

Bird Traffic casualties and road quality for breeding birds

a summary of existing papers with a bibliography.
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Introduction

▶ Conducting a study of traffic accident among birds in South Jutland, Denmark, I got the idea of undertaking a survey of all previous works upon this theme to gain new inspiration for profitable research. The result was astonishingly good, and as there has never before been produced an all-round review (traffic casualties are not included in the Zoological Record), this may be of some interest and - I hope - result in new research and future insight into this serious man-made problem. Birds are only a part of the total road death toll; mammals, reptiles and amphibians make up together maybe a still greater proportion, but to include these too would be a formidable task more suitable for a book, and because the problems are quite different for birds compared with those of non-flying animals, this separation may be defensible. In the following the most interesting results from ornithological articles from the whole world are presented. At the end there is a bibliography which also includes papers not cited in this account.

Already in 1926 in America Alden H. Hadley wrote: "It is perhaps, too much to state as yet that motor vehicles, at present constitute a menace of major importance to birds and animals, but at least they must be included among those agencies of modern civilization which in the long run are highly detrimental to wild life". Was his prophecy right or has evolution solved that problem?

The first time a report of animal traffic casualties was published that I know about was in the year 1925 (Stoner) in America, and here the interest in the case was so great that by 1940 an additional 52 papers had been printed, all presenting the results of counting carcasses on the road, usually from a car, narrative and without any analysis of the results. In Europe the interest awoke only slowly. Not till 1927 a little paper was published in England, in Germany in 1937 and two years later another one in England, but only in the fifties did it become a common theme in ornithological periodicals. The first thorough pioneer research was carried out by a Dane, Linhard Hansen, who during three periods, 1957-58, 1964-65 and 1980-81, travelled 23.299 km on a moped and counted all the animals found. The new aspects were that he did it all the year round on the same three sorts of roads: secondary roads, main roads and highways. From this material it was possible for the first time to form a rough estimate of the total number of road-killed animals in a country.

Inspired by Hansen's work, a Swedish team, Göransson *et al.*, carried out a similar study but collected more data, e. g. the various types of roadside cover and their influence upon bird casualty numbers. Later followed many other important works, of which I will here only emphasize Jesper Bruun-Schmidt's paper 'Trafikdræbte dyr' from 1994, where also the quality of habitats along roads

was taken into consideration, but also many other parameters like the influence of the weather, age and sex composition, etc.

What makes roads so attractive to many birds?

▶ Roads work as ecological traps (Dhindsa *et al.* 1988) or, as many authors state, as emergency hunting grounds. Highways should be considered as separate ecological systems with a character of their own as specific barriers which separate habitats of varied plant and animal communities (Nankinov & Todorov 1983). Roads have an 'edge effect', because they are experienced as the end of a habitat, and there is a tendency for many animals to have a larger population near the border of the habitat (Dhindsa *et al.* 1988). Roads break the uniformity of the farmland and offer a greater variety of food than can be found in the fields, e. g. garbage that has been thrown into the roads by car drivers (Dill 1926) or spilt grain after harvest (Bräutigam 1978, Slater 1994). In the winter of 1982 a highway with central reserve in France was examined for voles. There were 250-400 voles per ha along the road (Bourquin 1983). The road also serves as a larder for scavengers, (Borrmann 1969). Many stakes and fencing posts along roads give birds of prey fine observation posts and from these they can rush on prey without a great energy consumption (Robertson 1930, Bourquin 1983). In moist weather there should be more earthworms because these come up to the surface due to vibration on the road (Tabor 1974), for, e. g. Rooks *Corvus frugilegus* to eat, and Song Thrushes *Turdus philomelos* use the road as an anvil to smash their snails, and many birds like sparrows drink from and bathe in puddles along the road (Hodson 1962). Because of the heat on the road many insects arrive which swallows and Swifts *Apus apus* make use of, but also wagtails and Skylarks *Alauda arvensis* forage on insects here, most of all, maybe, because they are much easier to find (Bergmann 1974). After heavy rain numerous insects are washed onto roads or driven out of the ground (Zumeta & Holmes 1978).

It can be fatal for insectivorous birds in northern regions when bad weather starts in early spring, and in such situations many early arriving forest birds are forced to forage on roads (Zumeta & Holmes 1978), and in winter these are the first places cleared of snow (Lindsdale 1929). Salt on roads used for de-icing in wintertime attracts crossbills in great numbers (Meade 1942, Oeser 1977).

The high concentration of breeding birds along roads can perhaps be explained by the rare occurrence of their enemies there [?] (Nankinov & Todorov 1983). May be mud for swallows' nest building should maybe also be mentioned (Finnis 1960). The telephone and power pole lines are conspicuous features along most roads used as observations posts and should be considered as part of the road system. Birds also collect grit for their gizzards on roads (Meinertzhagen 1954).

Like stones, road surfaces have the property that they can absorb and keep large quantities of sun heat. The average temperature on the road surface is 6.7 ° higher than the air in shade. The greatest number of birds on the roads in America was seen when the road surface was 7-10° warmer than the surroundings (road temperature 26-34° and the air 19-26°). The lower critical temperature for thermoregulation in many passerines is 22-23°, however, for the Common House Sparrow *Passer domesticus* it has been documented by laboratory test that it is most active at 22°. (Whitford 1985).

In Wisconsin, USA, the road temperature is in July and August 22° seven hours longer in the daytime than the surroundings. Birds which use this heat energy save many calories that they would otherwise have to use to maintain their body temperature. A warm and wet road has more birds than a warm and dry one, but the number falls when the wind increases (Whitford 1985).

The negative impact of roads for the bird community

▶ The environmental impact of the road-traffic complex is greater than usually suspected. The discharge of substances such as gases, oil, poison and other liquids, salt and waste may lead to the pollution of air, soil and water and effect the population of both plants and animals throughout a large area (Zande *et al.* 1980). But also the noise from the vehicles is a stress factor. Thus a study in open grassland areas in the Netherlands showed that shorebirds like Lapwings *Vanellus vanellus* and Black-tailed Godwits *Limosa limosa* were sensitive to disturbance over surprisingly long distances, ranging from 5-600m for a quiet rural road to 16-1800m for a busy highway (Zande *et al.* 1980). Roads can work like traps. After rain the road may look like a water surface, which can explain why water birds can occasionally be found as traffic casualties (Short & Craigie 1958, Haas 1964). But first of all, the many millions of road killed birds each year is a serious problem. This work, however, does not treat all the problems in connection with pollution.

Methods used

▶ There are great differences among the methods used in the many published accounts, which makes a comparison of them difficult. Most papers state only how many dead birds were found on a trip in some vehicle, where date and route are given (e.g. White 1927, 1929, 1933, Beckmann 1961, Haas 1964, Blumel & Blumel 1980). Other counts were made by moped, bicycle or on foot (e. g. Barnes 1936, Günther 1979, Hansen 1982, Seibert & Conover 1991). In Sweden the roads were inspected by car at 'normal speed' and the car was stopped only when it was necessary to identify a bird. On the most thoroughly examined route the road was inspected at least once every day, but most often both mornings and evenings from 7-10 and 15-18. Date and site where the road killed bird was found was recorded and the exact place marked on a map 1: 50.000. For some sex and age were also registered (Göransson *et al.* 1978).

Dunthorn & Errington (1964) ringed a great number of young birds from nests directly in connection with the road in order to study mortality. Stewart's (1971) study noted how many road killed birds were found. The width of the road was measured, and the road was divided into middle, side and ditch to describe exactly where each bird was found. Hansen (1982) rode along different routes on dissimilar road types on a moped every week. In the Netherlands a population of Willow Warblers *Phylloscopus trochilus* in a 154 ha willow tree habitat was studied both near the highway with 45,000 vehicles passing every day and in the adjoining countryside to compare the condition of the birds. (Reijnen & Foppen 1991, Foppen & Reijnen 1994).

In India on four roads, each of 1km length, a trip was made on all "bright" days between 12 and 18 o'clock at 50-60km/h, counting all live birds on the roads. During the same study period seven line transects were made at some distance from the road to compare the species diversity with that found on the road (Dhindsa *et al.* 1988).

In a Spanish study of the Little Owl *Athene noctua*, a 40km route was gone over by two persons at night, dawn or dusk in a car at 40-50km/h, and the 'navigator' used an intensifier to find the owls. All cars coming from the opposite direction were counted, the owls' foraging height, time, kind of perch, perch posture and habitat were recorded (Hernandez 1988).

Sources of error

▶ Cats *Felis domesticus*, Foxes *Vulpes vulpes*, Stoats *Mustela erminea*, Weasels *Mustela nivalis*, Hedgehogs *Erinaceus europaeus*, Rats *Rattus norvegicus* and small rodents, but also gulls, Ravens *Corvus corax*, Magpies *Pica pica*, crows and many owls take many road killed birds (Göransson *et al.* 1978, Blümel & Blümel 1980). Bergmann (1974) found a traffic killed Hedgehog with a Robin *Erithacus rubecula* in its mouth. Cats are the most common nocturnal scavengers both in town and country, and the Carrion Crow *Corvus corone* can fly away with carrion up to approx. 150g (Slater 1994). Road cleaners remove many of the larger birds (Hodson & Snow 1965). Birds which can be eaten are taken by people, or the birds are caught on the radiators of cars (Bruun-Schmidt 1994).

Many works have studied the sources of error caused by scavengers, e. g. 42 dead birds were placed on the road, most of them already removed in the late afternoon, about dusk or early next morning (Hodson 1966, Johnson 1989). In another study the average time before a bird was gone was 48 hours (Vignes 1984). In one more work with 53 bird carcasses, 73% of small birds were removed after 32 hours, 17% after 12 hours and 56% of the larger birds already after 5 hours. However, those placed outside the paving were not all gone until after 14 days (Göransson *et al.* 1978:92).

