A study of the current status of the hedgehog (Erinaceus europaeus), and its decline in Great Britain since 1960

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Royal Holloway, University of London

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Declaration

All fieldwork in this thesis (chapter 4) has been conducted by Anouschka R. Hof with the help of several volunteers. All data analysis has been carried out by Anouschka R. Hof. This thesis is in its entirety the work of Anouschka R. Hof. A draft has been read and criticised in the normal manner by Paul W. Bright. This work has not previously been offered for or accepted in the application for a degree.

Anouschka R. Hof

"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."

Aldo Leopold (1949)

Abstract

The main aim of this thesis was to better understand the extent of, and the mechanisms behind, the apparent decline of the West European hedgehog (*Erinaceus europaeus*) throughout Great Britain since 1960. The current distribution and relative abundance of hedgehogs was assessed by using a nationwide public participation survey, and drivers behind geographical variations and changes over time were identified by comparing this data with data from the 1960s from the UK National Biodiversity Network. An additional aim was to identify mitigation measures necessary to ensure the viability of hedgehog populations. The impact of agricultural management on hedgehogs with particular reference to agri-environment schemes was investigated by means of a questionnaire aimed at farmers and a field study. An in-depth study of hedgehog presence in built-up areas investigated the role of urbanization using an existing database called ‘Living With Mammals’.

The findings in this thesis indicate that although hedgehogs are still widely distributed, their numbers have been falling considerably, which was mainly correlated with an increase in badger abundance, loss of suitable habitat and increased fragmentation. Recently, hedgehogs were more prevalent in the arable-dominated lowlands of Great Britain than in the pasture-dominated lowlands, mainly because of differences in badger abundance and major road coverage.

Since both practical and ethical issues are likely to arise with predator control, it seems imperative to seek effective non-lethal methods to preserve hedgehogs. The implementation of agri-environment schemes that include wide field margins and dense, well established hedgerows on farmland is expected to increase hedgehog populations. In urban areas the need for sound ecological management in new development plans emphasising habitat connectivity seems essential. Raising awareness amongst the general public and stressing the importance of wildlife-friendly features in, and connectivity between, urban green-spaces is also likely to benefit hedgehogs.

Acknowledgements

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The surveys could not have yielded such valuable data without the help of the thousands of people that contributed by submitting their hedgehog sightings or other data in one way or another. I would like to thank the 'Green-space Information Greater London Authority' for generously providing the data regarding the green-spaces in the greater London area. These data have made that particular project better than it would have been without it.

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1.1 General decline of biodiversity

Throughout the world numerous species of flora and fauna are currently threatened due to a wide range of factors. The (local) extinction of species is a normal phenomenon, and can be caused by a variety of intrinsic, extrinsic, natural and human-induced factors. Recently, however extinctions are occurring at an unprecedented rate due to increased levels of human disturbance and other factors directly and indirectly caused by mankind (Vitousek, 1994; McNeely *et al.,* 1995; Pimm *et al.,* 1995; Sala *et al.,* 2000). Human-induced loss, fragmentation and degradation of suitable habitat due to agricultural development and intensification, extensive tree logging and urbanization are amongst the most frequently mentioned causes for the extinction of species and the decline in biodiversity (McNeely *et al.,* 1995; Wilcove *et al.,* 1998; Gaston *et al.,* 2003).

In Great Britain, numerous species have been reported as declining in number. For example 456 species of vascular plants are listed as regionally extinct, endangered, vulnerable or near threatened (Cheffings *et al.,* 2005). In total, 40 species of birds in Britain appear on the red list of conservation concern with a high conservation concern (BTO, 2007). Also 15 out of 56 dragonfly species are currently regionally extinct, endangered, vulnerable or near threatened (Daguet *et al.,* 2008), and there are in total 140 species of flies from the Empidoidea, Nematocera and Aschiza listed as such (Falk & Chandler, 2005; Falk & Crossley, 2005). The ‘Tracking Mammals Partnership’ was able to assess the population status of 33 mammal species out of 65 terrestrial mammals present in Great Britain (Table 1.1), of which 10 showed signs of declining populations (Battersby, 2005).

The members of the Order Erinaceomorpha are amongst the living mammals that are most closely related to the ancestral mammals, having changed little since their origin (Butler, 1988). This Order mainly consists of medium sized, ground dwelling mammals that feed primarily on invertebrates. Members of the hedgehog family (Erinaceidae) belong to the Erinaceomorpha, and have been roaming parts of the world for many millions of years. Their fossil records date back to the Palaeocene (Corbet, 1988; Harris & Yalden, 2008), and the first fossils closely related to the genus *Erinaceus* were found in the early Pliocene (Butler, 1988). Nowadays the three species of hedgehogs in the genus *Erinaceus* (*E. amurensis, E. concolor and E. europaeus*) are widely distributed throughout Eurasia (Reeve, 1994). It is worrying that anecdotal evidence exists suggesting that at least one of these species (*E. europaeus*) is declining (Battersby, 2005; Davey & Aebischer, 2006), which could indicate deteriorating environmental quality on a higher level (see below).

Table 1.1 The status of 25 native and 9 introduced (indicated by *) species of terrestrial mammals in Great Britain assessed by Battersby (2005)

Scietific name	***Common name***	***Current status***
Capreolus capreolus	European roe deer	Increasing
Cervus elaphus	Red deer	Increasing
Cervus Nippon	Sika deer*	Probably increasing
Dama dama	Fallow deer*	Probably increasing
Hydropotes inermis	Chinese water deer*	Probably increasing
Muntiacus reevesi	Reeves' muntjac*	Probably increasing
Vulpes vulpes	Red fox	Uncertain
Lutra lutra	Eurasian otter	Increasing
Meles meles	Eurasian badger	Increasing
Mustela erminea	Stoat	Uncertain
Mustela nivalis	Least weasel	Possible long-term decline
Mustela putorius	European polecat	Increasing
Mustela vison	American mink*	Stable or declining
Eptesicus serotinus	Serotine bat	Indication of decline
Myotis brandtii	Brandt's bat	Stable
Myotis daubentonii	Daubenton's bat	Increasing
Myotis mystacinus	Whiskered bat	Stable
Myotis nattereri	Natterer's bat	Increasing
Nyctalus noctula	Noctule	Indication of decline
Pipistrellus pipistrellus	Common pipistrelle	Increasing
Pipistrellus pygmaeus	Soprano pipistrelle	Stable
Plecotus auritus	Brown long-eared bat	Indication of decline
Rhinolophus ferrumequinum	Greater horseshoe bat	Increasing
Rhinolophus hipposideros	Lesser horseshoe bat	Increasing
Lepus europaeus	Brown hare*	Stable or declining
Lepus timidus	Mountain hare	Significant decline
Oryctolagus cuniculus	European rabbit*	Significant decline
Erinaceus europaeus	West European hedgehog	Evidence of long term decline in parts of the UK, stable or increasing in other parts
Arvicola terrestris	European water vole	Significant decline
Rattus norvegicus	Norway rat*	Probably increasing
Muscardinus avellanarius	Hazel dormouse	Significant decline
Sciurus carolinensis	Grey squirrel*	Probably increasing
Talpa europaea	European mole	Stable

The implication of the loss of biodiversity is discussed and commonly referred to as the diversity–stability debate (McCann, 2000). The essence of the hypotheses is that diversity will increase the stability of communities. Community level stability is dependent on the capacity of species or functional groups to respond differently to variable conditions. This implies that the removal (extinction) or addition (invasion/ introduction) of any species can have a marked impact on the structure and composition of communities, which increases the probability that ecosystems may collapse. It is therefore thought important to conserve all species within an ecosystem in order to conserve that ecosystem (Naeem *et al.,* 1994; Naeem *et al.,* 1995; Tilman, 1996; Tilman & Downing, 1994; McCann, 2000; Tilman *et al.,* 2006). Species may differ in the level of contribution to ecosystems. The effect of the loss of a species such as *E. europaeus* from the ecosystem is therefore unknown. Nevertheless, it is important to gain an insight into the mechanisms behind the decline of a species so as to prevent its potential loss from the ecosystem.

1.2 The West European hedgehog (*Erinaceus europaeus*)

The West European hedgehog, (*Erinaceus europaeus*) (henceforth referred to as the hedgehog) is a distinctive insectivorous mammal widely distributed in Western Europe (Reeve, 1994). The hedgehog is currently classified as Least Concern on the IUCN Red List (IUCN, 2001) and listed under 'Appendix III' (protected fauna species) of the Bern Convention (Council of Europe, 2002). In the United Kingdom, hedgehogs are considered to be locally common, but there is evidence of long term decline in parts of the country (Battersby, 2005). Indeed, the survey 'Mammals on Roads', conducted by the Mammals Trust UK (MTUK), presented evidence based on road kills that numbers of hedgehogs have been declining consistently since the start of the survey in 2001 (MTUK, 2005). Furthermore, numbers are remarkably lower compared to a similar survey conducted in the early 1990s (Pat Morris, personal communication, 2008). Also a survey by the Game Conservancy Trust suggested a significant decline in the numbers of hedgehogs killed by gamekeepers in both England and Wales between 1961 and 2004, especially since 1995 (Davey & Aebischer 2006). However, this survey did not account for changes in effort through time.

Nevertheless, surveys such as these have led to the hedgehog being recently included in the UK Biodiversity Action Plan (BAP), which was created as a response to the Convention on Biological Diversity (UK BAP, 2007).

It is of concern that a mobile species such as the hedgehog, which was always thought to be very common and widespread, is in decline. The hedgehog is a generalist feeder and a predator of macro-invertebrates (which are the staple diet of numerous other taxa) and may therefore be regarded as a biotic indicator species. Its decline may signify a general deterioration of environmental quality and may have important implications for environmental management. Additionally, possible constraints faced by hedgehogs might be more severe for less mobile taxa that have to cope with an increasingly fragmented landscape in both rural and urban areas.

Farm management has been subject to major changes since the Second World War which resulted in a less diverse landscape (Robinson & Sutherland, 2002). These changes have partly been the driving force behind the loss of species diversity and abundance (Krebs *et al.,* 1999; Chamberlain *et al.,* 2000; Donald *et al.,* 2001; Vickery *et al.,* 2001; Robinson & Sutherland, 2002). The urban environment is also undergoing alteration in some parts of the United Kingdom, reflecting social, economic and demographic changes. This leads to, amongst other factors, increasing housing densities, which in turn result in the loss of urban green-spaces. The impacts of these changes have been well studied for several, mainly avian, taxa (e.g. Marzluff, 2001; Siriwardena *et al.,* 2002; Bland *et al.,* 2004); it is however less well understood how mammals such as hedgehogs have been affected. The most frequently mentioned possible causes of the perceived decline of the hedgehog population in Great Britain are briefly discussed in section 1.3.

1.3 Possible causes of decline

1.3.1 Habitat loss and fragmentation

Due to an increasing need for new development in urban and rural areas the landscape is more and more fragmented by buildings, roads, impenetrable fences and other man-made features, which results in habitat loss and reduced connectivity. Habitat loss and habitat fragmentation are often related to one another, but are distinct phenomena. Together, they lead to a reduction of the total amount and increasing isolation of suitable habitat, resulting in a heterogeneous landscape with patches of suitable habitat in an otherwise less inhabitable matrix. Nevertheless, pure habitat loss can occur without the fragmentation of habitat (Wilcox, 1980; Andrén, 1994; Fahrig, 1997). Habitat loss and fragmentation often have large-scale impacts on landscape dynamics. Both have long been recognised as a potential threat to the viability of various taxa (Hawksworth, 1974; Soulé, 1986), and can put populations at risk of reaching their extinction threshold (Wilcox, 1980; Burkey, 1989; Saunders *et al.,* 1991; Fahrig, 1997; Fahrig, 2002; Ovaskainen *et al.,* 2002). Species that have a large home-range, with low dispersal rates or short dispersal distances, species that occur at relatively low densities, have low reproduction rates, or are highly specialised to a specific habitat type, are especially at risk (Bright, 1993). One of the best known victims that are thought to be facing the risk of extinction mainly due to habitat loss and fragmentation is the giant panda (*Ailuropoda melanoleuca*) (Liu *et al.,* 2001; Loucks *et al.,* 2001). In the United Kingdom however, species such as the hazel dormouse (*Muscardinus avellanarius*) (Bright & Morris, 1996), and water vole (*Arvicola terrestris*) (Rushton *et al.,* 2000a) also face difficulties partly due to habitat loss and fragmentation.

Habitat fragmentation leads to the increase of edge habitat. Since hedgehogs are associated with edge habitat (e.g. Morris, 1986; Dowie, 1993; Huijser, 2000), it has been hypothesised that they might benefit from increased fragmentation of the landscape; moreover they are generalists and are not confined to a particular habitat type (Bright, 1993). However, when habitat loss reaches a certain threshold, edge species such as the hedgehog might also be at risk (Bright, 1993). In most landscapes the amount of suitable habitat left will be more important than the spatial arrangements of the suitable habitat (Andrén, 1994). This is especially so for less mobile species, and for habitat specialists. More mobile species might experience the environment surrounding suitable habitat patches as less hostile than species limited by habitat specialisation. Hedgehogs are relatively mobile; they are able to cover distances of over 1000m a night, and are also adapted to a wide range of habitat types (Reeve, 1994). It is thus expected that hedgehogs would be able to cope relatively easy with habitat loss. Nonetheless, some habitat loss threshold will suffice to cause their decline.

1.3.2 Agricultural intensification

Since the Agriculture Act of 1947 the British countryside has notably changed from a varied landscape to a more uniform and large-grained landscape with low floral diversity. This change is mainly due to increasingly intensified agricultural management (Robinson & Sutherland, 2002). Farms have seen an almost fourfold rise in yield since 1945, with amongst others the help of increased mechanisation, by the removal of about 50% of the total hedgerow stock, and by a significant increase in the use of agrochemicals and fertilisers. These alterations in farm management led to less favourable conditions for wildlife due to an increasing disturbance and/or mortality caused by farm machinery, (secondary) poisoning, and a general loss of suitable habitat (Stehn *et al.,* 1976; Hart, 1999; Shore *et al.,* 1999; Wilson *et al.,* 1999; Robinson & Sutherland, 2002). Unsurprisingly these changes resulted in declining species abundance and diversity in various taxa in Great Britain and other countries across Europe (Pain & Pienkowski, 1997; Burel *et al.,* 1998; Krebs *et al.,* 1999; Wilson *et al.,* 1999; Robinson & Sutherland, 2002). It has, for instance, been shown by Tucker *et al.,* (1994) that agricultural intensification, excluding (indirect) effects of increased pesticide use, affected 24% of the Species of European Conservation Concern (SPEC) – this is greater than any other threat.

The role of agricultural intensification in the decline of biodiversity in rural areas has been well documented for birds (e.g. Krebs *et al.,* 1999; Chamberlain *et al.,* 2000; Donald *et al.,* 2001), and invertebrates (Whalen *et al.,* 1998; Decaëns & Jiménez 2002; Zhiping *et al., 2*006). Less is known with respect to mammals. It is however thought that mammals such as hedgehogs might be negatively affected as well (George, 2004; MTUK, 2005; Davey & Aebischer, 2006). Indeed, results from the 'Mammals on Roads' study by MTUK suggested that the decline of hedgehogs was especially notable in the rural areas of England and Wales. Hedgehogs are generally associated with edge habitats and spend a great part of their time along grassland edges, boundaries between arable land, grassland and woodland fragments and in, or in the vicinity of, hedgerows (e.g. Morris, 1986; Dowie, 1993; Huijser, 2000). Agricultural intensification resulting in the loss of hedgerows and woodland fragments therefore reduces the area of suitable habitat. An additional effect of agricultural intensification is the increased use of pesticides and insecticides, which are potentially harmful for hedgehogs (Gemmeke, 1996; D'Havé *et al.,* 2006), both directly due to poisoning and indirectly through effects on prey populations (Curry, 1998; Whalen *et al.,* 1998; Decaëns & Jiménez, 2002; Zhiping *et al., 2*006).

1.3.3 Road mortality

An increase in human population is coupled with an increase in road coverage, especially in those areas that have to cope with a large amount of new development. Increasing complexity of the road network will add to fragmentation and habitat loss. Additionally, roads can also act as effective barriers to the dispersal of species through road kills (Forman & Alexander, 1998; Clark *et al.,* 2001). Traffic densities are continually increasing in many parts of the world, which will inevitably have an effect on various mammal populations. Huge numbers of mammals get killed or injured on roads every year (Adams & Geis, 1983; George, 2004; Hell *et al.,* 2004; Seiler *et al.,* 2004). The hedgehog is one of many species frequently found dead on roads (Brockie, 1963; Von Reichholf & Esser, 1981; Morris & Morris, 1988; Maternowski, 1998; Bergers & Nieuwenhuizen, 1999; Holsbeek *et al.,* 1999; Huijser, 2000; Huijser & Bergers, 2000; Rondinini & Doncaster, 2002; Orłowski & Nowak, 2004). According to Huijser & Bergers (2000) roads and traffic may reduce hedgehog populations in The Netherlands by about 30%, and Morris (2006) estimates that in Great Britain 15,000 hedgehogs die on roads every year. Fencing roads in order to reduce the possibility that wildlife crosses, unfortunately, does not seem to be a satisfactory mitigation measure. Bergers & Nieuwenhuizen (1999) showed that the viability of hedgehog populations decreased dramatically as a result of this practice.

1.3.4 Predation

Predation is another factor that might have an impact on the distribution and density of hedgehogs. Although a review by Reeve (1994) reveals that many species ranging from foxes (*Vulpes vulpes*) and dogs (*Canis lupus familiaris)* to various mustelids and birds of prey occasionally prey upon hedgehogs, badgers (*Meles meles*) pose the greatest threat in Great Britain. Although the earthworm (*Lumbricis terrestris*) is the most important food of the badger in Great Britain, badgers do occasionally prey upon hedgehogs (Doncaster, 1992; Doncaster, 1994; Micol *et al.,* 1994; Neal & Cheeseman, 1996; Del Bove & Isotti, 2001; Young, 2005). Middleton (1935) even found four hedgehogs in the stomach of a single badger. Additionally, badgers may compete with hedgehogs for suitable habitat and prey (Reeve, 1994; Neal & Cheeseman, 1996). It is therefore not surprising that local impacts of badgers on hedgehogs have been studied (Doncaster, 1992; Doncaster, 1994; Micol *et al.,* 1994; Ward *et al.,* 1997; Young, 2005). It has for instance been revealed that hedgehogs disperse further if they are introduced in areas with a high badger density (Doncaster, 1992; Doncaster, 1994). Surveys carried out by Young *et al.* (2006) showed that hedgehogs were almost absent from suitable habitats in rural areas, supposedly due to high abundances of badgers. Micol *et al.* (1994) predicted that in areas where the mean badger density exceeds 2.27 setts per 10km^{2} (10km * 10km) hedgehogs would not persist. If this figure holds true, it means that hedgehog populations are at risk of extinction due to badger predation and/or competition in large parts of England. In the south west of England for instance the mean number of badger main setts can be as high as 6 to 7 per 10km^{2} (Wilson *et al.,* 1997).

It is suggested that urban areas provide refuges from badgers for hedgehogs (Young *et al.,* 2006; Dowding, 2007). Badgers are mainly confined to rural areas although they occasionally dig setts in urban areas (Neal & Cheeseman, 1996). Recently however, the number of badgers in urban areas has been increasing (Delahay *et al.,* 2009). This might lead to increased predation pressure on hedgehogs in these areas. The question arises as to whether the increasing competition and predation due to rising numbers of badgers over the last decades (Wilson et al., 1997; Battersby, 2005; Delahay *et* *al.,* 2009) has become one of the main reasons for the apparent decline in hedgehogs.

1.3.5 Climate change

Recently the threat of a changing climate has been recognised as one of the main drivers behind (future) extinctions (Markham, 1996; Thomas *et al.,* 2004). The predicted impact of the changing climate is thought to be large scale and capable of affecting entire ecosystems, for example in the Polar Regions. The disappearance of large ice masses may cause the extinction of species such as the polar bear (Derocher *et al.,* 2004) and various penguin species (Baroni & Orombelli, 1994; Forcada *et al.,* 2006; Le Bohec *et al.,* 2008). Climate change is also thought to have a more local impact upon species. Some species of butterflies shifted their geographical range (Parmesan *et al*, 1999) due to a changing climate. Another example is the mismatch in timing of reproduction by great tits (*Parus major*) and high food abundances because of warmer temperatures earlier in spring, which might have consequences on the viability of great tit populations (Visser *et al.,* 1998). A study by Dowding (2007) was inconclusive about the impact of the weather upon hedgehog populations, but did show that rising temperatures in summer led to an increase of admissions of unfit hedgehogs to wildlife centres, arguably due to lack of food. Jackson (2007) on the other hand showed that warmer conditions promoted hedgehog survival and breeding success on the Hebridean island of South Uist.

1.4 Thesis objectives

Although various studies address hedgehog mortality and abundances (Kristiansson, 1990; Micol *et al.,* 1994; Ward, 1995; Huijser, 2000; Young *et al.,* 2006; Dowding, 2007; Jackson, 2007), only short-term or anecdotal evidence of a decline in the hedgehog population currently exists (MTUK, 2005; Davey & Aebischer, 2006). The current distribution and differences in abundance of hedgehogs throughout Great Britain is largely unknown and based upon local studies (e.g. Suffolk Wildlife Trust, 2000; Kay, 2002; Burdon & Morris, 2008). The distribution and abundance of hedgehogs is currently not known on a nationwide scale. Additionally it is not well understood which factors might underlie this supposed decline. Underlying factors of differences in the distribution and abundance of hedgehogs have so far only been studied on a local scale. Dowding (2007) investigated several factors that may relate to the decline of hedgehogs in Britain. She studied the impact of weather on the activity pattern of hedgehog and the rate of admission to wildlife care centres. She found that hedgehogs increased their activity with increasing temperature and days without rainfall. However, distance and speed of travel declined with an increasing number of days without rainfall. Additionally, high temperatures and rainfall influenced hedgehog admission to care centres. Furthermore, she investigated the presence of toxins in hedgehog carcasses across Britain, and found that exposure to toxins was widespread and may thus form a threat to hedgehogs. Dowding (2007), however did not address the more basic questions such as ‘Have numbers of hedgehogs fallen over the last few decades in Great Britain’, ‘What is the current distribution of hedgehogs’ and ‘Where are currently the highest and the lowest abundances of hedgehogs in Great Britain’. She also failed to investigate the role of predators and of changing habitat, mainly in the countryside. The impact of one of the main predators of hedgehogs, the badger (Reeve, 1994), on hedgehogs has been well studied on a local scale as described in section 1.3.4 (Doncaster, 1992; Doncaster, 1994, Micol *et al.* 1994, Young *et al.*, 2006). It is however not known whether badgers might influence the distribution and abundance of hedgehogs on a nationwide scale.

The main aim of the present study was to better understand the extent of and the mechanisms behind the apparent decline of hedgehogs in Great Britain since 1960, both in rural and urban areas. An additional aim was to identify the areas of conservation concern and possible mitigation measures necessary to ensure the viability of hedgehog populations. One of the ways to gain insight into the possible changes within the British hedgehog population was to ascertain the current distribution and abundance of hedgehogs throughout Great Britain in order to assess differences with past distributions.

The objective of chapter 2 was to assess the current distribution of hedgehogs using “HogWatch”, a nationwide public participation survey, and to compare this present day data with distribution data from the 1960s. Additionally, variables were sought that could explain differences in the distribution of hedgehogs throughout Great Britain. Chapter 3 focuses on the wider influence of agricultural management on the distribution and abundance of hedgehogs in rural areas, using a questionnaire survey aimed at landowners. Chapter 4 concentrates on the significance of agri-environment schemes for hedgehogs, using a radio-tracking study. In chapter 5 the presence and abundance of hedgehogs in urban green-spaces was studied in greater depth. The role of connectivity, wildlife attracting features and the presence of predators was investigated using an effort-based mammal survey. Chapter 6 focuses on the causes of local hedgehog extinction in Greater London between the 1960s and present day, comparing two surveys. A general discussion of this thesis, the main areas of conservation concern and possible mitigation measures are given in chapter 7.

Chapter 2

Hedgehog distribution across Great Britain

Chapter 2

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2.1. Introduction

Understanding factors that regulate changes in species distribution and abundance is becoming increasingly important, not only due to ongoing habitat loss, agricultural intensification and deforestation but also due to the more recently recognised threat of climate change. When estimations of population densities are difficult to obtain, species are often thought to be declining if their current extent of occurrence or area of occupancy are decreasing, and this is also part of the criteria for the IUCN red list of endangered species (IUCN, 2001). Studies often involve the re-sampling of (similar) sites in order to study changes in the presence or absence of a species over time (Shaffer *et al.,* 1998). However, if estimations of numbers are difficult to obtain and the species is widespread, it might be difficult to ascertain whether it is declining or not. A decrease in the distribution range of a species is often, but not always, positively correlated with a decrease in their overall abundance and *vice versa* (Gaston *et al.,* 2000). The long-term monitoring of species is therefore a valuable tool to detect possible declines, both in time and in space.

