THE SURVIVAL AND WELFARE OF HEDGEHOGS (*ERINACEUS EUROPAEUS*) AFTER RELEASE BACK INTO THE WILD

N J Reeve

School of Life Sciences, Roehampton Institute London, West Hill, London SW15 3SN, UK

Final acceptance: 3 April 1997

Abstract *Animal Welfare 1998, 7*: 189-202

The fate of rescued hedgehogs (Erinaceus europaeus) *released back to the wild has now been the subject of several follow-up studies. Although subject to various hazards, released hedgehogs have clearly shown essential 'life-skills'. However, all previous studies have involved releases into hedgehog-rich areas and the observed long-range (≥500m) dispersal movements shown by some subjects, of up to 5km, may be a consequence of local intraspecific competition. This study has reduced a number of potentially confounding subject variables and provides follow-up data on 12 age-matched female hedgehogs with similar histories. A main group (n = 10) was released into a rural woodland area (Surrey, UK) of low natural hedgehog density, and radio-tracked for up to 108 days. A pilot release of two animals in an urban area with an established hedgehog population also took place (tracked for 109 and 131 days respectively). Most of the main group dispersed (up to 3km) from the release site; the two animals in the urban site did not. These data, taken with those from previous studies, suggest that dispersal is not specifically the result of intraspecific competition. Overall survival at week 8 was 42 per cent (5 hedgehogs) plus two lost animals. This is comparable with previous studies. However, survival fell to 25 per cent (3 animals) plus two lost animals by week 15. Of seven recorded deaths, only one was the result of a failure to thrive and all other mortalities were accidental: four road deaths, one drowned in a pond and one predation. The study concludes that the hazards of the human environment were the principal threat to the welfare and survival of released hedgehogs in the area.*

Keywords: *animal welfare,* Erinaceus europaeus, *hedgehog, rehabilitation, survival*

Introduction

Hedgehogs are one of commonest mammals brought to British wildlife hospitals. Many of these hedgehogs are ill or injured. However, in the autumn a large number of juveniles which are either presumed to be orphans, or are judged to be below the minimum weight widely believed to be necessary for winter survival (about 450g in the UK [Morris 1984]) are encountered. These 'autumn orphans' commonly present with lungworm infestations (*Capillaria* and *Crenosoma*) and a variety of other health problems (Stocker 1987; Reeve 1994; Sykes & Durrant 1995). Nevertheless, many are in good overall health and require little more than food and shelter over the winter months before being released back into the

wild. The fate of such animals after release has recently become an important topic of investigation, as discussed below, but wildlife aid organizations require further empirical data if release and rehabilitation programmes are to be properly evaluated.

There have now been several studies of captive released hedgehogs (Table 1), each with somewhat differing aims: Morris *et al* (1992, 1993); Morris and Warwick (1994); and Morris and Sharafi (1996). In addition, there have been release studies aimed at obtaining details on movement patterns and habitat use using a combination of radio-tracking and spool and line tracking in Lower Moss Wood, Cheshire during 1994-1995 (Gillian Key personal communication 1995).

Table 1 Summary details of some previous hedgehog release studies.

Authors	No (sex ratio)	Study duration (days)	Year	Study area
Morris, Munn & Craig-Wood (1991, 1992)	4 (2m,2f)	13	1989	Yorkshire. Rural, mixed deciduous woodland
Morris, Meakin & Sharafi (1993)	8 (3m,5f)	57[1]	1991	Suffolk. Rural, pasture & arable farmland
Morris & Warwick (1994)	12 (6m,6f)[2]	63	1993	Devon. Rural, hilly pastureland
Morris & Sharafi (1996)	13 (6m,7f)	46	1995	Jersey. Semi-urban, hilly gardens & farmland
Reeve (present study)	12 (12f)[3]	131[4]	1995	Surrey. Deciduous woodland, mixed farmland, semi-urban & urban areas

[1] Time includes a 27 day break in observations after the first 3 weeks
[2] Two release protocols
[3] All females, 10 in main study plus 2 released in an urban area
[4] Main study period ended after 108 days - when final subject shed transmitter

Many constraints have limited these follow-up studies (and the present study), including:

i) sample size being restricted by the number of transmitters that can be used together in the same area, (bandwidth limitations can cause transmitters to interfere with each other and/or be hard to distinguish on the tuning dial of the receiver);
ii) the difficulties of conducting time-consuming field checks on each hedgehog at night – especially when animals have dispersed widely or are well-concealed amongst buildings and gardens where access is limited;
iii) the long follow-up period;
iv) the costs of radio-tracking equipment, personnel and field expenses.

Such restrictions have limited the development of more rigorous field experiments. Additionally, many of the above studies have involved rather miscellaneous sample groups unevenly matched for factors such as age, sex, state of health on release, previous history and style of release.

