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Short note

The effect of roads and traffic on hedgehog (*Erinaceus europaeus*) populations

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Abstract

We studied the effect of roads and traffic on hedgehog population density by comparing relative densities in 15 paired road and control plots matched for landscape parameters. Relative hedgehog density was determined by means of footprints in specially designed tunnels. The relative density was closely correlated with the total number of individual hedgehogs that were caught in traps in five of the plots immediately after the tunnels were removed. A power analysis indicated that, with the resources available, we could only detect an effect greater than 35%. We were unable to demonstrate a significant effect, i.e. hedgehog density in areas adjacent to roads is not reduced by more than 35%. However, we did find about 30% fewer tracks in road plots when compared to control plots and the *P*-values were marginally insignificant at the $P \leqslant 0.05$ significance level. These results suggest that roads and traffic are likely to reduce hedgehog density by about 30%, which may affect the survival probability of local populations.

Keywords: Erinaceus europaeus; Footprints; Hedgehog; Relative density; Traffic mortality

1. Introduction

The hedgehog (*Erinaceus europaeus* L.) is a common species in The Netherlands and it occurs throughout the country (Hoekstra, 1992; Thissen and Hollander, 1996). Hedgehogs are also frequently reported as traffic victims (see reviews in Reeve, 1994 and Huijser et al., 1998). Huijser and Bergers (1998) estimated that between 113,000 and 340,000 hedgehogs may fall victim to traffic in The Netherlands each year. These numbers may simply reflect the presence of thriving populations, but there is some debate on whether or not local populations are at risk of extinction because of traffic mortality (e.g. Reichholf, 1983; Kristiansson, 1990; Mulder, 1996; Bergers and Nieuwenhuizen, 1999). Other studies have shown that traffic and the proximity of roads can reduce the survival probability or density of populations of several species including amphibians (Fahrig et al., 1995; Vos and Chardon, 1998), reptiles (Fowle, 1996; Rudolph et al., 1998), birds (Van der Zande et al., 1980; De Bruijn, 1994; Reijnen et al., 1995, 1996) and mammals (Rost and Bailey, 1979; Lyon, 1983; Mech et al., 1988; Lankester et al., 1991; Maehr et al., 1991).

The effects of roads and traffic on animal populations are not restricted to traffic mortality alone. Direct habitat loss and factors related to roads and traffic that may affect habitat quality or animal movements can reduce survival probability or population density too. Isolation, traffic noise, visual stimuli (e.g. lights), pollution (e.g. salt, heavy metals, nitrogen-containing compounds, herbicides), management activities in the roadside verges, increased human access, and erosion and sedimentation (especially in uneven terrain) are generally considered to have the greatest effect on habitat quality (e.g. Forman et al., 1997; Forman and Alexander, 1998; Huijser et al., 1999). The 'effect zone' of these factors is not restricted to the actual road and road-side verges. Depending on the factor concerned, the affected area may be a few metres up to several kilometres wide (Forman et al., 1997).

We aimed to investigate whether the presence of roads and traffic affects hedgehog population density, but we

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had no prior knowledge of the extent of a possible effect. Fortunately we did have access to data that provided us with estimates of the expected statistical properties of the response variable. Since the power of a given test depends on sample size, and since our sample size was fixed due to limited resources, we conducted a power analysis (Sokal and Rohlf, 1995; Steidl et al., 1997) before starting the study. The power analysis gave us an estimate of the effect we should still be able to detect given our sample size (for details see methods). This then led to the null hypothesis that the effect of roads and traffic on hedgehog population density is absent or smaller than 35%, whereas our alternative hypothesis was that the effect is greater than or equal to 35%.

2. Methods

2.1. General study design

The field work was carried out between May and September 1996 on 15 locations in the provinces of Gelderland and Overijssel, The Netherlands. On each location a paired comparison was made of relative hedgehog densities in areas adjacent to roads (road plots) and areas that, because of their distance from roads, were expected to suffer little or no traffic mortality (control plots) (see also Reijnen and Foppen, 1994; Nieuwenhuizen and Van Apeldoorn, 1995).