Surveys are able to provide data on how a species is faring. Unfortunately, ongoing studies of particular species that encompass large areas are rare. Additionally, comparing present with past data on occurrence is often accompanied by various problems. Firstly, detailed information on the distribution and or abundance of species in the past is often not available and reconstructing past data is not always possible (Reznick *et al.,* 1994). Secondly, past data on distributions, such as those offered by the National Biodiversity Network (CEH & JNCC, 2007), is often based on presence-only surveys or museum collections (e.g. Mitchell-Jones *et al.,* 1999). The lack of absence records often limits the value of the survey, although reliable proof of absence can be difficult to obtain (Margules *et al., 1*994). That is why the incorporation of absence data in maps that display species distribution and abundance is often regarded as preferable to the use of presence data only (Brotons *et al.,* 2004). Furthermore, sampling methods, sampling effort, experience and expertise of the surveyors might have changed (McDonald & Harris, 1999). Possible changes in survey effort over time may obscure the detection of trends in time and space. Problems can also arise with distinguishing yearly fluctuations from ongoing declines in populations. Additionally, data concerning particular species might be collected in areas where the species is expected to be present or where the area is easily accessible. A further obstacle often arises due to logistic constraints; a useful survey requires, among other things, large numbers of observations that can only be obtained by a considerable amount of time and effort spent in the field.

The value of surveys to detect changes in population densities can be illustrated using an ongoing survey by the Mammals Trust UK, called Mammals on Roads. This survey records mammals seen by volunteers on roads, dead or alive. This led to the conclusion that hedgehogs (*Erinaceus europaeus*) may be declining in parts of Great Britain (MTUK, 2005). In order to get a better insight into the current status of hedgehogs and their whereabouts, a nationwide public participation survey called 'HogWatch' was designed by Royal Holloway University of London (RHUL) in co-operation with the British Hedgehog Preservation Society (BHPS) and the People's Trust for Endangered Species (PTES). I have used the data collected from this survey in 2005 and 2006 to create a present-day map of Great Britain with a measure of expected abundance of hedgehogs. One of the objectives of this chapter was to use this map, which includes both presence and absence records, as the basis for finding possible correlations between hedgehog presence and environmental variables such as habitat type, soil type and presence of predators, which might influence hedgehog numbers. Additionally, the present-day data have been compared with data from the past to detect possible changes and their causes in the presence of hedgehogs in time and space.

2.2. Methods

2.2.1 The survey

The HogWatch survey was developed and launched in 2005 in order to produce a nationwide map of hedgehog distribution based on public participation. The survey was both post and web-based. Publicity was sought by means of (local) media, personal communication and by the use of existing member databases of the BHPS and the PTES. The analyses of the survey cover the years 2005 and 2006. People were asked whether they saw living hedgehogs in their garden or elsewhere or not. They were asked to provide the grid references or the postcodes of the locations of their hedgehog sightings. Other data obtained from the surveyors in 2006 included the number of individuals they saw at one time, the date when they saw them, which habitat they were seen in, which habitat was surrounding the habitat they were seen in and whether they were adults, juveniles or newly born. The survey sheet that was sent to potential respondents is shown in Appendix I. Recordings of dead hedgehogs were disregarded in order to omit bias caused by road densities and traffic flow. People were also requested to give their perception of possible changes in hedgehog numbers over the last five and ten years.

2.2.2 Additional data

Landscape features such as habitat type, road coverage and built-up environment are likely to be related to the presence and abundance of hedgehogs. These data were derived from the 'Countryside survey 2000' (CS2000, DEFRA & NERC, 2007). The following variables have been derived:

1) coverage of major roads
2) coverage of minor roads
3) density of arable and horticultural area
4) density of broadleaved woodland
5) density of built-up area
6) density of coniferous woodlands
7) density of improved grassland
8) density of neutral grassland
9) density of semi-natural grassland; an amalgamation of neutral grassland, calcareous grassland, and acid grassland, and bracken, fen, marsh, and swamp
10) density of upland, dwarf shrub heath, bog, montane and inland rock
11) environmental zones
12) length of hedgerows

The data were available at the 1km^2 level and were converted to the 10km^2 level (10km * 10km, henceforth referred to as 10km^2) by taking the mean of the values for each 10km^2. The coverage of roads was thought to be negatively related to the presence and abundance of hedgehogs, since they add to habitat fragmentation and increase the risk of mortality due to traffic (Forman & Alexander, 1998; Huijser, 2000; Clark *et al.,* 2001). Unfortunately data on traffic flow were not available on a suitable scale. The density of arable and horticultural land, built-up area, coniferous woodlands and the density of upland areas were expected to relate negatively to hedgehog presence and abundance. Hedgehogs are frequently found to avoid landscapes with a high percentage of these habitat types in radio-tracking studies (e.g. Reeve, 1994; Zingg, 1994; Huijser, 2000). The density of broadleaved woodlands and the amount of hedgerows were expected to relate positively to the presence and abundance of hedgehogs. These habitats are frequently favoured by hedgehogs (e.g. Doncaster, 1992; Doncaster, 1994; Dowie, 1993; Reeve, 1994; Huijser 2000; Riber, 2006). Results from previous studies are divided with regard to the suitability of grassland for hedgehogs, (Doncaster, 1992; Doncaster, 1994; Dowie, 1993; Zingg, 1994; Huijser & Bergers, 1997; Huijser, 2000).

It is expected that badgers, being a predator of hedgehogs (see Reeve, 1994; Young *et al.,* 2006), negatively relate to the presence and abundance of hedgehogs. Data on badger presence were derived from the survey ‘Living with Mammals’ (LWM) years 2003-2006 inclusive from the ‘Mammals Trust UK’ (for a more in depth description of the LWM survey refer to chapter 5). Kriging (see below) was used to obtain an index of relative badger abundance throughout England. Soil data for England were obtained from the ‘National Soil Research Institute’ (NSRI). Most of the variables were available at the 1km^2 scale; the sum or the mean of the values, depending on the unit of the variable, has been taken to be able to use them at the 10km^2 scale.

Other factors such as invertebrate abundance, rainfall, temperature and pollutants might impact geographical differences in hedgehog presence and abundance as well. Unfortunately these data were not available at the appropriate scale. It is advised to study the impact of such factors on hedgehogs at a more local scale.

2.2.3 Data analyses current hedgehog distribution

Kriging is a geostatistical interpolation method based on linear regressions that produces maps from irregular spatial data and visualises suggested trends. It is a weighted moving average technique, which interpolates data in space, and bases predictions on known data values. It is used in spatial prediction applications in ecology (Cressie, 1991; Fortin & Dale, 2005; Rossi *et al.,* 1992; Sutherland, 2006). For more detailed information on its background see Cressie (1991). Kriging can be used to predict species numbers in regions where no data are available (e.g. Villard & Maurer, 1996; Carroll & Pearson, 1998; Certain *et al.,* 2007; Davis *et al.,* 2007). The method was used in the present study to estimate relative abundance of hedgehogs at the $10km^2$ level based on the presence-absence data derived from the HogWatch survey using 'Surfer 8' (Golden Software, Inc., Colorado, USA). To account for spatial autocorrelation a variogram, which is a function describing the degree of spatial dependence of the data, was integrated in the kriging method as is recommended (Isaaks & Srivastava, 1989; Meyers, 1997). Cross validation was used to select the best kriging model as is also recommended (Isaaks & Srivastava, 1989; Meyers, 1997). A map, showing the relative hedgehog abundance in each $10km^2$ grid-cell in England (see below), was produced in a Geographic Information System (MapInfo Professional Version 8, MapInfo Corporation, New York, USA). Some care must be taken when interpreting the map, since absence data are not necessarily valid. The lack of a sighting can be caused by true or false absence. Furthermore, data points situated close to each other in space will be more closely related, which is an inevitable consequence of using a geostatistical interpolation method to probe the structure of landscape scale distribution. Although a variogram has been used to account for spatial autocorrelation, probability values as displayed on the map should be viewed as approximate rather than exact.

The index of relative hedgehog abundance was established based upon the proportion of positive and negative sightings. The $10km^2$ grid-cells that produced less then 5 returns were omitted from the analyses, since these were thought not to provide sufficient data points within the grid-cell to extrapolate the data reliably in space by kriging. The data from Wales and Scotland were not kriged since only 23% of the $10km^2$ grid-cells in Wales and 4% of the grid-cells in Scotland returned more than 5 hedgehog (non-)sightings. In England a total of 986 10km^2 grid-cells (60% of the total), with a mean of 21 (se 0.63) hedgehog (non-)sightings, were kriged. Given the high percentage of grid-cells with more than 5 (non-)sightings and the large number of (non-)sightings per grid-cell, it was thought that reliable data could come from spatially extrapolating the data from England. Since not all records per grid-cell were consistent regarding the presence or absence of hedgehogs, the mean hedgehog presence was used (0=absence, 1=presence).

The kriged data for England were analysed with generalized linear modelling (GLM) in GenStat (for windows 8th edition, VSN International Ltd, Lawes Agricultural Trust, Oxford, UK), using the normal distribution and identity link function. Models were built for England and for the environmental zones within England separately. Due to lack of data from Scotland and Wales, the analysis of the current hedgehog distribution was based on England alone. For the purpose of display and the ease of detecting geographical differences in hedgehog presence and abundance, averages were obtained for the nine Government Office Regions of England; North East, North West, Yorkshire and The Humber, East Midlands, West Midlands, East of England, Greater London, South East and South West. The impact of landscape features and habitat types on the presence and abundance of hedgehogs differed per environmental zone. To avoid unnecessarily complex models, models were built per environmental zone as well, rather than incorporating environmental zones as a variable in the analyses. The environmental zones were defined by CS2000 (DEFRA & NERC, 2007) and were formed from aggregations of the 40 base classes of the ITE land classification of Great Britain (Bunce *et al., 1*996) (Figure 2.1). The environmental zones in Great Britain were defined as follows:

1) arable-dominated lowlands of England
2) pasture-dominated lowlands of England
3) uplands of England and Wales
4) lowlands in Scotland
5) marginal uplands and islands of Scotland
6) true uplands of Scotland

Of these environmental zones, only the first three occur in England, hence the latter three were not used for the analyses. In order to be able to directly compare the estimates of the variables included in the model, the variables were standardised using the following equation:

$$x' = (x - \bar{x}) / S$$ **Equation 2.1**

Where *x'* is the adjusted value, *x* the original value, $\bar{x}$ the mean value of the variable and *S* the standard deviation of the variable.

The models of best fit were selected using the backward stepwise method. All variables were entered in the model, withdrawing the variables that were not significantly contributing to the model ($p>0.05$) one by one until the minimum adequate models were left. The interaction between variables was investigated by Spearman correlation and used where relevant. The variable *built-up* was used as a weight factor to correct for differences in human habitation to account for a higher number of hedgehog sightings in more densely populated areas. Therefore, the variable could not be used as an explaining variable in the models. The variable *major roads* was omitted from the analyses since it showed strong collinearity ($r \geq 0.60$, Graham, 2003) with the weighing variable *built-up*. All names and explanations of the variables that were used in the analyses are shown in Table 2.1. Statistical analyses other than GLM were conducted using SPSS (for windows 14th edition, SPSS Inc., Chicago, USA).

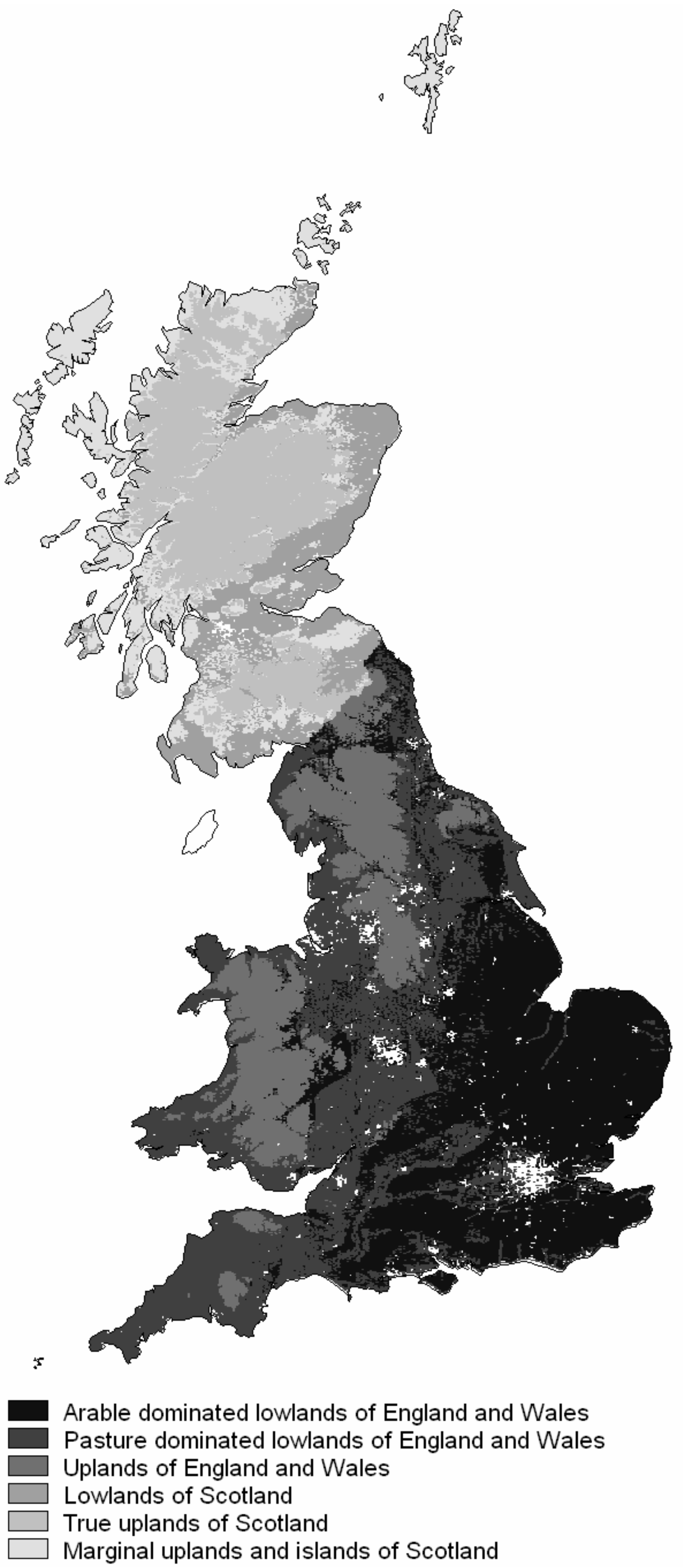


Figure 2.1 The environmental zones of Great Britain as defined by CS2000 (DEFRA & NERC, 2007)

Table 2.1 Explanation of the variables used for the GLM of hedgehog distribution.

Variable	***Explanation***
Arable and horticulture	Density of arable and horticultural area in 2000 (ha)
Badger	Relative badger abundance 2003-2006 (# animals)
Broadleaf	Density of broadleaved woodland in 2000 (ha)
Built-up	Density of built-up area in 2000 (ha)
Conifer	Density of coniferous woodland in 2000 (ha)
Hedgehog	Relative abundance of hedgehogs estimated by kriging (index)
Hedgerow	Length of hedgerows 1998 (km)
Improved grass	Density of improved grassland in 2000 (ha)
Minor roads	Coverage of minor roads in 2000(km)
Neutral grass	Density of neutral grassland 1998 (ha)
Semi-natural	Density of semi-natural grassland (amalgamation of neutral, calcareous, and acid grassland, bracken and fen, marsh and swamp) in 2000 (ha)
Soil type	The Soil types of England 1: soils with a clayey texture, 2: soils with a peaty texture, 3: soils with a sandy texture, 4: soils with a loamy texture and rich in lime, 5: soils with a loamy texture and a low fertility, 6: soils with a loamy texture and a moderate to high fertility
Upland	Density of dwarf shrub heath, bog, montane and inland rock in 2000 (ha)

2.2.4 Analyses of the change in hedgehog occurrence

The occurrence of hedgehogs in 2005-2006 based on the HogWatch dataset was compared with data on the occurrence of hedgehogs from the 'National Biodiversity Network' (NBN) (CEH & JNCC, 2007) from the years 1960 to 1975. Due to lack of data in Scotland and Wales, the analysis was again based on England alone. The NBN data from the years 1960 to 1975 did not follow the same methods as the HogWatch survey; it consisted of an amalgamation of hedgehog sightings provided by a variety of people. Nevertheless, this was the only available large dataset from the past that could be used to make comparisons. Since the 1960-1975 dataset only provided presence and no absence records, the absence records have been omitted from the HogWatch dataset. Analysis took place at the 10km^2 level again. It was assumed that hedgehogs occurred in a 10km^2 grid-cell if there was at least one positive sighting. The difference between the total number of occupied grid-cells in 1960-1975 and 2005-2006 was used to detect changes between the past and present occurrence of hedgehogs. The occurrence of hedgehogs in a grid-cell is dependent upon the amount of surveyor effort; the more effort the higher the chance that more grid-cells are classified as occupied. The 1960-1975 dataset was about four times smaller than the HogWatch dataset. To account for this difference in effort 10,000 random samples from the HogWatch dataset have been taken to match the size of the 1960-1975 dataset by use of a resampling stats add-in for Excel (Resampling Stats Inc, 2006). In this way it was possible to compare the occupancy of grid-cells in England by hedgehogs between the two periods based on similar effort.

It was assumed that a positive relation existed between the likelihood of sighting a hedgehog and their relative abundance. However, the likelihood of sighting a hedgehog increases with higher human population densities. Between 1971 and 2001 the number of residents in England increased by more than 5% (Hicks & Allan, 1999). Nevertheless, it was assumed that the distribution of high and low densities of residents remained more or less the same. Therefore, changes in the relative percentage of positive sightings per grid-cell between 1960-1975 and 2005-2006 were used as a measure of change in relative hedgehog abundance in that particular grid-cell.

Changes in environmental variables between the two periods were based on agricultural data taken from the 1970 and the 2006 datasets from the June Census (DEFRA & National Statistics, 2008). The 1970 dataset was available at the historic county level whilst the 2006 dataset was available based on the present counties and Unitary Authorities level. Minor discrepancies due to new boundaries between counties could therefore not be avoided. It was attempted to use the same variables as those used to study the current relative abundance of hedgehogs. However, due to changes in the June Census other, similar, variables were used. The following variables were obtained in hectares at the county level:

1) arable land
2) bare fallow
3) other land used for agriculture (e.g. paths, yards, buildings, ponds)
4) permanent grassland
5) rough grazing
6) woodland ancillary to farming

The variables *arable land*, *bare fallow*, *other land used for agriculture*, and *permanent grassland* all were expected to have a negative influence on hedgehogs. These landscape features and habitat types add to the fragmentation of the habitat or are commonly thought to be avoided by hedgehogs (e.g. Reeve, 1994; Zingg, 1994; Huijser, 2000). *Rough grazing* and *woodland ancillary to farming*, on the other hand, were expected to have a positive impact on the presence of hedgehogs (Riber, 2006).

The agricultural data per county were divided by county area before being summarized in order to get an estimate at the 10km^2 level. Changes in badger presence have been estimated based on the differences between the badger distribution shown by the LWM dataset (section 2.2.2) and the badger distribution according to the NBN dataset. The variables shown in Table 2.2 were used in the GLM in GenStat (for windows 8th edition, VSN International Ltd, Lawes Agricultural Trust, Oxford, UK), using the normal distribution and identity link function, to study the change in relative abundance of hedgehogs. Models were built for England and for the environmental zones within England separately. Again, the variable *built-up* was used to correct for the likelihood of detecting hedgehogs. Statistical analyses other than GLM were conducted using SPSS.

Table 2.2 Explanation of the variables used for the GLM of change in hedgehog distribution between the periods 1960-1975 and 2005-2006.

Variable	***Explanation***
Change badger	Change in badger presence between 1960-1975 and 2003-2006 (# animals)
Change built-up	Change in density of built-up area in 2000 (ha)
Change other	Change in area of other land used for agriculture e.g. paths, yards, buildings, ponds (1970-2006, ha)
Change arable	Change in density of arable land (1970-2006, ha)
Change bare fallow	Change in density of bare fallow (1970-2006, ha)
Change permanent	Change in density of permanent grassland (1970-2006, ha)
Change rough	Change in density of rough grazing, inc. common rough grazing (1970-2006, ha)
Change woodland	Change in density of woodland ancillary to farming (1970-2006, ha)
Soil type	The Soil types of England

2.2.5 Habitat selection

Estimation of habitat selection is dependent on the frequency of access by the observers, amongst other factors; people are more likely to encounter hedgehogs in habitats they frequently visit. Unfortunately, the frequency of access was not known. It is, however, highly likely that habitats such as gardens, greens, parks, roads and road verges were visited considerably more often by the general public than agricultural areas. Additionally, habitat selection is dependent on availability of different habitat types. The availability of the mentioned habitat types was not known. These habitats were therefore left out of the analyses. Although not likely to hold true, the assumption had to be made that the public visited the other habitat types in the countryside with an equal frequency in order to get some understanding of habitat selection. These habitats were: pasture (improved grasslands), unfarmed (neutral) grassland, arable land, deciduous woodland, coniferous woodland and downs, moors and heath land (upland). The availability of these habitats was derived from CS2000 (DEFRA & NERC, 2007). Estimated habitat selection is also dependent on the visibility of hedgehogs, which may differ not only in space but also in time and season. Since the time and season in which the sighting occurred was largely unknown, the visibility factor had to be ignored as well. Since the frequency of visits by the public, the visibility factor and even the habitat availability derived from CS2000 (DEFRA & NERC, 2007) were based on assumptions or estimations, these data only give an indication of the habitat selection by hedgehogs. Nevertheless, since the habitat selection was based on a large sample size (n=1944 hedgehog sightings), it was thought to be worthwhile adding it to the analyses.

Selection of habitat by hedgehogs was calculated by following the method of Manly *et al., (*1993). The analysis is based on differences in proportions of available habitat types and proportions of used habitat types, given that the selecting organism has unrestricted access to the entire distribution of available units. Selection ratios were used to distinguish preference or avoidance of a specific habitat type. The selection ratio quantifies the extent to which a habitat was selected; a selection ratio smaller than 1.0 indicates avoidance, larger than 1.0 implies preference. A selection ratio equal to 1.0 means there is no selection preference or avoidance. The selection ratio was calculated using equation 2.2.

$$\mathbf{B_{\underset{i=1}{\overset{1}{i}}} = W_i / (\sum W_j)} \qquad \textbf{Equation 2.2}$$

Where

$W_i = o_i / \pi_i$ **Equation 2.3**

and

$o_i = u_i / u_+$ **Equation 2.4**

With:

B_i The standardised selection ratio

W_i The selection probability for habitat i

o_i The proportion of observations of a species in habitat i

π_i The proportion of the total area of available habitat types.

u_i The number of observations of a species in a habitat i.

u_+ The number of observations of a species in the total area of available habitat.

A χ^2 statistic was calculated for each W_i value to determine if it significantly differed from 1.0 by using equation 2.5 and by using 1 degree of freedom.

$\chi^2 = (W_i - 1)^2 / se(W_i)^2$ **Equation 2.5**

where

$se(W_i) = \sqrt{\{o_i * (1 - o_i) / (u_+ * \pi_i^2)\}}$ **Equation 2.6**

Confidence intervals of selection probabilities were calculated using equation 2.7.

$W_i \pm Z_{\alpha/2} * se(W_i)$ **Equation 2.7**

Where $Z_{\alpha/2}$ is the percentage point of the distribution that is exceeded with probability $\alpha/2$. A Bonferroni adjustment was used, with α set at $0.05/I$, where I represents the number of habitat types. The selection probability is significantly different from 1 if the value 1 does not lie within the confidence interval.

2.3 Results

2.3.1 Current distribution and relative abundance of hedgehogs

A total of 17,607 positive and/or negative hedgehog sightings were obtained from participants from England in 2005 and another 8,304 records in 2006. Figure 2.2 shows a map of England with the distribution of the participants throughout England and whether they had seen hedgehogs or not. Respondents were distributed throughout England with a minimum of 535 respondents in the North East and a maximum of 5,160 in the South East. The response rate varied between $0.17^{0}/_{00}$ of the total population in the Greater London area and $0.63^{0}/_{00}$ in the South East. Of these people, the majority (75%, n=19,433) had seen hedgehogs. Most people (76%, n=19,692) saw hedgehogs in their garden the remaining 24% saw them in other sites, mainly on the road or road verges (Figure 2.3). The majority of people who stated the number of hedgehogs they observed saw a single adult (58%, n=4,194); two adults were seen in 18% (n=1,339) of the cases and other combinations all occurred in less then 4%. In 2% (n=68) of the cases a nest was observed with young of various ages.

