# MORTALITY FACTORS AFFECTING WILD HEDGEHOGS: A STUDY OF RECORDS FROM WILDLIFE RESCUE CENTRES

by

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ABSTRACT

This paper reviews the known principal causes of mortality in hedgehogs and uses a large data set (collected 1992-1998) from wildlife rescue centres to characterise the threats posed to the hedgehogs admitted. Data were obtained from the records of a total of 856 hedgehog fatalities from two hedgehog rescue centres in the United Kingdom (Jersey and Yorkshire) and one in the Netherlands (Den Haag). Summary data for a further 11,541 hedgehogs were obtained from the British Wildlife Rehabilitation Council (BWRC) quarterly statistics of wildlife casualties for the United Kingdom (1993-1997).

Hedgehogs accounted for a mean of 54% of the mammal casualties (16% of casualties of all taxa) received by rescue centres in the BWRC scheme. Combined data from all sources showed a significantly male-biased sex ratio of 1.2 (m:f) in the total admissions. Stronger male-biased ratios occurred early in the season.

Records from the three hedgehog rescue centres revealed 59% of deaths to be from causes that were probably natural such as parasitic diseases and infections; 41% of deaths resulted from factors that were clearly anthropogenic (unnatural), e.g., injuries from garden tools, road accidents, disturbance of nests (causing abandonment of young), drowning in waters with unnaturally steep banks, bite wounds from pets and poisoning. The BWRC data (including hedgehogs that recovered) showed a similar pattern, but a large non-specific category for 'other causes' (13% of cases) limited comparison.

Adult males outnumbered the females in the 'unnatural injuries' and 'traffic victim' categories. This in accordance with the expectation that males would suffer significantly more from accidents because of their wider ranging behaviour. Seasonal variation in the incidence of cause of death showed that most of the animals that died of natural causes did so in the second half of the year and that subadults were more common than the other age groups in this death category. The peak in deaths due to traffic and other unnatural causes was several months earlier in the year. Endoparasite infestations were found in 64% of 498 animals tested; the incidence varied significantly with age but not with sex. Subadult hedgehogs had a remarkably high infestation rate.

Despite the inherent biases in samples from wildlife rescue centres, anthropogenic factors seemed to make a significant contribution, additional to natural mortality. This appears to substantiate current concerns about their possible effect on hedgehog populations.

Key words: disease, *Erinaceus europaeus*, injury, mortality, orphans, parasites, poisoning, traffic.

## 1. Introduction

Admissions of mammals to wildlife rescue centres in western Europe typically include a large proportion of hedgehogs *Erinaceus europaeus* which are admitted with a very wide variety of illness and injuries. Natural mortality factors include the many parasites and diseases recorded from European hedgehogs (table 1). The literature is too extensive to review here, but see Reeve (1994) and more recent works e.g., Poduschka et al. (1995), Lambert (1995), Schicht-Tinbergen (1995), Zaltenbach-Hanßler et al. (1998) and Biewald et al. (1999). However, despite numerous surveys, the relative importance of parasitic diseases and other illnesses as causes of death remains poorly studied. In Germany, Timme (1980) used autopsy data to establish the cause of death of 410 hedgehogs from wildlife hospitals. Overall, parasitic diseases caused 39% of deaths,

Table 1. The principal parasites and pathogens of hedgehogs (*Erinaceus europaeus*) in Europe and their typical effects. A large number of less commonly found species are excluded. Adapted from Reeve (1994) and Zaltenbach-Hanßler et al. (1998).

*Tabel 1. De belangrijkste parasieten en ziekteverwekkers van egels (*Erinaceus europaeus*) in Europa en hun effecten. Een groot aantal minder algemeen voorkomende soorten is niet opgenomen in de tabel. Naar Reeve (1994) en Zaltenbach-Hanßler et al. (1998).*

| **organism** | | **effects ectoparasites** |
|---|---|---|
| fleas: | *Archaeopsylla erinacei* | Arthropod ectoparasites. Rarely cause death, but severe infestations may be complicated by bacterial infections (e.g., staphylococci). |
| ticks: | *Ixodes hexagonus, I. ricinus* | |
| mites: | *Caparinia tripilis, Demodex erinacei*, Sarcoptes spp. | |
| fungi: | *Trichophyton erinacei* | Skin infection, typically non-lethal. |
| maggots: | blowfly larvae (Fam. Calliphoridae) | Infest wounds, ears, anus etc. Can kill, but animal often already weak |
| **endoparasites** | | |
| nematodes: | *Crenosoma striatum* | Often lethal. Worms infest the lumen of trachea, bronchi, bronchioles and alveolar ducts. |
| | *Capillaria aerophila* | Often lethal. Worms infest the epithelium of the trachea, bronchi and bronchioles. |
| | *Capillaria erinacei, C. ovoreticulata* and at least one other *Capillaria* spp. | Infest intestine. All may kill if infestation is severe causing diarrhoea/enteritis and lesions. |
| trematodes: | *Brachylaemus erinacei* | |
| cestodes: | *Rodentolepis (=Hymenolepis) erinaceia* | |
| canthocephala: | *Moniliformis erinacei* & others of the intestinal wall | |
| **pathogenic microorganisms** | | |
| coccidia: | *Isospora rasegaivae* & others | Intestinal. Rarely lethal but haemorrhagic diarrhoea can kill. |
| | *Toxoplasma gondii* | Severity unknown. Affects blood and other tissues. |
| fungi: | *Candida albicans* | Affects gastrointestinal tract, mouth genito-urinary tract. Rarely lethal. |
| bacteria: | *Leptospira interrogans* | Several serotypes. Rarely lethal. Affects blood and urinary systems. |
| | *Salmonella enteriditis* and other *Salmonella* spp., *Escherichia coli, Pasteurella* spp. | Common enteric bacteria often enteric subclinically but infections often lethal. |
| | *Bordetella bronchiseptica* | Respiratory tract; often lethal in association with lungworm infections. |
| viruses: | | Many viruses isolated but importance not known. In Britain, paramyxoviruses of the morbilli group are common in wild hedgehogs (Visozo & Thomas, 1981). Symptoms: circle-running, poor coordination, lesions (eyes, feet and mouth, internal organs) and death. |

general bacterial infections (mainly *Salmonella* spp. and *Escherichia coli*) killed 19%. Diseases of organs, principally lung and gut infections, also killed 19%.