The landscape of the study sites was dominated by small scale grasslands and arable land, separated by hedgerows (usually with mature trees) and woodland fragments. In this landscape, hedgehogs have a relatively high population density (Huijser, 1999) while road density is low enough to allow for suitable control plots. To ensure valid paired comparisons, road and control plots were checked for similarity in landscape parameters (see analysis).

The roads adjacent to the road plots were characterized by relatively high traffic volumes between dusk and dawn when hedgehogs are most active. During the quietest hours, traffic intensity averaged 15–20 vehicles per hour. Over a 24 h period the average intensity was 7118 (SD = 2023) vehicles.

The road plots were located on one side of a road and were selected to ensure that there were no barriers (e.g. open water, fences, steep slopes, ribbon-development) between the roads and the road plots or on the other side of the road. The hedgerows and woodland fragments generally continued right up to the road.

2.2. Plot dimensions

The road and control plots had an elongated shape of fixed width and each pair of plots was equal in shape and size; minimum 1000×200 m (20 ha), but most of them were 1500 m in length (30 ha). The width of the plots and the minimum distance from a control plot to a paved road was based on the home range size of hedgehogs. Males have larger home ranges (32–47 ha) than females (10–20 ha) (Reeve, 1982; Kristiansson, 1984). Plot width was based on the animals that have the smallest home ranges (10 ha). Assuming a circular home range (which is not unreasonable, see Reeve, 1994), a radius of 180 m was calculated. Thus all animals with a home range centred within a road plot were potential traffic victims.

The distance between the road and control plots was determined by the animals with the largest home ranges (47 ha, diameter 775 m). Owing to high road densities in The Netherlands (Huijser, 1999), a distance of at least 800 m from a paved road was hard to obtain. Therefore, we settled for a minimum distance of 400 m. Thus, the animals that had the centre of their home range within a control plot were, at least theoretically, not at risk of becoming a traffic victim. Nevertheless we chose a distance of at least 800 m whenever possible.

In small scale agricultural landscapes one would expect to find a density of ± 30 hedgehogs per 100 ha (Huijser, 1999). Thus, in a 20 ha plot (minimum size) six hedgehogs could be expected.

2.3. Footprints and footprint tunnels

Relative hedgehog densities were determined through the presence or absence of their footprints in tunnels. We designed footprint tunnels that were light and easy to transport. A plastic board (50×20 cm) served as a base with two holes drilled half-way along the two longest sides at about 1 cm from the edge. Two tent-pegs stuck through these holes secured the tunnel to the ground and held a corrugated PVC roof in its place.

White paper (80 g/m^2) was attached to the plastic board. Then a 12 cm wide strip of the paper was smeared with a mixture of paraffine oil and carbon black on both sides of the tunnel (see also Lord et al., 1970; King and Edgar, 1977; Van Apeldoorn et al., 1993; Ratz, 1997; Brandjes et al., 1998). When a hedgehog entered a tunnel black footprints were left on the white paper in the middle of the tunnel. Tunnels were baited with canned dog food (beef: Saturn Petfood).

2.4. Density, location and checking of footprint tunnels

The number of footprint tunnels was set at 15 per km plot length (0.75 tunnels per ha). The tunnels were distributed throughout the plots according to a grid. However, the grid locations were not always acceptable for practical reasons. Open grasslands and arable land had to be avoided because of disturbance (cattle, people) and farming activities (mowing, etc.). In these situations the tunnels were located on the edge of a field, behind barbed wire, or along or in a ditch. Since we conducted the study in a small scale landscape the tunnels were often located along a hedgerow or a forest's edge.

We sampled each plot pair simultaneously. The tunnels were usually left in the plots for three consecutive nights. However, we settled for two nights when at least five different tunnels (road and control plot combined) had been visited by hedgehogs during the first two nights. The tunnels were checked for footprints and provided with fresh bait every day.

2.5. Analysis

An important assumption of our study design is similarity in landscape of road and control plots within a pair. We updated topographical maps in the field and then measured a number of landscape parameters in both the road and control plots (Table 1). Differences in landscape between road and control plots were not significant ($P>0.05$). However, we did find relatively low P-values for hedgerows ($P=0.06$) and forest edge ($P=0.09$). Both hedgerows and forest edge are characterized by a transition from cover to open habitat and these edges are positively selected by hedgehogs (Huijser, 1999). Thus the greater length of hedgerows in road plots may have been (partially) compensated for by more forest edge in control plots.