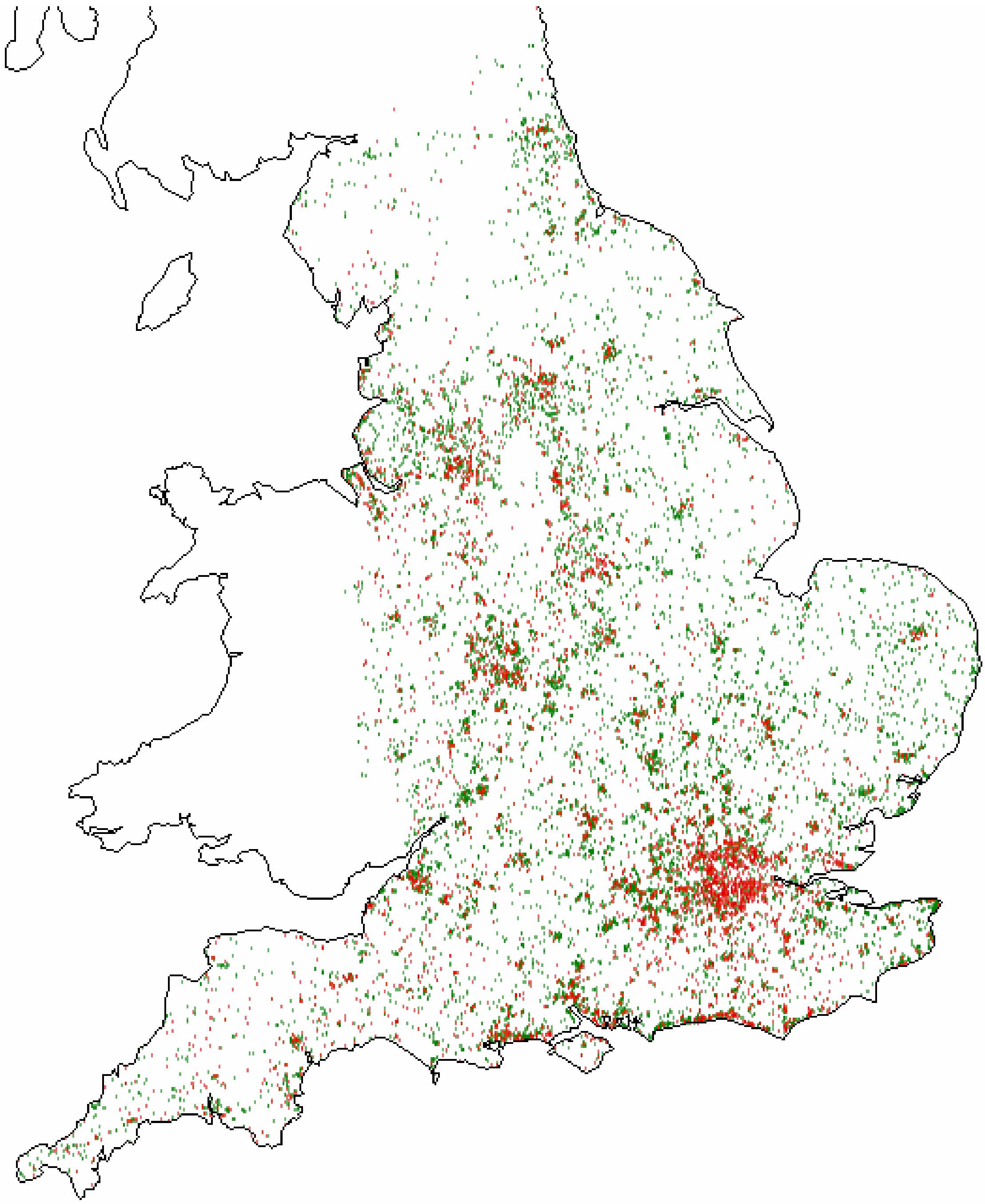


Figure 2.2 The distribution of the respondents of HogWatch (2005-2006) per 1km^2. Green dots refer to locations where hedgehogs were seen (n=19,433), red dots refer to locations where hedgehogs were not seen (n=6,478).

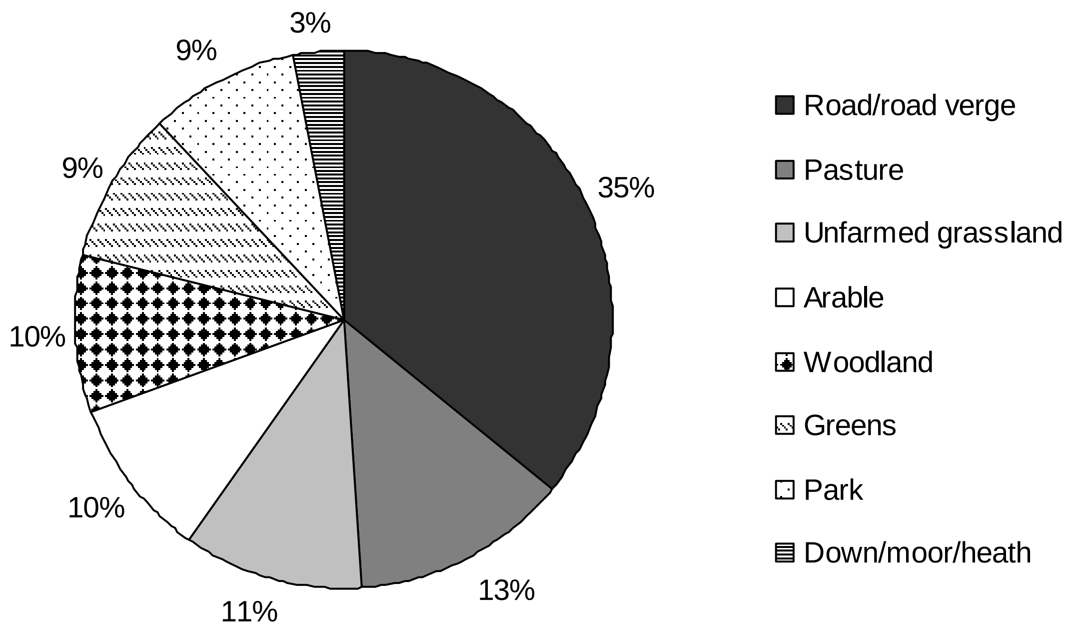


Figure 2.3 Sites where hedgehogs were seen other than gardens

Figure 2.4 shows the index of relative abundance of hedgehogs throughout England. The data are presented at the 10km^2 scale. The mean relative hedgehog abundance was significantly different per Government Office Region (ANOVA, F=168.752, df=8,1451, p<0.001) (Figure 2.5). The highest mean relative abundances were found in the North East and in the East of England. The lowest mean relative abundance was found in Greater London. Mean relative abundance of hedgehogs was also significantly different between environmental zones (ANOVA, F=69.894, df=2,1454, p<0.001) (Figure 2.6). The pasture-dominated lowlands had the lowest relative abundance of hedgehogs, whilst the arable-dominated lowlands had the highest relative abundance.

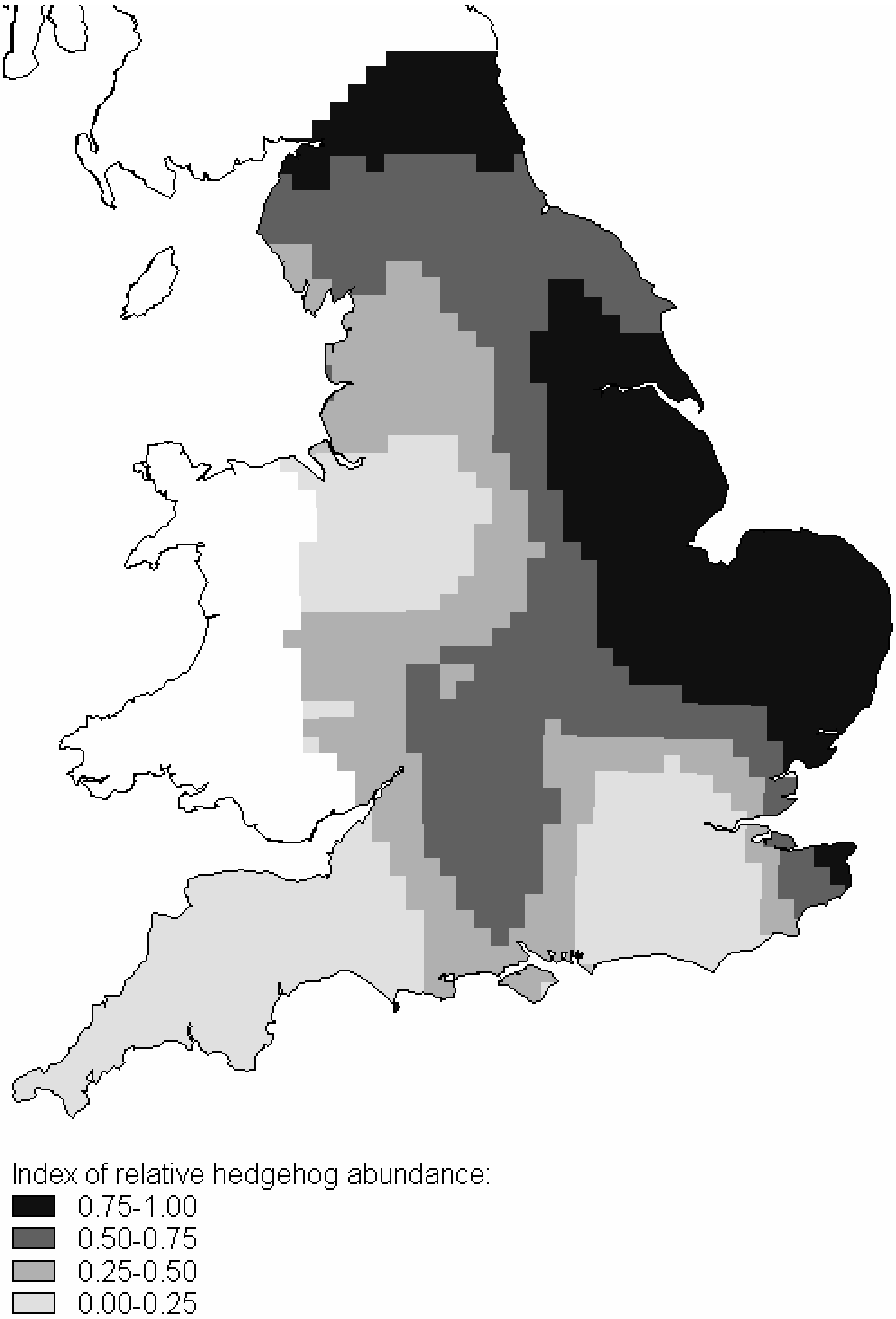


Figure 2.4 Index (0=low, 1=high) of relative hedgehog abundance throughout England estimated by kriging the data of the presence/absence of hedgehogs provided by the participants in the HogWatch survey, shown at a $10km^2$ scale.

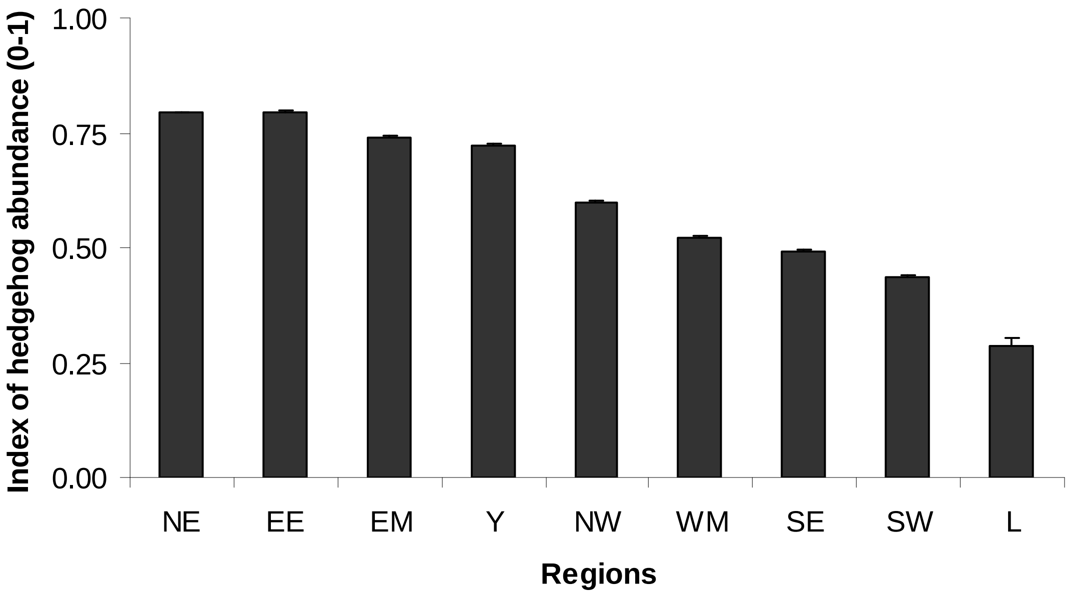


Figure 2.5 Index (0=low, 1=high) of mean relative hedgehog abundance per region (+se) (EE: East of England, EM: East Midlands, L: London, NE: North East, NW: North West, SE: South East, SW: South West., WM: West Midlands, Y: Yorkshire and The Humber.)

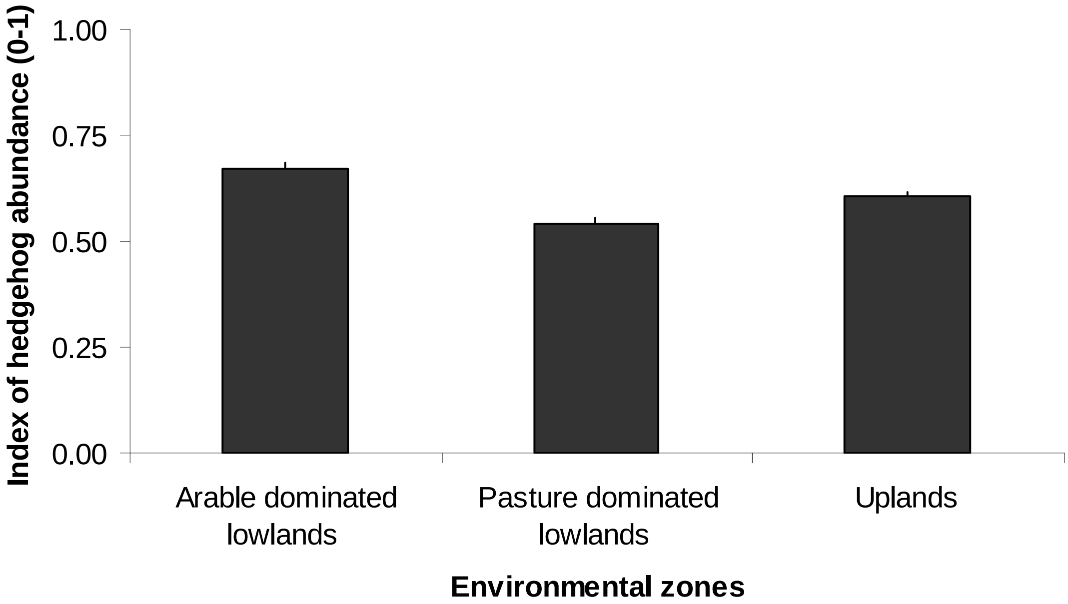


Figure 2.6 Index (0=low, 1=high) of mean relative hedgehog abundance per environmental zone (+se)

The GLM for England (Table 2.3) explained 68% of the variance in relative hedgehog abundance, of which 22% was explained by the variable *relative abundance of badgers*. A high relative abundance of badgers was related to a low relative abundance of hedgehogs (Figure 2.7). The GLMs for the environmental zones that are present in England explained, on average, 71% of the variance in relative hedgehog abundance. The variable *relative abundance of badgers* had the strongest negative impact on the relative abundance of hedgehogs overall as assessed by partial r^2. Variables that were positively correlated with the relative abundance were amongst others *density of arable and horticulture*, *coverage of minor roads*, *density of coniferous woodland*, and *density of upland*.

Table 2.3 Summary of the GLMs of relative abundance of hedgehogs

Model summary	***Variable***	***Estimate***	***Partial r^2***	***p.***
England Explained: 68%, n=1487, p. <0.001	Constant	0.774		<.001
	Badger	-0.054	0.220	<.001
	Arable and horticulture	0.022	0.011	<.001
	Conifer	0.010	0.006	<.001
	Neutral grass	0.011	0.006	<.001
	Semi-natural	-0.015	0.006	<.001
	Broadleaf	-0.008	0.005	<.001
	Upland	0.015	0.005	<.001
	Minor roads	0.004	0.004	<.001
	Hedgerow	0.007	0.001	0.015
	Improved grass	-0.005	0.001	0.038
The arable-dominated lowlands Explained: 77%, n=652, p. <0.001	Constant	0.802		<.001
	Badger	-0.072	0.204	<.001
	Upland	0.058	0.018	<.001
	Arable and horticulture	0.020	0.007	<.001
	Conifer	0.011	0.005	<.001
	Improved grass	0.017	0.005	<.001
	Broadleaf	-0.006	0.003	0.003
	Hedgerow	-0.017	0.003	0.002
	Neutral grass	0.007	0.002	0.024
The pasture-dominated lowlands Explained: 59%, n=666, p. <0.001	Constant	0.779		<.001
	Badger	-0.046	0.207	<.001
	Arable and horticulture	0.022	0.014	<.001
	Neutral grass	0.020	0.013	<.001
	Upland	0.031	0.013	<.001
	Improved grass	-0.011	0.008	<.001
	Hedgerow	0.010	0.005	0.006
	Semi-natural	-0.012	0.003	0.022
The uplands Explained: 78%, n=139, p. <0.001	Constant	0.829		<.001
	Badger	-0.035	0.099	<.001
	Upland	0.010	0.059	<.001
	Arable and horticulture	0.104	0.050	<.001
	Neutral grass	-0.01	0.032	<.001
	Conifer	0.005	0.029	<.001
	Hedgerow	-0.026	0.028	<.001
	Improved grass	0.010	0.016	0.002
	Semi-natural	0.006	0.009	0.023
	Broadleaf	0.006	0.007	0.041

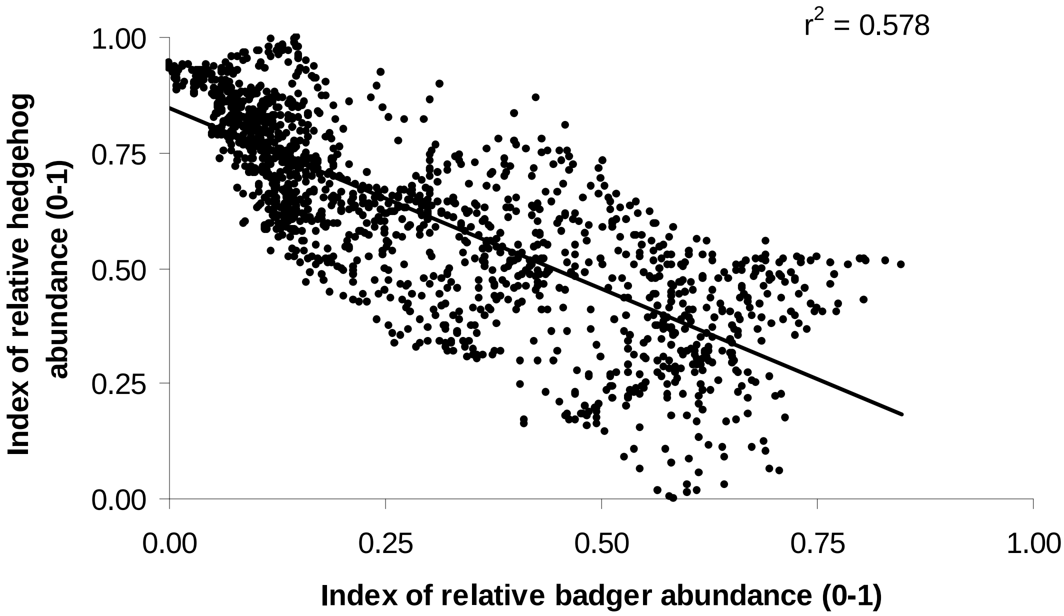


Figure 2.7 Relative abundance of hedgehogs versus relative abundance of badgers; displayed on an index of 0-1, (0=low, 1=high)

2.3.2 Change in relative abundance of hedgehogs

The majority of the respondents of the 2005-2006 survey (54%, n=1,005) who had a perception regarding a change in hedgehog numbers thought that hedgehogs had been declining over the last 10 years. More respondents (59%, n=3,220) thought so in respect of the last 5 years. Particularly people in Greater London felt that there had been a decline in hedgehog numbers; 68% (n=52) of the people living there sensed a decline compared with 10 years ago and 77% (n=217) compared with 5 years ago. In the North West the lowest proportion of people thought that hedgehog numbers had been declining compared with 10 years ago (49%, n=72), but compared with 5 years ago it was the people in the East of England (55%, n=429) who perceived a decline least often.

The area of occupancy changed significantly between the periods 1960-1975 and 2005-2006 (Chi-square Test, χ^2=18.132, df=1, p<0.001). In the period 1960-1975 3,596 people recorded hedgehogs in 79% of the 1,515 10km^2 grid-cells of England. However, in the period 2005-2006 14,529 people recorded seeing hedgehogs in 84% of the total number of grid-cells. Although the total area of hedgehog occupancy increased by about 5%, more than four times as many people took part in the survey in 2005-2006. If more people had taken part in the 1960-1975 survey, 100% of the grid-cells of England could theoretically already have been classified as occupied with about 6,000 sightings (Figure 2.8). Matching the number of participants in 2005-2006 to that in 1960-1975, by randomly selecting 3,596 recordings of the original 14,529 positive sightings of the 2005-2006 dataset 10,000 times, resulted in an average occupation of 63% (se=0.01%) of the grid-cells of England. This is remarkably lower than the 84% based on a larger number of participants. Hence, based on a similar number of participants the average difference in occupied grid-cells in England between 1960-1975 and 2005-2006 was -16%.

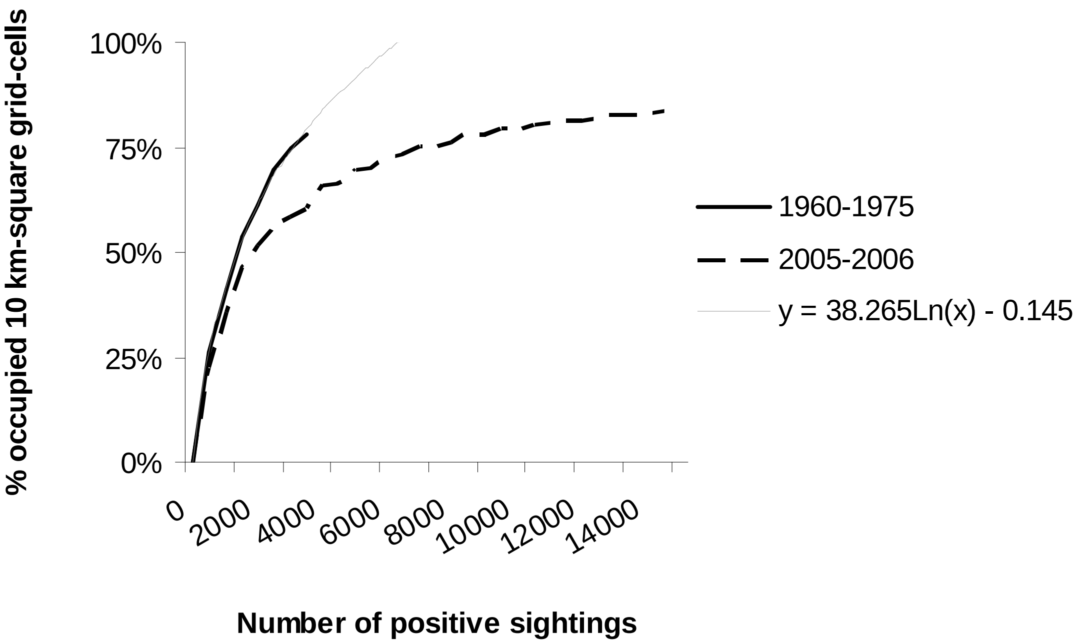


Figure 2.8 The percentage of $10km^2$ grid-cells in England where hedgehogs have been seen versus the number of positive sightings in the periods 1960-1975 and 2005-2006

The GLM explained 24% of the variance in change in relative hedgehog abundance between 1960-1975 and 2005-2006 (Table 2.4). The GLMs for the environmental zones explained, on average, 32% of the variance in change in relative hedgehog abundance (Table 2.4). The variable *change in other land used for agriculture* had the mean strongest negative impact on the change in hedgehog abundance. Other variables that also had a negative effect were *change in badger presence*, *change in bare fallow*, *soils with a peaty texture*, and *soils with a loamy texture and a low fertility*. Variables that were positively related to an increase in the relative abundance of hedgehogs were *change in* *arable*, *change in permanent grassland*, *change in woodland*, *change in rough grazing*, and *soil with a clayey and/or sandy texture*.