Direct anthropogenic (unnatural) causes of death were infrequently recorded by Timme (1980), only 7 (1.7%) of deaths were attributed to road traffic accidents and other injuries. Nevertheless, anecdotal evidence from numerous wildlife rescue centres,

Table 2. The principal anthropogenic hazards causing the death or injury of hedgehogs (*Erinaceus europaeus*). Sources: Stocker (1987), Reeve (1994), Sykes & Durrant (1995) Zaltenbach-Hanßler et al. (1998).
*Tabel 2. De belangrijkste gevaren voor egels* (Erinaceus europaeus) *die samenhangen met de mens en die tot verwonding of de dood kunnen leiden. Bronnen: Stocker (1987), Reeve (1994), Sykes & Durrant (1995) Zaltenbach-Hanßler et al. (1998).*

| hazard | notes |
|---|---|
| traffic: | studies throughout Europe have shown that hedgehogs are one of the commonest mammals to be found dead on the roads. |
| disturbance: | nests of dependent young are frequently disturbed by people or domestic dogs and cats. This may cause, directly or indirectly, abandonment and the death of the young. Hedgehogs are easy to catch and some, especially newly independent youngsters, may be unnecessarily 'rescued' from the wild. |
| injury (accidental): | agricultural and garden tools, forks, spades, strimmers, mowers etc. commonly injure hedgehogs of all ages. Injuries may also be caused by broken glass, barbed wire and similar hazards. |
| injury (by pets): | mainly attacks by domestic dogs. Domestic cats probably only affect youngsters which may be taken from nests. |
| fire: | hedgehogs may build day-nests, breeding nests and hibernacula in piles of leaves or wood and so may be burned in bonfires if these are not checked first. |
| poison: | direct consumption of slug pellets has been shown - indirect poisoning via consumption of poisoned slugs is less likely. Even if not ingested, contact with many other hazardous substances that are used in farms, parks, gardens, golf courses etc. may cause skin damage and subsequent disability and infection. |
| becoming trapped: | entanglement in netting or litter e.g., plastic binders for drink cans, becoming stuck in large-mesh fencing or becoming trapped after falling into steep-sided holes, drains, cattle grids etc. Hedgehogs may also be accidentally locked inside buildings which have been left open at night. |
| drowning: | any water-body with unnaturally steep sides e.g., garden ponds, swimming pools, canals, steep-sided ditches etc. may cause drowning. |
| animal traps: | hedgehogs are usually caught accidentally while trapping for other species. May be a problem in areas subject to ground predator control programmes e.g., game-keepered estates. |

such as those in the present study, indicates that unnatural deaths may have a significant effect on hedgehog populations. This is hard to verify from many published studies because of sample biases. For example Dickman (1988), in a study of hedgehog diet based on 109 hedgehog corpses, noted that 78% were road kills, 2.8% had apparently died from eating slug pellets, 1.8% were the result of accidental burning and 17.4% had died from unknown causes. However, 64% of the corpses had actually been collected from roads. In contrast, a study of 30 translocated wild hedgehogs (Doncaster, 1992) found road kills to account for 4 (33%) of the 12 known deaths. Also, in a 15 week follow-up study of 12 hedgehogs released from a wildlife hospital (Reeve, 1998) two died of natural causes (pneumonia and badger predation), one drowned in a garden pond and four were killed by road traffic. In both these studies the behaviour of the animals may have been affected by their release into an unfamiliar area which may have affected their vulnerability to certain mortality factors. However, these studies add to a general weight of circumstantial evidence that anthropogenic mortality factors may be important (see table 2 for a summary).

The demographic effect of deaths from road traffic accidents has received more attention than other anthropogenic mortality factors. The hedgehog is one of the most commonly recorded mammal species in road-kill surveys throughout Europe: for reviews of studies see Reeve (1994) and Huijser et al. (1998). Road accidents killed about 17-22% per year of a population of 23-27 hedgehogs in a three year study in southern Sweden (Göransson et al., 1976). In the same study area, Kristiansson (1990) used eight years of population data to estimate that road-kills accounted for most summer losses, averaging around 12% (range 3-22%) of the subadults/adults and between 0-6% of juveniles each year. This should be compared to estimates of total annual losses (deaths + emigration) which averaged 34% in juveniles and 47% in adults and subadults. In a rural area of the Netherlands, Huijser et al. (1997) found that road-kills accounted for 12% of the total losses (deaths + emigration) of the local population and that in two successive seasons 6% and 9% of the population were killed on the roads. Typically, studies have shown that the deaths are mainly males early in the season and during the rut (when males are more active than females) and most of the female deaths occur late in the season - probably after they have reproduced. This suggests that the demographic effects of road kills might be less than one might guess from the sheer numbers involved, because pre-reproductive females and juveniles are relatively unaffected (Kristiansson, 1990; Huijser et al., 1997).