Many birds are not killed at once and manage to fly some metres into scrub before they die, or they are thrown away from the road by the speed wind from other cars. Göransson *et al.* (1978) found some animals which had dragged themselves into the surrounding vegetation merely by watching carrion-eating birds like Hooded Crows *Corvus conone cornix* and Rooks. Haas (1964) tried to find several birds which had collided with his car, but without success

But not only scavengers are a great source of error, the speed with which vehicles totally wear out a carcass on the road is also astonishing: 50 dead sparrows were placed on a heavy traffic highway. After 90 minutes only remains of five were still to be recognized, and 30 minutes later these were also gone. The author also placed 20 sparrows on the roadside in the cut vegetation and the last was not gone till after 16 days (Stewart 1971). On another highway with 9,000 vehicles every day and night small birds were gone after 1.2 days $\pm 0,4$ and larger birds after 2.1 $\pm 0,7$ (Korhonen & Nurminen 1987). Bruun-Schmidt (1994) in Denmark came to nearly the same result: 50% of small birds gone after 9 hours, average 1.2 days, and larger birds 2.1 days. On average a road kill could be identified for 2.2 days (McClure 1951), 4 days (Scott 1938), and in cool weather even longer (Simmons 1938, Seibert & Conover 1991).

Most studies have been carried out from a car, where many birds are bound to be overlooked, especially the smaller ones. Therefore, these works record a disproportionate number of larger birds (Korhonen & Nurminen 1987). Going in a vehicle, it is often possible to check only one side of the highway (Haas 1964). In order to ascertain the error percentage a road in Sweden was checked every second hour for 25 days and nights. The result was that only about 1/3 of the small birds was found by the normal inspections, against which, birds of the size of a thrush or larger were registered in about 1/2 of all cases (Göransson *et al.* 1978:34-35). In an English report in which 76 ornithological researchers participated for a whole year, and 5,269 road kills were found, the following result was published: 12 ornithologists carried out the search by walking and found on average of 30.33 birds per mile in a year. 35 used a bicycle and got an average of 23.90 birds, 18 used a car, and their average was 10.92, or about one third of that of the walking participants. Four used a moped and got an average near that of bicycles: 22.68. The rest used a bus or partly bicycle

partly moped (Hodson & Snow 1965). Hansen (1982) used a moped and tried to double-check his findings, which demonstrated that he had overlooked about 10%. Havlin (1987) spotted only 1% from a car on highways compared with the result when walking, and Haas (1964) found only 26% by car compared with bicycle. Other sorts of errors may also be mentioned here. From the early years there is a suspicion of small boys with .22 rifles, slingshots and air guns as an extra hazard (Robertson 1930, Davis 1930, Lincoln 1931). Bad light like low sun ahead also means overlooked birds (Hansen 1982).

From the above it is obvious that all published traffic accident studies are encumbered with great uncertainty, due first of all to scavengers and to cars wearing out on birds on the road, but also the way the study is made, by car, moped, bicycle or by walking makes a great difference to the result.

Results

The quality of habitats along roads as breeding sites

▶ As a rule the more cultivated an area is, the more roads will there be, and the fewer different birds species will live there (Linsdale 1929). In England roadsides are mostly cultivated grasslands, but nevertheless they form the breeding habitat for 40 breeding species (Slater 1994). Several studies have shown that the forest population density is lower along roads than in areas away from roads (Ferris 1979, Rätty 1979, Adam & Geis 1981, Reijnen & Thissen 1987, Reijnen *et al.* 1995). However, the density of a population is not always a reliable indication of the quality of the area (Reijnen & Foppen 1995). Passerines breeding in hedges have less breeding success due to predation, this applies particularly to forest species like Blackbird *Turdus merula* and Song Thrush, whereas a bird like Yellowhammer *Emberiza citrinella* has more success because it breeds more in the open (Barkow *et al.* 2001). European Robins breeding in hedges along roads have low breeding success because of frequent disturbances, greater predation and less food supply. However, surprisingly the Cuckoo *Cuculus canorus* was the greatest disturber of all during the brooding period! The disturbance made by humans from engines, pedestrians and cyclists had little importance because it was always only for a short period. Out of 21 Robin nests along roads 19 were predated (Grajetzki 1991, 1992). Gassmann and Glück (1993) pointed out that the width and structure of the hedge influenced breeding success. The Great Tit *Parus major* has less loss of eggs and nestlings and greater body mass in the wild than in areas along roads (Bairlein & Sonntag 1994). The method used for all the cited works was to count the number of feeding visits of the parents. An American study has shown that for House Finches *Carpodacus mexicanus* the quantity of food brought at each visit was similar and therefore this method should be workable [!] (Nolan *et al.* 2001). In Holland the Willow Warbler was studied using colour rings. The area was 154ha with Willow Trees and it was crossed by a highway carrying 45.000 vehicles per day. The result was very interesting, because all Willow Warblers breeding near the road were young birds that all had poor breeding results, and the next year they all moved to territories further away from the road (Reijnen & Foppen 1991, Foppen & Reijnen 1994).

Burrowing Owls *Athene cunicularia* nest and forage often near roadsides in burrows made of Prairie Dogs. A study in the Rocky Mountain, Colorado gave the result that with a traffic of 0-16 vehicles/15 min the disturbance had little impact on nestling Burrowing Owl behaviour, and it had no impact on productivity even though nesting locations placed them in close proximity (Plumpton & Lutz 1993).

The importance of habitats along roads for the road kills

▶ If the road is higher than the surroundings, the crossing birds will fly low, and more are killed than on roads where the surroundings are higher and where fewer road kills occur (Wascher *et al.* 1988), but, by contrast, Bruun-Schmidt (1994:37) states that most dead birds are found where the road is level with the surroundings. Where the road runs through forests, wood edges and other marked changes to another vegetation, wet areas, in outskirts, and stretches with hedges on both road sides, there are many traffic casualties (Göransson *et al.* 1978), Wascher *et al.* 1988, Bosch 1989, Johnson 1989), e. g. was in Spandau, Berlin, on a 4.7km long forest stretch 1380 road killed birds were found between 1978 and 1988, i. e. on average 138 each year (Miech 1988), and in a four year German study 181 birds were found on a 400m long forest road, compared with 198 birds on a 3,000m road through farmland and meadow (Bräutigam 1978). In a Swedish study the traffic death toll was greatest near farms and large gardens and in a valley with deciduous trees on both sides (Göransson *et al.* 1978: 55). Most 'black spots' are found where there are gaps and openings for birds attempting to fly from one side of the road to the other (Hodson 1960, 1962, Dunthorn & Errington 1964, 1971). Several authors have found the greatest number of live birds and traffic accidents at traffic centres, maybe because these areas are more spacious, with more vegetation than the normal highway (Hodson 1962, Günther 1979, Havlín 1987, Bruun-Schmidt 1994). Many birds are killed where the road forms a curve, even though the cars have to slow down here (Bergmann 1974, Hernandez 1988). Most road kills in a study in France occurred on embanked road sections (Lodgé 2000). Also small streams crossing the road are mentioned as dangerous places for birds (Brown *et al.* 1986, Johnson 1989). On a road in Bulgaria 68.9% of the birds were killed by cars going downhill because the latter could move faster there (Nankinov & Todorov 1983).

A study in Tasmania demonstrated that there were more owl casualties on the higher part of a highway (Taylor & Mooney 1991), which tallies with a Danish study, in which more than half of all killed owls were found on a short stretch of the highway near Skovby, the highest point of the whole examined part of the highway (Erritzoe 1999).

In another Danish study most birds were found in a little village, Kolind, compared with those found on secondary and main roads in the countryside (Bruun-Schmidt 1994: 35). The most numerous road kills occur on the outskirts of towns with gardens, because the densest populations occur here (Bräutigam 1978, Smettan 1988), e. g. 23,8 birds km/year in a garden suburb near Stuttgart, compared with 19.8 birds km/year on roads in farmland (Smettan 1988). On the other hand, roads with fewer road kills are the tedious and dull ones! In France and USA there are many straight and open highways where the traffic flows more smoothly, and here there are fewer traffic casualties (Finnis 1960).

Highways versus other roads

▶ In Czechoslovakia fewer perching birds were killed on highways: 0.01 per 100km relative to other roads 0.12 (Holisova & Obrtel 1986). In Estonia on average 1.8 birds were found on a paved 10km road compared with 0.06 on gravel and earth roads (Löhmus 1994). Birds on highways are thrown farther away from the road because of the speed of the vehicles (Göransson *et al.* 1978). It is estimated that on German highways on average one bird per day for every 5km is killed in July and August (Haas 1964). In Denmark the peak for traffic accidents on secondary and main roads is June to August, but for highways February to April and July to September (Bruun-Schmidt 1994).

The difference in numbers of traffic casualties between areas.