Table 2.4 Summary of the GLMs of change in hedgehog distribution.

Model summary	***Variable***	***Estimate***	***Partial r2***	***p.***
England Explained: 24%, n=1506, p. <0.001	Constant	-0.020		0.026
	Change all other	-0.074	0.066	<.001
	Change arable	0.046	0.035	<.001
	Change bare fallow	-0.043	0.028	<.001
	Change badger	-0.051	0.022	<.001
	Soils: sandy	0.048	0.011	<.001
	Change rough	0.019	0.007	<.001
	Change permanent	0.018	0.005	0.003
	Soils: peaty	-0.048	0.004	0.004
	Arable-dominated lowlands	0.028	0.003	0.016
	Uplands	-0.073	0.003	0.014
The arable-dominated lowlands Explained: 19%, n=652, p. <0.001	Constant	0.036		0.001
	Change permanent	0.077	0.068	<.001
	Change all other	-0.056	0.063	<.001
	Soils: loamy, low fertility	-0.063	0.019	<.001
	Change badger	-0.042	0.016	<.001
	Change woodland	-0.030	0.016	<.001
	Change rough	0.037	0.010	0.005
	Soils: clayey	0.054	0.007	0.017
The pasture-dominated lowlands Explained: 35%, n=666, p. <0.001	Constant	-0.090		<.001
	Change all other	-0.127	0.101	<.001
	Change bare fallow	-0.087	0.059	<.001
	Soils: sandy	0.091	0.029	<.001
	Change permanent	0.040	0.021	<.001
	Change rough	0.028	0.014	<.001
	Change badger	-0.042	0.011	0.001
	Soils: loamy, low fertility	0.047	0.006	0.018
The uplands Explained: 43%, n=139, p. <0.001	Constant	0.038		<.001
	Change woodland	0.056	0.243	<.001
	Change badger	-0.013	0.064	<.001
	Change rough	0.008	0.035	0.005
	Change bare fallow	-0.025	0.031	0.008
	Soils: loamy, low fertility	-0.016	0.022	0.024

2.3.3 Habitat selection

Hedgehogs significantly selected coniferous woodlands and uplands and avoided arable lands (Table 2.5). Pastures, neutral grasslands and deciduous woodlands were not significantly selected or avoided. Hedgehogs did have a stronger, although not significant, preference for neutral grasslands and deciduous woodland than for pastures and/or improved grasslands.

Table 2.5 Habitat selection by hedgehogs based on the data of the HogWatch survey. * denotes significant positive or negative selection.

Habitat type	***Selection probability***	χ^2	***Confidence interval***	
			Lower	*Upper*
Pasture/ improved grasslands	0.958	0.682	0.824	1.092
Neutral grasslands	1.183	6.577	0.995	1.371
Arable and horticulture	0.668*	59.190	0.554	0.782
Woodland (deciduous)	1.156	3.434	0.934	1.378
Woodland (coniferous)	1.964*	7.221	1.017	2.911
Down/moor/heath (upland areas)	2.800*	25.625	1.861	3.739

2.4 Discussion

2.4.1 Hedgehog distribution and abundance

Mapping species distributions and densities is valuable since conservation issues often rely upon accurate information on where species occur and where they do not. However, the practice is liable to flaws caused by, for instance, misidentification, false absence records, spatial differences in survey effort and flaws in the models used to predict species densities. Additionally, species that are widespread, such as the hedgehog, are more likely to use many habitats thus increasing the likelihood that more factors determine its distributions (Osborne & Suárez-Seoane, 2002). This will increase the difficulty in identifying drivers behind the dynamics of a population. Nevertheless, it was thought that due to the high number of respondents and their wide distribution, a valuable map of current hedgehog distribution and an index of relative hedgehog abundance could be created for England.

The map (Figure 2.4) clearly shows an apparent division in relative hedgehog abundance between the eastern and the southern and western parts of England, with a higher chance of seeing hedgehogs in eastern England. There is a possibility that these trends have emerged because of differences in the eagerness of people to respond to surveys. In an attempt to minimise these possible effects, the analyses have been based solely upon 10km^2 grid-cells that had yielded five or more returns. As a result it was thought likely that a measure of relative abundance could be obtained from differences in the proportion of hedgehog sightings versus absences. Furthermore, the assumption has been made that a higher number of sightings was positively related to relative hedgehog abundance. This assumption needs to be made with some care, because of differences in visibility caused by environmental features.

2.4.2 The habitat

It is surprising that the relative hedgehog abundance was highest in eastern England, since this area is characterised by arable landscapes. Arable land is said to be unfavourable for hedgehogs (e.g. Zingg, 1994; Huijser, 2000; Riber, 2006). This is also supported by the negative selection of arable sites in the present study, but not by the GLMs that showed that hedgehogs were positively related to areas with a high density of arable and horticulture land. Arable fields are often surrounded by field margins and hedgerows, where hedgehogs may have retreated to in order to escape the unfavourable arable habitat (see chapter 4 for the utilisation of field margins and hedgerows by hedgehogs). This edge-retreating habit of hedgehogs (see chapter 4) with regard to arable habitat might enhance visibility which could partly explain the positive relation between areas with a high density of arable and horticulture and relative hedgehog abundance.

Nonetheless, it is unlikely that differences in visibility due to hedgehogs being 'pushed' towards edge habitat because of unfavourable habitat surroundings is the sole factor that led to a significantly higher number of sightings in the eastern regions of England compared with the south-western regions. This can be deducted from the fact that the south-western regions of England are characterised by pasture-dominated lowlands and from the fact that hedgehogs avoided improved grasslands. Although many studies state that hedgehogs often spend a lot of time foraging on grasslands (Doncaster, 1992; Doncaster, 1994; Dowie, 1993; Huijser & Bergers, 1997; Huijser, 2000), they do not equally favour all types. Intensively managed grasslands, for instance, often offer less prey (e.g. Bontadina *et al.,* 1993; Wilson *et al.,* 1999; Jonas *et al.,* 2002), although this is not necessarily the case for earthworm density (Muldowney *et al.,* 2003). Zingg (1994) found that the grasslands utilised were mainly mowed lawns or gardens and not agricultural pastures. Huijser & Bergers (1997) also found that hedgehogs avoided grasslands. Indeed, also in the present study hedgehogs avoided improved grasslands and they were negatively related to improved grasslands in the pasture-dominated lowlands of

England. Therefore, differences in relative hedgehog abundance between the areas dominated by arable land and those dominated by pastures cannot entirely be explained by the habitat itself, since hedgehogs avoided both habitats.

A high density of neutral grassland did show a positive effect on relative hedgehog abundance in the present study, and was preferred by hedgehogs. These grassland types were found in higher densities in the east of England than in the southeast and southwest, in agreement with where a larger number of hedgehog sightings were reported. Alas, neutral grasslands are still being converted to less favourable arable sites, whilst the already intensified grasslands become increasingly rich in nutrients and less diverse in plants, resulting in even less suitable habitat; not only for hedgehogs, but also for various other wildlife species (Haines-Young *et al.,* 2000; Haines-Young *et al.,* 2003). It is, however, not likely that the higher density of neutral grasslands alone can have accounted for the higher relative abundance of hedgehogs in the eastern parts of England since other factors related more strongly to the relative abundance of hedgehogs.

2.4.3 Badgers

One of the factors that related strongly to the relative abundance of hedgehogs and might largely explain the clear division between the eastern and southern and western parts of England is the abundance of badgers. Badgers are intra-guild predators of hedgehogs; they may not only compete with hedgehogs for prey but also predate on them (e.g. Reeve, 1994; Young, 2005 and see other chapters). With the increasing number of badgers (Wilson *et al.,* 1997; Battersby, 2005) the pressure of intra-guild predation on hedgehogs might have increased as well. The present study illustrates that the abundance of badgers had a strong negative correlation with the current relative hedgehog abundance and with the change in their relative abundance. Badgers are more abundant in the southwest (Wilson *et al.,* 1997, and see chapter 5), which relates well with the lower abundance of hedgehogs in these regions. One of the reasons that badgers are present at higher densities in the southeast and the southwest than in the east of England might be partly due to the higher density of broadleaved woodland (12 versus 6 ha/km^2 [DEFRA & NERC, 2007]) and more hilly and undulating habitat. Over 50% of the setts dug by badgers were found in deciduous and mixed woods and copses, and were positively correlated with the slope of the ground (Thornton, 1988; Neal & Cheeseman, 1996; Huck *et al.,* 2008). It is therefore not surprising that in several of the models for England, woodland related negatively to relative hedgehog abundance, because of its possible effect in enhancing badger numbers. There was, however, no collinearity between broadleaved woodland and the relative abundance of badgers in the data used.

As in the present study, the preference/avoidance of hedgehogs for woodlands is not consistent when reviewing the literature; various studies show that hedgehogs preferred woodlands (e.g., Dowie, 1993; Riber, 2006), while others show that they avoided them (Morris, 1986; Doncaster, 1994; Zingg, 1994; Huijser, 2000). The size of the patch and the undergrowth characteristics might explain these differences, where larger woodlands might sustain higher densities of badgers and offer less of the edge habitat preferable to hedgehogs. Additionally, woodlands characterised by little undergrowth might not provide sufficient nest-sites and cover-sites for hedgehogs.

Recently it is thought that the densities of badgers in urban areas have also been increasing (Rural Development Service, 2005; Huck *et al.,* 2008; Delahay *et al.,* 2009). This might have a further impact on hedgehogs, since urban areas were thought to be largely free of badgers and could therefore act as refugia for hedgehogs (Young *et al.,* 2006; Dowding, 2007). The impact of dogs (*Canis lupus familiaris*) and red foxes (*Vulpes vulpes*) is not thought to be high enough to regulate populations (Doncaster *et al.,* 1990; Doncaster, 1994), but studies that attempt to answer this specific question are currently not underway.

2.4.4 Urban areas

Hedgehogs have long been associated with urban areas (Reeve, 1994; Huijser, 2000). The present study revealed that in a heavily urbanized area such as Greater London people reported significantly more negative sightings then in less urbanized areas. Additionally, nearly 80% of the respondents from Greater London who reported a change in relative hedgehog abundance over the last five years reported a decline, compared with only 60% in the rest of Great

Britain. It is likely that this is partly caused by the coverage of roads in urbanized areas; Chapters 5 and 6 will deal more in depth with factors affecting hedgehog distributions in urban areas. Although the variable *coverage of major roads* was not incorporated in the GLMs due to strong collinearity with the weighting factor *built-up*, it can have a strong negative impact on the presence of hedgehogs. As mentioned before, Huijser & Bergers (2000) stated that roads and traffic alone could reduce hedgehog populations in The Netherlands by about 30%. This will inevitably have its impact on hedgehog populations. The possible effects of roads in Great Britain can therefore not be ignored.

One of the other reasons for the apparent declining trend in urban hedgehog populations might be an increase in predation by an increasing number of badgers and possibly red foxes (Sue Kidger, personal communication, 2008), which will be discussed in chapter 5. Yet, this population decrease is not only seen in hedgehogs but has also been observed in other species that used to be strongly associated with urban areas, such as the house sparrow (*Passer domesticus*) (Siriwardena *et al.,* 2002, Robinson *et al.,* 2005; De Laet & Summers-Smith, 2007). A reason mentioned for the decline in sparrows is the use of garden pesticides, which might also have an impact on hedgehog numbers. Also the increasing loss of habitat might make urban areas more and more unfavourable for many species of wildlife (Greater London Authority & London Assembly, 2001; Greater London Authority & London Assembly, 2005a; Greater London Authority & London Assembly, 2006a). Chapter 5 and 6 will look more in depth at the role of urban areas in the decline in hedgehogs.

2.4.5 Declining hedgehog numbers

Based on the available data, a trend towards a decline in the relative abundance of hedgehogs is suggested. Although over 80% of the total number of 10km^2 grid-cells were occupied by hedgehogs in 2005-2006, which suggests that the hedgehog is still widespread, a 16% decline in occupied grid-cells was observed when compared with 1960-1975 after adjusting for differences in effort. Unfortunately the methods of surveying were not entirely similar; recording effort and distribution of the surveyors might have been different too. I however feel that large datasets such as the Hogwatch one do show sufficient detection power to visualise a trend in populations. This method can be used in conjunction with small scale more detailed studies to get a more comprehensive impression on how a species is faring. Further more detailed and continuous research into the distribution and abundance of hedgehogs within Great Britain is recommended and clearly necessary.

Chapter 3

Factors affecting hedgehog presence on farmland as assessed by a questionnaire study

Chapter 3

Factors affecting hedgehog presence on farmland as assessed by a questionnaire survey

3.1 Introduction

Over 17,000,000 ha, comprising 71% of the total land area, was used for agricultural purposes in the United Kingdom in 2007 (DEFRA & National Statistics, 2008). This extensive area is potentially valuable for the conservation of biodiversity. Agricultural areas can sustain numerous species and high densities of certain species. Small patches of woodlands, natural grasslands and hedgerows within arable landscapes can provide refuges for insects (Öckinger & Smith, 2007; Woodcock *et al.,* 2007), birds (Hinsley & Bellamy, 2000; Vickery *et al.,* 2001), small mammals (Moore *et al.,* 2003; Michel *et al.,* 2006; Butet *et al.,* 2006) and other species (Hole *et al.,* 2005). However, especially after the Second World War, farm management rapidly changed and intensified resulting in a reduction in diversity of landscapes caused by, for instance, the removal of hedgerows and by an increase in mean field and farm size (Robinson & Sutherland, 2002). Consequently, changes in agricultural management have frequently been mentioned as one of the major causes for the loss of species diversity and abundance (e.g. Tapper & Barnes, 1986; Krebs *et al.,* 1999; Chamberlain *et al.,* 2000; Donald *et al.,* 2001; Vickery *et al.,* 2001; Robinson & Sutherland, 2002; Smith *et al.,* 2005). Small mammal diversity need not necessarily be affected by agricultural intensification (Burel *et al.,* 1998); nevertheless, many studies conducted throughout the world point towards it as a major reason for the decrease in mammal abundance (e.g. Tapper & Barnes, 1986; Robinson& Sutherland, 2002; De la Peña *et al.,* 2003; Butet *et al.,* 2006; Bilenca *et al.,* 2007). Indeed, agricultural intensification has also been suggested as a cause of the recent apparent decline in hedgehogs in Great Britain (George, 2004; Bunner, 2004; MTUK, 2005; Davey & Aebischer, 2006) (see also section 1.3.2)

Questionnaire surveys are a useful tool to study the distribution of elusive species and have become increasingly popular in ecology (e.g. Reading *et al.,* 1996; Seiler, 2003; Vaughan *et al.,* 2003; White *et al.,* 2005). Using questionnaires enables a specific group of people to be targeted and gathers extensive datasets in a relatively short period. Nevertheless, the data obtained from questionnaires have to be regarded with some care since the targeted group is often not specialist in the field. Hedgehogs however are easily recognized and it is thus felt that reliable data could come from a questionnaire survey. A questionnaire study has therefore been used to identify factors that may influence the presence and abundance of hedgehogs on farms. The aim of this chapter was to study the current distribution of, and perceived changes in, hedgehog numbers in the countryside of Great Britain over the last ten years, and to gain insight into which aspects are related to hedgehog distribution and abundance on farms.

3.2 Methods

3.2.1 The questionnaire

The distribution of hedgehogs on farms was determined from data collected by means of a postal based questionnaire survey aimed at a random selection of landowners. Landowners were chosen at random by geographic county, in order to get a representative selection. Addresses were obtained from the 'yellow pages' (available at URL: http://www.yell.com/). The aim was to cover at least 1% of the land under agricultural management by the questionnaires, distributed throughout Great Britain, and representing all government office regions of England, Scotland, Wales and all environmental zones (Figure 2.1).

Based on the total area under agricultural holdings, the total number of holdings (URL: https://statistics.defra.gov.uk/esg/publications/fiuk/2002/c5_t3-4.xls), and the average response rate from questionnaires used in ecology (63% [White *et al.,* 2005]), just over 2500 landowners needed to be send a questionnaire. In order to obtain a good distribution and to account for a lower response rate, the questionnaire was sent to 4000 landowners. Postal codes of the respondents were retained in order to be able to locate the farms on the 1km^2 level. The questionnaire was kept as simple and short as possible in order to maximize the return rate and to minimize the likelihood of mistakes. A small pilot study aimed at 10 landowners was set up in order to identify possible problems in the questionnaire. Recommendations as set out by White *et al.,*

(2005) were followed where possible. Unfortunately logistics did not allow a ground-truthing study to assess the accuracy of the data obtained from the questionnaire.

3.2.2 Data collection

The main data obtained from the questionnaire concerned the location of the farm provided by a postal code, the presence of hedgehogs, their estimated abundance (0, <3, ≥3≤6, >6), and any change in their abundance since 1996 as perceived by the respondents (increasing, decreasing or no change). The estimated abundance of hedgehogs is defined as the estimated number of hedgehog sightings by the respondent; throughout this chapter 'estimated abundance' is used. For purposes of analyses the estimated abundance was classed as follows: 0: 0 hedgehogs, <3:1 hedgehog, ≥3≤6: 4 hedgehogs, and >6: 7 hedgehogs. The following data regarding agricultural management were also obtained from the respondents:

- Size of the farm (ha)
- Percentage of grassland, woodland and arable land (0%, 1-25%, 26-50%, 51-75%, 76-100%)
- Length of hedgerows (m)
- Type of farm (arable, dairy, livestock, market garden/horticulture, other)
- Organic status (yes/no)
- Type of agri-environment scheme (none, Entry Level Stewardship, Higher Level Stewardship, Organic Entry Level Stewardship, other)
- Duration of agri-environment scheme (just started, <5 years, >5<10 years, >10 years)

The classes of the percentage of grassland, woodland and arable were converted to mean number of hectares based on the stated size of the farm. Other data derived from the questionnaire comprised the locations where hedgehogs were found most often, suggested reasons for change in hedgehog abundance during the period 1996 to 2006, the attitude of the respondents towards hedgehogs and their willingness to change farm management for the benefit of hedgehogs. See Appendix II for the details. The same environmental data as used in chapter 2 have been used for the analyses of the questionnaire returns. Data about landscape features and habitat types were derived from CS2000 (DEFRA & NERC, 2007), and soil data for England were obtained from the National Soil Research Institute (NSRI). The environmental data were available at the 1km^2 level, which was also used for the representation of the respondents to the questionnaire. Variables did not show strong collinearity with one another ($r \leq 0.60$, Graham, 2003).

3.2.3 Statistical analyses

Generalized linear modelling (GLM) of binomial proportions with logit transformation was used in GenStat (for windows 8th edition, VSN International Ltd, Lawes Agricultural Trust, Oxford, UK) for the analyses of the presence of hedgehogs, and the perceived change in hedgehog abundance. GLM with the normal distribution and identity link function has been used to analyse the current perceived abundance of hedgehogs. Names and explanations of the variables used in the analyses are given in Table 3.1. The models of best fit were selected using the backward stepwise method, similar to the procedure in chapter 2. Maps were produced in a Geographic Information System (Mapinfo Professional Version 8, MapInfo Corporation, New York, USA). The variable *built-up* was used as a weighting factor to account for differences in the amount of area available for farmland at the 1km^2 level. *Built-up* was used rather than *size of the farm* since a proportion of the respondents failed to state the size of their farm and farm buildings were not accounted for. The data for *built-up* on the other hand were available for all respondents and were assumed to directly relate to the area available for farmland. A model was developed for Great Britain and for the environmental zones separately in order to investigate the factors that had an impact on the presence of hedgehogs, and on the perceived change in hedgehog densities, in the period 1996 to 2006 at a smaller scale. In order to be able to directly compare the estimates of the variables included in the model, the variables were standardized using Equation 2.1 as set out in chapter 2. Statistical analyses other than GLM were conducted using SPSS (for windows 14th edition, SPSS Inc., Chicago, USA).

Table 3.1 Variables used for the analyses of the hedgehog distribution on farms in Great Britain

Variable	***Explanation***
Arable and horticulture	Density of arable and horticultural area in 2000 (ha)
Badger	Relative abundance of badgers 2003-2006 (# animals)
Broadleaf	Density of broadleaved woodland in 2000 (ha)
Built-up	Density of built-up area in 2000 (ha)
Conifer	Density of coniferous woodland in 2000 (ha)
Farm habitat	Amount of arable/woodland/grassland on the farm (ha)
Farm type	arable/dairy/horticulture/livestock/poultry
Hectares	Amount of ha of land on the farm (ha)
Hedgehog	Relative hedgehog abundance (estimated #)
Hedgerow	Length of hedgerows (km)
Improved grass	Density of improved grassland in 2000 (ha)
Major roads	Coverage of major roads in 2000 (km)
Minor roads	Coverage of minor roads in 2000 (km)
Neutral grass	Density of neutral grassland in 1998 (ha)
Regions	Government Office Regions of England, Wales, Scotland
Residential urban	Coverage of residential buildings, gardens and grounds in 2000 (ha)
Scheme	Presence of an agri-environment scheme on the farm land (yes/no)
Semi-natural	Density of semi-natural grassland (an amalgamation of neutral, calcareous, and acid Grassland, bracken and fen, marsh and swamp) in 2000 (ha)
Soil type	The Soil types of England 1: soils with a clayey texture, 2: soils with a peaty texture, 3: soils with a sandy texture, 4: soils with a loamy texture and rich in lime, 5: soils with a loamy texture and a low fertility, 6: soils with a loamy texture and a moderate to high fertility
Upland	Density of dwarf shrub heath, bog, montane/ inland rock in 2000 (ha)

3.3 Results

3.3.1 Presence of hedgehogs

Of the 4000 questionnaires sent out, 26% (n=1054) were returned. Figure 3.1 shows the distribution of the respondents. Questionnaires were returned from 724 (26%) of the 10km^2 grid-cells present in Great Britain. Over 310,000ha of farmland was covered by the farms of the respondents, comprising about 1.8% of the total agricultural area in Great Britain in 2006. Return rates were unfortunately biased geographically because not a similar percentage of people responded from each region (Median: 24%, Range 20-33% [Chi-square Test, χ^2=23.559, df=10, p=0.009). Nevertheless, the respondents were spread throughout the country.

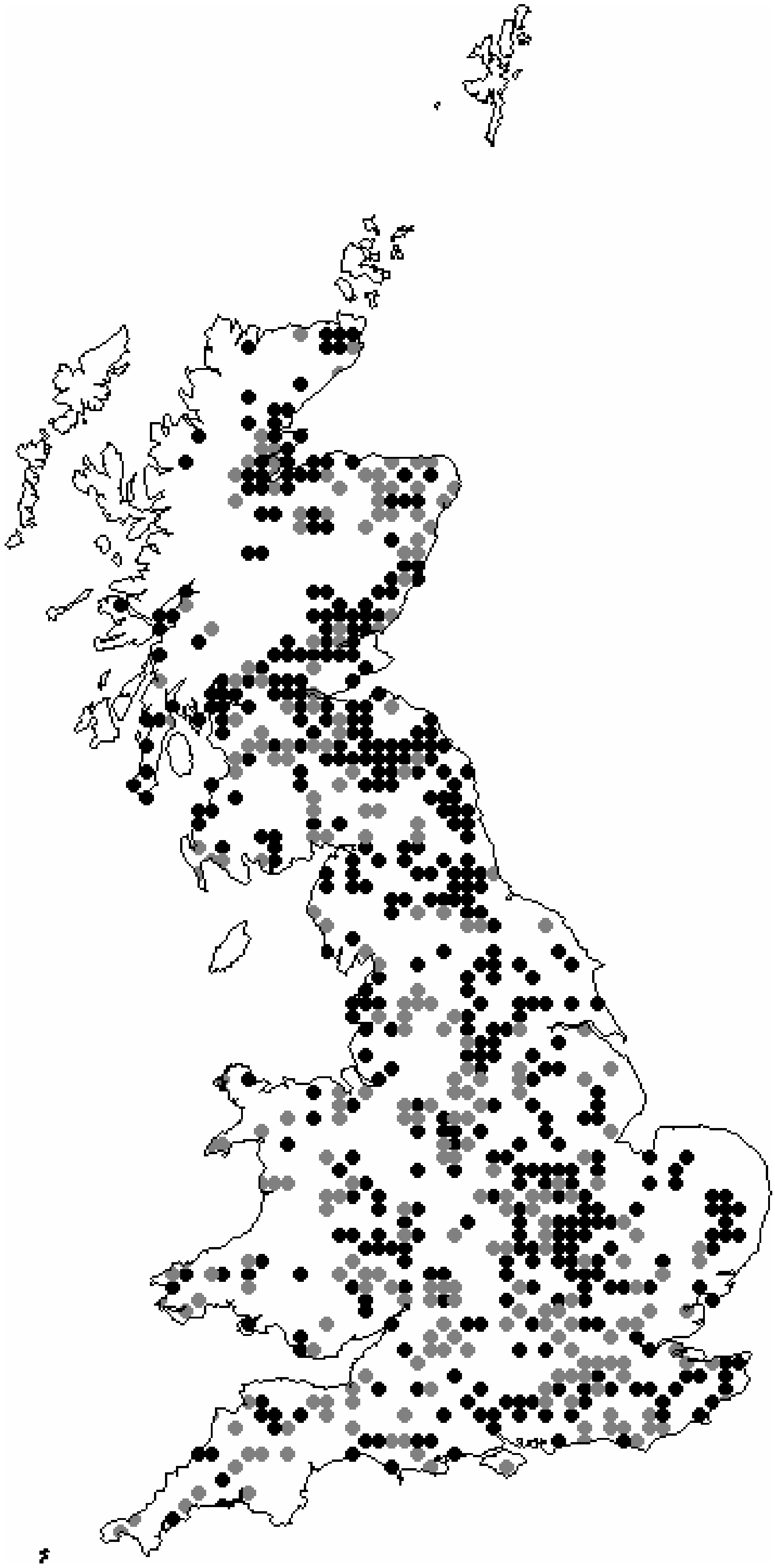


Figure 3.1 The locations of the respondents (n=1054) to the questionnaire. Black dots (n=580) represent farmers who saw hedgehogs, grey dots (n=474) represent farmers who did not see hedgehogs. Questionnaires were not sent to offshore islands, except the Isle of Wight.