A second assumption is that the number of tunnels in which hedgehog footprints were present reflects the actual population size (see also Stander, 1998). We checked this by capturing hedgehogs in five plots (32 ha each) during two consecutive nights, immediately after the footprint tunnels were removed. We used wooden cages that were located on the exact same spot as the footprint tunnels. The traps were also baited with dog food. The hedgehogs were individually marked by attaching coloured plastic tubes on 10 adjacent spines. We analyzed the relationship between the presence of hedgehog footprints and the number of captured hedgehogs in two ways. The 'total' analysis was based on the sum of the total number of tunnels visited by hedgehogs during two or three consecutive nights. The 'different' analysis dealt with the total number of different tunnels that were visited in this period. Thus in the 'different' analysis a particular tunnel had a maximum score of 1 whereas the 'total' analysis allowed for a maximum score of 2 or 3, depending on the length of the sampling period. For both analyses the number of tunnels with hedgehog footprints was significantly correlated with the number of individual hedgehogs that were captured in the same plot (Spearman rank correlation; 'total': $r_s=0.90$, $P=0.02$, $n=5$; 'different': $r_s=0.80$, $P=0.05$, $n=5$).

We used a t-test to analyze the difference between road and control plots. As before we did this in two ways; the previously described 'total' and 'different' analyses. The number of tunnels in which hedgehog footprints were present was standardized to numbers per 30 ha (x) for all plots (i). Since x was zero in some cases, a small value was added before we transformed these numbers to a logarithmic scale ($\ln(x+0.03)$; 0.03 was the lowest value that occurred for $x/30$). We then calculated the difference between all paired road (R_i) and control (C_i) plots ($\ln(R_i)-\ln(C_i)$) and tested whether these values differed from zero (t-test, one-tailed). A t-test was appropriate since the difference ($\ln(R_i)-\ln(C_i)$) was distributed normally for both the 'total' and 'different' analysis (Kolmogorov-Smirnov; 'total': $P=0.63$; 'different': $P=0.43$).

We conducted a power analysis to indicate the size of the detectable effect with a sample size of 15 plot pairs (t-test, Jansen, 1991). Data from a capture-mark-recapture study of ours in a similar landscape showed a mean of 2.9 (SD = 0.9) hedgehogs captured per 20 ha (Huijser et al., unpublished data). Given a significance level (α) of 0.05 (one-tailed test) and a power (π) of 90% we could only expect to detect differences of 35% or more.

Table 1
Comparison of landscape parameters in road and control plots (Wilcoxon matched-pairs signed-ranks, two-tailed test)

	Road plots		Control plots			
Landscape parameter	Mean[a]	S.D.[a]	Mean[a]	S.D.[a]	P	n[b]
Agriculture (ha)	13.36	(2.90)	14.98	(3.69)	0.13	15
Forest (ha)	7.04	(4.16)	7.26	(2.70)	0.65	15
Heathland (ha)	0.45	(1.76)	0.02	(0.09)	0.32	1
Farm buildings (ha)	0.47	(0.45)	0.31	(0.34)	0.20	15
Hedgerow (km)	1.39	(0.78)	1.06	(0.50)	0.06	15
Forest edge (km)	0.97	(0.47)	1.18	(0.40)	0.09	15

[a] Means and standard deviations were based on 30 ha plot sizes.
[b] n = number of study areas in which the landscape parameter occurred.

3. Results

The median of the number of footprint tunnels visited by hedgehogs in road plots was lower than in the control plots (Fig. 1). Furthermore, the sum of the number of footprint tunnels visited by hedgehogs in all road plots ('total': $n=31$; 'different': $n=22$) was 32.6 and 31.3% lower than in the control plots ('total': $n=46$; 'different': $n=32$). However, the effects were not significant ($P>0.05$): 'total': $P=0.076$; 'different': $P=0.077$ (t-test, one tailed).