Although studies of road mortality contribute valuable data, road deaths are only part of the overall problem. The impact of other anthropogenic mortality factors (table 2) should also be evaluated. Without expensive long-term demographic studies, records from hedgehogs admitted to wildlife rescue centres are the only practical source of substantial data. Some inherent biases of such data can be anticipated. The casualties admitted to wildlife rescue centres represent only animals that have not been killed outright and so must underestimate the effects of, for example, road traffic accidents or agricultural and garden machinery. Casualties from built-up areas will be over-represented because these will be more commonly found by the public and, because people commonly disturb breeding nests, dependent young and their mothers may also be over-represented. Also, the data in rescue centre records are principally concerned with issues of treatment and so may not always distinguish between different causes of injury and may only selectively contain detailed information on parasites, diseases and other potential causes of death that would only be apparent from faecal assays and/or autopsy examinations.

Nevertheless, with such biases kept in mind, an analysis of data from wildlife rescue centre records should allow some insight into which mortality factors most affect wild hedgehogs. This study is a first attempt at using a large data set collected from a number of wildlife rescue centres in order to characterise the nature of the problems affecting the hedgehogs admitted.

## 2. Material and methods

### 2.1. Sources of data

The records of a total of 856 hedgehog fatalities were obtained from three hedgehog rescue centres: 286 records (October 1992 - December 1997) Jersey, Channel Islands; 194 records (September 1997 - December 1998), Yorkshire, England; 376 (January 1992 - December 1997) Den Haag, The Netherlands. Only records of deaths were included mainly because many hedgehogs successfully treated for injuries, illnesses or simply brought in by the public, might not have died if left in the wild. It is also true that another bias may have been introduced because of this, since hedgehogs that would have died in the wild, but survived because of the help they were given in a rescue centre, were excluded. The percentages of all hedgehogs admitted that were later released, and hence excluded from the present study, were 66.8% (Jersey), 40.0% (Yorkshire) and 75.4% (Den Haag).

In addition, pooled data on a total of 11,541 hedgehog casualties (January 1993 - December 1997) were provided by the British Wildlife Rehabilitation Council (BWRC) who collate wildlife casualty records nationally from 20-30 rescue centres. The BWRC data included 35% of animals that recovered and were later released, but these could not be identified and removed *post-hoc* because the data were in the form of quarterly and yearly totals.

### 2.2. Coding cause of death

The casualties were coded into eight categories of illness or injury which encompassed the existing six categories into which the BWRC data were already classified; as indicated in brackets below:

1. Natural causes - all injuries and disease not associated with human activity (= BWRC category 4) interpreted by us to include congenital abnormalities and malformations, failure to thrive etc. Not all animals within this category may have died from natural causes alone. Anthropogenic factors may make hedgehogs more susceptible to parasites and diseases. However, all animals for which apparent natural injuries, disease or infections were clearly secondary to anthropogenic factors were classified into the appropriate non-natural death category.
2. Injured - from 'unnatural or wilful agents' (= BWRC category 1) other than road traffic accidents, injuries judged to be natural were recorded in category 1.
3. Road traffic accidents (included in BWRC category 1).
4. Orphaned - abandonment of dependent young (<6 weeks old) (= BWRC category 3).
5. Drowned in garden ponds and steep sided ditches etc. - an unnatural cause of death because hedgehogs (which swim well) should be able to escape from most natural ponds and rivers which have sloping banks that allow escape.
6. Injury caused by domestic cat or dog (similar to 'cat kill' category 6 used by BWRC).
7. Poisoned/polluted - can be hard to determine, only confirmed or highly suspicious cases were included (= BWRC category 2).
8. Other - any casualties not fitting into other categories (= BWRC category 5).

Thus category 1 represents death from natural causes, whereas categories 2-7 cover anthropogenic causes of death.

2.3. Other variables

The BWRC data also contained records (for each quarter of the year) of totals of animals of each sex (male, female, unknown) and age class (immature, adult, unknown), plus the numbers surviving 48 hours and the numbers released.

The more detailed records from the three hedgehog rescue centres did not all contain the same information, but all were coded as individuals for which each of the following were recorded: sex (male, female, unknown), the month of admission (quarter only for the Yorkshire data), and presence or absence of endoparasite infestations. Also three age categories were distinguished: juvenile (dependent young), subadult (independent young) and adult. However, because the young of the previous year (older subadults) grade into adults, such animals were classed as adults (>1 year) if admitted in July or later. Further data from the Jersey and Den Haag samples were available for body weight on admission, the exact number of days survived after admission, the presence or absence of maggots. The Den Haag sample alone contained presence or absence records of ectoparasites. Both the Yorkshire and Jersey samples contained records of endoparasite species from faecal samples.

## 3. Results

### 3.1. Seasonal variation

The BWRC data revealed that, over the five years, hedgehogs accounted for a mean of 54% of all mammal casualties received by participating rescue centres (16% of casualties of all taxa). Hedgehogs were 35% of all mammal casualties in the first quarter of the year, 52% in the second and 68% in each of the third and fourth quarters. All sources showed seasonal variation in the numbers of hedgehogs admitted with relatively few admissions in the first quarter and peak numbers in the third or fourth quarters. Off all admissions 73.5% took place in the second half of the year (table 3). The combined data from all sources showed that the sex ratio of the admitted animals depended on the

Table 3. Number of hedgehog casualties and the sex ratio (5592 animals of known sex) for each quarter of the year. Total BWRC data plus fatalities from the Jersey, Yorkshire and Den Haag rescue centres for all years.
*Tabel 3. Het aantal egelslachtoffers en de sex-ratio (5592 dieren waarvan het geslacht bekend is) per kwartaal. Het betreft het totaal van de BWRC gegevens en de in de opvangcentra van Jersey, Yorkshire en Den Haag gestorven individuen voor alle jaren gezamenlijk.*

| quarter of year: | Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec | total |
|---|---|---|---|---|---|
| total: | 655 | 2,627 | 5,395 | 3,720 | 12,397 |
| males: | 180 | 652 | 1,411 | 810 | 3,053 |
| females: | 119 | 486 | 1,188 | 746 | 2,539 |
| sex ration (m:f): | 1.5:1 | 1.3:1 | 1.2:1 | 1.1:1 | 1.2:1 |

