenes tendens til risikabel adfærd derfor måske også kan være elimineret ved naturlig selektion. En ny undersøgelse herhjemme, hvor 3521 fugles hjerner blev undersøgt, viste, at hjernerne hos de trafikdræbte fugle var mindre end hos individer af de samme arter, der var fløjet mod ruder (Møller & Erritzøe 2017).

Vi går stadig daglige ture, hvor vi vanen tro fortsat holder øje med trafikdræbte fugle på ruterne 2, 4 og 5; her har vi konstateret en yderligere nedgang. Også ved længere udflugter i bil har vi mange gange fået det samme bekræftet, fx i september 2017 på en tur til Viborg, her kørte vi 260 km uden at finde en eneste trafikdræbt fugl. Dette indicerer, at trafikdrab blandt fugle (modsat pattedyr) nok er i stærk aftagende i Danmark, og derfor ikke vil fordre så stor opmærksomhed fremover som andre menneskeskabte årsager, såsom rudedrab, el-ledninger, vindmøller og olieudslip.

References

Beckmann, H. 1961: Vogelverluste auf Autostraßen. – Orn. Mitt. 13: 128.

Bergmann, H.H. 1974: Zur Phänologie und Ökologie des Straßentodes der Vögel. – Die Vogelwelt 95: 1-21.

BirdLife International 2004: Birds in Europe. Population Estimates. Trends and Conservation Status. – BirdLife International, Cambridge.

Blumstein, D.T. 2003: Flight initiation distances in birds is dependent on intruder starting distance. – J. Wildlife Manage. 67: 852-857.

Bräutigam, H. 1978: Vogelverluste auf einer Fernverkehrstraße von 1974 bis 1977 in den Kreisen Altenburg und Geithain. – Orn. Mitt. 30: 147-149

Broekhuysen, G.J. 1965: An analysis if bird casualties on the roads in the south western Cape Province, South Africa. – L'Oiseau et R.F.O. 35: 35-51.

Brown, C.R. & M.B. Brown 2013: Where has all the road kill gone? – Current Biol. 23: 233-234.

Bruun-Schmidt, J. 1994: Trafikdræbte dyr – i relation til landskab, topografi og vejtype. – Upubliceret specialerapport, Biologisk Institut, Odense Universitet.

Cimprich, D.A. & F.R. Moore 2006: Fat affects predator-avoidance behavior in Gray Catbirds (*Dumetella carolinensis*) during migratory stopover. – Auk 123: 1069-1076.

Cramp, S. & C.M. Perrins (eds.) 1994: Handbook of the Birds of Europe the Middle East and North Africa. Vol. VIII. – Oxford University Press.

DeVault, T.L., B.F. Blackwell, T.W. Seamans, S.L. Lima & E. Fernandez-Juricic 2015: Speed kills: ineffective avian escape responses to oncoming vehicles. – Proc. Royal Soc. B: Biological Sciences 282: 1-8.

Dunthorn, A.A. & F.P. Errington 1964: Casualties among birds along a selected road in Wiltshire. – Bird Study 11: 168-182.

EBCC, RSPB, BirdLife & Statistics Netherlands: http://ebcc.info/index.php?ID=612

Errington, F.P. 1971: Bird deaths on roads. – Ibis 113: 416.

Erritzøe, J. 1999: Causes of mortality in the Long-eared Owl *Asio otus*. – Dansk Orn. Foren. Tidsskr. 93: 162-164.

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

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

Foppen, R. & R. Reijnen 1994: The effects of car traffic on breeding bird populations in woodland. II. Breeding dispersal of male willow warblers (*Phylloscopus trochilus*) in relation to the proximity of the highway. – J. Appl. Ecol. 31: 95-101.

Forman, R.T.T. 1995: Land mosaics. The ecology of landscapes and regions. – Cambridge University Press.

Forman, R.T.T. & R.D. Deblinger 2000: The ecological road-effect zone of a Massachusetts (U.S.A.) suburban highway. – Conserv.