Despite such problems, the previous studies have shown some consistent features. The released hedgehogs were typically found to be able to forage and feed on natural prey, to orientate, to make suitable day nests and to re-find former nest-sites which were used in much the same way as previously described for wild hedgehogs (Reeve 1982; Reeve & Morris 1985). The first day nest was often not used again, as was found for six of the 12 animals released by Morris and Warwick (1994), maybe because it was a poor site, poorly constructed or the hedgehog failed to find it. Observed interactions with resident hedgehogs included courtships (both sexes) but no aggressive encounters. Despite these generally positive indications, the released hedgehogs were subject to a variety of hazards and their longer-term survival rate has been low. Although 75 per cent of the eight animals released by Morris *et al* (1993) were alive at 5 weeks, by 8 weeks they could confirm only one survivor (12.5%), with four others unaccounted for. For the 12 animals released by Morris and Warwick (1994) there was an 8-week survival rate of 33 per cent, with two others unaccounted for. Confounding variables included two different release protocols, and an uneven sex ratio within the release groups. Furthermore, there was apparently no attempt to control for health-related factors such as levels of endoparasite infestation (Sainsbury *et al* 1996). Morris and Sharafi (1996) reported the highest survival rates yet from the predator-free and low traffic density environment of Jersey. They released 13 animals , all of which survived at least 4 weeks, with a minimum of 10 animals (77 per cent) surviving 6 weeks. None of the missing animals were known to have died.

There are no published data regarding summer survival rates in the wild for young adult hedgehogs in the UK, but with one exception (Morris and Sharafi 1996) all release studies have shown mortality rates over a period of a few weeks to be higher than reported annual mortality rates in the wild (an estimated adult mortality of 30% per year in Morris [1991]). Better data are available from an 8-year study in southern Sweden (Kristiansson 1990) that found a mean mortality rate of 47 per cent per year for adults and young non-breeding adults – although much of this could be accounted for by the mean winter mortality rate of 33 per cent for this age group. Such figures are comparable to estimates of 20-40 per cent adult winter mortality in southern Germany in studies cited by Hoeck (1987).

Most studies have observed a tendency for some animals to make sudden dispersal movements. It has been suggested that males, whose home ranges are typically three times the size of females' (Reeve 1994), are more likely to be the emigrants. What constitutes a dispersal movement is not precisely definable, but a linear movement of 500m would exceed the typical radius of a breeding male's home range (see Reeve 1994 for a review of home range studies). Morris *et al* (1993) reported unexpectedly long dispersals of up to 4km in four animals (three of which were male). Morris and Sharafi (1996) found all three individuals that left the study area were male; two remained within 1km of the release site, but one was eventually found 5.2km away. However, Morris and Warwick (1994) reported an emigration of 2km by one female and two others of $\geq$ 500m. Meaningful statistical analysis of potential factors associated with dispersal, including possible sex differences, has been prevented by the high individual variances and heterogeneous group composition in previous studies. There are many possible explanations for these dispersal movements (see, *Discussion*). However, in all previous studies the releases took place in areas with a thriving resident hedgehog population. One possibility is that the observed dispersal of certain animals from release areas is a result of intraspecific competition.

Study Aims

The principal aim was to obtain data on the fates of hedgehogs released into an area of low natural hedgehog density (low intraspecific competition) to provide a comparison with other studies. In order to reduce the number of potentially confounding variables affecting behaviour and survival, the subjects were matched as closely as possible for gender, age and condition (see, *Methods*).

Methods

All anaesthetic, diagnostic and drug administration procedures were conducted by a veterinary surgeon, or by trained staff under the supervision of a veterinary surgeon, at Wildlife Aid, Surrey.

Pre-release matching of subject variables

The present study could not escape the constraints affecting sample size discussed above and it was felt that the author's ability to properly monitor released animals should not be over-stretched. However, some potentially confounding variation in the release group was reduced by ensuring that all animals were of the same approximate age and sex (all autumn 1994 youngsters and all previously uninjured females). Females were chosen because they have been shown to be less wide ranging than males under natural conditions (Reeve 1982) and were considered more likely to remain within the study area.

Six of the 12 subjects (numbers 1-6) were supplied by Wildlife Aid (Leatherhead, Surrey), while numbers 7-12 came from Hedgehog Care (nr Louth, Lincolnshire). The difference in origin was considered unlikely to affect their post-release behaviour because all the hedgehogs were taken into care when juvenile and therefore had little previous experience of life in the wild.

The release weights of hedgehogs from the two wildlife hospitals were not significantly different (t = 0.33, two-tailed P = 0.75). The Lincolnshire group (mean weight 1001.66 ± 258.97 g) showed a rather greater coefficient of variation (25.8%) than the Surrey group (mean weight 1044.83 ± 17.98 g, coefficient of variation = 17.9%). There was no significant difference in variance between the two groups ($F_{5,5}$ = 1.9, P = 0.50). To reduce the variance in the weight of the main release group, the heaviest animal (number 11, weighing 1440g) was excluded – as was number 12 (weighing 850g) which was observed to have a slight limp. The 10 animals released in Nower Wood had a mean weight of 998.9 ± 184.89 g, coefficient of variation = 18.51%.