Hedgehogs were seen by 55% (n=580) of the respondents. Figure 3.2 shows the total number of respondents per region and the percentage of those who had seen hedgehogs. The majority of the respondents had seen hedgehogs on their farm in all northern regions. In the southern regions, except for East England and the South East of England, the majority of people did not see hedgehogs on their farm (Chi-square Test, χ^2=49.803, df=10, p<0.001). The respondents most often encountered hedgehogs in their garden followed by grassland and deciduous woodland. They were, on the other hand, least often seen in coniferous woodland and on heathland (Figure 3.3).

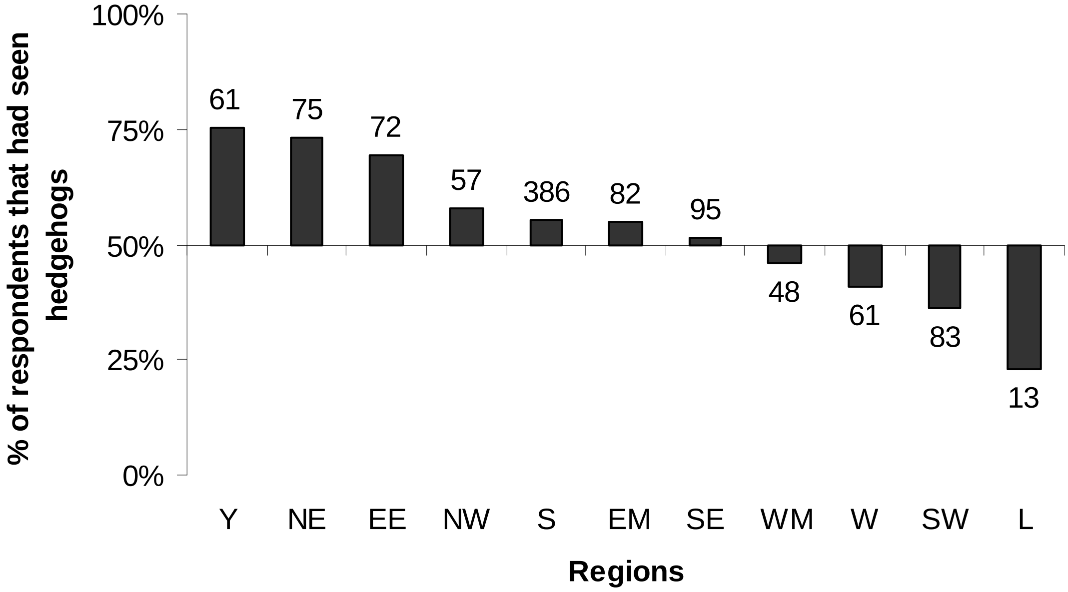


Figure 3.2 Percentage of respondents to the questionnaire that had seen hedgehogs on their farm in Great Britain, shown per region. Data labels show the number of respondents. EE: East of England, EM: East Midlands, L: London, NE: North East, NW: North West, S: Scotland, SE: South East, SW: South West., W: Wales, WM: West Midlands, Y: Yorkshire and The Humber.

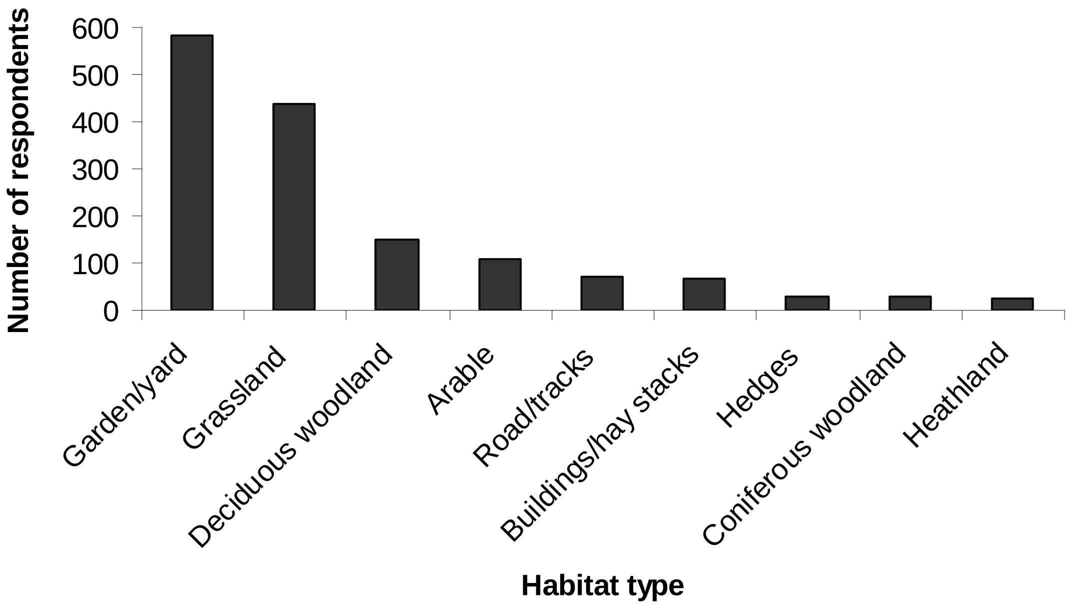


Figure 3.3 The most frequently mentioned locations where hedgehogs were seen on the farm by the respondents to the questionnaire

Table 3.2 shows the summary of the GLM for Great Britain and Table 3.3 shows the summaries for the six environmental zones. The organic status of the farm has not been used in the analyses due to lack of sufficient respondents with an organic farm (4%, n=42). For the whole of Great Britain only 35% of the variance in the presence of hedgehogs was explained by various variables, of which the variable *density of upland*, followed by *density of arable and horticulture*, had the strongest positive impact. The strongest negative effect on the presence of hedgehogs was explained by the variable *coverage of major roads*, followed by *livestock farms* and *relative badger abundance*.

The GLMs for the environmental zones explained on average 49% of the variance in hedgehog presence. In the arable-dominated lowlands of England and Wales the strongest negative variable was *livestock farms*. The variable *arable on the farm* showed on the other hand the strongest positive effect. In the pasture-dominated lowlands of England and Wales the strongest negative variable was *sandy soils*, whilst *density of arable and horticulture* was the strongest positive variable. In the uplands of England and Wales 60% of the variance was explained by three variables: the *coverage of minor roads*, *coverage of major roads*, and the *relative abundance of badgers*. Only the variable *relative abundance of badgers* was negatively related to the presence of hedgehogs. In the lowlands of Scotland the variables *density of broadleaved woodland* and *coniferous woodland* showed the strongest positive relations and *coverage of major roads* the strongest negative relation to hedgehog sightings. In total 60% of the variation in hedgehog presence was explained in the marginal uplands and islands of Scotland by *coverage of minor roads*, *density of broadleaved woodland*, *arable on the farm* and the *coverage of major roads*. The first two variables were positively correlated with the presence of hedgehogs, whilst the latter two had negative impacts. In the true uplands of Scotland, the variable *density of arable and horticulture* was the sole factor in the minimum adequate model explaining over 57% of the variance in hedgehog presence. Hedgehogs were seen less often in areas that had a high amount of arable land and/or horticulture. The variables *density of arable and horticulture* and *coverage of minor roads* showed, on average, the strongest (mainly positive) relationship with the presence of hedgehogs when considering all models. The strongest negative variable, on average, was the *relative abundance of badgers*.

Table 3.2 Summary of the GLM of hedgehog presence on farms in Great Britain

Model summary	***Variable***	***Estimate***	***Partial r^2***	***p.***
Explained: 35%, n=1050, p<0.001	Constant	1.768		<.001
	Major roads	-0.622	0.098	<.001
	Farm type: livestock	-1.642	0.056	<.001
	Badger	-0.642	0.041	<.001
	Upland	2.539	0.015	<.001
	Arable and horticulture	0.552	0.013	<.001
	Wood	-0.887	0.013	<.001
	Soils: clayey	-1.812	0.012	<.001
	Soils: peaty	2.598	0.012	<.001
	Hedgerow	0.444	0.009	<.001
	Farm type: arable	0.617	0.007	<.001
	Farm type: dairy	0.843	0.006	<.001
	Conifer	-0.546	0.002	0.014
	Farm type: poultry	0.701	0.002	0.023

Table 3.3 Summary of the GLMs of hedgehog presence of hedgehogs on farms per environmental zone

Model summary	***Variable***	***Estimate***	***Partial r^2***	***p.***
Arable-dominated lowlands of England and Wales Explained: 42%, n=294, p<0.001	Constant	5.024		<.001
	Farm type: livestock	-3.490	0.239	<.001
	Farm type: arable	-2.528	0.073	<.001
	Broadleaf	-0.897	0.060	<.001
	Badger	-0.662	0.041	<.001
	Soils: clayey	-1.983	0.023	<.001
	Arable	1.477	0.017	<.001
	Soils: sandy	1.691	0.014	<.001
	Minor roads	-0.487	0.013	<.001
	Farm type: dairy	-0.994	0.008	0.002
	Wood	-0.490	0.008	0.004
	Farm type: horticulture	1.052	0.007	0.006
	Upland	1.366	0.007	0.008
	Semi-natural	-0.483	0.005	0.014
Pasture-dominated lowlands of England and Wales Explained: 54%, n=274, p<0.001	Constant	0.745		0.036
	Arable and horticulture	1.698	0.113	<.001
	Soils: sandy	-6.379	0.086	<.001
	Wood	-4.340	0.066	<.001
	Farm type: arable	2.582	0.064	<.001
	Badger	-1.320	0.057	<.001
	Upland	6.625	0.050	<.001
	Improved grass	0.884	0.032	<.001
	Minor roads	-0.243	0.006	0.005
	Farm type: dairy	0.916	0.004	0.023
	Hedgerow	0.885	0.004	0.030
Uplands of England and Wales Explained: 60%, n=73, p<0.001	Constant	-5.640		0.046
	Minor roads	2.040	0.348	0.006
	Badger	-10.77	0.317	0.025
	Major roads	2.600	0.113	0.017
Lowlands of Scotland Explained: 22%, n=252, p<0.001	Constant	2.569		<.001
	Conifer	1.397	0.073	<.001
	Broadleaf	1.377	0.071	<.001
	Improved grass	1.231	0.046	<.001
	Arable and horticulture	0.857	0.017	<.001
	Semi-natural	0.555	0.016	<.001
	Major roads	-0.330	0.011	<.001
	Neutral grass	-0.644	0.009	0.003
	Residential urban	0.410	0.006	0.015
	Hedgerow	1.729	0.005	0.032
Uplands and islands of Scotland Explained: 60%, n=90, p<0.001	Constant	-1.547		0.031
	Minor roads	5.580	0.436	<.001
	Broadleaf	6.370	0.330	<.001
	Arable and horticulture	-7.760	0.289	<.001
	Major roads	-1.468	0.060	0.014
The true uplands of Scotland Explained: 57%, n=47, p<0.001	Constant	4.560		0.006
	Arable and horticulture	-0.264	0.572	0.044

3.3.2 Hedgehog abundance

Landowners were asked how often they saw hedgehogs on their farm during 2006, which was used as an indication of hedgehog abundance. In total 45% of the landowners (n=474) had not seen hedgehogs. Hedgehogs were seen less than three times by 19% (n=200) of the respondents, whilst 20% (n=211) saw hedgehogs between three and six times and 16% (n=169) saw hedgehogs more than six times. The mean abundance of hedgehogs was significantly higher on arable farms than on other farms (mean=2.5 hedgehogs seen per farm, n=203, se=0.2) and lowest on dairy farms (mean=1.4 hedgehogs seen per farm, n=57, se=0.3) (Chi-square Test, χ^2=33.054, df=9, p<0.001). Figure 3.4 shows the mean abundance of hedgehogs seen on farms per region. Again, the northern and eastern regions show a higher apparent abundance of hedgehogs than the south and western regions (Chi-square Test, χ^2=105.863, df=33, p<0.001).

The GLMs for Great Britain and five of the environmental zones are shown in Table 3.4. No minimum adequate model could be obtained for the true uplands of Scotland due to the low number of respondents from this area. The model for Great Britain explained 31% of the variance, with the *relative abundance of badgers* and the *coverage of major roads* as negative variables and the *coverage of minor roads* and the *density of arable and horticulture* as positive variables. The interaction between the *relative abundance of badgers* and *peaty soils* was also positively related to the relative abundance of hedgehogs. In total 20% of the variance in hedgehog abundance was explained in the arable-dominated lowlands of England and Wales by the same variables except for the *coverage of minor roads* and the *density of arable and horticulture*. In the pasture-dominated lowlands of England and Wales both the *coverage of major roads* and the *relative abundance of badgers* were strongly correlated with a low abundance of hedgehogs, with 50% of the variance being explained. Conversely a high abundance was correlated with the variables *arable farm* and *loamy, lime rich soils*. In the uplands of England and Wales a total of 68% of the variance was mainly explained by the interaction between the *relative abundance of badgers* and *peaty soils*.

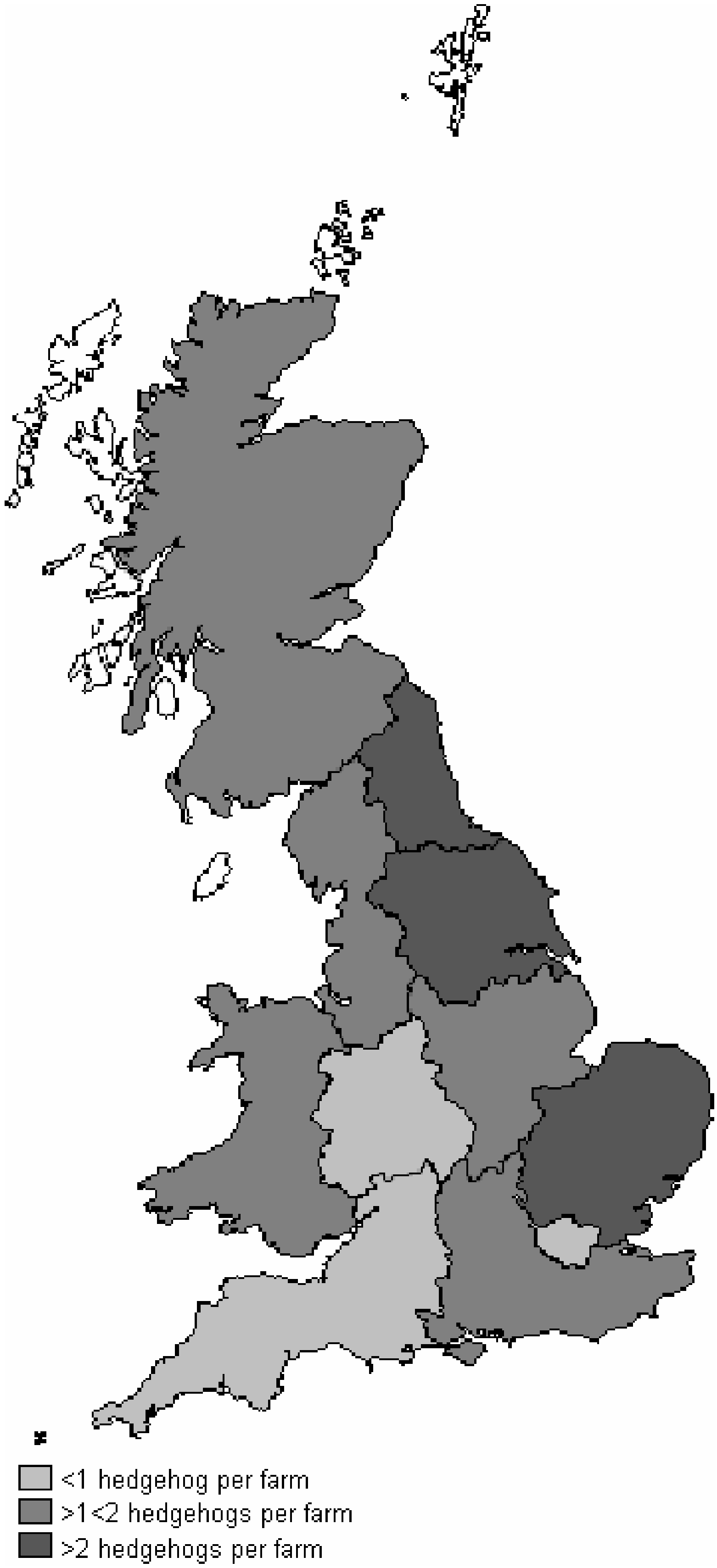


Figure 3.4 Mean perceived abundance of hedgehogs per farm per region in 2006 as observed by respondents to the survey. Questionnaires were not sent to offshore islands, except the Isle of Wight.

In the lowlands of Scotland 21% of the variance was explained by the variables *density of semi-natural grasslands*, *density of broadleaved woodlands* (both positive) and by *density of residential urban* (negative). The variable *dairy farm* explained 41% of the variance in the marginal uplands and islands of Scotland, and was positively related to hedgehog abundance.

Table 3.4 Summary of the GLMs of hedgehog abundance on farms in Great Britain and per environmental zone

Model summary	***Variable***	***Estimate***	***Partial r^2***	***p.***
Great Britain Explained: 31%, n=1050, p<0.001	Constant	2.223		<.001
	Badger*Soils: peaty	2.568	0.074	<.001
	Badger	-0.565	0.053	<.001
	Minor roads	0.468	0.051	<.001
	Major roads	-0.312	0.041	<.001
	Arable and horticulture	0.685	0.040	<.001
Arable-dominated lowlands of England and Wales Explained: 28%, n=294, p<0.001	Constant	2.263		<.001
	Badger*Soils: peaty	3.147	0.200	<.001
	Badger	-0.548	0.067	<.001
	Major roads	-0.340	0.044	<.001
Pasture-dominated lowlands of England and Wales Explained: 50%, n=274, p<0.001	Constant	1.781		<.001
	Major roads	-0.446	0.109	<.001
	Farm type: arable	1.599	0.093	<.001
	Badger	-0.812	0.089	<.001
	Soils: loamy, rich in lime	3.859	0.061	<.001
	Minor roads	0.448	0.060	<.001
	Semi natural	-0.590	0.017	0.026
	Upland	1.759	0.015	0.033
Uplands of England and Wales Explained: 68%, n=73, p<0.001	Constant	0.573		0.046
	Badger*Soils: peaty	10.340	0.440	<.001
	Farm type: dairy	5.217	0.374	<.001
	Soils: peaty	-7.090	0.292	<.001
	Hedge	0.706	0.203	<.001
Lowlands of Scotland Explained: 21%, n=252, p<0.001	Constant	1.734		<.001
	Residential urban	-0.856	0.120	0.010
	Semi natural	0.638	0.079	0.034
	Broadleaf	0.769	0.077	0.036
Uplands and islands of Scotland Explained: 41%, n=90, p<0.001	Constant	0.708		0.017
	Farm type: dairy	6.290	0.434	<.001

3.3.3 Perceived change in hedgehog presence 1996-2006

In total 62% of the respondents did not notice a change in hedgehog abundance between 1996 and 2006. A total of 33% said that they saw fewer hedgehogs in 2006 than in 1996 while only 5% said that hedgehogs were more abundant in 2006. A decline in the hedgehog population was most frequently observed by respondents from the pasture-dominated lowlands (40%) and from the uplands of Wales (41%). Almost half (48%, n=187) of all of the respondents who mentioned factors that might be related to the changing number of hedgehogs said they observed a negative relationship between the badger density on their farm and hedgehog abundance. Figure 3.5 shows the possible causes for observed changes in hedgehog numbers that were suggested most frequently by the respondents.

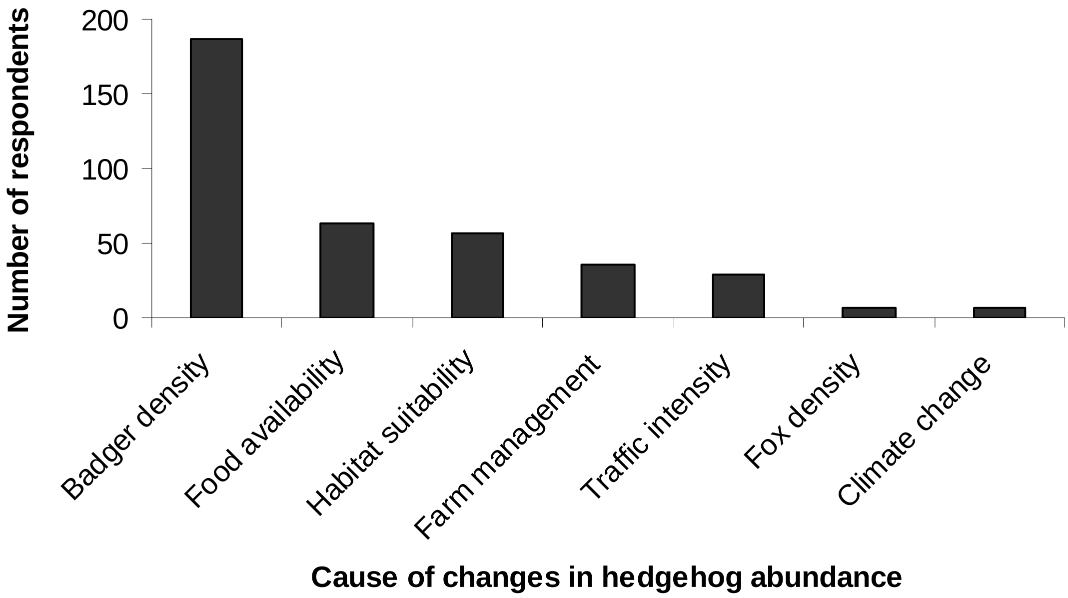


Figure 3.5 The frequency with which different reasons were given by respondents for apparent changes in hedgehog abundance

A total of 44% of the variance in perceived change in hedgehog abundance was mainly explained by the negative effect of *improved grasslands, coverage of major roads* and *arable farms,* and the positive effect of *poultry farms* and *agri-environment schemes*. Respectively, 22% and 47% of the variance was explained for the pasture and the arable-dominated lowlands of England and Wales. In the arable-dominated lowlands both the *density of broadleaved woodland* in the area and the amount of *woodland on the farm* were negatively related to the perceived change in hedgehog numbers. The *density of arable and horticulture* showed the strongest positive relation. In the pasture-dominated lowlands the variable *poultry farm* was positively related to the perceived change in hedgehog abundance and was the strongest predictor. Minimum adequate models could not be obtained for the other environmental zones. The three models (Table 3.5) showed that the *density of improved grasslands* and the *coverage of major roads* had, on average, the strongest negative relationship with the perceived change in hedgehog abundance. The strongest positive impact came from the variables *poultry farm* and *density of arable and horticulture*.