▶ In Nebraska the yearly average of traffic killed vertebrates per 100 miles was 9.1, in Iowa 42.9, in New England 70.5, and based on a small number 250 in Wisconsin (McClure 1951). Dickerson (1939) recorded the number of animals killed west of Mississippi as three times as large as east of the river, and Russell (1938) reached the same result: on a 3.532km long journey he counted 1,328 casualties west of the Mississippi and 867 east of the river. However, when the kilometres driven were taken into account, he found one bird for every 4.3km east of the river and a bird for every 9.5km west of the river. Few casualties were found in New Jersey and eastern Pennsylvania, but in western Pennsylvania and especially Ohio and Indiana the number increased (Hadley 1926). In Czechoslovakia on three different highways in different directions from Brno, on the oldest and almost completely stabilized one 14.7 birds were found for every 100km, on another later finished 16.3, and a newly completed section 28.8, suggesting that new motorways have the highest percentage of traffic casualties (Havlín 1987), which is also stated by Ward (1934). Near Hessen, Germany, on roads in farmland Bergmann (1974) found 6.5 birds per km/year, in another area with much vegetation and fruit trees 19.6 km/year, but in Ortsbereich Marburg only 1.8 km/year, in all three cases at about the same traffic intensity. Also other authors have noted the same great differences. On a road through farmland in Mecklenburg, Germany, only 7.4 birds were found per km/year (Lüpke 1970), but on a 5km road in Sachsen, Germany, which runs through villages, fields, meadows, forest and lakes, the number was more than double: 16.5 birds per km/year (Bräutigam 1978).

What is the importance of speed for the number of road killed birds?

▶ The speed of traffic has an important influence upon bird road accidents (e. g. Hodson 1960, Dunthorn & Errington 1964, Hansen 1969, Smettan 1988). At a speed of 35 miles (56km) the road kills start (Dickerson 1939). In Nebraska the traffic killed Pheasants *Phasianus colchicus* are significantly correlated with the average speed of cars (Case 1978). In Punjab, India 'formerly' few birds were road-killed because few cars could exceed 80km/h. In March-April 1985 a road (270km) was travelled both ways, one way the speed was more than 100km/h, and 11 birds collided with the car, however, only when the speed was over 100km/h, whereas on the return trip only 80km/h was driven and no birds were killed (Dhindsa *et al.* 1988). In Germany the speed of the traffic is a very important factor, but at a speed of below 40km/h collisions are rare (Wascher *et al.* 1988), however, even lower speed can be fatal: a car was hit by a Song Thrush at 20 miles/h (32km), and the bird was immediately killed (Govett 1960). In 1919 paved roads were the exception in America, and there were many miles of barely improved roads. Therefore, the speed of vehicles was much slower, and dead birds on the road were relatively few (Jones 1927). On earth roads in farmland no road killed bird was found and on smaller roads with less than 100 cars/day and 30-50km/h only 2 birds per km/year were traffic killed (Smettan 1988). However, exhausted birds on migration make an exception: On a rainforest jeep-track in Thailand Filip Verbelen (1993) found 25-30 Hooded Pittas *Pitta sordida* hopping around on the track, most of them so tired that it was possible to approach them to within 5-6m, eight dead pittas were also found, all very lean, traffic victims in spite of the very few cars using the track.

In a study of Little Owl in Spain 74.4% of the road-death victims were found on roads with many curves and therefore killed at a rather low speed (Hernandez 1988). German owls were 21 times more frequently killed when the speed of cars was more than 80km/h (Illner 1992). However, in

cities where the speed limit is mostly 50km many bird traffic casualties also occur (Bruun-Schmidt 1994: 39). Haas (1964) who travelled 46,000km on bicycle and car, found more traffic casualties on roads with high speed limits even if the traffic density was low, and Martens (1962) stated that traffic density has no importance, but the few very fast cars kill the birds.

However, it is difficult to calculate the difference of road kills on roads with high speed and density versus roads with lower speed and fewer vehicles, because the casualties on the former are worn out so fast (Fuellhaas *et al.* 1989). As a striking example of this the previously mentioned Stewart (1971) can be repeated. He placed 50 dead sparrows on the highway and after 90 minutes only parts of five were still there. Another snag is the difficulty of finding birds in the vegetation along the road. At high speed 5% of the birds were thrown in the ditch and at low speed only 0.5% (Nankinov & Todorov 1983). High speed also makes the turbulence stronger, which will throw a small bird over to an oncoming car (Göransson *et al.* 1978: 84).

Does traffic density effect the number of road killed birds?

▶ The density of traffic has an important influence upon bird road accidents (Hodson 1960, Dunthorn & Errington 1964, Hansen 1969, Smettan 1988, Washer *et al.* 1988, Lodé 2000). In Finland traffic density is at its peak between June and August with an average of 10,700 vehicles/day on a certain roads. There was most traffic and accidents on Mondays and less on Wednesdays, which the authors suggest that the number of cars may have some importance (Korhonen & Nurminen 1987). Hansen (1969) supported this. On small secondary roads he found 0.10 bird/km per day, on larger secondary roads 0.24, on main roads 0.79 and on highways 3.16. In a study 14 years later the same author found, however, that the number of road-killed animals had not risen despite more cars on the roads, but a reasonable explanation of this could be that in the meantime the bird populations had decreased (Hansen 1982). Another Danish study conducted from a car showed that on a 10km secondary road with 332 vehicles/day and night 43 birds were killed in a year, and on a 10km main road with 2823 vehicles/ day and night 96 birds were killed in a year, both roads situated in towns (Bruun-Schmidt 1994:38,56-57). A German research carried out on foot did not support this result: On a secondary road with 780 vehicles/ 24 h 320 road casualties were found in a year and on a main road with 2650 vehicles/24h only 154 birds were found (Fuellhaas *et al.* 1989). Odzuck (1975) noted that smaller roads present a greater danger to birds, because the birds here are not familiar with traffic, while roads with more denser traffic give birds 'Lehrneffect', learning effect. Martens (1962), Bergman (1974) and Case (1978) arrived at the same result, birds quite simply learn to cross the roads at a greater height. On Haas' (1964) journey through Morocco and Turkey he found comparatively many traffic casualties in spite of the less dense traffic there. The increase in the number of cars in France and Germany does not influence the number of owl and bird of prey traffic casualties, but the 3-4 year cycle of mice does ((Bourquin 1983, Illner 1992).

How much has the density of the traffic increased?

▶ In order to provide a basis for further studies of the effect of an increased number of vehicles on the total number of road killed birds the following information: In America there were eighteen million vehicles in 1926 (Dill 1926) against 216 million in 1999 (US Federal Highway Administration).

In England there were in 1938 less than 2 million motorcars and in 1960 4,250,000 (Hodson 1960).

In Denmark in 1958 6.8 billion km were driven, in 1978 28.1 billion kilometres (Hansen 1982). In 1999 the number was 46 billion kilometres in cars, trucks, busses and motor bicycles (Skriver 2001), that is more than a 600% increase in 41 years.

Does the behaviour of different bird species influence the number of road kills?

▶ Hansen (1969) suggested that bird behaviour determines whether a species is liable to be killed by traffic. The Blackbird has a visible peak in traffic accidents in March, when territory and pair building takes place, which means many birds chasing each other, and still more important, Blackbirds very often cross a road very low above the ground (Göransson *et al.* 1978:88, Heinrich 1978). Birds dipping in flight over the road as they fly from hedge to hedge often collide with vehicles (Slater 1994).

The House Sparrow is without doubt the bird most often found road killed worldwide, cf. tables 3 and 4. Its preferred habitat is human settlements like gardens with thick hedges and bushes, often in connection with farms. From here it flies to the nearest cornfield on the other side of the road and often in flocks. Every time the flock is alarmed it must cross the road to reach safety and the risk of a collision with a vehicle is great. Sparrows forage on the spilt corn on road sides, they sunbathe directly on the road and very often you can see young being fed by parents there (Göransson *et al.* 1978: 82). Sparrows are not so shy and thus may have less reaction when a car turns up (Heinrich 1978). Birds flying low over the ground are more exposed to collisions: besides the already mentioned Blackbird this also applies to Song Thrushes, Whitethroats *Sylvia communis* European Robins and Wrens *Troglodytes troglodytes*. The Great Tit, however, is very rarely traffic-killed because it usually crosses the road at great height (Odzuck 1975). Many birds dive to gain speed instead of flying away from a car, or they suddenly turn around to come back to the starting point, by which manoeuvre they lose speed. This is often observed in Pheasants and sparrows. Maybe this behaviour has got survival value in escaping from raptors (Govett 1960, Dunthorn & Errington 1964). In Australia the Western Rosella *Platycercus icterotis* typically crosses the road and collides with an oncoming car, whereas another common visitor on the roads, the Common Bronzewing *Phaps chalcoptera* is very seldom hit because it has a very quick take-off and it flies parallel with the road (Brown *et al.* 1986). The flight distance also has importance, large birds take off over a greater distance than smaller birds (Dhindsa *et al.* 1988).

Why do many birds fail to estimate the speed of a car?

▶ When a low-flying bird crosses the road, everything seems to it to be moving except the coming car, as it can only see with one eye and therefore the car appears to be stationary. Until it is too late to recognize the mistake. Its estimation of distance is abeyance because its eyes are placed on either side of its head. (Fremlin 1985, Dhindsa *et al.* 1988).

Crepuscular and nocturnal birds

▶ The headlights of the cars dazzle the birds. In Germany 51 Barn Owls *Tyto alba* died on a 2,5km stretch within 3 weeks (Uhlenhaut 1976). In Denmark 12 Long-eared Owls *Asio otus*, 2 Barn Owls, 1 Tawny Owl *Strix aluco* and 1 Short-eared Owl *Asio flammea* + 15-20 flattened owls were found on a 75km long highway stretch from mid February to mid March (Erritzoe 1999). In Louisiana, USA, 17 owls of two species: Great Horned Owl *Bubo virginianus*, and Southern Barred Owl *Strix varia* were found dead on a 16km long stretch of highway through a swamp (Ward 1934). Between 1984 and 1986 Hernandez (1988) examined 418 Little Owls, all traffic casualties, found

in Spain, and suggests that road casualties are the greatest non-natural mortality factor for this owl in Spain. During a period of five years Aronson (1979) came to know of 15 Hume's Owls *Strix butleri* which were killed by cars in Israel, indicating that this owl often hunts animals on roads. The most common owl victim in southern Brazil is the Burrowing Owl (Bencke & Bencke 1999). Also nightjars are often mentioned in the literature as traffic casualties (Stanford 1954, Winterbottom 1954, Harrison 1954, Benson 1955, Haverschmidt 1955, Müller-Using 1956, Brouwer 1992, Barlow & Gale 1999). A German study on chickens demonstrated that the headlights of a car are presumably only in darkness able to dazzle the chicken totally (Schoenemann 1977).

