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Hedgehog Traffic Victims: How to Quantify Effects on the Population Level and the Prospects for Mitigation

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Abstract

In western Europe hedgehogs are frequently killed by traffic. One of the reasons a reduction of the number of traffic victims is desirable is because of possible negative effects on (local) populations. We discuss four methods which quantify the effects on populations, using the hedgehog as an example. Two of these methods (i.e. reasoning based on available knowledge and determining the relative importance of traffic mortality through radio-telemetry or capture-mark-recapture studies) are not recommended because they can be unprecise, subjective, do not address the variables that really matter, have no general validity, or may not allow for statistical tests. The third method estimates the effect on population size by comparing relative animal densities in road- and control plots, while the fourth concerns a future model in which the effect of traffic mortality is related to the survival probability of a (local) population. The third and fourth method do not have severe drawbacks but can not be conducted without detailed knowledge on the ecology and population dynamics of the species concerned. Furthermore a model may provide key factors which may prove valuable in the process of mitigation. Finally a method is presented to investigate the prospects for the reduction of hedgehog traffic victims. The composition of the landscape in a zone adjacent to a road is related to the location of hedgehog traffic victims. If (strong) relations are found, adaptations of the landscape combined with wildlife passages may follow.

Introduction

Throughout their range in western Europe hedgehogs (*Erinaceus europaeus*) are frequently killed by traffic. Hedgehog traffic victims are easily recognized because of their characteristic spines and have become a classic example of the animal - car conflict in this part of the world. Minimum estimates on the number of victims per kilometre road per year vary between 0.3 and 2.9 (table 1). In the Netherlands, a country characterized by one of the highest road densities in Europe (Vos & Zonneveld, 1993), hedgehog traffic victims occur throughout the country (figure 1).

Traffic mortality is just one aspect of the impact of roads and traffic on animal populations. The Dutch Ministry of Transport, Public Works and Water Management distinguishes four major categories for habitat fragmentation effects (Anonymous, 1995a):

1. Loss of habitat (due to the space roads and related objects take)
2. Reduction of habitat quality (noise, visual, pollutants)
3. Barrier effect (reduction of contact between individuals on either side of a road, diminished dispersal)
4. Wounded and dead animals (traffic, but also as a result of mowing of road side verges or other activities)

It is important to be aware of the full spectrum of the effects of roads and traffic when interpreting the results of studies that address just one aspect. This applies to this paper too: here we focus on traffic victims.

Animal - car collisions need to be prevented or reduced for many reasons from both the animal and human perspective. The greatest attention is usually given to (large) species that may be a threat to human safety (e.g. ungulates (Groot Bruinderink & Hazebroek, 1996)), and species that may suffer negative effects on populations, particularly those that are (already) at risk of local, regional or absolute extinction (e.g. badger (*Meles meles*) (Lankester et al., 1991)). In case of the hedgehog, the most important reasons for the relatively great number of studies addressing its relation to traffic mortality, seem to be the intrinsic value of the animals and the abundance of the victims, a possible negative effect on (local) populations and a rather subjective but strong public sympathy for this species. Finally the hedgehog is a very suitable mammal to study since it is relatively common and easy to handle.

Preventing or reducing traffic mortality is not simple to achieve. The primary cause, car traffic, is still very much at the increase (Anonymous, 1995b). A drastic reduction of traffic intensity seems impossible to realize in the near future. Therefore mitigation and compensation seem the only ways through which traffic mortality can be decreased on short term. Since the (negative) effects of roads and traffic on landscape and species are so varied and numerous, priorities are set as to which species or what effects will be mitigated or compensated for.

As we have pointed out already, a negative effect on animal populations is considered one of the most important parameters on which such priorities should be set. In this paper we discuss four methods through which the effect of traffic mortality on animal populations can be determined, using the hedgehog as an example. Finally we present a method we use to investigate the prospects for mitigation.

Effects on Populations

There are several ways in which the effects of traffic mortality on (hedgehog) populations can be determined. We will discuss four methods:

1. Reasoning. Mammal species that seem to suffer most from habitat fragmentation in general, and traffic and roads in specific, are those that have low population densities, low reproduction capacity, large home ranges (particularly when also territorial), low dispersal rates, a strong preference for climax ecosystems, specialized feeding habits, slow movements, and species which are strongly attracted to roads and road-side verges for food or other reasons (Cuperus & Canters, 1997; Van Apeldoorn, 1994; Van Apeldoorn & Kalkhoven, 1991; Whitcomb et al., 1981). Although these characteristics are almost never quantified all we can confirm for the hedgehog is that this species has relatively great home ranges (several tens of hectares (Reeve, 1994)) and that they may be attracted to road-side verges by the presence of food (mainly invertebrates). On the other hand, hedgehogs have relatively high population densities (in small scale agricultural landscapes 21-179 animals 100 ha^{-1} have been reported), high reproduction capacity (females may start reproducing after their first hibernation with, in north-western Europe, one litter per season and a mean litter size of 4-5 young), are non-territorial, usually move several kilometres on a night during the summer months, occur in a broad range of landscapes, have a considerable variety in diet, are capable of running at a speed of 60 metres min^{-1}, and even up until twice this speed as a recorded maximum, and they avoid roads, at least the paved parts of it (Bontadina, 1991; Doncaster, 1994; Morris, 1977; Reeve, 1994; Wroot, 1984). Furthermore, 59-80% of the traffic victims are males that have survived at least one hibernation (Göransson et al., 1976; Niewold, unpublished data; Palm & Stöwer, 1990). Furthermore hedgehogs have a relatively long mating season (May-September) and are non-monogamous (Reeve, 1994). Based on these facts, one could state that the effect of traffic mortality on hedgehog populations is unlikely to be severe: the animals that are killed are mostly male, and the remaining females are likely to get pregnant anyway. Since no new field work is undertaken this can be a relatively quick and cheap method. However, it is unlikely that all essential information is available or adequately quantified. The assumptions and simplifications that inevitably follow will therefore lead to unprecise answers and conclusions that are not supported by statistical analysis.

2. Relative importance of traffic mortality. The relative importance of traffic mortality may show whether traffic mortality is a dominant mortality factor or not. The relative importance can be expressed in terms of percentage of total mortality or can be related to population size. Some studies determined the relative importance of hedgehog traffic mortality as a 'side-product' of a study that involved the use of radio telemetry (table 2). This method enables one to monitor the fate of individuals. The drawbacks of this method are numerous. The results usually suffer from small sample sizes (often just several tens of individuals) while loss or failure of the transmitters and animals dispersing out of the study area cause further reduction. The batteries dictate a relatively short study period, usually not more than a couple of months. A time period as short as this may not lead to meaningful results: hedgehogs may expect to reach the age of 4-6 years (10 at the most) (Reeve, 1994) if they survive their first winter and have a small chance of dying within one or two months. Furthermore it may be impossible to distinguish between technical problems with the transmitter, a violent death of the animal that may have destroyed the transmitter as well (e.g. traffic victims), the blocking of transmitter signals (e.g. rabbit burrows, concrete floors of sheds) or dispersal. Therefore a broad range in the values for the percentage of total mortality may occur, especially when the study period is long. Another point to take in consideration is that these studies are often conducted on one particular site which is at best a case study due to specific characteristics (e.g. traffic intensity, road density, size of study area) and chance factors (e.g. the number of traffic victims on a short stretch of road).

Another way to determine the relative importance of traffic mortality is by means of a capture-mark-recapture (CMR) experiment (Begon, 1979), combined with an intensive check for traffic victims in the same study area. Apart from relating traffic mortality to total losses (mortality and dispersal), a CMR study also allows for relating the number of traffic victims to the estimated population size (table 2). A CMR study can and should last at least one year to cover all stages in the life cycle of the individuals. Problems may occur in meeting the requirements of the CMR model that is selected and the fact that a CMR study can be very labour intensive. Finally, a CMR study suffers from the same limitations in space (often one study site) and time (one year, maybe a little longer) as a radio telemetry study does, but is generally based on more individuals.

3. Effect on population size. The number or percentage of traffic victims may not have a measurable effect on population size. Other factors (e.g. reproduction, immigration, dispersal) may dominate population fluctuations. So, it is not the percentage of traffic mortality, but rather the effect it has on population size (or density) which is of interest. We addressed this question by comparing hedgehog densities in pairs of road- and control plots (see also Reijnen et al., 1995). In these plots we determined relative hedgehog densities by means of the presence or absence of foot prints in feeding stations that were located throughout the plots. The plot pairs were located close to one another (0.4-1.4 kilometres distance) and had similar landscape characteristics. Although not statistically significant, we found 30% less tracks in road plots. The observed reduction in population density is likely to be caused by traffic mortality, although the possibility remains that another road or traffic related factor is involved. This method directly measures the effects roads and/or traffic have on population size. The results allow for statistical tests, and are founded on numerous sites (equal to sample size). Depending on the technique and sample size a study, like this can be conducted in a relatively short time period (several months). It is important to note that sample size can have a great influence on the outcome of the statistical analysis. This can be accounted for by conducting a power analysis. In our case the power analysis showed that our sample size was too small to allow for the detection of an effect of 40% or less.