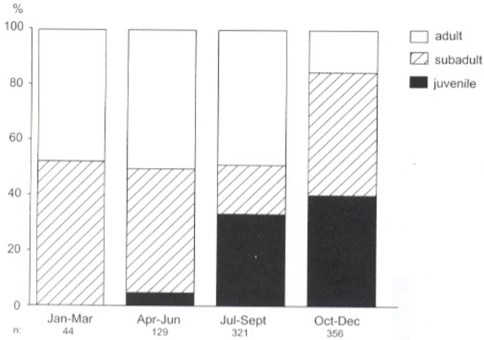


Figure 1. The proportion (%) of fatalities for each age group in each quarter of the year. Data from the three hedgehog rescue centres only. n = number of animals in each quarter for which age estimates were recorded.
*Figuur 1. Het percentage slachtoffers voor elke leeftijdsgroep per kwartaal. Het betreft hier uitsluitend gegevens van de drie egelopvangcentra. n = het aantal dieren waarvan de leeftijd in het betreffende kwartaal werd vastgesteld.*

quarter of year (G-test statistic (with William's correction) = 11.31, df=3, $p<0.025$). There was a progressive reduction in male-bias from 1.5:1 (m:f) in the first quarter to 1.1:1 in the final quarter of the year. Overall, there remained a significant male-biased sex ratio of 1.2:1 (n=5592 of known sex, G-test statistic = 47.31, df=1, $p<0.0001$).

### 3.2. Age structure

The proportion of juveniles, subadults and adults varied between the three hedgehog rescue centres. The Jersey sample contained relatively more subadults (41%), the Yorkshire sample contained relatively few juveniles (12%), whereas the Den Haag group had relatively few subadults (26%). However, when the data from the three hedgehog rescue centres are totalled, the three age classes are equally abundant (n=850 of known age, G-test statistic = 4.05, df=2, p=0.15) with approximately one third of casualties in each age group: juveniles 30%, subadults 35%, adults 35%. The BWRC data showed a similar pattern although only two age categories were used, 58% immature (juveniles and subadults) and 33% adult, plus 9% of unknown age.

The age structure of fatalities from the three hedgehog rescue centres varied seasonally (fig. 1). The combined data showed that from January to June, almost all casualties were subadults and adults (in roughly equal numbers) with only 4.6% of casualties being juveniles in the April-June period. The proportion of juveniles increased to about 33% and again to 40% in the third and fourth quarters respectively. The BWRC data set is less useful here because it did not distinguish between dependent and independent young. Nevertheless, for those of known age the same trend is shown with 57% adults and 43% immatures (n=2,740) in the first half of the year, and with 29% adults and 71% immatures (n=7,691) in the second half of the year.

3.3. Mortality factors

Fatality data from the three hedgehog rescue centres are presented in table 4 and in figure 2 which also provides a comparison with the BWRC casualty data. The data from the three hedgehog rescue centres show that 58.5% of deaths can be attributed to 'natural causes'. In contrast, categories 2 to 7 are all, in one way or another, the result of human activity. Overall, anthropogenic mortality factors may therefore account for up to 40.9% of deaths in this sample with 'other causes' accounting for an additional 0.5%

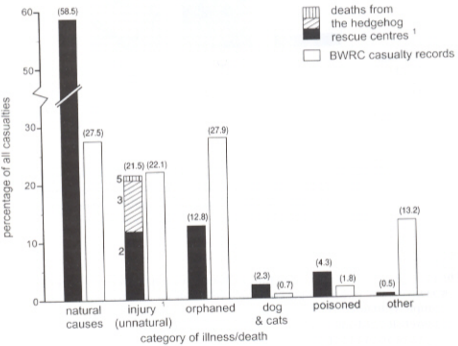


Figure 2. The percentage of hedgehog casualties in each cause of death category from the three hedgehog rescue centres (shaded bars) and the BWRC records (unshaded bars) which recorded all casualties, not just deaths.
[1] The hedgehog rescue centre data for unnatural injury (cat. 2), road accidents (cat. 3) and drowning (cat. 5) is here taken to be equivalent to the BWRC category 1 (unnatural injury, see table 4).

*Figuur 2. Het percentage egelslachtoffers voor de verschillende doodsoorzaken (gearceerde staven) van de drie egelopvangcentra en van de BWRC gegevens die ook betrekking hebben op dieren die overleefden (zwarte staven). 1 De gegevens van de egelopvangcentra voor onnatuurlijke verwonding (cat. 2), verkeersslachtoffers (cat. 3) en verdrinking (cat. 5) zijn hier gelijk gesteld aan de BWRC categorie 1 (onnatuurlijke verwonding, zie tabel 4).*

Table 4. The number of fatalities from the three hedgehog rescue centres (total = 856) classified into death categories. 1 = natural causes, 2 = unnatural injury, 3 = road traffic accident, 4 = orphaned, 5 = drowned, 6 = injury from dog or cat, 7 = poisoned/polluted, 8 = other.