Irruptive species

▶ In winter roads have been temporarily closed because swarms of Bramblings *Fringilla montifringilla* invaded roads passing through forests in Germany and Switzerland in search of beech mast (Berthold 2001: 41). In the Netherland a similar case has been reported (Osieck 1973). Also from North Zealand in Denmark there is a case many years ago when in winter the road through a wood was slippery with dead Bramblings (Own obs).

Scavengers

▶ Buzzards *Buteo buteo* and gulls are often themselves victims when they have landed on a carcass on the road; for instance five Buzzards were killed on one winter day in the former DDR because they were attracted by a traffic killed Hare *Lepus capensis* (Borrmann 1969, Göransson *et al.* 1978: 85, Jones 1980). Scavengers themselves get killed and in turn are eaten by cats, foxes and corvids (Slater 1994). The staple diet of the Wedge-tailed Eagle *Aquila audax* in Australia is rabbits. The release of the Rabbit Calicivirus has reduced rabbit numbers by up to 95% and there are now reports that the eagle has turned to road kills in New South Wales. By collision with a car this 5kg heavy bird with a wingspan of about 2.5m can break the windscreen (Slater 1997). The Kite *Milvus milvus* is also known as a scavenger often seen on carcasses on the road (Feindt & Göttgens 1967). Bosch (1989) states that most birds of prey are killed not by collision with a car itself but by collision with the antenna.

Are there species whose decline may be caused by traffic?

▶ Nightjars *Caprimulgus europaeus* may be declining in Europe chiefly because of collisions with cars (Göransson *et al.* 1978). Probably this problem is the same in other countries, e. g. in Sarawak, Borneo (Harrison 1954) and many places in Africa (Stanford 1954, Winterbottom 1954, Benson 1955, Haverschmidt 1955, Müller-Using 1956, Brouwer 1992). Also in the USA it seems to be a problem: on a 3,532km stretch 548 birds were found, of which 20 were Nighthawks *Chordeiles minor* (Russell 1938). The Red-headed Woodpecker *Melanerpes erythrocephalus* living in many parts of North America has declined heavily since 1960s due to habitat degradation and traffic accidents (Winkler & Christie 2002). The drastic decline of the Little Owl in many parts of Europe may also be partly due to because of the high number of road casualties (Hernandez 1988, Illner, 1992, Bultot 1996, Fajardo & Babiloni, 1996, Fajardo *et al.* 1998).

Is it possible to monitor a population in a given area by means of the number of traffic accidents?

▶ The number of traffic killed House Sparrows vary much from place to place because of local conditions and the sparrows' exposure to traffic (Finnis 1960, Hodson 1960, Dunthorn & Errington 1964). The percentage of traffic-killed birds is not by far the same for species with the same population density (Sargeant & Forbes 1973), but it is logical that the population density is an important factor, and all small passerines with territories within 150-200m from the road are in the risk zone (Göransson *et al.* 1978: 55, 71). In a study in Nebraska in 1941, 1942 and 1943, when the number of driven kilometres in the same years are incorporated the rate of casualties found was in 1941 100, in 1942 109, and in 1943 46; if the traffic density was also rectified the number would be 100, 137 and 64, which shows that the number of traffic accidents in each year depends on the number of live animals or in other words how good the breeding season was (McClure 1951). In Czechoslovakia the 15 (+ Blackbird) most seen live birds on highway were: 1576 Linnets *Carduelis cannabina*, 1238 House Sparrows, 960 Skylarks, *Alauda arvensis*, 936 Rooks *Corvus frugilegus*, 781 Serin *Serinus serinus*, 697 Starlings *Sturnus vulgaris*, 603 Black-headed Gulls *Larus ridibundus*, 588 Goldfinchs *Carduelis carduelis*, 448 Pheasants *Phasianus colchicus*, 304 Sand Martins *Riparia riparia*, 273 Yellowhammers *Emberiza citrinella*, 254 Barn Swallows *Hirundo rustica*, 249 Partridges *Perdix perdix*, 212 Swifts *Apus apus*, 190 White Wagtails *Motacilla alba* 50 Blackbirds *Turdus merula*. The 15 most often found traffic casualties were: 46 Pheasants, 20 Partridges, 7 House Sparrows, 6 Rooks, 5 Blackbirds, 2 Barn Swallows, 1 Lapwing *Vanellus vanellus*, 1 Sparrow Hawk *Accipiter nisus*, 1 Kestrel *Falco tinnunculus*, 1 Long-eared Owl *Asio otus*, 1 Song Thrush *Turdus philomelos*, 1 Red-backed Shrike *Lanius collurio*, 1 Skylark, 1 Tree Sparrow *Passer montanus*, 1 Goldfinch. If we compare the number of carcasses found with the number of live individuals observed in the motorway area, it corresponds to about 10% for the Pheasant, Partridge and Blackbird, in the other species and in the overall total the figure is about 1% (Havlín 1987). In comparisons 'in ringed populations the losses caused by collisions with vehicles reached 11-12% in Blackbirds and Song Thrushes, in other species considerably less' (Dunthorn & Errington 1964).

It is possible to monitor only common species to reduce the error due to the small number of road kills. ['For species with a high population density the counting of traffic casualties could show the range of different populations, local variation in density in the general yearly population cycle'] (Bruun-Schmidt 1994).

In America the number of the Whitetail *Odocoileus virginianus* has been estimated with traffic kill as a basis and the result used for banning hunting (Göransson & Karlsson 1979), and in England the westerly spread of the Muntjac *Muntiacus reevesi* is largely monitored via road-kills (Slater 1994). Here it must, however, be taken into consideration that a deer cannot like a bird fly when it has to cross a road and therefore cannot remove the risk by flying higher.

In which months are the birds killed by traffic?

▶ Here authors are in agreement both for North Europe and North America: April and May and July-September (October). The former in connection with breeding activities and reduced attention, the latter the dispersal of young and unexperienced birds (Hansen 1969, Bräutigam 1978, Günther 1979, Smettan 1988). In Holland the peak is June; in Hessen, Germany July (Bergmann 1974), and Hansen (1982) gives August for Denmark. Around Berlin the peak for House and Tree Sparrows is

August, Chaffinch June and July, Greenfinch *Carduelis chloris* and Song Thrush July and Barn Swallow August and September (Müller 1995), In South Europe, however, the difference between the months of the year is not so distinct because many of the migrating birds from northern Europe winter there (Göransson *et al.* 1978: 85). In Sweden at the most 10% of the summer population winters. One would expect the peak of traffic casualties to be dawn and dusk, when this coincide with the peak of traffic mornings and evenings, but this is not the case, because most have migrated and the rest are less active to save calories (Göransson *et al.* 1978: 89). That so few adult birds are killed in autumn is maybe because of their moulting period, when they live more hidden (Bergmann 1974). In the winter months November to January the fewest are killed, partly because there is less traffic and the cars do not move so fast (Hodson & Snow 1965), and partly because the daytime is shorter (Hodson 1960). There are about twice as many road collisions in the breeding season as during the rest of the year in South Africa (Broekhuysen 1965).

How much influence has the weather on road kills?

▶ Scott (1938) found a direct relation between weather and the number of traffic casualties. After heavy rain many insects in the USA are 'washed' down on the road and many of the terricolous insects and earthworms come up to the surface and are there an easy prey for birds, and many birds are road-killed (Zumeta & Holmes 1978). Contrary to this statement: if there has been rain during the last half of the night, fewer road kills are found (Dickerson 1939). In the USA on a 500 miles trip by car fewer carcasses were found on the return trip when in the meantime it had rained (Davis 1934). In storm and rainy weather the traffic casualties are much fewer than in normal weather, whereas on close and sultry July days the number of killed birds can be extremely high (Hodson 1960, Bergmann 1974). In 1931 in Minnesota many dead road-killed Bank Swallows *Riparia riparia* were found in two cases, in one case the road was black with an estimated 1,000 birds. In both cases on hot days (Stevens 1932). Swifts and swallows fly close to the ground in moist, cold and rainy weather and are killed (Bräutigam 1978, Harding 1979, Wascher *et al.* 1988). Birds prefer to fly against the wind when they take off, therefore they will lose valuable time if they have to change their direction (Göransson *et al.* 1978: 85). Black-shouldered Kites *Elanus caeruleus* are most susceptible to collisions in Africa during strong winds (Mendelsohn 1983). In Florida, near Miami in 1958 the winter was very severe. In February John V. Dennis (1958) found 572 traffic killed birds on a one mile stretch and earlier the same month 96 birds, Myrtle Warblers *Dendroica coronata* represented 76% of all the birds found during the first trip, and Tree Swallows *Tachycineta bicolor* 95% on the other. After heavy snow with many frost degrees a great number of Lapland Buntings *Calcarius lapponicus* (estimated at 12,000) were killed by cars in only one snowstorm, because they foraged on the snow-free part of the highway (Gollop & Pulich 1978).


