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Factors causing traffic killings of roe deer *Capreolus capreolus* in Denmark

Aksel Bo Madsen, Helmuth Strandgaard & Allan Prang

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In Europe, roe deer *Capreolus capreolus* is one of the biggest mammal species killed in traffic, and the number of accidents seems to increase. The purpose of our paper is to point out the most important factors causing traffic killings and to suggest conservation measures that may reduce the number of roe deer killings in traffic. Our study is based on data including 115 roe deer killed in traffic at the Kalø estate in East Jutland, Denmark, during 1956-1985. No significant correlation was found between the number of traffic killings of roe deer and mean daily traffic, but the number of roe deer killed in traffic varied significantly over the seasons. The distribution pattern of roe deer/car collision sites was clumped. The risk of being killed in traffic was highest for young and old roe deer. Significantly more adult females, adult males and subadult males than expected were killed in traffic, and significantly more individuals were killed in years when most of the fields next to the roads were left unsown in winter. We suggest that the following measures be taken to prevent traffic killings: increasing areas with winter cereal or wintergreen fields, clearing the vegetation adjacent to roads and reducing car speed in high-risk areas.

Key words: accident sites, Capreolus capreolus, conservation measures, mean daily traffic, traffic killings

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In Europe, roe deer *Capreolus capreolus* is one of the biggest mammal species killed in traffic and the number of accidents seems to be increasing. Moreover, roe deer/car collisions may result in loss of human life and extensive damage to cars (Groot Bruinderink & Hazebroek 1996, Putman 1997).

Although a large number of roe deer are killed every year, the species only appears in small numbers in systematic studies of animals killed in traffic (Holisová & Obrtel 1986). However, the data collection method used is of crucial importance when evaluating the results of the different studies. Few studies provide information on the impact of traffic killings on the population of roe deer (Vincent, Bideau, Cibien & Quéré 1988, Gaillard, Delorme, Boutin, van Laere, Boisaubert & Pradel 1993).

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Several German studies point out that roe deer are involved in the majority (60-73%) of road accidents caused by game (Ueckermann 1964, 1969, Böttcher 1989, Hartwig 1991). Ueckermann (1969) estimated that at least 60,000 roe deer were killed in traffic each year in the western part of Germany. In Sweden, 80,000 roe deer out of a population of 500,000 are killed in traffic each year (Skolving 1987). In a study focused on German drivers and factors causing the collisions between motor vehicles and wildlife, Hartwig (1993) found that collisions most often occur at sites with poor viewing and light conditions, dry road lanes and at rather high car speed.

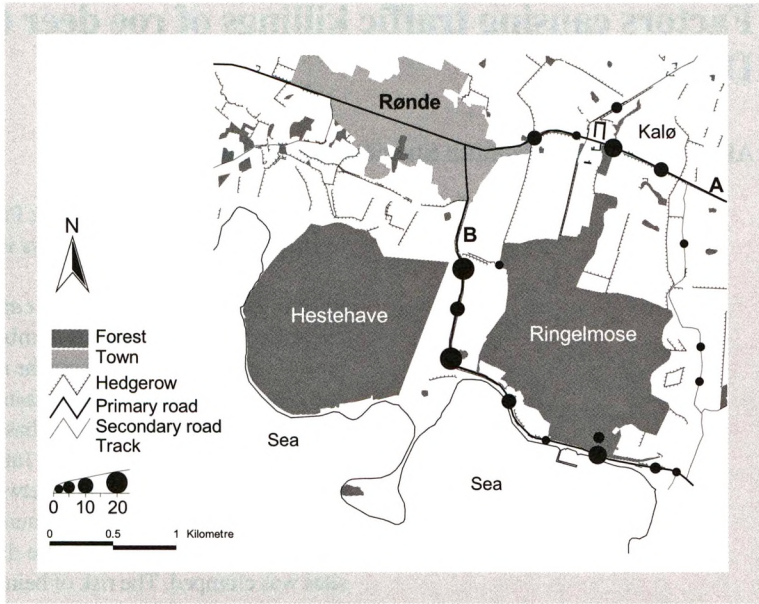


Figure 1. Study area and collision sites for 115 roe deer killed in traffic during 1956-1985. The collision site for one roe deer was unknown. The forests, Ringelmose and Hestehave (shaded areas), are surrounded by areas of agricultural crops (white areas).