Table 3.5 Summary of the GLMs of perceived change in hedgehog abundance on farms in Great Britain and in the environmental zones

Model summary	***Variable***	***Estimate***	***Partial r^2***	***p.***
Great Britain. Explained: 44%, n=364, p<0.001	Constant	-4.568		<.001
	Farm type: poultry	3.959	0.135	<.001
	Farm type: arable	-2.821	0.105	<.001
	Improved grass	-1.701	0.104	<.001
	Major roads	-1.080	0.104	<.001
	Scheme	1.484	0.028	<.001
	Soils: loamy, mean/high fertility	1.534	0.027	<.001
	Conifer	-2.207	0.019	<.001
	Soils: loamy, rich in lime	2.508	0.019	<.001
	Semi-natural	0.475	0.007	0.002
	Badger	-0.373	0.006	0.006
Arable-dominated lowlands of England and Wales. Explained: 21%, n=105, p<0.001	Constant	-3.846		<.001
	Arable and horticulture	1.728	0.127	<.001
	Grass	5.040	0.069	<.001
	Farm type: dairy	2.399	0.063	<.001
	Wood	-3.646	0.054	<.001
	Conifer	-3.280	0.051	0.008
	Minor roads	0.562	0.022	0.006
	Hedgerow	0.546	0.015	0.011
Pasture-dominated lowlands of England and Wales. Explained: 47%, n=114, p<0.001	Constant	-4.480		<.001
	Farm type: poultry	11.720	0.285	<.001
	Major roads	-1.279	0.096	<.001
	Neutral grass	-2.722	0.052	<.001
	Minor roads	-3.334	0.049	<.001
	Farm type: arable	-1.968	0.046	<.001
	Farm type: dairy	-1.721	0.032	<.001
	Broadleaf	-0.808	0.025	0.001
	Badger	-0.638	0.015	0.002

3.4 Discussion

A questionnaire was used to collect data on the distribution and abundance of hedgehogs in agricultural landscapes. The target-group, landowners, was not trained at identifying hedgehogs and did not especially aim to find them. Therefore, the presence of hedgehogs might have been over- or underestimated. Hedgehogs, however, are easily recognized, and it was thought that landowners do in general display knowledge about presence of wildlife on their property. Thus it was felt that the respondents were able to give a fair estimation of the presence and abundance of hedgehogs on their holdings and valuable data could come from a questionnaire survey. The assumption has been made that the likelihood of seeing a hedgehog was positively and linearly correlated with their abundance. Nevertheless, differences in visibility and in amount of time a landowner spent on the field could not be accounted for and might have biased the dataset. The response was not geographically biased and respondents that had seen hedgehogs were not overrepresented (55%). It was therefore assumed that the dataset is a fair indication of the presence and relative abundance of hedgehogs in British agricultural landscapes.

The impact of several variables was rather ambiguous, displaying positive effects in some models and negative effects in other models. This is likely to be caused by geographic variations and environmental variations within the variable. It is also likely that factors that were not taken into account, such as differences in rainfall, temperature, pollutants in the soil and habitat fragmentation, were interacting with the variables used in the model and/or influencing the presence of hedgehogs directly. Although variables did not show strong collinearity ($r \geq 0.60$, Graham, 2003), hedgehogs might respond to a feature in the landscape depending on the surrounding landscape.

3.4.1 Hedgehog presence and abundance on farms

Both the presence and the perceived abundance of hedgehogs were highest in the northern and eastern regions of England and lowest in the southern and western regions similar to the results in chapter 2. Hedgehogs were more frequently seen on dairy farms and other farms with a relatively large amount of grass. Both semi-natural and improved grasslands were more often positively correlated with the presence of hedgehogs than negatively, which is in contradiction with the results in chapter 2. Clearly more research is needed to investigate the role of grassland on the presence of hedgehogs. Differences in food availability, and other factors not included in the present study, might play a significant role.

Arable farms were also associated with high relative hedgehog abundance. Arable land, contrary to pasture, is generally negatively selected by hedgehogs (Doncaster, 1992; Doncaster, 1994; Dowie, 1993; Huijser, 2000). It is therefore surprising that the density of arable land and horticulture on and in the surroundings of the farm was frequently positively related to the presence and abundance of hedgehogs, and with their perceived change between 1996 and 2006. This finding is similar to the findings of the survey in chapter 2. As previously discussed, the edge-retreating habit of hedgehogs (see chapter 4) with regard to arable habitat might enhance visibility which could explain this positive relation to some extent. However, since the results from chapter 2 and the current chapter (and see chapter 5) are similar with regard to geographic variations in the abundance of hedgehogs, whilst using different approaches, it is likely that enhanced visibility on arable habitat only plays a minor role. Especially since in both studies other factors also seemed to have large impacts on hedgehog abundance (see chapter 2 and see below). Factors associated with arable landscapes and not investigated, such as food availability, might play a role as well.

3.4.2 Soil characteristics

The soil texture, likely related to invertebrate availability, had a significant impact on hedgehogs in several models, sometimes in combination with the abundance of badgers. The texture of the soil can have a large influence on the abundance of invertebrates such as earthworms, which in turn may have implications regarding the presence of species such as the hedgehog and the badger that feed on them (Reeve, 1994; Neal & Cheeseman, 1996; Muldowney *et al.,* 2003). In general, medium-textured soils appear to be more favourable for earthworms than sandy soils or soils with high clay contents (Curry, 1998). However, although the soil texture could have a direct effect on earthworm activity, the influence of soil texture is more often indirect through its effect on moisture (Curry, 1998). Rainfall is therefore also a significant determinant factor of the abundance of earthworms in the soil. Consequently, it seems important to study the relation between invertebrate abundance and hedgehog abundance directly.

3.4.3 Roads

The fact that a high coverage of minor roads was related to a high number of hedgehog sightings is almost certainly partly caused by the impression gained from seeing dead hedgehogs on roads and also by the high visibility of hedgehogs on roads. Additionally, minor roads are abundant in small-scale landscapes that are often characterised by high densities of hedgerows and woodlands; habitat types frequently thought to hold a high abundance of hedgehogs (Morris, 1986; Huijser, 2000; Riber, 2006). On the contrary, major roads, which were negatively related to hedgehog presence, form a greater barrier for hedgehogs (Bontadina, 1991; Rondinini & Doncaster, 2002). Furthermore, the amount of traffic is expected to be higher on major roads, which might result in more traffic victims amongst hedgehogs. Fencing major roads to reduce road mortality had adverse effects on hedgehog populations due to increased habitat fragmentation in The Netherlands (Huijser, 2000), and is therefore not a sustainable option. Wildlife passages on the other hand, frequently used in various countries, but so far largely unexploited in Great Britain (Jackson & Griffin, 2000), are likely to provide hedgehogs, and other taxa, with safe passages across roads.

3.4.4 Agri-environment schemes

The management and (re)establishment of hedgerows and woodland patches are frequently included in agri-environment schemes (DEFRA, 2007), but the effectiveness of such schemes is often questioned (Kleijn & Sutherland, 2003; Kleijn *et al.,* 2006). Since agri-environment schemes only appeared to have a relatively small positive effect regarding the perceived change in abundance, a conclusion with respect to the benefits of such schemes to hedgehogs could not be reached. Nevertheless, increasing the amount of hedgerows, which is often incorporated in agri-environment schemes, might be beneficial to hedgehogs. Hedgerows were associated with both a higher presence and abundance and less often a perceived decline in hedgehogs on farms. The role of broadleaved woodland is less clear. As discussed in chapter 2, some studies provide evidence that broadleaved woodlands are positively selected (Dowie, 1993; Riber, 2006) while others state otherwise (Berthoud, 1982; Doncaster, 1992; Doncaster, 1994). The results derived from the questionnaire survey were ambiguous, similar to the results form chapter 2. Different abundances of hedgehogs within forested areas might be explained by differences in factors such as size of the habitat patch and clearings within forested areas, and thus presence of edge habitat (Huijser, 2000; Riber, 2006). Large woodlands with a low number of clearings offer little edge habitat and are often associated with avoidance by hedgehogs, whilst small patches of woodlands on the other hand will increase the amount of edge habitat and perhaps their attractiveness to hedgehogs. Other factors that might affect the avoidance or preference of woodlands are undergrowth and predator and prey densities (see chapter 2 and Doncaster, 1992; Micol *et al.,* 1994; Young *et al.,* 2006).

3.4.5 Badgers

Research points towards a strong local impact of badgers upon hedgehogs (Doncaster, 1992; Young *et al.,* 2006). Results from this questionnaire study, similar to the results in chapter 2, seem to suggest that the abundance of badgers had a negative impact on the presence and relative abundance of hedgehogs on a wider scale as well. Additionally, badger abundance was negatively related to perceived changes in hedgehog densities. However, a decline in hedgehog numbers cannot be attributed directly to an increase in badger density based on the questionnaire data since changes in badger densities in the same period and in the surveyed areas are not known. Since legal, ethical and sustainability issues might arise with predator control, it seems imperative to seek other measures to preserve hedgehogs. A reduction in the pressure of intraguild predation, such as hedgehogs receive from badgers, might be achieved by increasing the complexity of the structure of the landscape (Janssen *et al.,* 2007). Hedgerows, associated with high relative hedgehog abundances in this study, provide such higher complexity in landscape structure and are therefore likely to benefit hedgehogs.

Chapter 4

Investigating the importance of agr-environment schems for hedgehogs in intensive arable farmland

Chapter 4

Investigating the importance of agri-environment schemes for hedgehogs in intensive arable farmland

4.1 Introduction

Agri-environment schemes were introduced into the agricultural policy of the European Union (EU) in the late 1980s partly with the aim of protecting biodiversity and also in an attempt to reverse some of the negative impacts of agricultural intensification on wildlife and the environment. The intention was to maintain the countryside by means of farming practices. In the same period, arable farms were obliged to implement set-aside policies in which a proportion of existing farmland would be taken out of economic use in order to reduce surplus production (European Commission, 2003). In 2007, there were about 440,000 ha of set-aside land in the United Kingdom, just over 2% of the total agricultural area (DEFRA, 2008). In England alone, around 2,500,000 ha of land were managed through various agri-environment schemes, which accounted for over 13% of the total agricultural area. Until recently the area of land in agri-environment schemes was still increasing; between 1992 and 2006 there was about a six-fold expansion in the total area (DEFRA, & National Statistics, 2007). Agri-environment field margins and hedgerows are among the features included in these agri-environment schemes that are potentially important for small and medium-sized mammals.

There has been much investigation into the effectiveness of set-aside and agri-environment schemes on wildlife conservation, showing mixed results (e.g. Kleijn *et al.,* 2001; Kleijn *et al.,* 2004; Kleijn *et al.,* 2006; Kleijn & Sutherland, 2003; Bengtsson *et al.,* 2005; Knop *et al.,* 2006). It is however suggested that set-aside land and well-managed agri-environment field margins and hedgerows can have a beneficial impact on small mammal populations (e.g. Bright & MacPherson, 2002; Shore *et al.,* 2005; Tattersall *et al.,* 2000; MacDonald *et al*, 2007). Agri-environment field margins and hedgerows are frequently mentioned as an important corridor habitat for various small mammals. They are known to support a higher abundance of small mammal species than arable fields and pastures (Bright, 1996; Burel, 1996; Shore *et al.,* 2005; Silva *et al.,* 2005; Butet *et al.,* 2006; Gelling *et al.,* 2007). They not only add to the amount of potentially suitable habitat for mammals; the increased food availability due to a higher abundance of invertebrates and grass seeds may also benefit various species of mammals. Several studies confirm, for instance, the positive impact of enhanced invertebrate abundance in agri-environment field margins and set-aside on a variety of farmland birds (e.g. Henderson *et al.,* 2000; Vickery *et al.,* 2002). Insectivorous mammals such as hedgehogs could potentially benefit in a similar way from agri-environment field margins and set-aside land.

Arable fields are commonly under-selected by hedgehogs (see chapter 2), and are often thought to be avoided (Doncaster, 1994; Zingg, 1994; Riber, 2006). Both agri-environment field margins and hedgerows may enhance the suitability of such fields for hedgehogs, especially in arable-dominated areas. Enhanced suitability offered by hedgerows could be due not only to increased food availability and corridor function, but also to possible increased protection against predators and increased nest site availability. Hedgehogs are often found in the vicinity of hedgerows and other edge habitats in rural areas (Zingg, 1994; Huijser, 2000; Riber, 2006; cf. chapter 1). Large fields that have a low proportion of edge habitat may act as a barrier to their movement. Creating corridors such as hedgerows increases the amount of edge habitat and may simultaneously increase overall habitat suitability in such areas. The question arises whether agri-environment schemes, in particular the management of agri-environment field margins and hedgerows, and set-aside, can enhance the habitat suitability for hedgehogs in arable-dominated areas.

Although several studies investigate the behaviour of hedgehogs by means of radio-tracking, these studies primarily took place in landscapes other than arable (e.g. Reeve, 1981; Morris, 1985; Morris, 1986; Doncaster, 1992; Morris & Warwick, 1994; Doncaster *et al.*, 2001; Riber, 2006) and/or did not address or come to a conclusion regarding the use of agri-environment schemes by hedgehogs (Dowie, 1993; Bunner, 2004). Dowie (1993) investigated the spatial organisation and habitat use of hedgehogs on farmland. He intensively studied a low number of hedgehogs and looked into their activity pattern. He failed to investigate habitat utilisation on arable fields by hedgehogs in general. Bunner (2004) investigates the importance of edge habitat for hedgehogs in arable farmland. She however found that hedgehogs mostly utilised urban areas and pastoral fields and was unable to be conclusive regarding the use of edge habitat in comparison to arable fields. It was thus felt that more research was needed to investigate the movement of hedgehogs in arable landscapes specifically. Radio-tracking was used in the present study to obtain information about the movements of hedgehogs and their habitat selection in an arable dominated landscape.

4.2 Methods

4.2.1 The study site

The study site was located in the area surrounding the villages of Burnham Deepdale, Brancaster Staithe and Brancaster along the north coast of Norfolk, United Kingdom (52º, 58'N, 0º, 40'E). The study site (Figure 4.1) covered 609 ha, outlined by the natural boundary of the sea to the north and the outermost sightings of radio-tracked hedgehogs as determined by a minimum convex polygon (MCP). Two mainly arable farms were located at the site. Wheat, barley and turnip were the most common crops on the farms. One farm had several fields as set-aside. These fields were mainly overgrown with thistles, grasses, various weeds and low shrubbery. Nearly every arable field was surrounded by 6m wide agri-environment field margins, which were entered in agri-environment schemes (Environmental Steward Scheme). In total about 33km of hedgerows surrounded the fields. Hedgerows were generally well-developed, 2 to 3m high and 1 to 3m wide. Hawthorn (*Crataegus monogyna*) was the main woody species present. Dense growth of weeds such as nettles (*Urtica* spp) and alexanders (*Smyrnium olusatrum*) bordered the hedgerows. There were a few pasture fields in the area, which were not intensively managed and had a sward height between 10 to 30cm. Badgers were thought to be absent from the area according to the farmers and gamekeepers. Nonetheless, a badger was observed twice during the fieldwork period. No badger setts have been found locally, but not the entire area could be searched due to access restrictions.

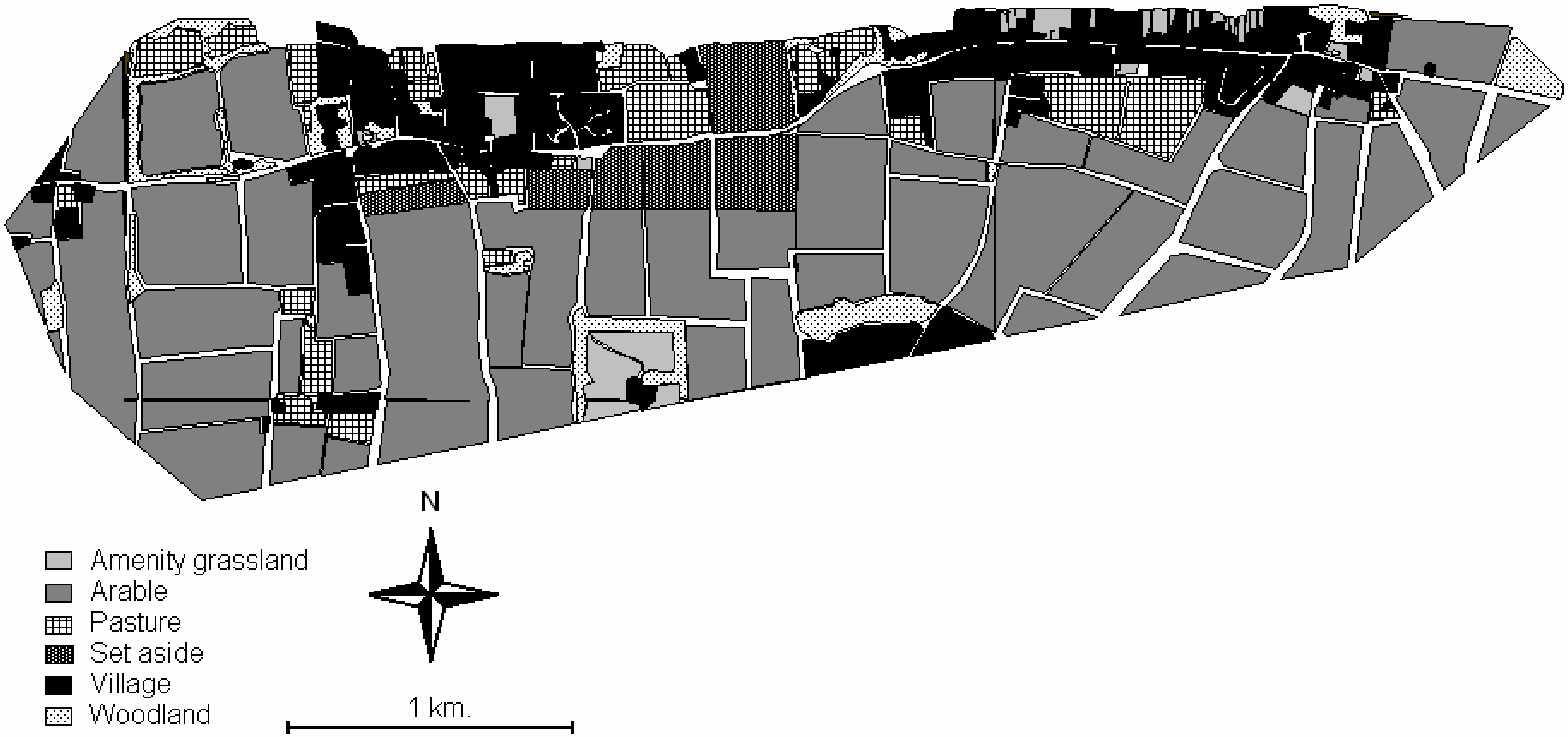


Figure 4.1 The site used for the radio-tracking study in 2008 (52º, 58’N, 0º, 40’E). Agri-environment field margins and hedgerows are not shown but exist around nearly every arable field and are shown as white linear features.

4.2.2 Radio-tracking

Twelve adult male hedgehogs that were due for release were obtained from wildlife centres and fitted with radio transmitters in order to find hedgehogs present in the study site. It was thought that male hedgehogs would actively search for females during the breeding season (May-July [Reeve, 1994]) and thus facilitate the finding of hedgehogs. Introduced hedgehogs were, based on findings from previous studies (Morris *et al.,* 1992; Morris & Warwick, 1994; Molony *et al.,* 2006), not seen as a threat to the local population. A licence to catch hedgehogs in the field was granted by natural England. Radio transmitters were especially manufactured for hedgehogs by Biotrack Ltd. (Dorset, UK) and weighed 10g. Hedgehogs that weighed less than 400g were not equipped with a radio transmitter in order to comply with the ethic guidelines as set by The American Society of Mammologists, which recommends that the weight of the radio transmitter should not exceed 5% of the animal's bodyweight (The American Society of Mammologists, 1998). Radio transmitters were equipped with a beta light and attached to the back of the hedgehogs on a small trimmed patch of spines by using adhesive. Beta lights allow visual detection at a distance, avoiding disturbance by close approach of the fieldworker. Receivers (Telonics Inc. Arizona, USA) were used in combination with Yagi antennas (Biotrack Ltd, Dorset, UK) to track the hedgehogs. The radio transmitters were removed from the hedgehog when sufficient data points (see below) were obtained.

Six males were released at the farm in Burnham Deepdale in the beginning of May 2008, and tracked from dusk till dawn in order for them to find wild hedgehogs to use in the present study. Four of these six hedgehogs disappeared from the study site within a few days to surrounding villages. One was attacked, most likely by a fox, a dog or a badger, and died. The remaining hedgehog settled in the village of Burnham Deepdale. Therefore, a second group of six male hedgehogs was released a week later at the same place. Of these six males, one settled in Burnham Deepdale, one settled in Brancaster Staithe, two in Brancaster, one disappeared from the study site and one was admitted at a local veterinary hospital after getting injured by an attack from either a fox, a dog or a badger.

Local hedgehogs were found while interacting with the released males, near the released males or by actively searching the area with a spotlight. Newly caught hedgehogs were sexed, weighed and equipped with a radio transmitter as described above. The local hedgehogs were radio tracked between the 5th of May and 18th of July 2008. Radio-tracking took place from dusk until dawn. It was attempted to locate each hedgehog at least every hour, and at the most once per half an hour. When a hedgehog was found, data about the habitat type (see below) it was located in and its behaviour were noted. Behaviour was classified as: foraging (eating including short walks in between eating), interacting, resting, running, and walking. Resting could be determined from a distance by the lack of modulation in the radio-signal. The behaviour and speed of movement of hedgehogs were used as additional measures of the function and value of different habitats to them. The proximity of hedgehogs to edge-habitats that are likely to provide them with a refuge from predation (hedgerows and woodland) was also examined. When hedgehogs were located in agri-environment field margins or in hedgerows the proximity to edge-habitats was not estimated since these habitat types never exceeded 6m in width. The distance to the nearest edge-habitat could not be estimated accurately in the village habitat, since the location of hedgehogs there was impeded by bad visibility and the exact position was frequently estimated using triangulation instead of by visual contact. Causes and sites of mortality of hedgehogs were also recorded. The habitat in the study site was recorded in the field and digitised into a Geographic Information System (Mapinfo Professional Version 8, MapInfo Corporation, New York, USA). The following habitat types were defined on the farmland: arable field, agri-environment field margin, hedgerow, pasture, set-aside and (mixed deciduous) woodland. Habitat types within urban areas were defined as village (mainly gardens) and amenity grasslands such as greens, cemeteries and playing fields.

Hedgehogs were not closely approached upon sighting them in order to disturb their natural behaviour as little as possible. The position of the hedgehogs was visually estimated in the field and recorded on a map. Sufficient landmarks enabled locations to be determined reliably. It was noted how many hedgehogs, with and without transmitters, were accidentally encountered without especially searching for them. Sighting an animal depends on the observation area and on the visibility in the field, which may differ in time and space. Visibility was, for instance, better during bright nights with a full moon than during cloudy nights. Visibility also depended largely on the sward height of the vegetation in which hedgehogs were situated. However, the intention was not to be able to discriminate between habitat types, but to obtain a general understanding of the approximate density of hedgehogs in the area. The area of observation therefore was standardised at 10m either side of the observer, based upon trials in the field. Furthermore, based upon 10 tracking nights, the mean distance walked was 12km (se=0.5) per night. The total observation area was therefore 0.24km^2 per night.

4.2.3 Analyses

A minimum of 30 radio fixes was deemed necessary to analyse home-ranges (Kenward, 2000). Minimum Convex Polygons (MCPs), excluding 5% of the outermost locations, were used to define home-ranges using Ranges 6 (Anatrack Ltd., Dorset, UK). Gaussian kernel centres were used as a peel centre for exclusion of the 5% outermost radio fixes. Additionally, cluster analysis was used as an alternative method to estimate home-range size. Objective cores were estimated by means of nearest neighbour distribution and exclusion of outlying locations. A 95% incremental analysis was used to show when the home-ranges reached an asymptote (Kenward, 2000).

The method of Aebischer *et al.,* (1993) was used to determine whether radio tracked hedgehogs preferred to use habitat types in urban areas or in rural areas, and which particular habitat types within these areas were preferentially used. This method uses compositional analysis to study proportional habitat use by individual animals. The proportion of utilised habitats is compared with the proportion of available habitats, ranking the habitat types according to relative use. Significant differences between preferred habitats can be detected. An Excel tool for Compositional Analysis (Compos Analysis v6.2, Smith Ecology Ltd., UK) was used to perform the calculations. The assumptions underlying the use of this method were met; hedgehogs provide an independent measure of habitat use within the population, since they are solitary and non-territorial animals (Reeve, 1994). Another assumption is that compositions from different animals should be equally accurate. It was attempted to track each hedgehog for a minimum of ten days, obtaining a radio location each hour per night. However, due to deaths and loss of transmitters, the number of radio fixes varied widely between hedgehogs. The accuracy of the analysis can be improved by increasing the number of animals in a radio-tracking study. This even holds if the number of radio fixes per animal is reduced (Aebischer *et al.,* 1993). Therefore rather than omitting animals from the database, the log ratios from the habitat composition of each hedgehog were weighted by the square root of the number of radio-locations, as recommended by Aebischer *et al.,* (1993). Habitat use was represented by the number of radio fixes per habitat type per hedgehog. Data were obtained for 44 hedgehogs, which was well above the recommended number of 30 animals (Kenward, 2000).