In a further attempt to improve matching between subjects and to reduce the factors that could adversely affect the health of the hedgehogs following release, all animals were treated with the antiparasitic drug ivermectin (Ivomec®, Merial Animal Health, Essex, UK) at a dose rate of 200 $\mu g\ kg^{-1}$, administered by subcutaneous injection with one repeat dose after 10 days. A few days before release, faecal samples were examined microscopically for signs of helminth endoparasite eggs and larvae – both by direct examination of faecal smears and after extraction by flotation (under centrifugation at 900 rpm for 3min) in a saturated solution of sodium chloride. Extractions of faeces from the animals' cages typically showed no sign of helminth adults, larvae or eggs, but six *Capillaria aerophila* eggs (a very low count) were found in a bulk sample of three droppings from the Lincolnshire group. The delay associated with any further treatment would have precluded the study and even then could not have

assured helminth-free subjects. Negative faecal samples, the only practical in vivo method of establishing freedom from infestation, may miss up to third of histologically confirmed *Capillaria* infestations – so cannot guarantee complete freedom (Majeed *et al* 1989). It was therefore decided that all reasonable precautions had been taken to ensure that the hedgehogs would not be clinically affected by pre-existing infestations of helminth endoparasites after release and the animals were released on schedule.

Oocysts of coccidia (*Isospora rastegaivae*) were detected in moderate numbers in faecal sample extracts (obtained by flotation) from the Surrey group, and occasional single oocysts in the Lincolnshire group. Infestation with coccidia is common and usually asymptomatic in hedgehogs (Saupe & Poduschka 1985) but, as a precaution against any possible effects on post-release welfare, each animal was given a single subcutaneous injection of 0.2ml trimethoprim sulphadiazine (Tribrissen® 24%, Schering Plough Animal Health Ltd, Middlesex, UK). Only isolated oocysts were found in faecal samples obtained the day before release.

Pre-release physical examination and transmitter attachment

On 6 June 1995 all subjects were given a general physical examination under gaseous anaesthesia using Halothane RM™ (Merial Animal Health Ltd, Essex, UK) delivered in an oxygen and nitrous oxide mixture via a face mask. Anaesthesia was induced using 4 per cent Halothane and maintained according to effect using 1-2 per cent Halothane RM™. The animals appeared to be in good physical condition and no fleas or ticks were found. A radio transmitter was glued to the dorsal spines over the shoulders using epoxy resin (setting time 10min) as described in Reeve (1982).

No obvious cause for number 12's limp was found and, as both this animal and number 11 appeared to be in generally good health, they were released in the author's garden in an urban area (Byfleet, Surrey) with a resident hedgehog population and provided an *ad hoc* pilot for future urban releases. Data from these animals are not included in the main analyses but as both survived to the end of the study they have provided useful additional information.

Release protocol and study sites

Releases took place in Nower Wood (51°16'48''N, 0°17'6''W) on 7 June 1995 and in Byfleet (51°20'39''N, 0°28'12''W) on 8 June 1995. On the basis of Morris and Warwick's (1994) reports that supplementary food and shelter remained unused after release, there was no attempt at a carefully staged 'soft release' and food was not provided.

Nower Wood is an ancient deciduous woodland nature reserve of about 0.33km^2 (owned and managed by the Surrey Wildlife Trust) about 1km south of the M25 motorway and about 1.5km east-south-east from the outskirts of Leatherhead. Nower Wood is flanked on the west side by a golf course, rough grassland and arable farms. Grazing pasture and woodland lie to the south and east and low density housing and mixed farmland (the areas of Tyrrell's Wood and Headley village) extend in an arc from the north-west to the east of the wood. Reports from Surrey Wildlife Trust staff at Nower Wood and local inhabitants indicated that hedgehogs were either absent or very rare in the area, despite the apparent suitability of available habitat. A systematic survey of hedgehogs in the area, for which resources were not available, would have been necessary to confirm the reported absence of hedgehogs. Nevertheless, the reports of absence were supported by the fact that no wild hedgehogs were

seen in the vicinity of Nower Wood throughout the study, despite intensive nocturnal searching. Because badgers (*Meles meles)* are predators of hedgehogs (Doncaster 1992; Morris and Warwick 1994) the location of badger setts and records of badger activity in the area were obtained from the Surrey Wildlife Trust. There were no actively used setts in the wood or north of the road (Mill Way) on the southern boundary of the study area. There were three active setts within a 1km radius of the release point, all south of the road. Although badgers were occasionally seen in the study area, activity north of the road was very limited and unlikely to pose a major threat to released hedgehogs. Apart from the M25, there are no major roads in the immediate vicinity. However, the A24 Leatherhead bypass (about 1.5km to the west at its nearest) is an extremely busy road linking the M25 to Dorking and the South.

Byfleet (Surrey) is an urban area of busy roads, industrial and retail developments, fairly dense suburban housing and gardens with nearby or adjoining areas of waste ground and copses. Hedgehogs were commonly seen in the gardens where the releases took place. Foxes (*Vulpes vulpes*), occasional predators of hedgehogs, were also a common sight but no badgers have been recorded in the area (personal communication Dave Williams 1997) or were seen by the author during the present study.