4. Effect on population survival. Again we may not be satisfied knowing whether roads and traffic have a negative effect on population size. It could be argued that it is far more relevant to know whether (local) populations are at risk of extinction (Van Apeldoorn, 1995). This could be tested using a model in which the effects of traffic intensity and road density on population size (or survival probability) are determined. The results of this analysis should indicate to what extend traffic mortality leads to the extinction of (local) populations, and whether such traffic intensities and road densities occur in reality or are within the range of prognoses for the nearby future. We have not yet developed such a model for the hedgehog, but other studies (e.g. on the badger (Lankester et al., 1991) have demonstrated that this approach can be a valuable management tool. The advantages of such a model lie in a direct insight in the effect on the survival probability of populations. Problems may occur in selecting an appropriate model and obtaining reasonable accurate values for the relevant parameters. If the latter is the case, extensive field studies may be required before the model can be run.

What Makes A Good Method?

As we have demonstrated above there are several methods through which the effect of traffic mortality on (hedgehog) populations can be quantified. Each method has its pros and cons, but some of these characteristics are more important than others.

Direct Measure of Impact

The effect of traffic mortality on an animal population is a rather general concept. One needs to be more specific in order to obtain the results one may or should expect. The results should be directly related to the effect on parameters like population size, population structure or survival probability. The first method (reasoning) and the third and fourth (the effect on population size or survival) allow for this type of results. The second method, the percentage of traffic victims, produces results that may not be directly related to the population at all, but rather to mortality factors themselves. On the other hand the effect we determine may not be caused by traffic mortality alone but may (partly) originate from possible effects of roads and traffic on e.g. habitat quality. This holistic character may not necessarily be a problem. On the contrary, the habitat fragmentation effects of roads and traffic were split into four groups (see introduction) to be able to deal with the complexity of the problem.

Quantitative Criteria

Regardless of the way one chooses to determine the effect of traffic mortality, the results alone are insufficient to evaluate whether action should follow to reduce the number of traffic victims. Criteria are essential since it has to be decided whether the effects are severe enough to justify mitigation or compensation. To prevent subjective or inconsistent interpretation of the results, these criteria should be set before the actual study is conducted. For all four methods discussed above, some sort of criteria can be set. These can be either qualitative (reasoning) or quantitative (percentage traffic victims, effect on population size or survival). However, if a priority sequence must be given as to which species should be mitigated or compensated for, quantitative criteria are better suited than logic (yes/no) criteria.

Testing Hypotheses and General Validity

Having specific criteria is one thing, but there is often some degree of uncertainty in the results. To prevent misinterpretation, a hypothesis and appropriate statistical tests are necessary. The methods of reasoning and percentage of traffic victims are not very suitable for such an analysis. Apart from rejecting or accepting a hypothesis, one is also interested in obtaining conclusions that have general validity. Studies that are conducted on one location may be influenced by the specific character of that study area and chance factors. These considerations favour the methods that determine the effects on population size and survival probability.

We think the two best ways to determine the effect of traffic mortality on (hedgehog) populations are to determine the effect on population size or on survival probability. These methods are based on a direct effect on the population, have the option of setting quantitative criteria, allow for the testing of hypotheses and their conclusions have general validity. However, if the effect on population size is great, and if the population density was high to begin with, many animals may remain after all. Therefore a method which determines the survival probability of a population and the way it is affected by traffic mortality or roads and traffic in general, has our preference. Furthermore, if a sensitivity analysis would be performed for a population survival probability model, key variables may be identified which could have a direct relevance for mitigation and compensation.

Prospects for Mitigation

Our pairwise comparison of relative hedgehog densities in road- and control plots indicated that roads and/or traffic may lead to 30% reduction in population size. However, this is not the only reason why one may wish to reduce the number of (hedgehog) traffic victims (see introduction). To achieve a reduction in traffic mortality, one has several options. Putting up an impermeable fence on both sides of a road is a very straight forward way to do this. However, this method has severe disadvantages since an increased barrier effect of the road inevitably follows. To reduce both traffic victims and the barrier effect, fences are often accompanied by wildlife passages under or over the road (Oord, 1995). Since negative effects of fences will remain and other species, which may not use the passages at all, will also be affected, alternatives should be looked for. We investigate an alternative which involves a combination of adaptations in the landscape and the construction of wildlife passages.