*Tabel 4. Het aantal slachtoffers van de drie egelopvangcentra (totaal = 856) geclassificeerd naar doodsoorzaak. 1 = natuurlijke oorzaak, 2 = onnatuurlijke verwonding, 3 = verkeersslachtoffer, 4 = wees (geen moeder meer, verstoring nest), 5 = verdronken, 6 = verwondingen toegebracht door hond of kat, 7 = vergiftigd, 8 = overig.*

| death categorie: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Jersey | 200 | 40 | 12 | 15 | 3 | 9 | 4 | 3 |
| % | *69.9* | *14.0* | *4.2* | *5.2* | *1.0* | *3.1* | *1.4* | *1.0* |
| Yorkshire | 131 | 7 | 33 | 17 | 0 | 4 | 2 | 0 |
| % | *67.5* | *3.6* | *17.0* | *8.8* | *0* | *2.0* | *1.0* | *0* |
| Den Haag | 170 | 54 | 30 | 78 | 5 | 7 | 31 | 1 |
| % | *45.2* | *14.4* | *8.0* | *20.7* | *1.3* | *1.8* | *8.2* | *0.3* |
| total | 501 | 101 | 75 | 110 | 8 | 20 | 37 | 4 |
| % | *58.5* | *11.8* | *8.8* | *12.8* | *0.9* | *2.3* | *4.3* | *0.5* |

The BWRC data, which included hedgehogs that recovered, showed a somewhat similar pattern (fig. 2) with 22.1% of animals suffering unnatural injuries, 1.8% poisoned and 0.7% taken by cats. This latter figure compares well to 0.2% cat kills, and 2.1% dog kills (total 2.3%) in the hedgehog rescue centre data. There was a relatively high proportion (27.9%) of abandoned young - over twice the total from the hedgehog rescue centres although these varied from 5.2% to 20.7%. Those admitted with problems of a natural origin were 27.5% of cases, just under half the hedgehog rescue centre sample total. Additionally, 13.2% of deaths were from 'other causes'.

Table 5. Fatalities from the three hedgehog rescue centres showing the incidences of causes of death of animals of known sex and age (n=753) across the four most common death categories. j = juvenile, s = subadult, a = adult.

*Tabel 5. Het aantal slachtoffers van de drie egelopvangcentra, ingedeeld naar geslacht en leeftijd, voor de vier meest voorkomende doodsoorzaken (n=753 dieren met bekend geslacht en leeftijd). j = juveniel, s = subadult, a = adult.*

| death categorie | age | male (n) | female (n) |
|---|---|---|---|
| natural causes | j | 50 | 39 |
| | s | 111 | 106 |
| | a | 89 | 78 |
| unatural injury | j | 9 | 16 |
| | s | 8 | 11 |
| | a | 34 | 22 |
| road traffic accident | j | 1 | 1 |
| | s | 13 | 10 |
| | s | 31 | 17 |
| orphaned | j | 47 | 60 |
| | s | 0 | 0 |
| | a | 0 | 0 |
| total | | 393 | 360 |

Table 6. Fatalities from the three hedgehog rescue centres showing the incidences of causes of death for each quarter of the year across the four most common death categories.
*Tabel 6. Het aantal slachtoffers van de drie egelopvangcentra per kwartaal voor de vier meest voorkomende doodsoorzaken.*

| quarter of year | Jan-Mar | Apr-Jun | Jul-Sep | Oct-Dec |
|---|---|---|---|---|
| natural causes | 32 | 74 | 161 | 235 |
| % | *6.45* | *14.7* | *32.1* | *46.8* |
| unnatural injury | 1 | 15 | 57 | 28 |
| % | *1.0* | *14.9* | *56.4* | *24.8* |
| road traffic accident | 5 | 20 | 34 | 16 |
| % | *6.7* | *26.7* | *45.3* | *21.3* |
| orphaned | 0 | 0 | 50 | 59 |
| % | *0.0* | *0.0* | *45.9* | *54.1* |

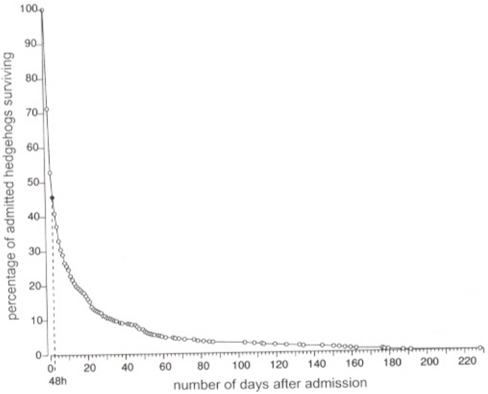


Figure 3. The percentage of hedgehogs that survived a certain number of days after admission (n= 658 hedgehog fatalities from the Jersey and Den Haag hedgehog rescue centres). Animals that died within the first day were recorded as having a survival of 0 days. Only 45.7% of admissions survived 48 hours.
*Figuur 3. Het percentage egels dat nog een bepaald aantal dagen overleefde na binnenkomst (n=658 egelslachtoffers van de egelopvangcentra van Jersey en Den Haag). Voor de dieren die op de eerste dag stierven werd een overleving van 0 dagen geregistreerd. Slechts 45,7% van de dieren overleefde langer dan 48 uur.*

Table 7. The incidence of endoparasite species recorded from the Jersey and Yorkshire hedgehog rescue centres (combined data). Results were obtained from faecal analysis (usually simple faecal smears) and/or autopsy examination. Not all animals were examined in each case (sample sizes are as shown).

*Tabel 7. De mate van voorkomen van endoparasieten bij de egels van de opvangcentra in Jersey en Den Haag (gecombineerde gegevens). De resultaten werden verkregen op basis van faeces analyse (meestal eenvoudige uitstrijkjes van de faecaliën) en/of autopsie. Niet alle dieren werden op elk van de endoparasieten onderzocht (de steekproefgrootte is weergegeven).*

| endoparasite | hedgehogs examined (n) | positive (n) | positive (%) |
|---|---|---|---|
| *Capillaria* spp. | 256 | 128 | 49.6 |
| *Crenosoma striatum* | 265 | 103 | 38.9 |
| *Capillaria aerophila* | 263 | 55 | 20.9 |
| *Brachylaemus erinacei* | 256 | 42 | 16.4 |
| Coccidia | 269 | 41 | 15.2 |
| Cestodes | 258 | 3 | 1.2 |
| Acanthocephal | 256 | 4 | 1.6 |

Given the more or less equal abundance of the three age categories in our sample from the three hedgehog rescue centres, subadult hedgehogs are relatively vulnerable to dying of natural causes (table 5). Adult males are most susceptible to 'unnatural injuries' and becoming a traffic victim. By definition juveniles were the only age group in the 'orphaned' category.