Radio-tracking equipment

The transmitter package (Biotrack Ltd, Wareham, Dorset, UK) weighed between 7 and 8 g, with a 20cm flexible whip aerial and a lithium battery with a predicted life in excess of 6 months. Transmitter frequencies ranged from 173.214 to 173.339 MHz . This gave adequate separation of tuning positions using a Mariner 57 receiver with a 3-element hand-held Yagi (both rigid and collapsible types) and a vehicle-mounted whip (Mariner Radar Ltd, Lowestoft, Suffolk, UK).

Results

Movements

A major feature of the results was a very high level of dispersal from the Nower Wood study site. The first dispersal from the wood occurred on day 5 (number 10) and another three animals (numbers 2, 3 and 4) dispersed on day 6; number 3 was never relocated and number 4 was not relocated until day 33, when she was discovered 2.7km from her former position. Other examples of movement included number 1 which moved over 1km between day 9 and day 17, and number 7 which (having remained close to the release point) suddenly vanished on day 12 to be re-found 2.8km away on day 33.

Two animals emigrated in two phases. Number 5 moved out of Nower Wood to gardens in Tyrrell's Wood on day 17 and remained there (about 760m from the release point) until day 31 when she suddenly moved to the outskirts of Leatherhead, over 2km from the release site. Number 10 first moved about 600m east to a cottage garden in Headley on day 5 but then disappeared on day 17, only to be found the next day on the outskirts of Leatherhead almost 2.6km to the west.

By day 33, when most emigrants had been re-found, three animals (numbers 2,6 and 8) were dead and contact had been lost with a further two (numbers 3 and 9). Of the remainder, the nearest animal was almost 1.5km from the release site. Figure 1 shows the change in mean distance from the release site during the course of the study. In all cases, hedgehogs

moved to areas of human habitation ie private gardens, school grounds and other such places (see, *Discussion*). Intriguingly, neither of the Byfleet animals undertook such dispersal movements. Number 12 was recovered on day 12 for veterinary treatment and was re-released on day 54. By the end of the study neither female had been found more than 400m from the release point.

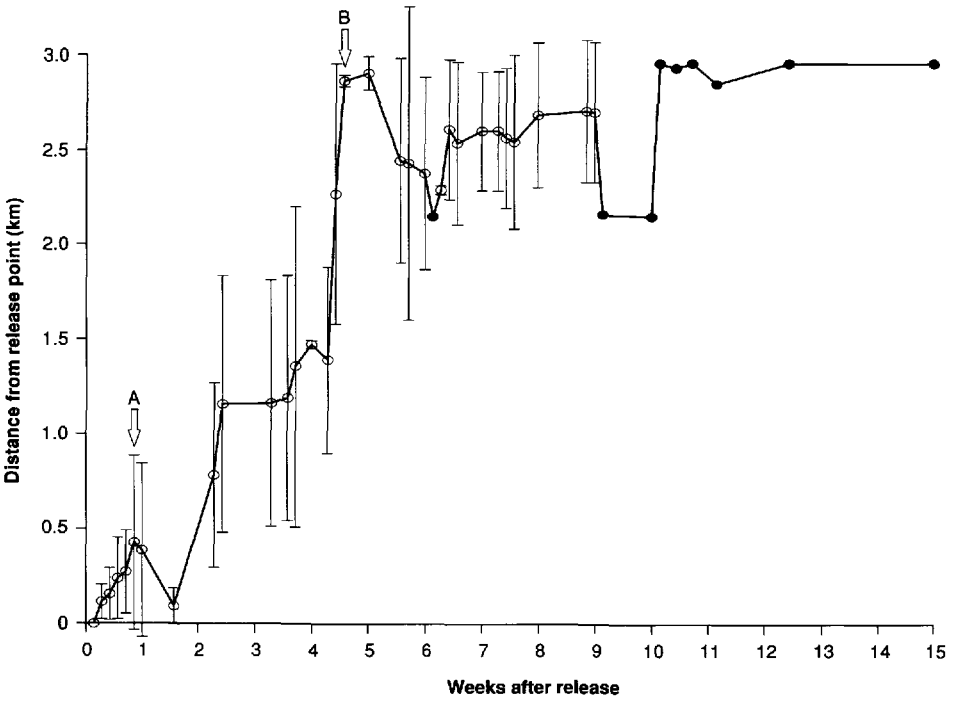

Figure 1 **The change in mean distance (km) of female hedgehogs from the release point over time (Nower Wood release group, n = 10). Error bars show ± 1 standard deviation. Filled points indicate that a value is for a single individual. (At time A, the first three long range dispersals (numbers 2, 3, 4) occurred; by time B, most emigrants had been re-found, with the nearest animal 1476m from the release point).**

Body weight changes

The difficulties experienced in keeping track of the released hedgehogs and the access problems created by their movement onto private land meant that the animals were weighed less often than planned. Nevertheless, for the eight animals for which there are sufficient data, there is a clear pattern of initial and dramatic weight loss for the first 3-5 weeks, followed by a period of recovery (shown by four subjects) and with one animal (number 7) reaching 113 per cent of her release weight by the end of August (Figure 2). Number 1 showed the greatest proportional weight loss, dropping to 60 per cent of her release weight after 5 weeks. However, she was particularly heavy (1214g) when released, as was number 8 who showed a similar trend before her accidental death. Minimum weights for other animals ranged between 71.6 per cent and 84 per cent of release weight.