Other causes of traffic casualties


▶ Foraging birds or birds merely seeking the warm surface of the road mostly fly to the left when a car approaches because the high vegetation to their right obstructs the view and acts like a wall (Lüpke 1983). Birds are often killed by an overtaking vehicles (Hodson 1962).

At which time of the day and on which day of the week are most birds road killed?

▶ In New England, USA most casualties were found in the evenings between 15.30 and 21.00 (Zumeta & Holmes 1978).

In DDR and Czechoslovakia most were killed in the early morning hours (Lüpke 1983, Havlin 1987). In Sweden a study was conducted over 25 days and nights with a check every second hour. The peak was at seven in the morning and 17 in the evenings, with most in the morning, and Saturday-Sunday in the middle of the day. However, House Sparrow, Tree Sparrow and Barn Swallow had their peak about 12 o'clock also on weekdays. The day with most road kills was Saturday with 20, Sunday had 16, Monday, Tuesday and Friday 14, Wednesday 13 and Thursday had the fewest, 9 (Göransson *et al.* 1978: 49-50-51, 54). Schoenemann (1977) also got to the result that Saturday and Sunday are the days with most collisions, yet in his research mammals are also included.

 Table 1 which sex is more often killed?			
Species	Males	Females	Source
House Sparrow	63*	37*	Hansen 1982
House Sparrow	69	120	Hodson 1982
House Sparrow	14	17	Govett 1960
Blackbird	22	24	Beckmann 1961
Blackbird	7	2	Govett 1960
Blackbird	25	6	Finnis 1960
Greenfinch	7	12	Govett 1960
Chaffinch	8	7	Govett 1960
Yellowhammer	5	6	Govett 1960
Various species	67	33	Bruun-Schmidt 1994
Total	287	264	
*Hansen states only the percentage.			

 Table 2 Which age-group is most often killed?			
Species	Adult	Juvenile	Source
House Sparrow	232	43	Hodson 1962
House Sparrow	409	173	Govett 1960

House Sparrow	65	333	Bräutigam 1978
House Sparrow	20	25	Scott 1938
Tree Sparrow	45	15	Bräutigam 1978
Various species	307	201	Bergmann 1974
Various species	44	44	Bruun-Schmidt 1994
Various species	39	25	Fuelhaas <i>et al.</i> 1989
Black-backed Magpie	0	53	Burger & Gochfeld 1992
Little Owl	25	328	Hernandez 1988
total:	1186	1240	

The percentage road-killed young birds versus adult birds?

🔺 In summer more young birds are killed, as they do not yet have their full flight power (Barnes 1936). In Denmark 5% young birds were found in May, 43% in June, 72% in July and 82% in August (Hansen 1982). Bergmann (1974) recorded only juvenile Barn Swallows between July-September and 93% Blackbirds killed in August were young birds. On the other hand Göransson *et al.* (1978) found for Pheasant that here the age distribution was the same as in the live population. In Germany the number was 65 adult and 333 juvenile House Sparrows, however, 90% were found in August and September. The same author found for Tree Sparrow mainly in July and August 45 adults and 15 juveniles (Bräutigam 1978). In another German study the distribution was 307 adults and 201 juveniles, but the distribution was very different from species to species: For the Barn Swallow the young were nearly 80%, White Wagtail *Motacilla alba* and House Sparrow 60%, Blackbirds 40%, against 20% Greenfinch and 12.5% for Skylark and Whitethroat (Bergmann 1974). On a 1803km stretch in New Zealand 603 live Black-backed Magpies *Gymnorhina tibicen* were counted and 53 traffic killed which were all young birds (Burger & Gochfeld 1992). Among 88 road killed birds, which were age determined, 50% were young birds, but in July the young birds were 63%, August 89% and September 86%, however, among 9 Barn Swallows 89% were young and surprisingly for the Blackbird 90% were old birds (n = 21) (Bruun-Schmidt 1994:40)

Are traffic casualties lean, normal or fat?

🔺 In Pennsylvania in 1924 82 Screech Owls *Otus asio* were road killed. Only 'few' of them lean, the rest with a normal body mass and many even with plenty of food in their stomachs (Sutton 1927). Nine Long-eared Owls, eight Tawny Owls and 12 Barn Owls, all road killed, were examined in 1992-94 in France and not found lean (Massemin & Handrich 1997). From the USA reports of mass road killing of Lapland Longspurs *Calcarius lapponicus* in cold winters, but these were mostly extremely fat and had their crops filled with seeds gathered along the road (Gollob & Pulich 1978). Black-shouldered Kite *Elanus caeruleus* is most susceptible to collision with cars while

carrying heavy prey items because its flight is then laboured and low over the ground (Mendelsohn 1983).

Overview of the calculated total number of road killed birds or animals/year in different countries

Bulgaria: more than 7 millions birds (Nankinov & Todorov 1983). 110,842 km² 63 road-killed per km² /year

Denmark: 1,269,744 birds in 1957-58 (Hansen 1982)** 44,334 km² 29 road-killed per km² /year

Denmark: 3,520,682 birds in 1964-65 (Hansen 1982).** 79 road-killed per km² /year

Denmark: 3,272,518 birds in 1979-81 (Hansen 1982).** 74 road-killed per km² /year

Denmark: 1.1 million birds in 1992-93 (Bruun-Schmidt 1994). 25 road-killed per km² /year

Denmark: 350,000 birds (Thomsen 1992)* 8 road killed per km² /year

England: nearly 4,000,000 birds at the beginning of the 1960s (Hodson 1966). 130,349 km² 31 road-killed per km² /year

England: 2,500,000 birds 1961-61 (Hodson & Snow 1965). 19 road-killed per km² /year

England: 27,000,000 birds (Errington 1971). 207 road-killed per km² /year

Germany: 9.4 million birds (Fuellhaas *et al.* 1989).**** 356,270 km² 26 road-killed per km² /year

Netherlands: 653,000 birds (Junkers & Vries 1977, cited in Dhindsa *et al.* 1988) 32,437 km² 20 road-killed per km² /year

Spain: 10 million animals (CODA 1992). 491,258 km² 20 road-killed per km² /year

Sweden: 750,000 birds i 1977 (Göransson *et al.* 1978:98)*** 449,605 km² 2 road-killed per km² /year

USA: one million animals per day (Lalo 1987). 7,828,000 km² 47 road-killed animals per km² /year

*Thomsen do not state how he has worked out this number. It looks as if it is strongly underestimated (Bruun-Schmidt 1994).


**Hansen (1982) has not worked out the importance of the habitats. Besides, in some cases the findings of one day has been multiplied by 30 to get the result for a whole month. This method is not sure. Moreover he states that Lolland-Falster where his study was conducted, maybe has more birds per area than the rest of the country (Bruun-Schmidt 1994).

***In these calculations the different habitats are taken into consideration, but not the density of the traffic (Bruun-Schmidt 1994)

****In these calculations the traffic density and different habitats are not taken into consideration (Bruun-Schmidt 1994)

Which species are most commonly road killed in Europe?


For more documentation about which species are most commonly road-killed in Europe [click here](#)

 **Table 3 The ten most common traffic victim species in Europe summarized from the above list.**

Species	Bulgaria	Denmark	England	Finland	France	Germany	Netherland	Switzerland	Sweden
Total number recorded	594	7724	7446	116	597	5615	1492	161	7
House Sparrow	216	2258	3959	9	349**	1407	393	35	1
Blackbird	6	1038	989		15	668	717	14	
Tree Sparrow	299	479				335	16	24	
Song Thrush		288	635		6	96	48	5	
Chaffinch	2	400	265	4	2	242	15	5	
Barn Swallow	8	462			7	314	40	5	
Pheasant		139	254		4	18	143		
European Robin	3	139	165		103	136	11	5	
Yellowhammer	1	214		14	2	182		4	
Mallard						16	302		

Most commonly killed species in other continents

For more documentation about the most commonly road-killed species in other continents [click here](#).

 **Table 4. The ten most often killed birds in the USA**

Species	California	Illinois	Iowa	Ohio	Pennsylvania	Western States	total
Total number found	136	134	143	21	460	459	1.353
House Sparrow	28	84	42		10	223	387
Red-headed Woodpecker		20	27		2	64	113

Screech Owl			2	1	55		58
Mourning Dove	4	1	3	1	24		33
Northern Flicker	1	2	3		12	8	28
Western Meadowlark	15		2			6	23
American Robin		1			17	5	23
Yellow-billed Cuckoo				19		2	21
Red-eyed Vireo				18			18
Starling				18			18

Traffic killed House Sparrows and Tree Sparrows calculated as per cent compared with all other traffic killed species

Australia: 3.4% in 1988-90 (Lepschi 1992).

Bulgaria: 50.3% House Sparrows, 36.4% Tree Sparrows in 1979-80 (Nankinov & Todorov 1983).

Czechoslovakia: 63% (Holisová & Prbtel 1986),

Czechoslovakia: 9% (Havlín 1987).

Denmark: 37% in 1957-65 (Hansen 1982).

Denmark: 32.8% in 1979-81 (Hansen 1982).

Denmark: 4.4% in 1992-93 (Bruun-Schmidt 1994)

England: 50% in 1959-61 (Hodson 1962)

England: 45% (Errington 1971).

England: 50% (Johnson 1989).

France: 59% in 1978 (Vignes 1984).

Germany: 32% in 1973-76 (Smettan 1988).

Germany: 57% in 1974-77 (Bräutigam 1978).

Germany (DDR): 37% in 1979 (Lüpke 1983).

Germany: 33%, Tree Sparrow 5% in 1982-91 (Müller 1995).