The prospects for alternatives to fencing become brighter if the traffic victims occur in high concentrations on certain 'hotspots' or when the location of traffic victims is strongly related to landscape characteristics in a zone adjacent on either side of a road. If hotspots occur and can be localized, a passage and limited fencing or other landscape adaptations in the direct vicinity of such a passage may be sufficient. However, we found no evidence for hotspots in 100 m units in a preliminary check on three roads which were monitored for hedgehog traffic victims (figure 2). The traffic victims seem widely scattered but their distribution is not necessarily random. They may be strongly related to specific landscape characteristics. If this is the case, landscape adaptations on a greater scale may be an option. The greater part of a zone along both sides of a road may be transformed into an unattractive habitat, while the animals may be guided to wildlife passages by landscape elements that are attractive to them (Figure 3). Although the effect on population parameters is still unknown, the use of several types of wildlife passages (e.g. culverts, underpasses and overpasses) by hedgehogs has already been confirmed (Nieuwenhuizen & Van Apeldoorn, 1994; Oord, 1995). The model which we discussed earlier may play an important role in determining the effect of such mitigation measures on the survival probability of the (local) populations.

A habitat study we conducted pointed out that hedgehogs spent a great amount of their time (54%) in hedgerows or in a five metre zone adjacent to a hedgerow or a forest's edge. They proved to select these habitat types positively. Forests, grassland, arable land and premises were avoided to a certain extend in the small scale agricultural landscape of the study site. Therefore we expect sites characterized by the proximity of hedgerows or a forest's edge to show most hedgehog traffic victims.

Volunteers monitored the presence and location of hedgehog traffic victims on an estimated 600 km road length during 1995 and 1996. They spotted ±950 hedgehog traffic victims. The location of the victims was determined in 100 m units corresponding with the numbered hectometre signs along the side of the roads. If these signs were absent maps were used (scale 1:25.000). We described the landscape along these monitoring routes in the same 100 m road length units which enables us to make a link to the observed number of traffic victims. Most of the registered variables concerned landscape characteristics of a zone adjacent to the roads. The majority of these variables fall within one of three main groups (table 3).

We expect to find a positive effect of hedgerows and forest edge's on the number of hedgehog traffic victims (i.e. more victims). Before the study was conducted hypotheses were formulated for the other variables also, which may provide us with additional knowledge that can be used in the practice of mitigation. Unfortunately the data were not yet analyzed when this paper was written. However, if the results indicate we may expect positive results of a combination of wildlife passages and adaptations of the landscape, we still need to test this in practice. For instance, we could experience problems when wildlife passages are also used by badgers since hedgehogs were shown to avoid sites tainted with badger odour for a number of hours (field) up to several days (enclosure) (Ward et al., 1997). Apart from that landscape adaptations should be evaluated for their effect on other species before they are carried out on a large scale.

Conclusion

There are several ways to quantify the effect of traffic mortality on (hedgehog) populations. The methods and results that can be obtained differ greatly. Therefore it is important to specify in which way one wants to have the effects quantified. We conclude that estimates of the effect of traffic mortality on population size or survival probability are far more useful than the results that can be obtained through reasoning based on available knowledge or studies concerning the relative importance of traffic mortality. However, studies on the effect on population size or survival probability can not be conducted unless the ecology and population dynamics of a species are sufficiently known. It is through extensive field studies, which may not always address the heart of the problem in the best way, that such valuable data can be obtained. If the effects on survival probability of a population are obtained through a model, key factors may be identified which could prove to be relevant for mitigation.

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Table 1

Estimates on the minimum number of hedgehog traffic victims per kilometre road per year in various parts of western Europe.

Source	Location	No. victims $km^{-1}yr^{-1}$
Berthoud (1980)	W Switzerland	0.3-0.8
Keymer et al. (1991)	SE Great-Britain	0.5-2.1
Reichholf and Esser (1981)	SE Germany	0.6-1.0
Jonkers and De Vries (1977)	Central Netherlands	0.9
Meijer and Smit (1995)	SW Netherlands	1.1-2.1
Göransson et al. (1976)	S Sweden	1.7
Garnica and Robles (1986)	N Spain	1.7
Hodson (1966)	S Great-Britain	2.3
Heinrich (1978)	NW Germany	2.9

Table 2

Relative importance of traffic mortality. For radio-telemetry studies the range in the percentage traffic mortality of total losses was calculated according to minimum = (M_t/(M+U)) and maximum = (M_t/M) (M_t = no. of traffic victims, M = total no. of dead animals, U = no. of animals whose fate is unknown). Sample size is the number of animals that carried a transmitter. For capture-mark-recapture studies the percentage traffic mortality of the estimated total losses was calculated for yearly periods, as was the percentage traffic mortality of the (mean) of the estimated population size. Sample size is the number of marked animals.