Reviews on statistics and different mitigation measures (e.g. chemical repellents, wildlife fencing, wildlife reflectors) for prevention of deer/car accidents have been made by Groot Bruinderink & Hazebroek (1996) and Putman (1997), but the conclusions as to the effect of the mitigation measures on deer seem to be ambiguous. Controlled behavioural studies (e.g. Ujvári, Baagøe & Madsen 1998; Ujvári, Baagøe & Madsen, unpubl. data) conclude that wildlife warning reflectors and acoustic road markings are not reliable methods to reduce the number of deer/car accidents on a long-term basis.

In the USA, comprehensive studies have been carried out on traffic and white-tailed deer *Odocoileus virginianus* and mule deer *Odocoileus hemionus* (Bellis & Graves 1971, Puglisi, Lindzey & Bellis 1974, Allen & McCullough 1976, O'Gara & Harris 1988, Waring, Griffis & Vaughn 1991).

The purpose of our paper is to point out the most important factors causing traffic killings and to suggest conservation measures that may reduce the number of traffic killings of roe deer. Our analysis is based on a comprehensive and long-term study with individually marked roe deer.

Study area and roe deer population

The study area is part of the Kalø estate in East Jutland, Denmark (56°17'N, 10°30'E), and covers 800 ha with two forests, Ringelmose Forest and Hestehave Forest, each covering about 170 ha (Fig. 1). The remainder is agricultural fields separated by hedgerows and coverts. The landscape slopes towards the sea to the west and to the south and is elevated less than 100 m a.s.l. The town of Rønde is located to the north of Hestehave Forest. The estate is traversed by two primary roads (A and B) with a mean daily traffic in 1972 of 6,200 and 3,200 cars, respectively, and by a few minor roads. The speed limit on road A is 80 km/hour and the speed limit on road B is 60 km/hour. Signs warning against crossing deer are placed along road B.

The roe deer population at Kalø has been closely studied (e.g. in regard to food, reproduction, population dynamics and home range) for more than 25 years (Strandgaard 1972, 1977, Jeppesen 1987, 1989, 1990, 1995; M.R. Petersen & H. Strandgaard, unpubl. data). Parturition occurs in May and June, centred around 1 June, and the rut lasts about one month from around the end of July till the end of August. The population was not exposed to hunting before or during the period from which the data originate.

Material and methods

Each winter (December-February) free-living roe deer at Kalø were captured and marked according to the procedures described in detail by Strandgaard (1972). During 1967-1987 more than 90% of the roe deer from Ringelmose Forest and 5-10% of the roe deer from Hestehave Forest were individually collar-marked. All animals from the Kalø estate found dead were collected

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and handed over to us by private persons or by the staff of the National Environmental Research Institute (NERI), Department of Landscape Ecology (the former Game Biology Station) throughout the study period.

Animals found dead were examined, and data on time, sex, site, cause of death and collar number were registered. The animals were classified as juveniles, subadults and adults (see Strandgaard 1972). Based on dates of death the animals were grouped into four seasons: winter (December-February), spring (March-May), summer (June-August) and autumn (September-November).

During 1975-1978, an effort was made to reduce the agricultural area as a biotope for roe deer and to test the carrying capacity of the area. All fields around Ringelmose Forest were ploughed in early autumn and were then left until spring when spring barley was sown. A comparison of the relationship between the proportion of unsown fields and the number of roe deer killed was made based on the ratio of unsown fields in winter to fields with spring cereals in summer.

Apart from the period 1975-1978, the agricultural conditions on both sides of road B which runs between the two forests were identical. It therefore should be expected that for a roe deer the risk of being killed would be the same irrespective of the direction in which road B was crossed.

Data on home ranges collected by Jeppesen (1990), including 2,751 radio-fixes of eight roe deer (17 yearly home ranges) during 1981-1983 were compared and evaluated in relation to the primary roads A and B as well as the smaller secondary roads.