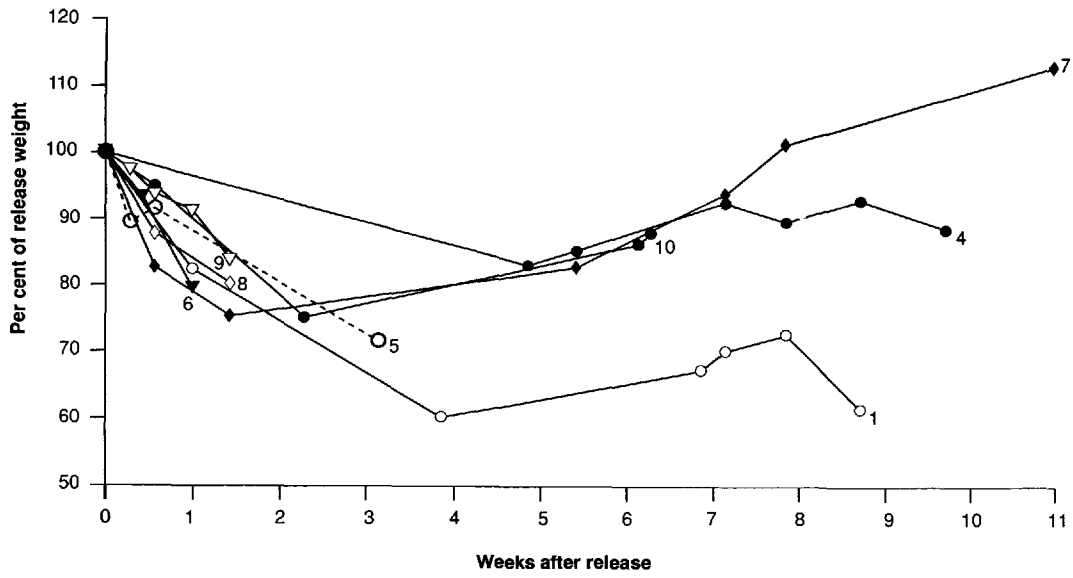

Figure 2 **The relative weight change (expressed as % of release weight) of female hedgehogs (n = 8) following release into Nower Wood; animals are denoted by different symbols with their identifying numbers at the end of their respective lines. Numbers 2 and 3 have been omitted because of insufficient data.**

Survival and welfare

The released animals suffered a variety of mishaps. Only three hedgehogs (one from the Nower wood group and both the Byfleet animals) definitely survived in the wild until the end of the main study at 108 days, although the fates of two animals remained unknown. Table 2 shows a summary of the fates of the released hedgehogs and the survival rate at various times during the study.

Only one animal (number 6) was unable to cope with life in the wild; her weight loss was not unusual but she never moved further than 76m from the release point and became lethargic, remaining in her nest even by night. She was dug out of her nest on the evening of day 9 and found to be weak and dehydrated. Despite treatment she died the next day. A post-mortem (Vetlab Services, Horsham, West Sussex, UK) revealed clear signs of bacterial pneumonia and pericarditis and a culture of purulent pleural fluid showed heavy growths of *Pasteurella multocida* and *Bacteroides levii*. Road traffic accidents were the certain cause of death of two animals, and the probable cause of death of number 8 which was found dead within Nower Wood with a smashed snout (although other accidental causes of death are possible). The jaw of number 4 was broken in a road accident but she was rescued and subsequently recovered at Wildlife Aid. Nevertheless, this incident was counted among the 'deaths' of the study as she could not have survived in the wild without intervention. Overall, four of the deaths could be attributed to road traffic - a high proportion of the total mortality. One animal (number 2) was predated, apparently by a badger, shortly after moving to Headley Heath (just under 1.5km away). Number 1 drowned in a steep-sided garden pond; this animal had previously been rescued from a 1.5m deep concrete shaft.