Seasonal variation in the incidence of cause of death shows that most animals that died of natural causes did so in the second half of the year (table 6). The peak in deaths due to unnatural causes and traffic victims was several months earlier in the year whereas orphaned hedgehogs were first found in the third quarter.

The number of days from admission to death were obtained from two of the hedgehog rescue centres (Jersey and Den Haag) which showed no significant difference between the centres (Mann-Whitney U test, $p=0.96$ $n_1=282$, $n_2=376$). Non-parametric analysis was used because the data showed a very strong positive skew, with most animals having low survival rates but with some surviving for long periods, up to 228 days. The median survival period was two days, with only 25% surviving beyond 10 days (fig. 3).

### 3.4. Parasites

Of the animals that died at hedgehog rescue centres 64% of 498 animals tested had endoparasite infestations confirmed by routine faecal analysis or autopsy. There was no interaction of sex and age (G-test statistic (with William's correction) = 0.74, df=2, $p>0.50$). The incidence of parasites was equally distributed over the sexes (G-test statistic = 0.19, df=1, $p>0.90$), but not over the age categories (G-test statistic = 21.83, df=2, $p<0.001$). Only 49% of dependent juveniles were infected but the incidence was 67% in adults and 85% in subadults. The records of endoparasite species are summarised in table 7. Ectoparasites were only recorded (presence or absence) consistently by the Den Haag rescue centre. Of the 315 animals examined, 87.6% had ectoparasites. Myiasis (maggot infestation) was more reliably reported by all three centres, of 664 animals examined, 7.5% had maggots or fly eggs.

## 4. Discussion

### 4.1. Sample composition

Both sexes and all age groups were well-represented in the sample and the seasonal changes in the sample composition conformed to expectations based on field studies and a knowledge of the life-cycle of the species (Reeve, 1994). The seasonal variation in the number of casualties can be partly explained by the seasonal activity cycle of hedgehogs which typically hibernate from November to March or April in the areas studied. Hedgehogs were 35% of mammal casualties even in the first quarter but the absolute numbers were relatively very low. However, in the fourth quarter, hedgehogs still made up 68% of mammal casualties and the absolute numbers remained high. These late casualties were dominated by juveniles and newly independent subadults (almost 85% of admissions) which commonly remain active to boost their fat stores prior to hibernation while the majority of adults have begun hibernation by November (Reeve, 1994). The appearance of juveniles in small numbers in the second quarter, and then in larger numbers in the third and fourth quarters also corresponds to the known breeding season, the rut typically begins during May and few young are born before mid June (Reeve, 1994; Huijser, 1997).

The male bias in the sex ratio was most marked in the first quarter of the year and reduced to an approximately even sex ratio late in the year. This is in line with the results of field studies and studies of road casualties (e.g., Göransson et al., 1976; Reeve, 1982). Early in the season males become fully active earlier than the females (Zingg, 1994) and during the rut adult males typically travel longer distances and range more widely than females (Reeve, 1982), behaviour likely to result in a greater risk of accidents.

### 4.2. Mortality

That hedgehogs accounted for 54% of recorded wildlife casualties could be a result of a thriving population in association with areas of human habitation and the relative ease with which hedgehogs may be caught. However, the finding that 41% of recorded deaths are attributable to anthropogenic factors must be a cause for concern. Although some biases may have artificially inflated this estimate, it is also true that many deaths must have been unrecorded, such as those that are killed immediately or never found after injury e.g., after road accidents, or those affected by pesticides and pollution but with non-specific symptoms. Built-up areas are one of the most important refuge habitats for hedgehogs in the UK and the Netherlands (Morris, 1993; Huijser, 1999) yet these data suggest that hedgehogs are under considerable pressure from anthropogenic mortality factors which must be acting strongly in such areas. However, without corroborative population studies, the demographic effects of such mortality can only be guessed.

The three hedgehog rescue centres showed some variation in the numbers in each cause of death category. The Yorkshire centre recorded proportionately more road casualties but many fewer unnatural injuries of other types, this may represent a genuine difference but could also have been due to differences in the interpretation of injuries and their context, or stochastic effects on a relatively small sample. The comparatively few road casualties recorded from Jersey (4.2%) may be partly explained by the slow traffic on the island (speed limits from 24-64 km/h) a factor associated with a reduced number of road-kills (Gunther et al., 1998). Furthermore, in contrast to studies elsewhere (e.g., Doncaster, 1992; Reeve, 1998) none of 13 released hedgehogs in Jersey was killed on the roads (Morris, 1997).

Another disparity between the three hedgehog rescue centres was in the number of deaths of orphans - relatively high (20.7%) in the Den Haag sample, however this was closer to the 27.9% of orphans recorded in the BWRC data. In contrast the figure for death by natural causes was consistently much higher in the Jersey and Yorkshire samples (67.5 and 69.9%) than in the Den Haag and BWRC samples (45.2% and 27.5%). It should be remembered that the BWRC data also included animals that recovered and therefore the numbers would be boosted by successfully reared orphans, nevertheless, these differences suggest a systematic difference in coding where an underweight youngster could either have been recorded as an orphan (still dependent) or as a death by natural causes (failure to thrive of an independent subadult). More precise criteria for recorders could help to improve consistency in future.