Information on the mean daily traffic on the two primary roads traversing the study area was provided by the Danish Ministry of Transport (A. Christensen, pers. comm.).

Data analysis

To test the hypothesis that the distribution of deer/car accidents along the road is random, road A and B were divided into 150 m sections, and the numbers of deer/car accidents were counted for each section. The observed distribution was compared with a theoretical Poisson probability distribution. The Poisson distribution is appropriate in this case as the hypothesis is that the accidents occurred at random in a continuum of space. How well the observed probabilities fitted the theoretical random probabilities was tested by means of the Kolmogorov-Smirnov One-sample test (Ebdon 1977).

No juveniles (<9 months) are found in the months March-May. Hence, the statistics were corrected for this condition to test the hypothesis that more juveniles were killed in autumn (September-November) than during the rest of the year. The probability of the success parameter p was estimated as the proportionate number of days in autumn (30 + 31 + 30 = 91) and the number of days in the rest of the year minus the months March-May (360 - (31 + 30 + 31) = 268). All statistical tests were two-tailed.

Results

Collision sites

Out of 115 roe deer registered as having been killed in traffic, 70 were killed on road B, 33 on road A and 12 on the smaller secondary roads (at the estate; see Fig. 1), of which one was killed 8 km west of Kalø. A relatively high number of killings (21) were registered on the section of road B running along the coast.

The division of road A and B into 150 m sections showed that the collisions between roe deer and cars were distributed in a clump-like pattern (Kolmogorov-Smirnov One-Sample Test: $D_{max} = 0.2353$, $N = 40$, $P < 0.05$). At the sites where the main part of the roe deer were killed the vegetation along the road was more dense (e.g. hedgerows, bushes and coverts) on one or both sides of the road than along the sections where no killings occurred (Binomial test: $P = 0.013$).

Distribution of killings by year and season

In total, 115 roe deer were killed in traffic near the Kalø estate during 1956-1985. Of these, 110 (96%) were marked and observed only in Ringelmose Forest. The annual number of roe deer received by NERI ranged

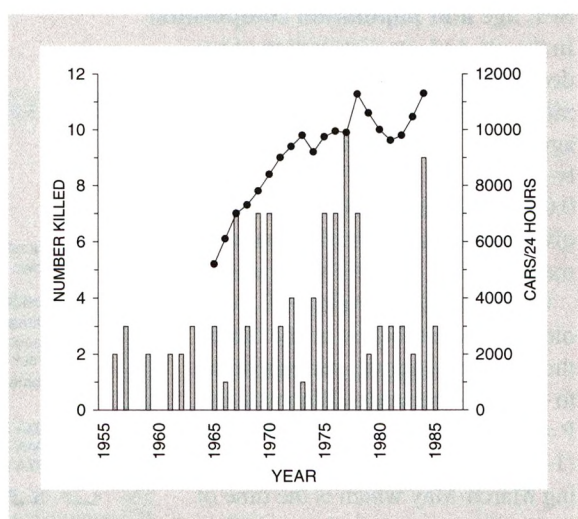


Figure 2. Yearly distribution of 110 roe deer killed in traffic at Kalø during 1956-1985 and mean daily traffic (only available for the period 1965-1984).

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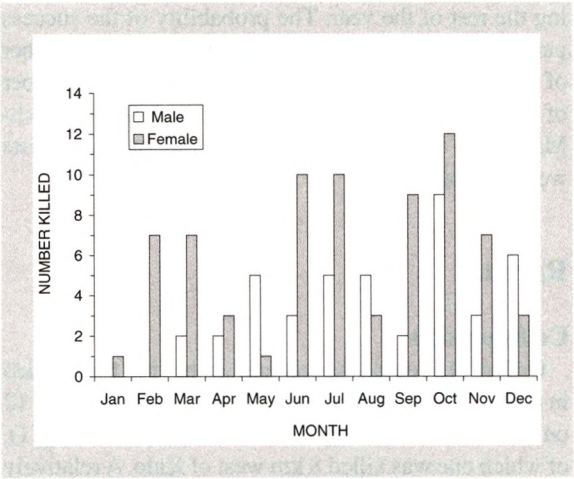


Figure 3. Distribution according to sex and months of 115 roe deer killed in traffic at Kalø during 1956-1985; Winter = December-February, Spring = March-May, Summer = June-August and Autumn = September-November.

between 0 and 10 (Fig. 2). The number of individuals killed peaked in 1967-1970, 1975-1978 and 1984.