Table 2 **Summary of the fates of 12 female hedgehogs released at Nower Wood (numbers 1-10) or Byfleet (numbers 11 and 12) at various intervals after release. Survival rate figures assume all losses are deaths, unless otherwise indicated. (A = Alive, D = Dead, I = Injured, L = Lost.)**

Animal No	2 weeks	4 weeks	8 weeks	15½ weeks	Notes
1	A	A	A	D	Drowned in garden pond (day 71)
2	A	A	D	-	Predated by badger (est day 29)
3	L	L	L	L	Unknown (emigrated from site day 8)
4	A	A	A	I	Broken jaw - road accident (day 68)
5	A	A	D	-	Road accident? (about day 40)
6	D	-	-	-	Died of pneumonia (day 11)
7	A	A	A	A	Transmitter found detached (day 108)
8	A	D	-	-	Road accident? Dead in woods (day 18)
9	A	A	L	L	Transmitter found detached (day 29)
10	A	A	D	-	Road kill (day 54). Was pregnant
11	A	A	A	A	Transmitter found detached (day 109)
12	A	I	A	A	Bad shoulder treated. Was pregnant. Survived until study ended (day 131)
Survival rate	83%	75%	42%	25%	Survival rate of 42% at 15½ weeks if the two lost animals survived

Despite an initial period of weight loss, the animals seemed to be able to maintain themselves adequately in the wild, build nests and forage for wild prey. If number 4's broken jaw is counted as a death, then six of the seven recorded deaths were accidental in nature rather than failures to thrive.

Number 12, released at Byfleet with a slight limp, was closely monitored and found lying partially exposed amongst a pile of broken fence panels on day 11, having not made a proper day nest. As her limp had become more pronounced (trauma was diagnosed), she was taken back into captivity on day 11 to allow her forelimb to rest. She fed well and seemed fit but the limp persisted. On day 43 she unexpectedly bore a litter of five (which were rejected); back-calculation suggests a conception date of day 10 - and she had been seen being courted by a male on the day after release. Number 10 (killed in a road accident on day 54) was pregnant with at least one full-term foetus at the time of death. This places conception at about day 21, exactly the time she moved over 2.5km to the outskirts of Leatherhead. Number 11 was also observed courting several times but, as far as could be judged without breaking open her nests, did not rear a litter during the study period.

Ectoparasites

Both fleas (*Archaeopsylla erinacei*) and ticks (*Ixodes hexagonus*) had been eliminated from the hedgehogs before release, but were found in abundance on both hedgehogs released in Byfleet within 1week of release. Among the Nower Wood release group, numbers 7, 8 and 9 were all found to have numerous larval *I. hexagonus* attached (Paul Hillyard personal communication 1995). Number 7 was particularly badly infested with well over 100 ticks around her eyes, on the underside and around the forelimbs. No fleas or adult *I. hexagonus* were recorded from hedgehogs while in the wood, but numbers 1,4,5,7,10 were all observed to have both fleas and ticks after moving into built-up areas.

Discussion

The present study supports the conclusion that released hedgehogs quickly become accustomed to life in the wild and learn to feed themselves, make nests and orientate (Morris *et al* 1992, 1993; Morris & Warwick 1994; Morris and Sharafi 1996). However, it is clear that the transition is not easy and some individuals, as in the case of number 6, may fail to adapt and do not thrive. In this case, the stress of coping with life in the wild may have exacerbated the severity of illness. *Pasteurella multocida* has been reported as a pathogen of the respiratory tract in European hedgehogs, but one that usually presents as a secondary infection (studies reviewed by Reeve 1994).

The rapid infestation of both Byfleet animals with fleas and ticks, and the eventual infestation of the animals released in Nower Wood after moving into areas with other hedgehogs, confirms that fleas can spread rapidly through the adult population. The separate use of the same, established wild hedgehog's nest by both Byfleet animals, is one route by which both fleas and ticks could be rapidly transmitted. Such non-simultaneous nest sharing was first described in Reeve and Morris (1985) and probably also occurred in the study by Morris *et al* (1992). The rapid colonization of released hedgehogs by ectoparasites suggests that any putative welfare benefits of specifically treating flea or tick infestations will be very short lived once the animal is released.

None of the recorded deaths were attributable to illness resulting from endoparasitic infestation. This contrasts with the results from hedgehogs in the study by Morris and Warwick (1994) which had not received pre-release anthelmintic treatment (see Sainsbury *et al* 1996). It also suggests that the pre-release ivermectin treatments used in the present study may have been worthwhile.

The observed pattern of initial weight loss, with a subsequent period of stability or weight gain is consistent with that shown by the previously mentioned studies. For example, Morris and Warwick (1994) who closely monitored body weight after release found weight loss (up to 38% of release weight) was significantly higher among the largest animals ($P < 0.005$). In the present study, the maximum recorded weight loss (40%) was for one of the heaviest animals (number 1). The same pattern was observed by Morris and Sharafi (1996) with a typical weight loss of 10-20 per cent of release weight by the second or third week after release and then a stabilization. Previous studies have also shown that, despite their initial weight loss, released animals maintained weights in excess of normal for wild animals of the same age. All hedgehogs from the Nower Wood site remained within the 600 - 900 g range after their initial weight loss. This compares well with a mean weight of 509g for a sample

of 34 wild hedgehogs of the same age in May (unpublished data cited by Morris & Warwick, 1994). A weakness of the present study is that animals were weighed less frequently than in earlier studies, but this was a consequence of the unusually high levels of dispersal, access problems and limited manpower.