In other respects the hedgehog rescue centres and the BWRC data showed reasonable consistency with a very similar proportion of animals suffering from human-related injuries (21.5% and 22.1% respectively) but the comparatively heavy use of the 'other causes' category in the BWRC data makes detailed comparison unsafe. Poisoning/pollution is clearly a minor cause (4.3% and 1.8%) but is likely to be under-reported because of the difficulty and expense of obtaining laboratory confirmation of suspected poisoning. Under-reporting is also likely when poison results in either the immediate death or the hiding and reduced activity of poisoned animals. The Den Haag sample reported 8.2% of deaths being due to poisoning or pollution, this is considerably more than the 1.0 - 1.8% range from the other three sources. This may be due to less conservative reporting or could be related to the more densely urban nature of Den Haag. Dog bites are a well-known cause of injury of hedgehogs (2.1% of hedgehog rescue centre deaths) although they were not separately recorded in the BWRC scheme. Cats are less important at 0.7% and 0.23% (BWRC and hedgehog rescue centre data respectively) and the reports are related to the taking of nestlings or the desertion of dependent young after nest disturbance.

Adult males outnumbered the females in the 'unnatural injuries' and 'traffic victim' categories. This in accordance with the expectation that males would suffer significantly more from accidents because of their wider ranging behaviour.

The effect of age on the likelihood of death from certain causes was obvious in some cases. Only juveniles can be orphaned and dependent juveniles are unlikely to have been victims of road accidents (only three instances) unless they were out with their mother, hence these two categories showed strong age differences. However, the strong bias towards subadults (and away from juveniles) dying of natural causes is of interest. Subadults also have particularly high endoparasite infestation rates (see later). The majority of juveniles dying of natural causes would never have been discovered and taken to a rescue centre, hence the data may reflect the general vulnerability of the young; as shown in population studies of survivorship (Kristiansson, 1984). Why adults (with an even sex ratio) should have been more susceptible to unnatural injury than subadults is not fully clear. However, not all unnatural injuries may have occurred during the day and since adults travel greater distances than subadults they run a greater risk of injuries. That juveniles should also outnumber subadults in this category is also baffling, although it is certainly possible that juveniles may be accidentally injured (a whole litter at a time) in their nests by, for example, agricultural and garden tools.

Most of the seasonal differences in the causes of death can easily be accounted for. The 'orphaned' casualties can only be associated with the birth of youngsters, and hence are confined to the third and fourth quarters. Unnatural injury peaks in the second and third quarters when gardeners are most active. Road accidents also peak in the middle two quarters when males are most active and subadults may be dispersing (Reeve, 1982). Deaths from natural causes show a large increase, to 66.6% of all deaths, in the fourth quarter. This seems likely to be associated with the relatively large numbers of newly independent subadults which are very vulnerable late in the year.

The BWRC records included a count of the number of casualties surviving 48 hours, the assumption being that the 37% of all admissions that died within 48 hours were unlikely to have survived, whatever the treatment. Applying the 48 hour criterion to the median of 2 days from admission to death in both the Jersey and Den Haag centres, it might be suggested that half those animals that died had little chance of being saved. However, the fact that as many as 25% survived beyond 10 days before dying indicates that 48 hours is too short a period for an accurate prognosis.

### 4.3. Endoparasites

Endoparasite infections were common overall (positive in 64% of animals tested). Juveniles, who will have had only limited exposure to vectors, had predictably lower infection rates (49%); as was also found by Majeed et al. (1989) and Schicht-Tinbergen (1995). In the present study, the comparatively high 85% infection rate in subadults (67% in adults) may contribute to an explanation of why they had such a high rate of mortality from natural causes. The lack of a significant sex difference in the incidence of endoparasite infections found in the present study was also reported for lungworm infections by Majeed et al. (1989).

The recorded incidences of particular parasites are comparable with those from published studies - but these are highly variable. Lungworms, *Crenosoma striatum* and *Capillaria aerophila* infections are commonly fatal in hedgehogs (Reeve, 1994). *Crenosoma striatum* were found in 38.9% of animals, this is similar to the 35.9% incidence reported by Epe et al. (1993) but rather lower than typical; in order of incidence: 45.2% (Bauer & Stoye, 1984), 47.8% (Löwenstein et al., 1991), 52-72.3% (Barutzki et al., 1984), 74-79.9% (Laux, 1987), 76.9% (Giannetto, 1995), 79.2% (Schicht-Tinbergen, 1995), 79.4% (Schütze, 1980). *Capillaria aerophila* infections had an incidence of 20.9% of hedgehogs, within the range of other studies but slightly lower than typical: 23.4% (Schicht-Tinbergen, 1995), 15.1-40.7% (Barutzki et al., 1984), 41.7% (Schütze, 1980), 47% (Laux, 1987).

Intestinal *Capillaria* species (e.g., *C. erinacei, C. ovoreticulata*) were found in 49.6% of animals tested. Again, the figure is within the range of published studies; in order of incidence: 12% (Timme, 1980), 30.7% (Giannetto, 1995), 48.8% (Epe et al., 1993), 55.8% (Schicht-Tinbergen, 1995), 56.4% (Schütze, 1980), 61.8% (Bauer & Stoye, 1984), 72.3-74% (Barutzki et al., 1984), 74% (Laubmeier, 1985), 79% (Boag & Fowler, 1988), 74% from faeces and 89.6% from autopsy (Laux, 1987).

The 16.4% incidence of *Brachylaemus erinacei* in the present study represents a moderate value within the very variable published range. In order of incidence: 0.2% (Timme, 1980), 0.3% (Löwenstein et al., 1991), 1.6% (Bauer & Stoye, 1984), 2.3% (Epe et al., 1993), 2.7% (Keymer et al., 1991), up to 4.8% (Barutzki et al., 1984), 24.4% overall but 1-80% depending on region (Schütze, 1980), 34.2% (Schicht-Tinbergen, 1995), 41% (Giannetto, 1995), 14.5% from faecal samples, but 53.4% from autopsy (Laux, 1987).