Travel speed of hedgehogs per habitat type was based on consecutive radio fixes of hedgehogs less than an hour apart, within a particular habitat type. Hedgehogs were not continuously monitored; therefore, travel speed is an indication rather than exact. The mean distance travelled per hedgehog per night was calculated for hedgehogs that had been seen at least once per hour per night from 22:00 until 04:00 the following morning, resulting in at least six sightings.

Statistical analyses other than used for the home-range analyses and for the habitat selection were conducted in SPSS (for windows 14th edition, SPSS Inc., Chicago, USA). The nonparametric Kruskal-Wallis Test was used to study the differences between field sizes per habitat type, differences between the mean distance hedgehogs were located to the edge per habitat type, and differences between the mean travel speeds of hedgehogs in various habitat types. The Chi-square Test was used to investigate differences in the frequency of displaying a type of behaviour per habitat they were located in. Linear regression was used to study whether the mean distance travelled per individual related to the number of sightings, and whether it related to the sex of the individual. ANOVA with the Bonferroni post hoc test was used to study the difference between the mean distances travelled regarding sex and locality (‘farmland’ versus ‘urban’). A t-Test was used to study the difference between the mean distances travelled per sex.

4.3 Results

4.3.1 Estimated density

In total 44 hedgehogs (24 males and 20 females) were caught at the study site (minimum density of 0.073ha^{-1} [7.3km^{-2}]). Appendix III shows the data recorded per hedgehog. On average 1.8 hedgehogs (se=0.2) were accidentally encountered (n=51) per night, representing a density of 0.075ha^{-1} (7.5km^{-2}). Figure 4.2 shows the radio fixes of the hedgehogs (n=2319).

Figure 4.2 Map of the site used for the radio-tracking study showing the hedgehog radio-fixes as red dots. The perimeter of the site represents the MCP including all radio fixes and is limited by the coastline in the north

4.3.2 Home-range

Based on the 95% MCPs females (n=17) had a mean home-range of 4.4ha (se=1.0) ranging between 0.8 and 16.5ha. Males (n=16) had a mean home-range of 24.9ha (se=3.7) with a minimum of 3.2 and a maximum of 57.2ha. There was a non-significant relationship between home-range and weight of male hedgehogs (Pearson Correlation Test, r=0.393, n=16, p=0.133) and female hedgehogs (Pearson Correlation Test, r=0.002, n=17, p=0.995) (Figure 4.3).

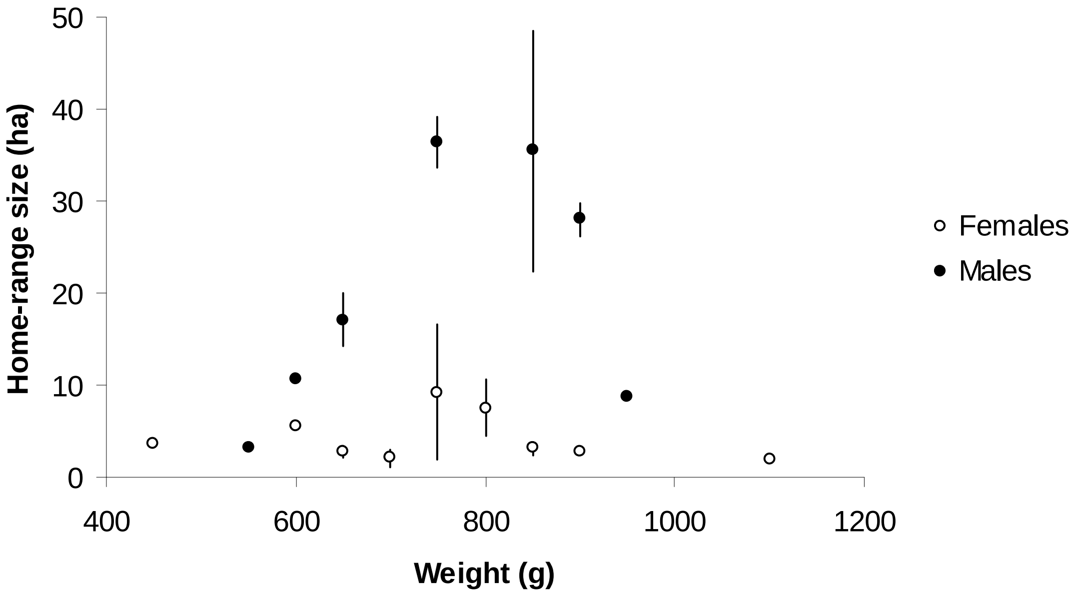


Figure 4.3 MCP home-range size of male and female hedgehogs in relation to bodyweight; the relationships are not statistically significant (+/-se)

Cluster analysis consistently yielded smaller home-range size estimations than the MCP method. The mean core area of the home-range for females was 1.56ha (se=0.3) with a minimum of 0.20ha and a maximum of 5.49ha using cluster analysis. For males the mean was 9.71ha (se=2.6) with a minimum of 0.93ha and a maximum of 44.25ha. Incremental analysis excluding 5% of the outermost radio fixes showed that for males 45 radio fixes were needed before an asymptote was reached, for females an asymptote was reached at 38 radio fixes. Differences in home-range size between the sexes were significant (Kruskal-Wallis Test, χ^2=7.868, df=1, p=0.005)

4.3.3 Habitat selection

Arable land formed 58% of available habitat in the study area, followed by village (16%), woodland (5%), pasture (8%), set-aside (5%), agri-environment field margins (5%), amenity grasslands (3%) and hedgerows (1%). Mean field size was significantly larger for arable fields (10.4ha, se 2.4), followed by set-aside (4.9ha, se 1.0), pasture (1.6ha, se 0.5), woodland (1.1 ha, se 0.3) and amenity grasslands (0.5 ha, se 0.2) (Kruskal-Wallis Test, χ^2=72.296, df=4, p<0.001). Hedgehogs did not randomly use habitats within the study site (Wilk's lambda test, χ^2=118.291, λ 0.068, p<0.001). Habitat preference by hedgehogs at the landscape level was ranked as follows: hedgerows >>> village > agri-environment field margins > pasture > amenity grasslands > woodland >>> set-aside > arable, where >>> indicates a significant difference at p<0.05 between two consecutively ranked habitat types and > indicates a ranking which is not significantly different.

Males preferred other habitats then females at the landscape level. The habitat ranking preference of males was: hedgerows >>> agri-environment field margin > pasture > village > woodland > amenity grassland > set-aside > arable. Females on the other hand were more frequently seen in the urban areas than males. The habitat ranking for females was: hedgerows >>> village > amenity grassland > woodland > agri-environment field margin > pasture >>> set-aside > arable. There was significant non-random habitat utilisation within the study site by males (Wilk's lambda test, χ^2=56.533, λ 0.095, p<0.001) and by females (Wilk's lambda test, χ^2=78.032, λ 0.020, p<0.001). Table 4.1 shows the habitat preference ranking matrices.

Habitat selection within the individual home-ranges resulted in a different outcome than habitat selection at the landscape level. A distinction between males and females could not be made due to the scarcity of several habitat types within individual home-ranges. The ‘set-aside’ habitat had to be ignored since few hedgehogs had set-aside in their home-range. Hedgehogs which used fewer than three habitat types were ignored as well since the outcome of such analyses could bias habitat preference. There was significant non-random habitat utilisation at the home-range level (Wilk's lambda test, χ^2=79.552, λ 0.064, p<0.001). Habitat preference by hedgehogs within their home-ranges was ranked: hedgerows >>> agri-environment field margins >>> village >>> woodland > pasture > arable > amenity grasslands (Table 4.2).

Table 4.1 Habitat preference ranking matrices at landscape level; A. based on 44 hedgehogs, B. on 24 male hedgehogs and C. on 20 female hedgehogs. More preferred habitats have higher ranks. Positive signs indicate preference of the habitat types in column one, negative signs indicate avoidance. Triple signs indicate significant selection at p<0.05.

A.

Habitat type	***AR***	***SA***	***WO***	***AG***	***PA***	***FM***	***VI***	***HR***	***Rank***
hedgerow (HR)	+++	+++	+++	+++	+++	+++	+++		8
village (VI)	+++	+++	+++	+++	+	+		---	7
agri-environment field margin (FM)	+++	+++	+++	+	+		-	---	6
pasture (PA)	+++	+++	+	+		-	-	---	5
amenity grassland (AG)	+++	+++	+		-	-	---	---	4
woodland (WO)	+++	+++		-	-	---	---	---	3
set-aside (SA)	+		---	---	---	---	---	---	2
arable (AR)		-	---	---	---	---	---	---	1

B.

Habitat type	***AR***	***SA***	***AG***	***WO***	***VI***	***PA***	***FM***	***HR***	***Rank***
hedgerow (HR)	+++	+++	+++	+++	+++	+++	+++		8
agri-environment field margin (FM)	+++	+++	+++	+++	+	+		---	7
pasture (PA)	+++	+++	+++	+	+		-	---	6
village (VI)	+++	+++	+++	+		-	-	---	5
woodland (WO)	+++	+	+		-	-	---	---	4
amenity grassland (AG)	+	+		-	---	---	---	---	3
set-aside (SA)	+		-	-	---	---	---	---	2
arable (AR)		-	-	---	---	---	---	---	1

C.

Habitat type	***AR***	***SA***	***PA***	***FM***	***WO***	***AG***	***VI***	***HR***	***Rank***
hedgerow (HR)	+++	+++	+++	+++	+++	+++	+++		8
village (VI)	+++	+++	+++	+	+	+		---	7
amenity grassland (AG)	+++	+++	+	+	+		-	---	6
woodland (WO)	+++	+++	+	+		-	-	---	5
agri-environment field margin (FM)	+++	+++	+		-	-	-	---	4
pasture (PA)	+++	+++		-	-	-	---	---	3
set-aside (SA)	+++		---	---	---	---	---	---	2
arable (AR)		---	---	---	---	---	---	---	1

Table 4.2 Habitat preference ranking matrix at home-range level. Based on hedgehogs with three or more available habitat types within their home-range (n=29). More preferred habitats have higher ranks. Positive signs indicate preference for the habitat types in column one, negative signs indicate avoidance. Triple signs indicate significant selection at p<0.05.

Habitat type	***AG***	***AR***	***PA***	***WO***	***VI***	***FM***	***HR***	***Rank***
hedgerow (HR)	+++	+++	+++	+++	+++	+++		7
agri-environment field margin (FM)	+	+++	+++	+++	+++		---	6
village (VI)	+	+++	+++	+++		---	---	5
woodland (WO)	+	+	+		---	---	---	4
pasture (PA)	+	+		-	---	---	---	3
arable (AR)	+		-	-	---	---	---	2
amenity grassland (AG)		-	-	-	-	-	---	1

4.3.4 Attraction to edge habitat

Hedgehogs rarely selected arable fields (154 out of 2319 position fixes from 44 hedgehogs), and when they did, the distance to hedgerow, woodland or agri-environment field margin was 1m or less in 50% of the sightings. Only in 4% of the cases (n=6) was the hedgehog located more than 10m away from an edge. Hedgehogs were also more frequently situated near an edge in amenity grassland and to some extent in woodland, but not in pasture and set-aside (Figure 4.4) (Kruskal-Wallis Test, χ^2=20.880, df=4, p<0.001 [animal identity is retained in the model]). In both pasture (n=156) and set-aside (n=38) hedgehogs were located at a mean distance of between 30 and 40m from the nearest boundary. Contrarily, in amenity grassland (n=173), arable (n=142) and woodland (n=38) hedgehogs were, on average, located less than 10m away from the nearest boundary (Figure 4.5).

The distance to the nearest sign of badger activity (sighting of a badger, or a hedgehog predated by a badger) was also significantly related to the distance between where a hedgehog was located and the nearest boundary (Kruskal-Wallis Test, χ^2=7.326, df=2, p=0.026 [animal identity is retained in the model]). Hedgehogs were more frequently seen at a greater distance from the nearest boundary when their home-range was located further away from the nearest badger activity.

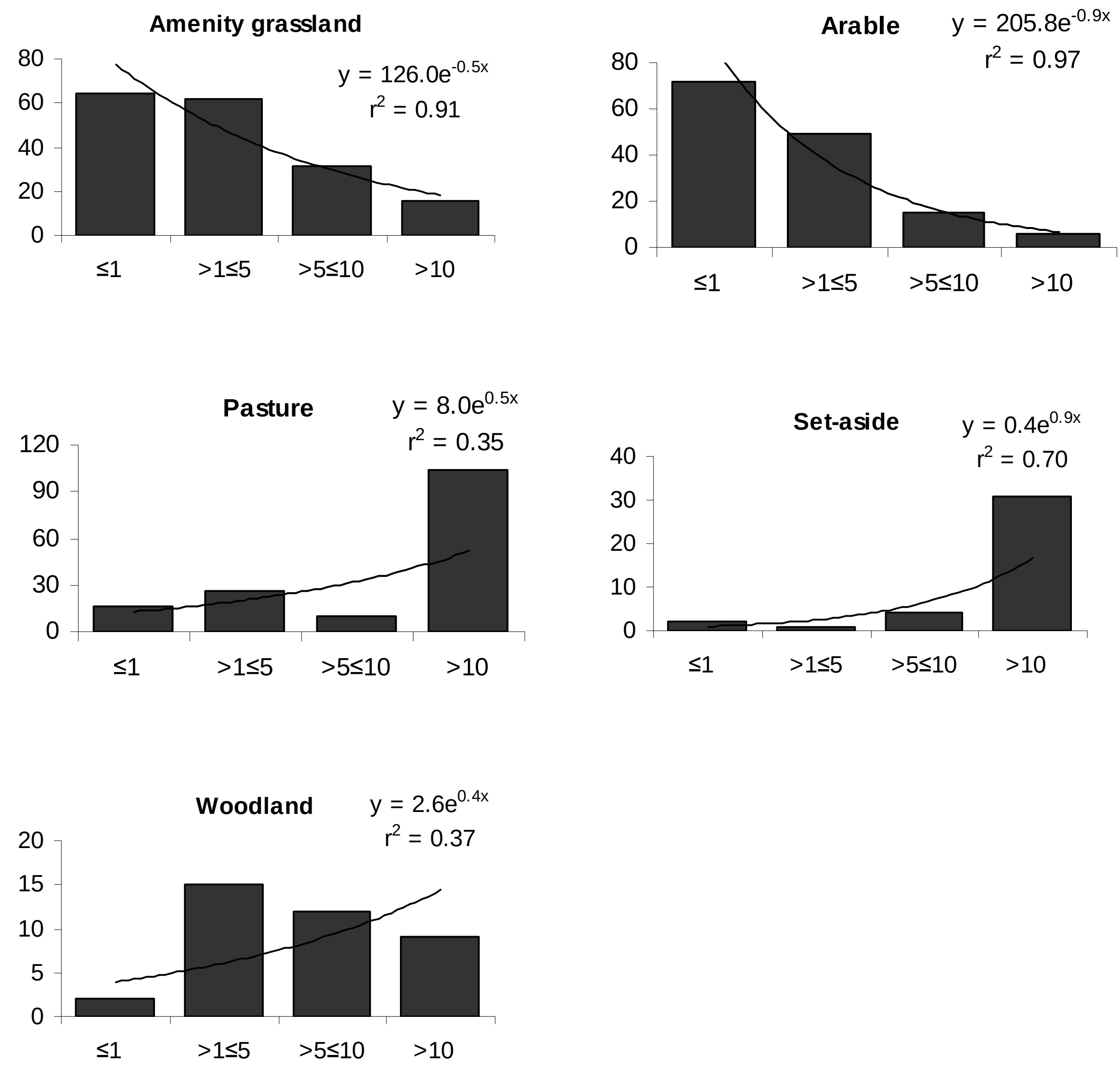


Figure 4.4 Number of sightings of hedgehogs (y-axis) located at distances from the nearest edge habitat (agri-environment margins, hedgerows or woodland) in m (x-axis) per habitat type

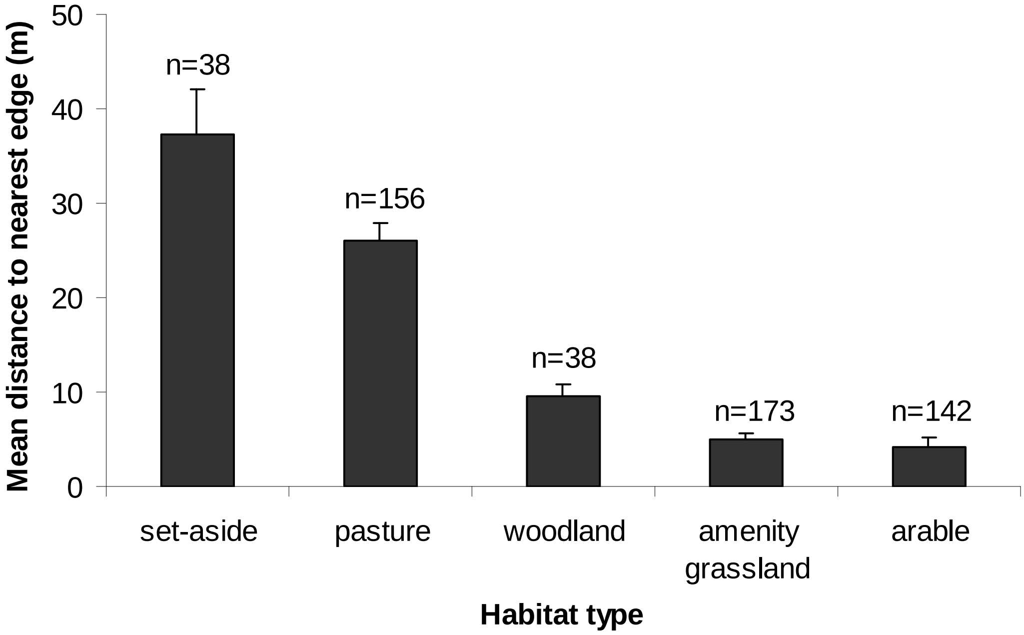


Figure 4.5 Mean distance (m) at which a hedgehog was located from the nearest boundary per habitat type (+se)

4.3.5 Behaviour, travel distance and speed

The frequency with which hedgehogs were displaying a type of behaviour was dependent on the habitat they were located in (Figure 4.6). Foraging was the main activity in all habitat types except for in hedgerows and woodlands, where hedgehogs were observed resting respectively 61% and 48% of the time. Hedgehogs were foraging the largest proportion of the time in amenity grassland (64%) and in pastures (57%).

The mean distance travelled per night did not significantly relate to the number of sightings obtained (Linear regression, r^2=0.006, df=1,210, p=0.266), when hedgehogs were sighted at least once per hour. The distance travelled per night ranged from 39m to 2484m, and was about twice as far for males as for females (mean=837m versus 419m) (t-Test, t=8.728, df=210, p<0.001). Hedgehogs with home-ranges that comprised at least 50% of urban habitat travelled less than hedgehogs with a relatively low amount of urban habitat in their home-range. This effect was evident in both males and females (Figure 4.7) (males: ANOVA, F=4.580, df=1, p<0.035, females: ANOVA, F=18.860, df=1, p<0.001).

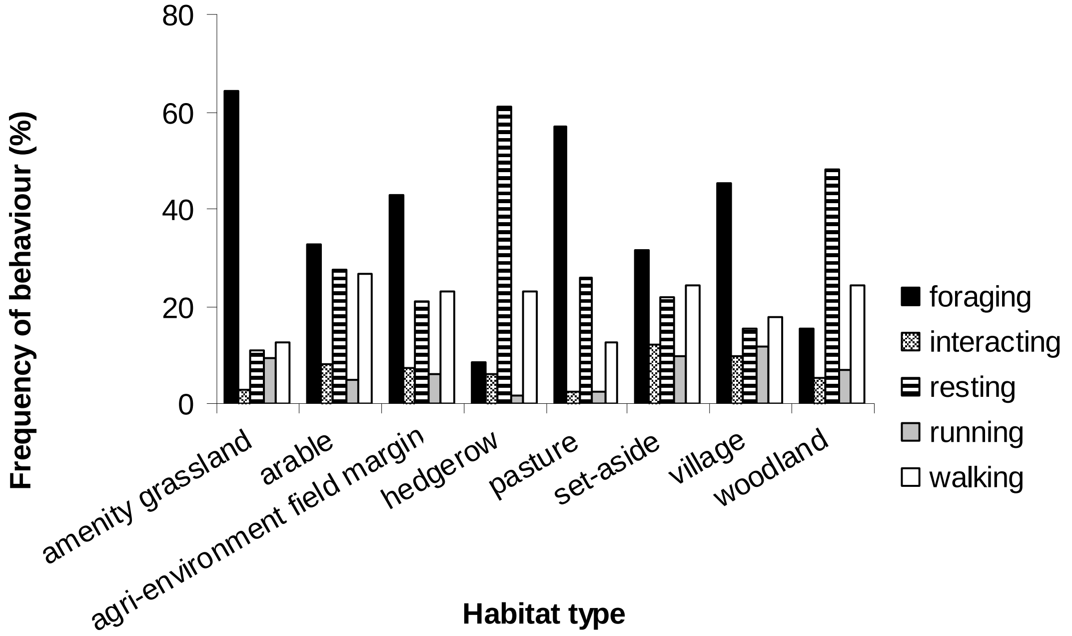


Figure 4.6 The percentage of sightings of hedgehogs displaying different behaviours per habitat type (amenity grassland n=190 position fixes, arable n=146, agri-environment field margin n=346, hedgerow n=118, pasture n=206, set-aside n=41, village n=135, and woodland n=58)

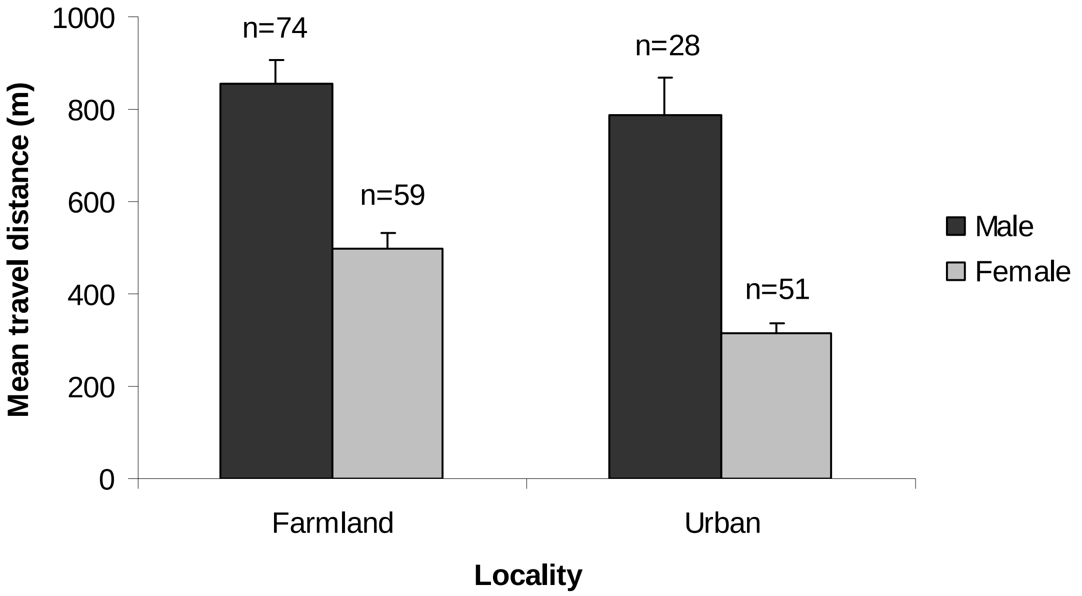


Figure 4.7 Mean distance (m) travelled per night according to sex and locality; with hedgehogs with >50% farmland habitat in their home-range classified in a farmland locality and hedgehogs with <50% farmland habitat in their home-range classified as urban locality (+se).

The mean travel distance per night, based on a total of 212 tracking nights from 44 animals, was not significantly related to the weight of the individual (Linear regression, F=0.029, df=1,35, p=0.867). This was also the case when the sex of the animal was taken into account (total of 102 tracking nights from 24 males: Linear regression, F=0.094, df=1,16, p=0.763, total of 110 tracking nights from 20 females: Linear regression, F=0.007, df=1,17 p=0.936). The mean travel speed of hedgehogs based upon sightings of an individual between 30 to 60 minutes apart was 2.0m·min^{-1} (n=1079 radio pairs of 44 animals, se=0.06), with a minimum of 0 and a maximum of 4.2 m·min^{-1}. However, hedgehogs have been seen travelling up to 53m·min^{-1}. The mean travel speed for males was significantly higher than for females (t-Test, t=-11.382, df=724, p<0.001). Males travelled at nearly twice the speed of females; 2.7m·min^{-1} (n=490 radio fixes of 24 individuals, se=0.11) versus 1.4m·min^{-1} (n=589 radio fixes of 20 individuals, se=0.05). The mean travel speed was significantly different per habitat type (Kruskal-Wallis Test, χ^2=31.72, df=7, P<0.001 [animal identity is retained in the model]), the highest speed was observed when hedgehogs were travelling in set-aside, followed by agri-environment field margins and arable fields. However, it must be noted that the travel speed in set-aside was male biased, due to the lack of females travelling in this habitat. Hedgehogs were most static in woodlands and hedgerows (Figure 4.8).