This study shows conclusively that long-range dispersal (in this case up to 3km) following release is a feature common to females and not just a male characteristic. This confirms suspicions raised by Morris and Warwick's (1994) study in which three of the furthest dispersing animals were females (although only one moved much over 500m). A key question for the present study is, why did the hedgehogs disperse from the apparently suitable site of Nower Wood and its surroundings? Six possible explanations are discussed below.

The release site was in some way poor habitat

There would appear to have been plenty of suitable nest sites and abundant invertebrate prey both in the wood and in the surrounding rural pasture, golf course and low-density housing with large gardens. Although 1995 was a very dry summer, ponds in the wood did not dry out and were accessible. Only number 6 (which died of pneumonia) seemed unable to maintain herself while in the wood. The possibility that the release site was lacking in some key, but unknown, ecological requirement cannot be ruled out. However, the apparent absence of wild hedgehogs in the release area does not necessarily prove this. The area may have been quite suitable habitat but with a low hedgehog density created by chance population fluctuations. Recolonization may have been inhibited because the area is bounded to the north and east by the M25 motorway and to the west by the A24 and other busy roads of the Leatherhead conurbation. To the south and east, recolonization may have been inhibited both by the high ground and dense badger population of the North Downs.

The violent death of number 8, could have resulted from a predator's attack. However, with no other injuries evident, the most likely cause of death seems to be a road accident on Mill Way (unrelated to conditions in the wood) from which she returned to the wood before dying.

Predator avoidance

Although there is some good evidence for hedgehogs avoiding badgers and their odour (Doncaster 1992; Jane Ward personal communication 1996), it seems to be an unlikely explanation for the dispersals in this study. First, the area was not heavily used by badgers. Furthermore, at least three of the dispersals were into or straight through areas of high badger density.

Youngsters are 'instinctively' driven to disperse, or the act of release triggers dispersal

There is some evidence that juveniles disperse to their eventual home area in the first few months of life (Reeve 1994). The animals in this study may not have been through this phase and might somehow have be driven to disperse. Similarly, it could be argued that newly released animals may be disorientated and that this triggers dispersal (or homing) movements. Evidence against both of these suggestions includes observations that many released hedgehogs do not disperse (eg Morris & Warwick 1994) and those that do, seem to disperse after a latent period of a few days or a couple of weeks.

A drop in body weight triggers dispersal

It may be an adaptive response to disperse when an animal experiences a rate of weight loss exceeding a certain threshold. Exploring new areas when prey availability in the vicinity becomes unsustainably low could prevent starvation. All released animals in the present study (and previous studies) showed significant post-release weight losses (Figure 2). Such weight losses were probably due to a combination of factors such as the shedding of excess weight accompanying a shift from a sedentary lifestyle to full activity, and a lack of practice in foraging for natural foods.

The hedgehogs were seeking other hedgehogs

The two animals released in Byfleet, where there was a resident hedgehog population, did not disperse. The Nower Wood hedgehogs were all released in the same area, so dispersal could not simply be a matter of the presence or absence of other hedgehogs. However, it is possible that the released females dispersed in search of males as potential mates. All the surviving, released animals ended up in areas with resident hedgehogs - and the females were sexually active. This suggestion challenges the image built up by home range studies (see review by Reeve 1994) of comparatively sedentary females sought out by highly mobile males with large home ranges encompassing the ranges of several females. Nevertheless, it would not be necessarily inconsistent to suggest that females, in the absence of encounters with potential mates, may seek them out. The apparent absence of other hedgehogs (none observed by researchers or householders) could explain why numbers 1, 5, and 10 subsequently left areas of apparently suitable gardens reached after their first dispersal. The adult hedgehog ticks (*I. hexagonus*) found on numbers 1 and 10 may have been an indication that other hedgehogs were in fact present in these areas, but the fairly wide host range of this tick species mitigates against this assumption.

Hedgehogs seek out areas of human habitation

It is interesting that with the exception of three animals (numbers 2, 6 and 8; all of which died) all the released hedgehogs ended up around human habitation. Urban/suburban areas may be more attractive and favourable habitats for hedgehogs than much of the countryside. Possible positive factors include food availability (perhaps enhanced by the irrigation of gardens), a reduction in the number of badgers, and/or the number of secure nest sites (eg under garden sheds). One negative aspect of the apparent preference for areas of human habitation, however, is the risk of death and injury on the roads.

Summary

By week 8, the 42 per cent overall survival rate in the present study was comparable to that reported by previous release studies (see, *Introduction* and Table 2), but the survival rate at 15½ weeks was only 25 per cent - although it must be remembered that a further two lost animals could possibly have survived. The low survival figure may simply be an artefact of this being the longest follow-up study so far conducted.

Animal welfare implications

The low overall survival rates of hedgehogs released from captivity are a serious cause for concern. However, one should remember that these animals would almost certainly have died

were it not for human intervention. As in previous studies, the present study found that most released hedgehogs could adequately maintain themselves. It is clear that in the Nower Wood release area, animals were at most risk from road traffic (probably accounting for four deaths) as they dispersed widely from the release area.