During 1965-1984 the mean daily traffic increased from a total of 5,200 cars to 11,832 on the two main roads traversing the study area (see Fig. 2), but the correlation between the annual number of traffic-killed roe deer and the mean daily traffic was not significant ($R_s = 0.108$, $N = 22$, $P = 0.63$).

Significant differences in the number of traffic-killed roe deer were found between seasons (winter, spring, summer and autumn; $\chi^2 = 15.23$, df = 3, $P = 0.0016$), and the total numbers of traffic-killed individuals were highest in autumn (Fig. 3).

Sex, age and population composition

In the sex and age distribution of roe deer killed in traffic (Table 1) a significant difference was found in the age group distribution between the two sexes ($\chi^2 = 15.71$, df = 2, $P < 0.001$). In total, 73 (63.4%) of the individuals killed in traffic were females, and 64 (55.7%) were adults.

Of the 14 adult males (≥3 years old), six were killed in traffic during the rut (July-August), corresponding to 43% in two months (Binomial test: $P = 0.0099$). Of the 18 subadult males (1-2 years old) eight were killed during March-May which is the time of emigration, corresponding to 44% in three months (Binomial test: $P = 0.0446$). Of 10 subadult females (1 year old), three were killed in June corresponding to 33% in one month (Binomial test: $P = 0.0134$). Significantly more adult females than adult males were killed in summer and autumn ($\chi^2 = 9.89$, df = 3, $P < 0.01$). Out of a total of 23 juveniles (<9 months old) killed in traffic, 14 were killed in autumn (Binomial test: $P = 0.0043$).

Table 1. Sex and age distribution of 115 roe deer killed by traffic in the study area during 1956-1985.

	Sex		
Age	Males	Females	Total
Juveniles	10	13	23
Subadults	18	10	28
Adults	14	50	64
Total	42	73	115

Foraging pattern and home ranges

We found that the mortality rate of roe deer during 1975-1978 when most of the fields at the Kalø estate were unsown, was significantly ($R_s = 0.459$, $N = 23$, $P = 0.03$) higher than during the periods before and after the change in cultivation methods.

A 2½-year-old female, which was observed in Ringelmose Forest in the spring of 1968 may serve as an example to illustrate the change in foraging patterns occurring after the change in cultivation methods. From June onwards this female started to forage in the nearest barley fields. After harvesting she still stayed in this area until 1 October when the field was ploughed. On 2 October she was killed on the road between her earlier foraging area and the stubble field near Hestehave Forest. Of the individually marked adult males six were killed in traffic accidents on the border of their territories during the rut.

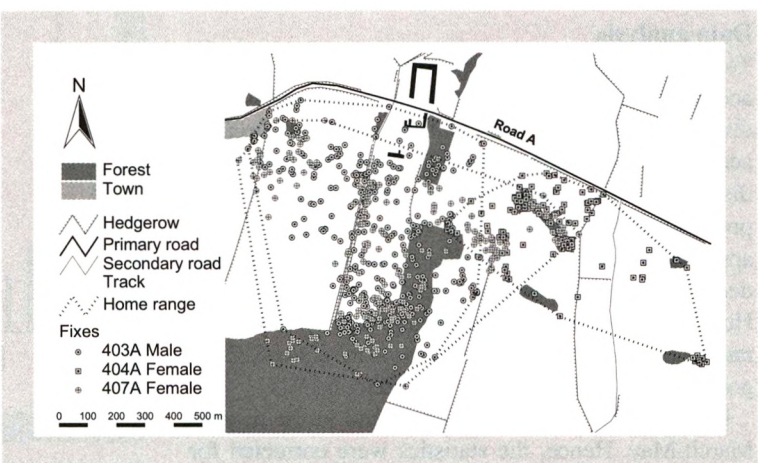


Figure 4. Home ranges and radio fixes for three roe deer; Male 403A = 435 fixes, female 404A = 151 fixes, and female 407A = 204 fixes.