Germany: 14% in 1986-87 (Wascher *et al.* 1988).

Italy: 79% in 1980 (Quadrelli 1984).

USA near Boston, among 85 traffic casualties no House Sparrows (Zumeta & Holmes 1978).

USA, Iowa, 56% in 1926 (Spiker 1927).

USA, New Jersey and Arisona, 43% in 1938 (Russell 1938).

USA, Illinois, in 1938 78% (Starrett 1938).

And a count of all live birds seen on or near the road:

India: 29.47% of all live birds seen on the roads were House Sparrows, but by four transects, each of 1km length near the road the House Sparrow was only 9.37% of the total population (Dhindsa *et al.* 1988).

Has traffic killing any influence on the bird populations?

🚩 Studies and estimates of the influence of road kills on bird populations is lacking (Bezzel 1982). Traffic kills represent an inconceivably great number of birds worldwide. In India, e. g. on a 5km stretch of the National Road number 11 near Bharatpur 219 birds were found in a year (Sharma 1988), and in New South Wales, Australia on a 301 km road between Canberra and Lake Cowal between 1970 and 72 1095 traffic casualties were found (Vestjens 1973). These few quite normal examples (the first 44 birds year/km, the second 2 birds year/km) should be enough to demonstrate how many birds are yearly victims of traffic, when one takes into consideration that only in Denmark there are nearly 72.000km public and 15.000 private roads (Skriver 2001). However, Bergmann (1974) wrote that habitat changes and pollution is a much greater cause of the decline of some species.

Dunthorn & Errington (1964) found that for Song Thrush, Blackbird, Linnet and House Sparrow respectively 11, 12, 3 and 4% of the young birds are killed, and for the House Sparrow approx. 5% of the total population within the risk zone of the road are victims. In England 13% of all House Sparrows are killed by traffic (Hodson & Snow 1965). By contrast, Hansen (1982) found that nearly all House Sparrow young in the population were killed in the traffic at a highway near Copenhagen. In a German study 1973-76 4.8% of the House Sparrow population was road killed, 8% Blackbirds and 4% Greenfinches; all bird species taken together were worked out to 0.5% in farmland and 3.6% in built-up areas (Smettan 1988). In Sweden only 1-4% of most species are traffic killed, but for some species it is 10%. Most exposed are Pheasants, Partridges, hawks, Rooks and owls in that order (Göransson *et al.* 1978). In Western Australian 28,687 birds were ringed in an area between January 1984 and December 1985 and only 10 of these were found as road casualties, all within 1km from the ringing place (Brown *et al.* 1986). Only the Nightjar family, the Red-headed Woodpecker and maybe the Little Owl seem to have declined drastically because of traffic, as already mentioned.

Already in 1929 Linsdale wrote that birds profit from using the roads even when traffic kills are taken into consideration and most of the victims are quite common species.

Proposed measures against traffic kills

🚩 For mammals and reptiles many measures to prevent road kills have been made, but the fact that most birds can fly makes nearly all the proposed arrangements for mammals superfluous for birds. The following is a summary of recommendations special for birds taken from the papers consulted in this work:

Studies on migrations and population changes to preserve local populations and to minimize the impact on ecosystem equilibrium (Lodgé 2000).

Making speed bumps through forests with rare owls at the most critical portions and construction of roads through national parks with rare owls should be avoided (Bencke & Bencke 1999).

Most animals are killed near crossroads and where highway networks meet, because the highway here is wider and often with a rich vegetation (Havlín 1987, Madsen et al. 1998), so these places should maybe be more sterile (Madsen *et al.* 1998).

To avoid road collisions with Little Owls it is desirable to plant trees or scrub near roads, or even better, to place 2m high perches 5m from the road border and 10 to 15m apart, and illuminate the road where many owls are killed (Hernandez 1988). Areas with Olive trees is a strong habitat preference for the Little Owl, therefore preserve them (Fajardo *et al.* 1998).

Plant high hedges on both roadsides on elevated banks and make corridors through farmland with wide verges to link otherwise isolated habitats (Slater 1994). Make hedge plantations on roadsides on embanked road sections (Lodgé 2000).

Reduce the speed (Fuellhaas et al 1989).

Restrictions against leaving dead animals on the roads and a alarm system installed on the cars to warn the birds in time (Dhindsa *et al.* 1988).

Driver education and adaptation of driving (Havlín 1987).

Do not plant hedges on both sides of roads with dense traffic (Finnis 1960, Lüpke 1983).

Do not plant trees or bushes along the roads with berries and fruits that birds like to eat. On a Texas highway Silverberry *Eleagnus pungens* was planted in the middle of the road. Between 8 March and 5 April 1981 298 dead Cedar Waxwings *Bombycilla cedrorum* were found along 275m of such a planting and 133 birds on 11 March. The speed on the highway was only 55 mile ph = 88km (Dowler 1982).

Statements that deal with the impact of roads yet disregard long-term effects should be rejected. Extra care should be taken in planning new roads, not merely in deciding how to construct them, but primarily in deciding whether or not to construct them (Zande *et al.* 1980).

Farmers should not waste so much corn on the roads (Günther 1979).

The largest number of traffic casualties are found where there is plentiful of vegetation (Heinrich 1978).

Better planning of the highway environment should be considered as a means of reducing the death toll, and, most important, do not plan roads through valuable habitats (Dickinson 1939, Wascher *et al.* 1988). Especially moors, swamps, ponds, fallow lands and nearby forests are important habitats where no roads should be planned, and it should also be avoided to let a road run as a borderline to forests, meadows or lakes (Institut für Naturschutz und Tierökologie 1977).

Remove the road illumination through villages and in towns (Davis 1934), it attracts many insects (Institut für Naturschutz und Tierökologie 1977).

Make a steppe habitat with short grass as a 'bufferzone' next to the road followed by a zone with flowers, bushes and trees and small lakes, established when the road is constructed, free from human access (Institut für Naturschutz und Tierökologie 1977).

Plant hedges of whitethorn on embankments to force the birds to fly higher when crossing them (Ratcliffe 1974).

The vegetation along the highways in America has very little effect on the number of traffic kills (Joselyn *et al.* 1969: 8-9).

In the USA the fewest traffic kills are where there is sparse vegetation (Russell 1938, Seeker 1960).

Frequent use of the horn when birds are on the road. Building the highways wide and straight (Finnis 1960).

McClure (1951) concluded that road kills were proportional to the density of cover along the roads, to the age composition, and to the density of the wildlife population rather than to the amount of traffic and the degree of road improvement, e. g. the increasing speed of traffic.

A net stretched on the radiator to catch the birds (Creutz 1935)!

Dill (1926) examined the stomach of about 20 dead Red-headed Woodpeckers and found that the content was bread, crumbs, sweet corn, bits of doughnuts and pieces of apples. His advice is therefore, do not throw food-scrap into the roads.

Discussion

🔥 The number of bird traffic casualties worldwide must be astronomic, considering how many km of roads exist. It becomes still more surprising how the birds survive if for a moment we consider all the other man-made causes of bird deaths like window collisions, electrocutions and other collisions with human constructions. (Robin K. Panza from the Carnegie Museum in Pittsburgh, Pennsylvania pers. comm.): "I've always been more impressed by TV-tower mortality, where 100 or more Red-eyed Vireos die in a single night than by traffic mortality as a population problem. We have [in our museum] 1.300 carcasses listed as tower kills, and 1.100 from hitting windows, compared to less than 500 road kills".

As seen from the above there are great differences in the conclusions of the works by the various authors. There seems, however, to be great agreement among authors in classifying breeding habitat on or near roads as generally of less quality because of the many disturbances, compared with farther away from the road, which is demonstrated by worse breeding success than that found in real nature. Roads intensifying the toxic contamination among roadside population, increase the habitat fragmentation with limited population exchange as a result, and induce higher mortality, which can have a strong impact on small-sized populations (Lodé 2000). However, as a feeding habitat outside the breeding season most authors consider the advantage greater than the risk of being killed by the traffic. Roads save many birds in cold winters because road kills are in no report recorded having a lean body mass. The 'black spots' where most birds are killed seem to be where there are gaps and openings in hedges, hedges on both sides of the road, traffic centers, where the highway is wider and with a luxuriant vegetation and in villages with many gardens where the bird population is larger. The roads with fewer accidents are those with long straight parts without much vegetation along the roadside. Table 6 shows better than many words that the number of road-kills found depends not only upon the density of populations along roads, but also on the powers of

observation in the reporters, one having found a bird for each 2km and another for each 3,889km! The same table shows an average of 62km for each found carcass found by car (omitting the three unlikely: 905-, 2,000- and 3,889km), the half by bicycle, 28km, and 17km by walking. If we take all the possibilities of error into consideration: birds overlooked, taken by scavengers or worn down by cars, half of 17km, 8.5km/day is maybe more realistic. With 87,000km of roads in Denmark (Skriver 2001) this will make 10,235 birds per day and 3,700,000 traffic-killed birds in a year, not far from the estimated 3.2 million given by Hansen (1982) for the years 1979-81.