	% Traffic † of total losses	% Traffic † of pop. size	Sample size
Radio-telemetry			
Doncaster (1992)[1]	33-?		30
Doncaster (1994)[1]	17-?		48
Johansen (1995)	23-33		17
Capture-mark-recapture			
Göransson et al. (1976)[2]	?	17-22	23-27
Huijser et al. (1997)[3]	10-13	9-12	65
Kristiansson (1990)[3]	11-83	2-24	220
Reeve (1981)[4]	9-18	0-15	103

[1] *Animals introduced to new environment*
[2] *No insight in nature of analysis*
[3] *Excluding juveniles*
[4] *Combined with radio-telemetry*

Table 3
Main groups of landscape characteristics and the way they were measured
(see also Fig. 4).

Parameter type	Procedure
Distance	If the landscape element was present within the section (e.g. 12.65-12.75 (see fig. 4)), the shortest distance was measured from the edge of the pavement to the landscape element with a maximum of 100 m. If the landscape element was not present within the section, but was present within a radius of 100 m from the edge of the section, the shortest distance was measured from the edge of the pavement on the edge of the section (e.g. point location 12.65 or 12.75) to the landscape element with a maximum of 100 m.
Percentage	Percentage of road length a landscape element was present within a section (e.g. 12.65-12.75). Examples: 0 = not present within a section. 100 = for 100% present on one side of the road, or the sum of both sides is 100%. 200 = for 100% present on both sides of the road.
Perpendicular	If the landscape characteristic is linear by nature, it was noted whether it was (also) situated perpendicular to the road or not (either within the section or in one of the adjacent sections within a 100 m radius from the edge of the section concerned.

Figure 1.
Preliminary distribution of hedgehog traffic victims (1995-1996) in the Netherlands as reported to the VZZ. Most of the white areas are likely to result from a lack of observers, and not because of an absence of traffic victims.

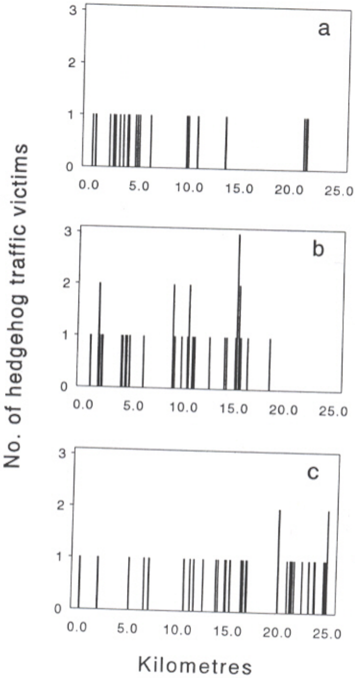

Figure 2.
Frequency distribution of hedgehog traffic victims on three road stretches (each 25 km) dived in 100 m. sections. The roads were monitored during (parts) of 1995 and 1996. A. Gieten-Groningen, b. Lelystad-elburg, c. Rilland-Goes.

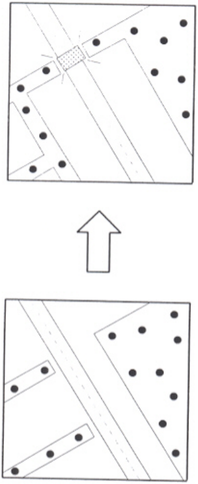

Figure 3.
Schematic transformation of a zone on both sides of a road in a habitat unattractive to hedgehogs in combination with passeges to which the animals are guided by attractive landscape elements. .

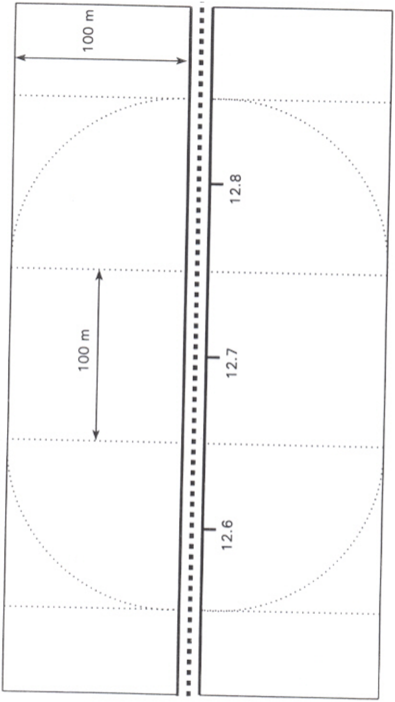

Figure 4.
Schematic road, the division into sections (e.g. 12, 65-12, 75) and the radius (r=100 m) in an adjacent section which serve to determine the shortest distance of a landscape characteristic to the road (see Table 3).