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Data collected by Jeppesen (1990) illustrate that roads with a rather high traffic volume may constitute natural home-range boundaries for roe deer. Male 403A, female 404A and female 407A may serve as examples of this (Fig. 4), as these individuals stayed south of road A and were never radio-located or observed on the northern side of the road.

Discussion

In recent years, animals killed in traffic have received increasing attention and the problem of deer/car accidents is common to many countries all over the world. Studies have primarily been concerned with the number of traffic-killed individuals along roads, and studies focused on the proportion of traffic killings and accident sites are scattered.

Skolving (1987) stated that only 50% of all wildlife accidents in Sweden are reported to the police. Although the number of animals killed in traffic has been registered in Denmark by different authors (Hansen 1982, J. Bruun-Schmidt, unpubl. data) only a few roe deer have been reported. In Denmark, it is not mandatory to give information to central authorities about accidents involving wildlife. The large number of roe deer collected and handed over to NERI is a result of a very constructive dialogue between researchers and locals/hunters which is quite unique compared to other European countries (e.g. Germany). This constructive dialogue has earlier been documented by high return rates of questionnaires sent out to hunters by Asferg & Jeppesen (1996), who mention that 88.5% of 1,441 answers to their questionnaire related to roe deer.

Collision sites, year and season

The lack of significant correlation between the number of roe deer killed in traffic and the mean daily traffic over the year confirms that higher traffic intensity is not in itself the main reason for a high number of traffic-killed roe deer.

The roe deer/car collision sites were distributed in a clump-like pattern. In general, the sites were characterised by hedgerows, bushes and cover on one or both sides of the road. The 800-m stretch where road B traverses the agricultural areas between the two forests could be pointed out as a 'black spot'. On this stretch the road geometrics are slightly curved and hedgerows follow the road on both sides from the town of Rønde to the coast, resulting in very poor viewing conditions for both deer and drivers in contrast to road A where viewing conditions are good. This result is in agreement with the findings of Hartwig (1993). Even though signs along road B warn against crossing deer, a large number of individuals are killed.

Sex, age and population composition

The different sex and age groups were not equally exposed in all months. Adult males seemed to be most at risk in July-August because of increased activity during the rut. Allen & McCullough (1976) reported for white-tailed deer that more females than males were generally killed in traffic, but during seasonal peaks, primarily during the rut, more males than females were killed.

Subadult males are especially at risk in the emigration period. On the whole, it is concluded that territorial behaviour may be an essential cause of traffic killing of males which is in accordance with data from France (Vincent et al. 1988).

In our study, more than 63% of the roe deer killed in traffic were females which is in contrast to the findings of Vincent et al. (1988) who reported that more males than females were killed in traffic. Most roe deer populations hold more adult females than males; this also applies to the population of roe deer at Kalø for which the sex ratio of adult females to males was 1.9:1 (Strandgaard 1972).

In our study, the majority of the adult females were killed in traffic during the summer and autumn months, but Vincent et al. (1988) did not find any significant differences between seasons.

In Denmark, the game bag of roe deer has increased drastically in recent years, and the annual number bagged more than doubled during 1956-1985 (from 24,000 to 56,000) as a result of an increase in the roe deer population (Asferg & Jeppesen 1996). Data collected in the western part of Jutland, Denmark, show that the number of traffic accidents involving roe deer increases with increasing population size (H. Strandgaard, pers. obs.). Vincent et al. (1988) indicated the same trend for roe deer in France, but their correlation between these parameters was not straight. McCaffery (1973) reported similar results for comparisons between traffic killings and the game bag of male white-tailed deer in Wisconsin, USA.