The most often traffic-killed bird worldwide is without any doubt the House Sparrow with approx. 62% of all birds killed in many countries, see table 3 where most killed in Europe is the House Sparrow with 8,430 victims, compared with all other birds together 13,575. The Blackbird is number two with 2,784, Tree Sparrow number three with 1,170, Song Thrush 1,030, Chaffinch 929, Barn Swallow 852, Robin 557, Pheasant 504, Yellowhammer 417, Dunnock 235, Starling 145, Great Tit 112, Whitethroat 109, Linnet 101, Wood Pigeon 60, Brambling 59, Rook 51, Goldfinch 51, Hooded Crow 49, White Wagtail 45, Pied Flycatcher 39, Blue tit 38, Black-headed Gull 36, Magpie 20, House Martin 18, Mallard 16, Red-backed Shrike 15, Partridge 15, March Warbler 11. The last 15 species not mentioned here have less than ten road kills. In comparison the American road killed birds are: House Sparrow 387, Red-headed Woodpecker 113, Screech Owl 58, Mourning Dove 33, Northern Flickers 28, Meadowlark 23 American Robin 23, Yellow-billed Cuckoo 21, Starling 18, Red-eyed Vireo 18, American Goldfinch 17, Chuck Will's Widow (nightjar) 14, Bronzed Grackles 14, Red-tailed Hawk 13, Common Cardinal 13, Great Horned Owl 11, Barred Owl 11, California Shrike 10. The last 27 species not mentioned here have less than ten road kills. The European list is dominated by passerines, with only a duck, a gull, a pigeon, a pheasant and Partridge as non-passerines. Unlike the American list which have hawks, owls, pigeons, cuckoos, nightjars and woodpeckers as common road victims, families which all also occur in Europe. However, in the European list it must be by chance that no owls with their nocturnal habits are mentioned because they are otherwise often mentioned in the literature (Uhlenhaut 1976, Hernandez 1988, Illner, 1992, Fajardo & Babiloni, 1996, Fajardo *et al.* 1998, Erritzøe 1999), and from Israel (Aronson 1979).

Most authors ascribe to the speed of the vehicles great importance for the number of road kills, although as to the effect of the density of the traffic and what role it plays for collisions with birds a great difference exists between authors. Some found that roads with much traffic had more accidents, others that dense traffic gives birds a faster 'learning effect' so that they learn to cross the road at a greater height. In other words that the solitary fast-driving car kills more birds due to the element of surprise.

The behaviour of the different bird species seems to be of great importance, e. g. some birds fly lower than others and are therefore more exposed to collisions. Other birds make diving maneuvers or turn around, which may be is a good strategy when attacked by a raptor, but catastrophic in the case of an approaching car. The headlights of cars seems to be of great importance for collisions in the dark for nocturnal birds like owls and nightjars. It is only possible to monitor very common bird populations by means of road casualties, because it is connected with many diverse factors how many road kills happen to most bird species. Most collisions occur in the breeding season, roughly about 50%, about this all authors are in agreement; the only exception is the countries around the Mediterranean, where many new species now winters and the numbers are therefore more equal all the year round. Some authors found most casualties after rain, others in warm weather, stormy

weather or snowstorms. Mornings show most road kills, but sparrows and swallows peak about midday.

▶ About the question of which sex is more often killed, there were great differences among authors, and the same goes for age distribution, although for the Barn Swallow the overwhelming number were young birds. Surprisingly, few cases of lean body mass on road killed birds are reported. The overall picture of the estimated total number of road kills from different countries demonstrates how difficult it is to work out a realistic picture of road deaths. In this list the area in square km for each country is given as a very rough value for comparative reason. By excluding the extremes among the results: Thomsen, Errington, Göransson *et al.* and Lalo, an average among the rest of 38.6 traffic killed birds per km²/year. Keeping in mind all the sources of error, which are mentioned at the beginning of this paper, the double number will may be be more realistic.

The House Sparrow is the most common victim to traffic – often 50% or more of all bird casualties, but now with a falling tendency, most probably because it is a declining species. In spite of this, only 5-13% of the House Sparrow population in England are said to be traffic killed, and in Sweden the number is even lower, 1-4% for most species but 10% for Pheasants, Partridges, hawks, Rooks and owls (Göransson *et al.* 1978)..

As the number of birds worldwide has decreased and the number of birds varies from year to year due to the varying success of the breeding season in different areas a comparison between periods is difficult. In the former DDR in the year 1975 one bird was killed for every 1.58km, in 1976 2.37km, and in 1977 (with bad weather) 5,12km (Günther 1979). In 1976-78 in Czechoslovakia considerably more birds were killed than in 1981-1985, in numbers per 100km : 1976: 0.30, 1977: 0.23, 1978: 0.18. In the last period the numbers were between 0.01 and 0.05 The count was made from a car which ran at 60-70km/h, and only dead birds on the paved road were counted (Holisová & Orbtel 1986). Hansen's (1982) numbers suggest the same: 3.5 million in 1965, and 3.2 million in 1981. Tables 3 and 4 do not give any hint of a decrease or increase in traffic casualties.

The chief question one must pose after reading this survey of papers about traffic casualties must be whether natural selection will sharpen the evolution of birds' road behaviour or, in other words, make some species develop an 'antimortality strategy'? In an Australian paper the author records that old birds fly first and the young birds last when a car approaches. The great number of young birds killed in summer and early autumn is not surprising in view of the greater number of juveniles at that time, their lack of experience, and the adults' more reclusive behaviour during the moulting period.

Most surprising is maybe the Barn Swallow, which is a frequent bird on the road and especially often seen flying low over the road very near vehicles, but in spite of this very few adults are hit by cars, and the few unlucky ones are nearly always get killed during the first days after arrival. An exception was a report of more than 500 adult swallows killed on roads in and around the Ebro Delta, Spain in spring 1992 due to bad weather (Estrada & Riera 1995). The Barn Swallow is the species where the difference between the number of adult as opposed to juvenile road kills is greatest; the Blackbird is an example of the opposite: both Bergmann (1974) and Smettan (1988) found that 60% of the road-killed Blackbirds in summer were adults and Lidauer (1983) stated that older Blackbirds from towns had more old wounds, which does not support the idea of a learning effect.

▶ If the density of traffic at one site is low, the probability that birds living there will learn to beware of the cars will be small, and the same will apply to young birds, migrating birds and newly arrived ones, but if the traffic density is high, the birds will more easily learn to take care (Bergmann 1974). On a highway in Louisiana, USA, which had been opened a few weeks earlier, 17 owls – Great Horned Owls and Southern Barred Owls – were found road-killed within a stretch of only 16km through a swamp (Ward 1934). Also Havlin (1987) and Lodgé (2000) reported how new opened roads have more traffic accidents, but the incidence may stabilize later

In Illinois, USA, in 1925 134 birds were found road-killed on 481km of highway. That makes one for every 3.6km. The author wrote that "the average speed of from twenty-five to thirty-five miles [40-60km] is maintained by nearly all cars" (Flint 1926). This example indicates that birds have learned to be more wary of the cars since 1925. Even at a speed of 100km, a much heavier traffic, but of course also a much smaller population, the result today would rarely reach such a high number (table 2).

However, the question whether natural selection has modified bird behaviour on roads is impossible to answer before long-time studies on the same sites have been conducted, in which not only the traffic-killed birds are counted, but the live populations along the roads are monitored by point counts or transects, and any changes in population size, density of traffic and the maximum speed of cars are taken into consideration.

The next important question is whether there are different abilities to learn the danger of traffic in different populations of the same species, and here this review gives some hints which look promising for future research

The omnivorous **corvids** are worldwide frequent guests on roads where they e. g. forage on carrion. Nevertheless, this family is very rarely reported road killed in most countries, America, Bulgaria, Denmark, French, Germany, South Africa, and Switzerland. Finland and Sweden are the great exception; the Hooded Crow accounts in Finland for 40% of all traffic accidents and the Magpie for 17%. This result confirm as earlier Finnish study, according to which 23% were Hooded Crows (Moilanen 1978, here cited in Korhonen & Nurminen 1987). In Sweden a calculation of the number killed in per cent of the calculated total population has been carried out: Magpie 0.9-1.6%, Hooded Crow 0.8-1.2% but Rook 10-11% (Göransson *et al.* 1978). In Schleswig-Holstein, Germany on a 43.2km long stretch there were three Rook colonies and the Rooks from there were often seen foraging in the roadside or even eating carcasses directly on the road, but in spite of this none were found traffic-killed (Heinrich 1978). In another German study near Stuttgart, where Hooded Crow, Rook and Magpie were often seen on the roads, none were found among 200 road-killed birds (Smettan 1988), and only one corvid (a Jay) was found among 508 other bird carcasses (Bergmann 1974). In Denmark 19 Rooks and 7 Magpies were found in a c. 220.000km study (Jensen 1996). In South Africa only one dead Pied Crow was found among 585 traffic kills. All three crow species living in the Cape Province are very often seen on the roads seeking carcasses (Broekhuysen 1965). However, from other countries the figures show higher numbers: In a study from Czechoslovakia there were 8% Rooks. Two papers from England show 3% and 4% Rooks among respectively 864 and 585 road kills. Italy recorded 3 Hooded Crows among 133 bird casualties. From six studies in America, all with small numbers of road-killed birds, none were corvids, but on a journey from Ohio to the Pacific Coast 3 crows were recorded, 3 Black-billed Magpies and surprisingly also 3 Ravens among a total of 106 casualties. On a 46,400km journey through many countries in Europe,

Morocco and Turkey only 4 Carrion Crows 2 Hooded Crows, 1 Rook, 9 Jackdaws *Corvus monedula*, 9 Magpies and 2 Jays *Garrulus glandarius* were found (Haas 1964).

Jesper Bruun-Schmidt wrote in his study from Denmark (1994): ['Some species are apparently better adapted to the life on the roads. For instance the Starling, the Hooded Crow, the Jay and the White Wagtail are all often seen on the roads, but only the Hooded Crow are in a few cases found traffic-killed']. In New Zealand 603 live Magpies *Gymnorhina tibicen* were counted and 53 traffic-killed, which were all young birds. When both age groups were on the road together the old birds flew before the young when a car came nearer (Burger & Gochfeld 1992).