Other endoparasites included a 1.2% incidence of tapeworms (Cestodes), a rate comparable to the range of other studies: 0.5% (Barutzki et al., 1984), 0.7% (Schütze, 1980), 1.4% (Keymer et al., 1991), 2.6% (Boag & Fowler, 1988), 3.7% (Laubmeier, 1985), 4.3% (Löwenstein et al., 1991), 7.6% (Giannetto, 1995). Acanthocephala were rare at 1.6%, not far from the 2.9% reported by Löwenstein et al. (1991) but far below the very high figure of 69.2% given by Giannetto (1995). Coccidia were found 15.2% of animals tested. This figure fits very well with published results (in order of incidence): 1.4-12.9% (Barutzki et al., 1984), 2.5% (Giannetto, 1995), 10.5% (Laux, 1987), 11.3% (Schütze, 1980), 13.3% (Bauer & Stoye, 1984), 13.5% (Schicht-Tinbergen, 1995), 15% (Laubmeier, 1985), 17% (Epe et al., 1993), 21.6% (Löwenstein et al., 1991).

Overall the incidences of these endoparasites were similar to those reported in the literature, indicating that the hedgehog rescue centre samples were not unusually heavily parasitised, but it should be noted that the majority of animals used in the published studies were also casualties from rescue centres. Thus these figures cannot safely be generalised to the wild hedgehog population as a whole.

### 4.4. Recommendations

Casualty records of hedgehogs from wildlife rescue centres provided a large sample representing both sexes and all age groups throughout the year. Hence, despite the likely biases of such data, hedgehog rescue centre records can provide useful insights into the mortality factors affecting wild hedgehogs. We recommend that researchers and carers work together to develop a more standardised and somewhat more detailed scheme of casualty records for hedgehogs, but that the system should use a coding compatible with the current BWRC scheme. As it stands, the BWRC scheme imposes severe limitations on the possible analysis because fatalities and survivors are combined and each case is not individually coded. This makes it impossible to attribute certain causes of death to particular age or sex classes. The added value of such analyses is considerable and the hedgehog scheme should therefore use a case by case coding (as was used by the three participating hedgehog rescue centres). However, the BWRC scheme is comparatively simple to operate and there is likely to be a trade-off between the complexity of the scheme, the level of participation and the ability of participating centres to comply.

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Most sick or injured hedgehogs are found in built-up areas. This habitat confronts them with many human related dangers such as traffic. Photograph: Marcel Huijser.

*De meeste zieke of gewonde egels worden gevonden in de bebouwde kom. Deze omgeving brengt veel aan mensen gerelateerde gevaren met zich mee voor egels, waaronder het verkeer. Foto: Marcel Huijser.*


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SAMENVATTING

Sterftefactoren bij in het wild levende egels:
een studie aan de hand van gegevens van egelopvangcentra

Dit artikel beschrijft de belangrijkste doodsoorzaken van egels op basis van de gegevens (verzameld tussen 1992 en 1998) van verschillende opvangcentra om de aard van hun problemen bij binnenkomst in de centra te achterhalen. In totaal gaat het om de gegevens van 856 dode egels afkomstig van twee opvangcentra in Groot-Brittannië (Jersey en Yorkshire) en één in Nederland (Den Haag).

Daarnaast hadden we de beschikking over een data set van de British Wildlife Rehabilitation Council (BWRC) met de samengevatte kwartaalgegevens van nog eens 11.541 egels uit Groot-Brittannië (1993-1997).

Uit de BWRC gegevens bleek dat egels gemiddeld 54% van alle zoogdierslachtoffers uitmaakten (16% van de slachtoffers van alle taxa).Uit de totale jaarlijkse opnamen van de drie opvangcentra en de BWRC bleek dat significant meer mannelijke dan vrouwelijke dieren werden opgenomen (sex-ratio M:V = 1,2:1), maar vroeg in het seizoen was de afwijking nog sterker.

De gecombineerde gegevens van de drie opvangcentra gaven aan dat 59% van alle individuen een natuurlijke dood stierf, bv. ten gevolge van parasieten of infecties. De overige 41% van de sterftegevallen bleek toe te schrijven aan aan de mens gerelateerde (onnatuurlijke) activiteiten zoals verwonding door tuingereedschap, verkeer, verstoren van nesten met jongen (hetgeen leidt tot het in de steek laten van de jongen), verdrinken in water met steile oevers, beten van huisdieren en vergiftiging. De BWRC dataset, die ook betrekking had op egels die overleefden, liet een vergelijkbaar patroon zien, maar een relatief omvangrijke categorie met 'overige doodsoorzaken' (13%) maakte een gedetailleerde vergelijking niet mogelijk.

Er waren meer adulte mannelijke dan vrouwelijke egels die stierven aan de gevolgen van 'onnatuurlijke verwondingen' en 'verkeer'. Dit komt overeen met de verwachting dat mannetjes meer kans lopen om een ongeluk te krijgen doordat ze zich over veel grotere afstanden verplaatsen. De meeste dieren die een natuurlijke dood stierven deden dat in de tweede helft van het jaar, en dat waren dan vooral subadulten. De piek voor onnatuurlijke doodsoorzaken en verkeer lag enkele maanden eerder in het seizoen. Verder had 64% van de 498 onderzochte dieren endoparasitaire infecties. In tegenstelling tot het geslacht had de leeftijd een significant effect op het voorkomen van dit type infecties. Vooral subadulte dieren hadden een opvallend hoge aanwezigheid van endoparasieten.

Ondanks de afwijkingen die nu eenmaal eigen zijn aan steekproeven afkomstig van egelopvangcentra lijken de gevolgen van menselijk handelen, naast natuurlijke sterfte, een belangrijke factor te zijn. De zorg die tegenwoordig bestaat ten aanzien van de mogelijke nadelige effecten van menselijk handelen op egelpopulaties lijkt daarmee gerechtvaardigd.

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