The size and composition of the roe deer population at Kalø were based on observations from the period February-April and on the accumulated number of animals captured, marked and released during 1965-1967 (Strandgaard 1972) of which the fate of 96% was known. The total size of the spring population during this period was approximately 100 individuals in the two forests together. We assumed that the size and composition of the roe deer population from this period were

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representative of the whole period 1956-1985. Traffic killings accounted for 3.6% of the population and seemed to be negligible for the population which was not exposed to hunting and was estimated at ca 3,200 (1,290 males + 1,929 females) individuals for the whole period 1956-1985.

In spite of an estimated negligible proportion of roe deer killed in traffic in our study, it should be mentioned that in a population exposed to hunting, it cannot be ruled out that traffic killings can be a serious additional cause of death. When pregnant females and females with juveniles are affected, collisions with vehicles may represent an important factor in roe deer population dynamics, but at present there is no evidence supporting that hypothesis.

Roe deer foraging pattern and home ranges

The high number of roe deer killed at Kalø during 1975-1978 coincides with a period when efforts were made to reduce the agricultural areas as a winter biotope for roe deer. The conclusion drawn from this is that if cover and food are not available on either side of the road, the number of roe deer passages and the risk of collision seem to increase. This implies that the rhythm and rotation of crops must be essential factors for the movements of the roe deer. Natural development of the crops and the nutritional value of the plants, together with harvesting and ploughing practices, can change a good roe deer foraging area into a useless roe deer foraging area.

Our study also indicates that dense vegetation (e.g. coverts and hedgerows) used by roe deer as moving corridors, ending or crossing at angles to the road represent high-risk areas. Waring et al. (1991) pointed out that 70% of road crossings by white-tailed deer occurred at sites with agricultural land on one side and forest on the other, and 36% occurred at sites with forest on both sides of the road. Carbaugh, Vaughan, Bellis & Graves (1975) pointed out that if a highway is located between wooded areas where deer rest during the day and agricultural areas where they feed during the night, the deer will show a strong tendency to cross the traffic lanes.

Feldhammer, Gates, Harman, Loranger & Dixon (1986) reported that road salt may be one of the factors inducing white-tailed deer to forage along roads. The relatively high number of traffic killings on the section of road B running along the coast at Kalø and infrared video monitoring of foraging behaviour of roe deer along roads (M. Ujvári, pers. comm.) indicate that roe deer has high motivation to forage at road sides. In our study area, roe deer could satisfy their need for salt by exploiting saline plants or by licking stones on the beach on the other side of road B.

It is remarkable that roads with a rather high traffic volume may constitute home-range boundaries for roe deer. At first glance such boundaries could prevent some individuals from being killed in traffic, but on a long-term basis they could have a genetic influence on the population. This problem is illustrated in Danish badgers *Meles meles* (Pertoldi, Loeschcke, Madsen & Randi 2000, Pertoldi, Loeschcke, Madsen, Randi & Mucci 2001) and the importance of roads as barriers for roe deer and other wildlife must not be underestimated.

In light of the reviews presented by Groot Bruinderink & Hazebroek (1996) and Putman (1997), it is remarkable that of the large number of different mitigation measures in use to prevent traffic killings at specific sites, only a few have been tested in objective scientific experiments, and we would like to emphasise the need for further investigation in this area to impede the introduction of equipment without a long-term documented effect.

Conclusion

Man-made conditions have a great influence on the risk of roe deer/car collisions. Thus, foraging possibilities, location of roads, road geometrics, viewing conditions (drivers' visibility) and height and density of vegetation along roads may greatly influence the number of killings.

With the construction of highways and high-speed railways, constant upgrading of other primary and secondary roads and the ever-increasing traffic volume, the proportion of deer/car accidents will increase unless preventative action is taken.

It seems impossible to avoid all collisions between roe deer and cars, but our study points out the following measures which may reduce the number of accidents: 1) increasing the areas with winter cereal or wintergreen fields on both sides of roads, 2) clearing the vegetation adjacent to the roads (hedgerows, forests and plantations) to allow the driver to see the animal before it enters the roadway, and 3) reducing vehicle speed in high-risk areas to allow the driver more time to react after spotting the animal.

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ed us admission to radio-location data on home ranges of the roe deer at the Kalø estate. The Danish Animal Welfare Society sponsored the participation of A.B. Madsen in this study.

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