But in many populations not only corvids seem to have learned how to use roads without being killed. In Osnabrück, Germany, no **White Wagtails** were found, even though they were commonly seen on the roads; the author wrote that their reactions were very effective, and often when the car had passed, the birds at once came back on the road (Fuellhaas *et al* 1989); in Czechoslovakia 190 White Wagtails were seen on the roads, but none found dead among 99 traffic casualties (Havlin 1987). In a Swedish study from 1973-76 no Wagtails are mentioned among 742 casualties (Göransson *et al.* 1978: 40-41). However, in Hessen, Germany among 625 traffic casualties there were 19 White Wagtails (Bergmann 1974). In his studies 1957-58, 1964-65 & 1979-81 Hansen mentioned no White Wagtails among 7,724 traffic casualties, but in his figures there are unfortunately 1,102 unspecified birds. In France there were among 597 road kills 10 White Wagtails (Vignes (1984).

🔴 The **Starling** figures seldom on lists of road-kills even though it is such a common bird, often seen on or near roads. One exception is the paper by Govett (1960) who recorded 42 Starlings among 585 casualties between 1949 and 1959. The author gives no information about where he counted traffic accidents, presumably somewhere in the north of England, because the journal "Naturalist", in which the paper was published, is a periodical for the North of England. The only information about the Starlings is that 28 adults and 14 juveniles were found.

In America a great number of woodpeckers are traffic-killed, earlier mostly the **Red-headed Woodpecker** and already in 1926 four alarming papers appeared (Baldwin, Dill, Flint, Hadley), followed by Sharp and Clarke in 1930. In 1934 among 353 road-killed birds Baumgartner found 33 Red-headed Woodpeckers, only surpassed by 166 House Sparrows, and at midsummer in Illinois Flint (1926) 20 Red-headed Woodpeckers, mostly young birds. During a 354km trip in Iowa in August Dill (1926) found 21 dead Red-headed and 182 live ones. However in the rest of the world woodpeckers figure rarely as road kills. On a journey around Europe, Turkey and Morocco, a total of 46,400km, partly on bicycle partly by car, only 2 Green Woodpeckers *Picus viridis*, 1 Grey-headed Woodpecker *Picus canus* and 2 Great Spotted Woodpeckers *Dendrocopus major* were found (Haas 1964). What can be the reason? (Dayton Stoner, 1932, cited in A. C. Bent 1939: *Life History of North American Woodpeckers*. Smithsonian Inst., Washington, D. C. p 206) on a 211-mile trip in 1924 on well-gravelled roads in Iowa found 105 dead animals 39 of which were Red-headed Woodpeckers. He claims that the explanation of this high number is that this species feeds on insects and waste grain along the roads, and they delay taking wing before an approaching car and do not quickly gain sufficient speed to escape a car. Unfortunately no modern study of traffic accidents has been made, which might give a hint of whether the Red-headed Woodpecker has learned to be more careful when it frequents roads. Since 1966 it has declined annually 2.2% in the eastern USA, and it is also declining over most of its other range due to habitat destruction and collisions with motor vehicles (Winkler & Christie 2002). An enquiry among American curators

gave a hint. Janet Hinshaw from the University of Michigan believes that the many road kills were due to their habit of nesting in wooden fence posts, which were formerly common along roads. As the birds flew to or from their nests, they crossed the road and were killed. In North Carolina it is still a rather common species with about 25 road-killed Red-headed Woodpeckers given to the museum in Raleigh since 1960 (John Gerwin in litt.) as opposed to only two among 460 carcasses delivered to the Carnegie Museum in Pittsburgh (Robin K. Panza in litt.).

All the common traffic victims today are quite numerous bird species, and the few studies which have tried to estimate the percentage give such low figures – none higher than 10% of the population and most less than 5% – that there is no reason for concern for the near future.

A glance into the future: In the event of specific environmental changes like, e. g. still more roads, cleaner and less noisy cars, more human settlements and fewer and fragmented natural habitats, so that the carrying capacity of the natural environment has gone beyond the possible, the genetic basis for rapid and diverse micro-evolutionary development affecting patterns of future road use may start to work, so that more and more bird species will be forced to forage on roads. With increased traffic density and traffic jams more and more garbage dumps will be left on the roads, and with high traffic density natural selection will presumably work faster, because the birds will learn about the danger on the roads, so that fewer birds will become victims. The global warming can end up with conditions similar to those currently prevailing in the Mediterranean region, where new ecological niches have been created for the greater and greater number of formerly migratory but now resident birds. The scenario will be still worse when the desertification of the Sahel in Africa continues, because that will mean still more migrants forced to find new winter sites in the Mediterranean countries. All these circumstances may work towards more use of our roads by an increased number of bird species, and the roads will more or less also serve as corridors between small fragmented habitats for weak flying species

If this image of the future is realistic, there must still be a great demand for more research about how we can make our roads more 'user-friendly' for the avian fauna, because the future advantages will presumably be greater than the disadvantages, and therefore birds will use our roads in increasing number, with or without our accept.

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 Table 5 House and Tree Sparrow traffic kills per month:																
		J	F	M	A	M	J	J	A	S	O	N	D			
House Sp.	Germany	2	2	4	5	10	12	35	44	22	5	1	2	1974-1977	Blümel & Blümel 1980	
House Sp.	Denmark			12	19	65	70	78	174	89	53			1957-1965	Hansen 1982	
House Sp.	Denmark			16	41	83	115	154	330	467	116			1979-1981	Hansen 1982	
Tree Sp.	Denmark			3	5	11	15	19	32	24	19			1957-1965	Hansen 1982	
Tree Sp.	Denmark			4	11	21	22	24	71	72	17			1979-1981	Hansen 1982	
House Sp.	Sweden			17	5	1	11	35	100	25	3			1973-1976	Göransson <i>et al.</i> 1978	
Tree Sp.	Sweden				1		2	5	13	7	5			1973-1976	Göransson <i>et al.</i> 1978	
House Sp.	England	2	0	7	5	9	52	124	49	21	12	1	1	1957-1960	Dunthorn & Errington	

															1964
House Sp.	England	23	47	119	150	400	383	472	478	175	75	26	17	1960- 1961	Hodson & Snow 1965

 **Table 6. Bird kills calculated according to the average number of km between each carcass**

Country	dist. travelled	year	transport	number killed	Average	Source
Australia	14.440km	70-72	car	1.095	13km	Vestjens 1973
Australia	496km	77-78	car	56	33km	Disney & Fullagaer 1978
Australia	3.395km	88-90	car	265	13km	Lepschi 1992
Austria-Yogo.-Greece	4.510km	60	car	210	21km	Haas 1964
Denmark	8.075km	57-65	moped	2.172	4km	Hansen 1982
Denmark	15.224km	79-81	moped	5.144	3km*	Hansen 1982
England	16.111km	34-37	car	1.885	12km	Breadnell 1937
England	6436km	35	bicycle	940	7km	Barnes 1936
England	619km	Jan-Mar55	bicycle	9	69km	Finnis 1960
England	619km	May-Jun 55	bicycle	61	10km	Finnis 1960
England	788km	Sep-Dec 55	bicycle	8	99km	Finnis 1960
England	134km	56	car	55	2km	Harrison in: Finnis 1960
England	c.4.518km	57	bicycle	415	11km	Dunthorn in: Finnis 1960
England	c. 805km	Aug-Sep 57	walking	30	27km	Jones in: Finnis 1960
England	c. 282km	1-14 Aug 58	walking	14	20km	Jones in: Finnis 1960
Finland	32.250km	82-84	car	116	278km	Jones in: Finnis 1960
N Finland + N Norway	3.403km	61	car	23	148km	Haas 1964
France	3.623km	56	car	4	905km	Harrison in Finnis 1960
Germany	1.030km	76-77	bicycle	375	3km	Günther 1979

Marocco	2.589km	59	car	67	39km	Haas 1964
South Africa	30.803km	60-62	car	343	90km	Broekhuysen 1965
Spain	1.900km	56	bicycle	68	28km	Haas 1964
Spain	1.900km	60	bicycle	183	10km	Haas 1964
Spain	2.200km	62	car	37	59km	Haas 1964
Sweden	1.774	61	car	83	21km	Haas 1964
Sweden	5.290km	74-76	car	742	7km	Göransson <i>et al.</i> 1978
Switzerland-France	2.474km	62	car	56	44km	Haas 1964
Texas	1.768km	75-76	car	49	36km	Wilkins & Schm
USA	508km	24	car	142	4km	Stoner 1925
USA	481km	25	car	134	4km	Flint 1926
USA	17.700km	26	car	106	167km	Jones 1927
USA	4.000km	26	car	2	2.000km	White 1927
USA	5.632km	26	bicycle	277	20km	Spiker 1927
USA	14.006km	27	?	136	103km	Robertson 1930
USA	26.870km	27-29	car	353	76km	Baumgartner 1934
USA	35.000km	27-29	car	9	3.889km	White 1929
USA	579km	28	car	34	17km	Komarek 1929
USA	418km	28	car	18	23km	Komarek 1929
USA	800km	33	car	69	12km	Davis 1934
USA	78.052km	32-50	car	4.039	19km	Schorger in Finnis 1960
USA	8.858km	34-36	car	22	402km	Dickerson 1939
USA	10.917km	34-36	car	84	129km	Dickerson 1939
USA	3.532km	38	car	548	6km	Russell 1938

USA	12.114km	38	car	607	20km	Starrett 1938
USA	80km	87-88	walking	21	4km	Seibert & Conover 1991

* In the last study the winter months were not examined.

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