Biol. 14: 36-46.
Gollob, T. & W.M. Pulich 1978: Lapland Longspur casualties in Texas. – Bull. Texas Orn. Soc. 11: 44-46.
Govett, J.R. 1960: Mortality of wild birds on roads. – Naturalist 872: 5-6.
Göransson, G. & J. Karlsson 1978: Changes in population densities as monitored by animals killed on roads. – Statens Naturvårdsverk, PM 1151, Sweden.
Göransson, G., J. Karlsson & A. Lindgren 1978: Vägars inverkan på omgivande natur. - Rapport från Statens Naturvårdsverk.
Haas, W. 1964: Verluste von Vögeln und Säugern auf Autostraßen. – Orn. Mitt. 16: 245-250.
Hallmann, C.A., M. Sorg, E. Jongejans, H. Siepel, N. Holland *et al*. 2017: More than 75 percent decline over 27 years in total flying insect biomass in protected areas. – PLoS ONE 12(10):e0185809
Hansen, L. 1982: Road kills in Denmark. – Dansk Orn. Foren. Tidsskr. 76: 97-110 (in Danish, with English summary).
Harding, B.D. 1979: Road mortality of swifts. – Brit. Birds 72: 392.
Havlin, J. 1987: Motorways and birds. – Folia Zool. 36: 137-153.
Heinrich, D. 1978: Untersuchungen zur Verkehrsopferrate bei Säugetieren und Vögeln. – Zeitschrift für Natur- und Landeskunde 8: 193-208.
Heldbjerg, H. & A.D. Fox 2016: Regional trends amongst Danish specialist farmland breeding birds. – Dansk Orn. Foren. Tidsskr. 110: 214-222.
Hodson, N.L. 1960: A survey of vertebrate road mortality. – Bird Study 7: 224-231.
Hodson, N.L. 1962: Some notes on the causes of bird casualties. – Bird Study 9: 168-173.
Hodson, N.L. & D.W. Snow 1965: The road deaths enquiry, 1960-61. – Bird Study 12: 90-99.
Illner, H. 1992: Road deaths of Westphalian owls: methodological problems, influence of road type and possible effects on population levels. – UK Nat. Conserv. 5: 94-100.
Jensen, B. 1996: 11 års registreringer af trafikdræbte større pattedyr og fugle på Midtsjælland. – Flora og Fauna 101: 65-70.
Jones, P.H. 1980: Bird scavengers on Orkney roads. – Brit. Birds 73: 561-568.
Korhonen, K. & L. Nurminen 1987: Traffic deaths of animals on the Kuopio-Siilinjarvi Highway in eastern Finland. – Aquilo Ser. Zool. 25: 9-16.
Legagneux, P. & S. Ducatez 2013: European birds adjust their flight initiation distance to road speed limits. – Biol. Letters, doi: 10.1098/rsbl.2013.0417
Loss, S.R., T. Will & P.P. Marra 2014: Estimation of bird-vehicle collision mortality on U. S. roads. – J. Wildlife Manage.78: 763-771.
Massemin, S. & Y. Handrich 1997: Higher winter mortality of the barn owl compared to the long-eared owl and the tawny owl: influence of lipid reserves and insulation? – Condor 99: 969-971.
Massemin, S., Y. Le Maho & Y. Handrich 1998: Seasonal pattern in age, sex and body condition of Barn Owls *Tyto alba* killed on motorways. – Ibis 140: 70-75.
Moshøj, C.M., D.P. Eskildsen, T. Nyegaard, M.F. Jørgensen & T. Vikstrøm 2017: Common Bird Census in Denmark 1975-2016. – Dansk Ornitologisk Forening (in Danish, with English summary).
Møller, A.P. 2008: Flight distance of urban birds, predation, and selection for urban life. – Behav. Ecol. Soc. 21: 63-75.
Møller, A.P. & J. Erritzøe. 2017: Brain size is related to traffic accidents. – Royal Soc. open Sci. 4: 161040.
Møller, A.P., H. Erritzøe & J. Erritzøe 2011: A behavioral ecology approach to traffic accidents: Interspecific variation in causes of traffic casualties among birds. – Zool. Res. 32: 115-127.
Nankinov, D.N. & N.M. Todorov 1983: Bird casualties on highways. – Sov. J. Ecol. 14: 288-293.
Oeser, R. 1977: Der Fichtenkreuzschnabel (*Loxia curvirostra* L.) als Opfer des Straßenverkehrs im Fichtenberggebiet. – Beitr. Vogelkd. 23: 278-280.
Orlowski, G. 2008: Roadside hedgerows and trees as factors increasing road mortality of birds: Implications for management of roadside vegetation in rural landscapes. – Landscape Urban Planning 86: 153-161.
Reijnen, R. & R. Foppen 1991: Effect of road traffic on the breeding site-tenacity of male Willow Warblers (*Phylloscopus trochilus*). – J. Orn. 132: 291-295.
Schoenemann, W. 1977: Wildunfälle im Straßenverkehr. – Zool. Beiträge 23: 169-219.
Smettan, H.W. 1988: Wirbeltiere und Straßenverkehr – ein ökologischer Beitrag zum Straßentod von Säugern und Vögeln am Beispiel von Ostfildern/Württemberg. – Ornithologische Jahreshefte für Baden-Württemberg 4: 29-55.
Snow, D.W. 1958: A Study of Blackbirds. – George Allen and Unwin Ltd., London.
Stoner, D. 1925: The toll of the automobile. – Science 61 (1568): 56-57.
Summers-Smith, J.D. 1963: The House Sparrow. – Collins, London.
Sutton, G.M. 1927: Mortality among Screech Owls of Pennsylvania. – Auk 44: 563-564.
Thomsen, K. 1996: Project Vildtregistrering. – Rapport for Falck Danmark.
Wäscher, S., A. Janisch & M. Sattler 1988: Verkehrstraßen-Todesfallen der Avifauna. – Luscinia 46: 41-55.

Appendix 1: http://dof.dk/dof/doft/2018/4.appendix1
Appendix 2: http://dof.dk/dof/doft/2018/4.appendix2
Appendix 3: http://dof.dk/dof/doft/2018/4.appendix3

Author's addresses:
Johannes and Helga Erritzøe (erritzoe@birdresearch.dk), Ødisvej 43, Taps, DK-6070 Christiansfeld, Denmark
Marius Nørgaard, Storegade 65, DK-6560 Sommersted, Denmark