4. Discussion

The power analysis indicated that we would only be able to detect an effect greater than 35%. Since we were unable to demonstrate a significant effect, we conclude that hedgehog density in areas adjacent to roads is not

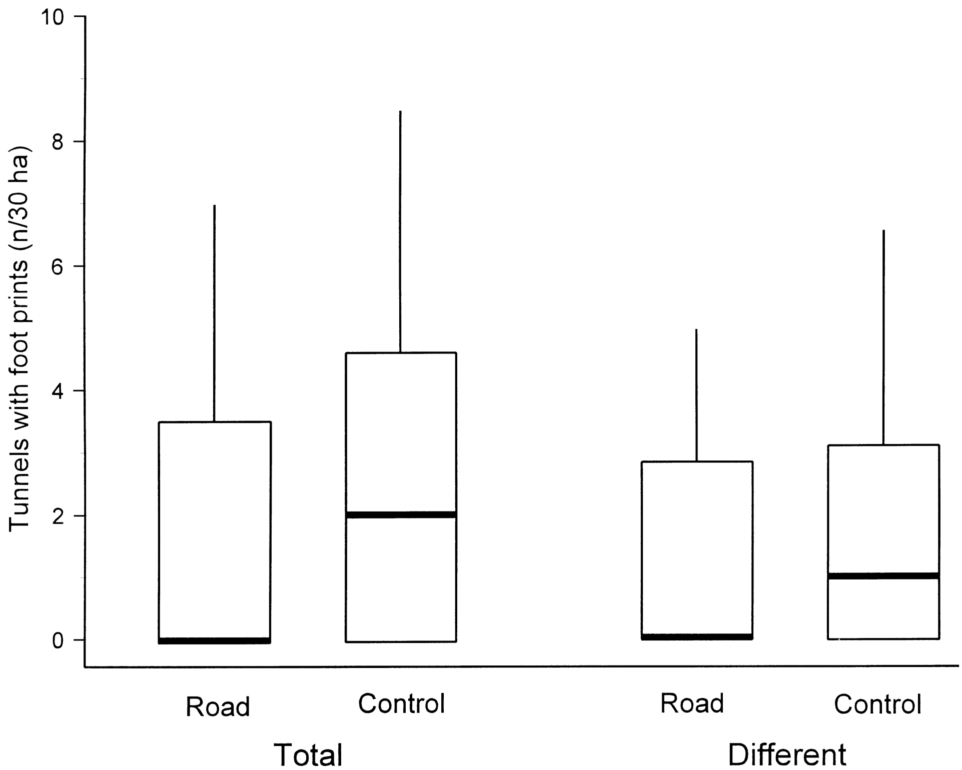

Fig. 1. The number of footprint tunnels visited by hedgehogs in road and control plots (standardized to 30 ha plot sizes). 'Total' = total number of tunnels visited during two or three sampling nights; 'Different' = number of different tunnels visited during two or three sampling nights. The boxes represent the inter-quartile range and the median is indicated by the bold horizontal line. The vertical lines at the top of the boxes extend to the largest value within 1.5 times the interquartile range (Sokal and Rohlf, 1995). In this particular case the vertical lines all reach the maximum value of the variables concerned.

reduced by more than 35%. However, we did find about 30% fewer hedgehog tracks in road plots when compared to control plots and the *P*-values were close to reaching the $P \leqslant 0.05$ significance level ('total': $P = 0.076$; 'different': $P = 0.077$). These results suggest that roads and traffic are likely to affect hedgehog density by ±30%.

Although this study was designed to detect a possible effect of traffic mortality, it is important to be aware of the fact that an effect could have been obscured by proximity of some of the control plots to the road (<800 m) and that traffic mortality could not be isolated from other road-related factors (e.g. those that affect habitat quality). Thus, a reduction in population density is not necessarily caused by traffic mortality alone. Another issue to take into account is that an effect on population density may be hidden when there is a high-overall population size (Van Horne, 1983). In years with many individuals, low quality habitats that are close to roads may also be fully occupied, and the effect of roads and traffic may be seriously underestimated (e.g. Reijnen and Foppen, 1995). However, based on the knowledge we have on the relationship between the presence of footprints in tunnels and absolute population density (Huijser et al., unpublished data) we do not think the median population density in the plots was high for the habitat concerned: seven ('total') or eight ('different') hedgehogs per 100 ha (for comparison see review in Huijser, 1999). Finally, a reduction in hedgehog density due to roads and traffic may not remain constant over the years. We are looking at a snapshot in time and road density and traffic intensity still are very much on the increase in The Netherlands (Huijser, 1999).

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