One death (by drowning in a steep-sided pond) claimed an animal which had been previously rescued from a deep concrete shaft. Such hazards are a product of the human environment, accidental in nature and presumably representative of the risks affecting all hedgehogs. The risk of predation is also faced by most wild hedgehogs, as they have no effective defence against a determined badger. Such accidental deaths (six of seven recorded) have little direct relationship with a lack of adaptive experience on the part of released animals. The 25 per cent overall survival rate in this study, though lower than one might hope for, still represents a positive step in compensating for the various sources of mortality affecting wild hedgehog populations.

There remains a need for further comparative studies using matched groups to determine the key factors influencing the survival and welfare of released hedgehogs. These studies should aim to develop a release protocol that maximizes survival and minimizes health and welfare problems for released animals. Despite preliminary observations to the contrary (Morris & Warwick 1994), a carefully staged ('soft') release protocol may reduce potentially hazardous long-distance dispersal movements. This possibility should be properly investigated.

Acknowledgements

Thanks to the British Hedgehog Preservation Society for a grant to cover the costs of transmitters used in this study. I also acknowledge the financial support and use of facilities of the Faculty of Sciences, Roehampton Institute, London. Thanks to Hedgehog Care and Wildlife Aid for providing suitable hedgehogs and observing pre-release protocols. The staff at Wildlife Aid also provided veterinary services and practical support during the study - I am particularly grateful to Simon Cowell for his enthusiastic support and the help of supervising veterinary surgeon Rosie Smith (VetMB MA MSc MRCVS). Thanks also to the Surrey Wildlife Trust for their cooperation, especially Pam Johnson and Fiona Hann; Alison Tutt and Dave Williams (of the West Surrey Badger Group) supplied badger records. On various days I was helped in the field by Simon Cowell, Kate Jones, Fiona Hann, Rachel Trim, Alison and Simon Tutt, and my wife Kati. I am grateful to Paul Hillyard (Natural History Museum, London) for identifying the larval and adult ticks.

References

Doncaster P 1992 Testing the role of intraguild predation in regulating hedgehog populations. *Proceedings of the Royal Society of London* Series B 249: 113-117

Hoeck H N 1987 Hedgehog mortality during hibernation. *Journal of the Zoological Society of London 213:* 755-757

Kristiansson H 1990 Population variables and causes of mortality in a hedgehog population (*Erinaceus europaeus*) in southern Sweden. *Journal of the Zoological Society of London 220:* 391-404

Majeed S K, Morris P A and Cooper J E 1989 Occurrence of the lungworms Capillaria and Crenosoma spp. in British hedgehogs (*Erinaceus europaeus*). *Journal of Comparative Pathology 100:* 27-36

Morris P A 1984 An estimate of the minimum body weight necessary for hedgehogs (*Erinaceus europaeus*) to survive hibernation. *Journal of Zoology 203:* 291-294

Morris P A 1991 Family Erinaccidae. In: Corbet G B & Harris S (eds) *The Handbook of British Mammals,* 3rd edition pp 37-43. Blackwell Scientific Publications: Oxford, UK

Morris P A, Meakin K and Sharafi S 1993 The behaviour and survival of rehabilitated hedgehogs (*Erinaceus europaeus*). *Animal Welfare 2:* 53-66

Morris P A, Munn S and Craig-Wood S 1992 The effects of releasing captive hedgehogs (*Erinaceus europaeus*) into the wild. *Field Studies 8:* 89-99

Morris P A and Sharafi S 1996 *Released, rehabilitated hedgehogs: a follow-up study in Jersey, April-May 1995.* Unpublished report, Royal Holloway College, University of London

Morris P A and Warwick H 1994 A study of rehabilitated hedgehogs after release into the wild. *Animal Welfare 3:* 163-177

Reeve N J 1982 The home range of the hedgehog as revealed by a radio tracking study. In: Cheeseman C L and Mitson R B (eds) *Telemetric Studies of Vertebrates* (Symposium of The Zoological Society of London 49) pp 207-230. Academic Press: London, UK

Reeve N J 1994 *Hedgehogs*. T & A D Poyser: London, UK

Reeve N J and Morris P A 1985 Construction and use of summer nests by the hedgehog (*Erinaceus europaeus*). *Mammalia 49 (2):* 187-194

Sainsbury A W, Cunningham A A, Morris P A, Kirkwood J K, Macgregor S K 1996 Health and welfare of rehabilitated juvenile hedgehogs (*Erinaceus europaeus*) before and after release into the wild. *Veterinary Record 138:* 61-65

Saupe E and Poduschka W 1985 Igel. In: Gabrisch K and Zwart P (eds) *Krankheiten der Heimtiere* pp 75-96. Schlütersche: Hanover, Germany

Stocker L 1987 *The Complete Hedgehog*. Chatto and Windus: London, UK

Sykes L and Durrant J 1995 *The Natural Hedgehog*. Gaia Books Ltd: London, UK