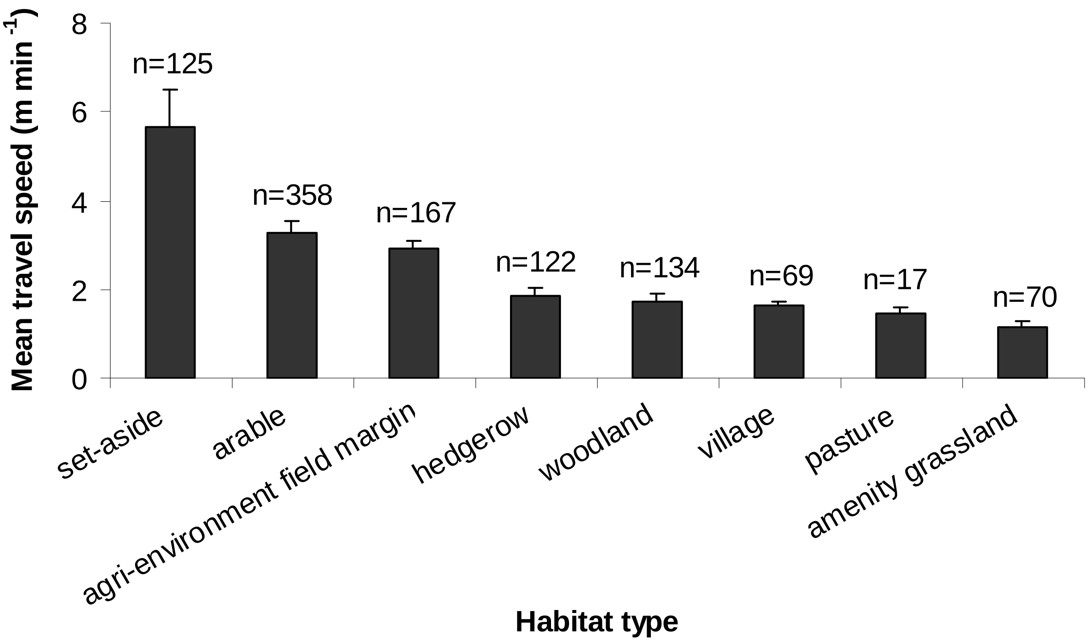


Figure 4.8 Mean travel speed of hedgehogs in m min^{-1} per habitat type. N defines the number of paired radio fixes per habitat type. Radio fixes were paired if an individual animal was seen twice in a habitat type between 30 to 60 minutes apart (+se).

4.3.6 Mortality

In total 9 hedgehogs out of 44 died during the 75-day long tracking period, which is a mortality rate of 20%. A failed pregnancy was the likely cause of death for one of those animals. The eight remaining hedgehogs were all predated by badgers, as evidenced by the retrieved carcasses (Reeve, 1994). Seven of these predated hedgehogs were male. All these predations took place on the farm, with four remains being found in an open, badly established, hedgerow, two in an arable field, one in pasture and one in an agri-environment field margin.

4.4 Discussion

The present study attempted to investigate the movements of hedgehogs in a rural landscape. External factors, however, might have had an impact on the natural behaviour of the studied hedgehogs. The impact of the five introduced males that remained in the study site upon the behaviour of the local hedgehog population is, for instance, unknown. Nevertheless, they were not considered a threat to the local population. Firstly, they were effectively compensating for the high mortality amongst the local males. Secondly, hedgehogs are mainly solitary and non-territorial animals (Reeve, 1994). Possible changes in behaviour of local animals due to the introduction of males, which would affect the study, were thought to be unlikely. This was also concluded by a study from Morris *et al.,* (1992), Morris & Warwick (1994), and Molony *et al.,* (2006). Other external influences such as the presence of the fieldworker upon the behaviour of hedgehogs were seen as a bigger issue. Measures such as attaching a beta light to the transmitter, which allowed visual detection at a distance, and keeping a distance from the hedgehogs were used to ensure the least possible disturbance of the natural behaviour of hedgehogs in the field. The impact of the beta light on the behaviour of hedgehogs and attraction of visually-oriented predators is not known. Badgers, however, mainly forage by olfactory senses (Neal & Cheeseman, 1996). It was therefore thought unlikely that the high rate of badger predation was caused by hedgehogs equipped with a beta light being more prone to badger predation than hedgehogs without a beta light. Nevertheless, it cannot be ruled out that there was some minor alteration in behaviour of the hedgehogs.

4.4.1 Hedgehog density

The estimated density of 7.5 hedgehogs·km^{-2} is low in comparison to earlier works which estimated ranges from a mean of 8 hedgehogs·km^{-2} (Young *et al.,* 2006) to 29 hedgehogs km^{-2} on pasture fields (Micol *et al.,* 1994) using comparable methods. Unfortunately no historical data on hedgehog density in the study area are available. It is therefore not known whether the population of hedgehogs has always been in this order of magnitude in this particular area or if the number of hedgehogs has declined over the years. Based on a map from the area made in 1952 (available at URL: http://www.old-maps.co.uk), the habitat composition and field sizes have remained virtually unchanged, although predator densities, traffic intensity, habitat accessibility and use of fertilizers might have altered. Nevertheless, the density of hedgehogs in the area in which the study site was situated appears to be among the areas of England with the highest densities (chapter 2).

A total of 2084 effective trap nights and 15 hours of spotlighting as part of the present study in a rural area of approximately 50ha in Kent in 2007, resulted in the capture of only one hedgehog. This results in an estimated density of two hedgehogs·km^{-2}. Direct comparisons, using similar methods, between other areas within the United Kingdom may clarify the varying levels of hedgehog density.

4.4.2 Habitat selection

Hedgerows and agri-environment field margins were highly selected by hedgehogs at both the landscape and home range levels. There were differences between male and female hedgehogs at the landscape level; females were mostly active in village habitat and this was significantly more selected than agri-environment field margins. This difference mainly reflected the much larger home range sizes of male hedgehogs during the mating period (5.6 times that of females), but also selection by females of relatively small patches of higher quality habitat in villages compared to the adjoining arable landscape. (Note that the sex-disparity in home range size that was found here is much greater than the pan-seasonal norm of around 3x [Harris & Yalden 2008]). It is thus clear that hedgerows and agri-environment field margins are very important to hedgehogs in a coarse-scale arable landscape, but that adjoining village habitats are very important for females. The implications of this for population structure and viability are discussed below.

The behaviour and travel speeds of hedgehogs in hedgerow habitat suggest that they were primarily used for resting during short nocturnal inactive periods (hedgerows are also a major site of diurnal nest sites [Reeve, 1994]) and less so for movement around the landscape in a concealed habitat. Agri-environment field margins were most used for foraging (and to a lesser extent walking and resting). Given the degree to which they were selected, agri-environment field margins were therefore important foraging habitats in this arable-dominated landscape.

It is commonly thought that hedgehogs prefer mown amenity grasslands to pastures (Micol *et al.,* 1994; Zingg, 1994; Young *et al.,* 2006). Whereas the present study indeed shows that female hedgehogs preferred amenity grasslands to pastures at the landscape level, this was not the case at the home-range level. Females frequently had home-ranges that were mainly located in the urban area which explains the different results. Male hedgehogs preferred pastures above amenity grasslands at both landscape and home-range level. The pastures within the study site were not intensively managed which might be one of the reasons why amenity grasslands were not frequently preferred. Not all types of pasture are equally favourable for hedgehogs as observed and discussed in earlier chapters. Intensively managed grasslands often offer less prey than more natural grasslands such as those found in the study site (e.g. Bontadina *et al.,* 1993; Wilson *et al.,* 1999; Jonas *et al.,* 2002). Nevertheless, hedgehogs, including those equipped with a transmitter and beta light, were extremely difficult to see in pastures, even at short distance (<1m) and low sward height (<10cm). In comparison, the visibility of hedgehogs on amenity grasslands was higher. Studies comparing hedgehog densities in different habitats based upon numbers found during spotlight surveys should therefore be regarded with care.

Set-aside and arable fields were least preferred by both males and females at the landscape level. Both set-aside and arable fields were mainly used for foraging and travelling. The travel speed of hedgehogs was the highest on these habitat types. Low food availability and little access to cover might explain this higher travel speed. However, the travel speed on set-aside was strongly biased since this was entirely based on data observed from males, which had a higher mean travel speed than females. As commonly found in the literature, the mean travel distance of males was about twice that of females (e.g. Morris, 1985; Zingg, 1994; Riber, 2006). Males also had a larger mean home-range than females. This is often observed during the mating season which coincided with the fieldwork season (e.g. Reeve, 1981; Kristiansson, 1984; Zingg, 1994; Riber, 2006). Published home-range sizes vary, which is likely to be partly due to differences in objectives and methods used. Additionally, different habitat composition and food availability is bound to have an impact on the home-range size of an animal, where larger home-ranges are needed in less favourable settings with low food resources. This will simultaneously affect the travel distance and possibly travel speed of individuals.

4.4.3 Attraction to edge habitat

In arable fields hedgehogs were seldom found more than 5m from the field edge. This was not the case in set-aside, formerly arable fields, or pasture, where hedgehogs moved well away from the edge. The hedgehog is well-known to be an edge-refuging species (e.g. Huijser 2000). There are three evidence-based hypotheses that may explain this behaviour, which has profound consequences for the conservation of hedgehogs in coarse-grained landscapes (i.e. with large field sizes as in most UK arable-dominated landscapes) where hedgehogs are also subject to significant predation pressure. The first hypothesis is that proximity to hedgerows offers a refuge from predation; this is supported by studies showing that badgers (the most significant predator of hedgehogs in the UK (Reeve, 1994; Young *et al.,* 2006)) do not mainly forage along linear landscape features (White *et al.,* 1993; Neal & Cheeseman 1996). Furthermore, hedgehogs that were located furthest away from badger activity were on average seen significantly further away from the edge than the other hedgehogs. Since these hedgehogs were most often observed in a pasture field it remains uncertain if the lack of badger activity or other factors determined their movements (see below).

Huijser (2000) thinks that it is unlikely that the possibility to offer cover from predators is the reason why hedgerows were selected positively in his study. He observed that hedgehogs did not always run away when they were disturbed. If they did run away they would not always go in the direction of the hedgerow to seek cover, even though hedgehogs were aware of their location in their home-range according to Huijser (2000) and others (Reeve, 1994; Zingg, 1994). Similar observations were made during the present study. Nevertheless, hedgehogs did walk with a significantly higher mean speed in areas that provided less cover; such as set-aside fields, arable fields and agri-environment field margins, although this could be also due to ease of rapid movement compared to habitats with denser vegetation. Furthermore, it has been shown that hedgehogs are able to recognise the smell of badgers and avoid areas which display their odour (Ward *et al.,* 1996; Ward *et al.,* 1997). It is therefore likely that the behaviour displayed by hedgehogs as a response to human proximity is not comparable to behaviour displayed in the proximity of predators such as badgers. Regardless, a higher complexity in landscape structure such as hedgerows offer, has been shown to decrease intraguild predation (Finke & Denno, 2002; Janssen *et al.,* 2007), such as hedgehogs receive from badgers.

A second hypothesis is that macro-invertebrate food for hedgehogs may be more abundant on the margins rather than in the interior of arable fields (Thomas *et al.,* 2001; Meek *et al.,* 2002; Woodcock *et al.,* 2007). Earthworms (Lumbricidae), on the other hand, which can form an important part of the diet of hedgehogs, appeared to be more abundant on arable fields in comparison to agri-environment field margins (Reeve, 1994; Lagerlöf *et al.,* 2002). However, studies seem to be ambiguous about this matter (Curry, 1998). A third hypothesis is that hedgehogs often nest in the base of hedgerows or adjoining long grass or bramble-dominated vegetation (e.g. Reeve, 1994), and thus may be more likely to be active close to field edges. Another factor that has been mentioned as a possible reason for hedgehogs' preference of being near edge habitat is orientation in the field (Reeve, 1994; Zingg, 1994). It has been argued that hedgehogs might use linear features such as hedgerows, tree lines and roads as a point of reference in their home-range. This point has however currently not been tested in the field.

The results from the current study suggest that edge-refuging in hedgehogs is likely to primarily be a consequence of concealment from predators; where the sward was very short (<10cm) as in amenity grassland or open as in arable fields, hedgehogs were most active close to edges. Where sward heights were higher and the vegetation was denser, as in pasture and set-aside, hedgehogs ventured into the interior of these habitats. Food availability might also be an important factor. For instance in set-aside, although hedgehogs were observed feeding they also travelled rapidly despite the high sward height of that habitat (note though that the data for this habitat type are biased towards males, which travelled faster). Set-aside fields in the study area tended to be especially dry and stony and were thus not likely to have high abundance of macro-invertebrate prey. Further work is required to clarify these relations, but edge distant-dependent predation and cover-dependent predation rates are very widespread ecological phenomena (Moller, 1988; Sih, 1997; Hartley & Hunter, 1998).

4.4.4 Mortality

Mortality was largely (eight out of nine deaths) due to predation by badgers. This amounts to an 18% predation rate, and that is in a landscape where badgers were scarce. Extrapolated over an entire active season the observed predation rate would amount to about 52%; clearly this would not likely be sustainable for a population in solely arable habitat. Hedgehogs were only found predated by badgers outside villages, where badgers were presumably more active (e.g. Neal & Cheeseman 1996). This supports the contention that villages and suburban areas can act as refugia from badger predation and facilitate hedgehog persistence (Young *et al.,* 2006; Dowding, 2007). Female hedgehogs had a higher preference for habitat types within the boundaries of the village in comparison to male hedgehogs. Males traversed beyond the village boundaries and thus were more prone to predation. This is reflected in the prevalence of males amongst the predated individuals. All but one of the badger-predated hedgehogs was male and hedgehogs have a promiscuous mating system with males travelling over relatively large areas during the mating period (Reeve 1994). Thus the impact of male losses would likely have a disproportionately low impact on population viability. However, necessary gene flow mainly driven by migrating males to prevent inbreeding cannot be ignored (Greenwood, 1980; Frankham, 1995; Keller & Waller 2002). Mortality during dispersal caused by an increased predation pressure may hamper migration between populations and consequently affect the dynamics of fragmented populations (Hanski & Gilpin, 1991).

The present study and others have shown that hedgehogs are susceptible to predation by badgers in areas where the latter are numerous (Doncaster, 1992). Hedgehogs tend to avoid these areas (Doncaster, 1992; Ward *et al.,* 1997), and such areas thus may act as a barrier for hedgehogs to disperse between suitable sites and may threaten populations (Doncaster *et al.,* 2001). The question arises as to whether badgers recently moved into the study area, consequently surprising an existing hedgehog population unaware of potential dangers, or whether other factors underlie this high badger-induced mortality of hedgehogs. Decreased food availability may increase the pressure of intraguild predation on taxa (Polis *et al.,* 1989). It is probable that food availability for badgers in the study area, especially earthworms (*Lumbricus terrestris*) which are a staple food (Neal & Cheeseman 1996), was limited and this may have enhanced predation on hedgehogs. Although a high predation rate by badgers on local hedgehog populations has been reported elsewhere (Doncaster, 1992; Morris & Warwick, 1994; Strøm Johansen, 1995), more research regarding the direct impact of badgers on local hedgehog populations is needed to be able to reach a conclusion in this matter. Continuous monitoring of both the badger and the hedgehog population might provide valuable answers.

4.4.5 Management implications

The present study has clear implications regarding the value of agri-environment schemes for hedgehogs; the management of arable landscapes to promote hedgehog conservation; and the likely impact of predation on population structure and persistence in the presence of spatial refugia.

It is clear that agri-environment field margins are heavily utilised by foraging hedgehogs; they provide a place to forage in an otherwise inhospitable arable landscape. The addition of such margins to arable fields, especially in the vicinity of villages or other parts of the landscape where badgers are less active will thus be beneficial to hedgehog conservation. Existing UK Government Countryside Stewardship and current Environmental Stewardship agri-environment schemes both have provision for grass field margins beneficial to hedgehogs. The findings in the present study are also a reminder of the importance of hedgerows to this species, for foraging, building nests and probably avoiding predators (Reeve, 1994; Huijser, 2000). The great loss of hedgerows in previous decades and the creation of much larger fields (Robinson & Sutherland, 2002) are likely to have significantly reduced the hedgehog carrying capacity, especially of arable-dominated landscapes. Again, existing agri-environment schemes in the UK have provision for the (re)creation of hedgerows. Appropriate management of hedgerows and adjoining vegetation is probably also important if they are to be suitable for nesting. This requires further research.

Hedgehogs did not select set-aside fields. This may at least partly be due to lower food availability (see above) on these fields. The evidence from this study suggests that agri-environment field margins will be much more beneficial to hedgehogs than set-aside. Although it has been suggested that both habitat types are able to provide a higher abundance of invertebrates than arable fields (Moreby & Aebischer, 1992; Vickery *et al.,* 2002), general invertebrate availability is said to be larger on grass field margins (Gates *et al.,* 1997).

The high rate of predation by badgers in a landscape where badgers were scarce adds weight to the conclusion that greatly increasing badger abundance is one driver of hedgehog decline (Young *et al.,* 2006 and see earlier chapters). The implications for management are, firstly, that features of the landscape that militate against predation should be enhanced; the results from the present study suggest this means maintenance of field margins and the creation of more edge habitat, be it hedgerows, shelterbelts or woodland patches. Secondly, the reduced habitat quality over the last decades (as it has been for farmland birds; Chamberlain *et al.,* 2000) coupled with increased predation rates is strongly promoting the fragmentation of hedgehog populations (Doncaster, 1992). It may thus be that current patchily distributed populations are morphing into a meta-population-like distribution, the conservation of which will require a focussed landscape level approach (as for other declining mammals in human dominated landscapes e.g. Carter & Bright 2003).

Chapter 5

Hedgehog presence in green-spaces in built-up areas

Chapter 5

Hedgehog presence in green-spaces in built-up areas

5.1 Introduction

Urban areas are still expanding in Great Britain. Almost 80% of the human population lived in urban areas in 2001 which covered about 9% of the total land area (National Statistics, 2005). Semi-natural patches such as parks, road verges and gardens are often maintained within these areas, and support wildlife populations (Harris, 1984; Harris & Rayner, 1986; Dickman, 1987; Mason, 2000; Bland *et al.,* 2004; Angold *et al.,* 2006). Sheltered climatic conditions, extra food supplied by wildlife-friendly gardeners, compost heaps and scattered organic waste all provide good situations for various species in built-up environments. Mammals however can also face high mortality risks in built-up areas. High road and traffic densities, (Rondinini & Doncaster, 2002; Huijser, 2000), and high levels of predation by feral and domestic pets and other predators (Doncaster *et al.,* 1990; Baker *et al.,* 2003; Woods *et al.,* 2003) can have negative impacts. High concentrations of garden pesticides causing diminishing food supplies and direct and secondary poisoning (Stehn *et al.,* 1976; Hart, 1999; Reeve & Huijser, 1999; Shore *et al.,* 1999; Wilson *et al.,* 1999, D'Havé *et al.,* 2006) also do not benefit mammal populations. Additionally, general disturbances through human actions can cause increased mortality rates (Reeve & Huijser, 1999; Frid & Dill, 2002; Ditchkoff *et al.,* 2006), and changes in built-up landscapes can have a substantial impact on species diversity and abundance as well (Dickman, 1987; Baker & Harris, 2007).

Increasing fragmentation, housing density and loss of habitat due to growing needs for development all have negative effects on wildlife. A lot of research has, for instance, been done on the decline in various bird species associated with built-up areas such as the house sparrow (*Passer domesticus*), house martin (*Delichon urbica*), and the starling (*Sturnus vulgaris*) (Crick *et al.,* 2002; Crick *et al.,* 2004; Robinson *et al.,* 2005; De Laet & Summers-Smith, 2007). Various urban dwelling mammals may be affected in a similar way by these factors. The fragmentation of habitat and the impact of predators such as feral and domestic cats are, for instance, mentioned as causes for population decline and high mortality rates amongst species of small mammals (Dickman, 1987; Baker *et al.,* 2003; Woods *et al.,* 2003; Baker & Harris, 2007).

Green-spaces in built-up areas such as gardens, greens and parks are also frequently visited by and closely associated with hedgehogs (Reeve, 1994; Morris, 2006). Urban areas might offer hedgehogs refugia from predators (chapter 4 and Young *et al.,* 2006; Dowding, 2007). On the other hand, people recorded negative sightings of hedgehogs significantly more in urban areas than in rural areas (chapter 2). The perceived decline in hedgehogs was also larger in urban areas. One of the reasons for this apparent low number of hedgehogs and perceived decline might well be the small and declining amount of available green-spaces in urban and other built-up areas that are accessible to mammals such as hedgehogs. The number of gardens, allotments and playing fields has for instance diminished in built-up areas in Great Britain due to the increasing need for houses and off-road parking spaces (Greater London Authority & London Assembly, 2001; Greater London Authority & London Assembly, 2005a; Greater London Authority & London Assembly, 2006a; Greater London Authority & London Assembly, 2006b). Additionally, the trend to tidy up and enclose gardens also does not improve the suitability and accessibility of these habitats for hedgehogs and other small to medium-sized mammals. It is therefore important to get an understanding of the current value of green-spaces in built-up areas and which features in particular might enhance habitat suitability for hedgehogs.

Volunteer surveys have yielded valuable results in the monitoring of mammals in gardens (Toms & Newson, 2006; Baker & Harris, 2007), and provide relative low-cost and little time-consuming means of sampling large areas. Unfortunately, many surveys rely solely on presence/absence data, and changing effort over time can greatly affect the results. Trends may be over expressed or suppressed in long running studies that fail to record survey effort (McDonald & Harris, 1999). However, effort based wildlife surveys that encompass large areas are rare. The survey ‘Living with Mammals’ (LWM) was designed by the Mammals Trust UK in conjunction with Royal Holloway, University of London to record mammals in green-spaces within and around urban and built-up environments. This survey took recording effort into account. Although the vast majority of the sites surveyed (75%) were gardens, other green-spaces near built land such as churchyards, greens and parks were also surveyed, returning valuable data on mammal diversity in built-up areas in Britain. The LWM database is extensive, for the purpose of the present study the analyses were concentrated on the hedgehog and two of its main wild predators: the badger (*Meles meles*) and the red fox (*Vulpes vulpes*) (Reeve, 1994).

One of the aims of this study was to investigate whether the connectivity between gardens and adjacent areas that are suitable for hedgehogs is an important factor determining hedgehog presence in built-up areas. Furthermore, the role of increased tidiness, such as the lack of compost heaps and shrubs, upon the presence of hedgehogs in gardens was studied. Another aim was to find out whether the presence of predators such as badgers, foxes and pet dogs (*Canis lupus familiaris*) limit hedgehog presence.

5.2 Methods

5.2.1 The Survey

The survey took place between 2003 and 2006. During each of these years data were recorded throughout 13 consecutive weeks starting at the beginning of April. A few people took part in the survey for several years and in order to avoid double counting, only their data from 2004, or from the first year that the person had taken part, were used in the analyses. The data collected in 2004 were more extensive than in 2003 and were therefore preferred over the data from 2003. People were provided with five survey sheets (Appendix IV).

Sheet A was used to record site data such as site address, county and postcode, and the site type (garden, park/mown village green/residential square, common with rough grass or scrub, wasteland/derelict land, churchyard/cemetery, playing field, golf course, allotment, railway embankment/roadside verge, river bank/stream bank, arable land, pasture, woodland). Also noted was when the site was established (pre 1900s, 1901-1949, 1950-1999, since 2000), and the approximate area of the site (<25m^2, 26-50m^2, 51-200m^2, >200m^2). Additionally, this sheet was used to record site description. The following data were requested: the percentage of the site that consisted of grass, shrubs, trees, concrete/gravel/paving, shed/hut/building and wild untended areas (0%, 1-25%, 26-50%, 51-75%, 76-100%), and the presence of features meant to attract wildlife (garden shed, pond or lake, bat box, hedgehog nest box, bird box, compost heap, piles of dead wood, bird table, bird bath, bird feeder or other animal feeder). Also information regarding the plants and domestic animals at the site was collected. The recorder was asked whether any of the plants at the site produced fruit or berries, nuts, seeds or cones, bulbs or root vegetables and above ground vegetables, and whether dogs, domestic or feral cats, or other domestic animals regularly used the survey site. Information regarding the presence of artificial illumination at night was also requested. In addition, sheet A contained questions regarding the nature of the boundary (none, all fenced, partially fenced, all hedgerows, partially hedgerows, all walled, partially walled, all trees, partially trees). The height of the boundary was recorded, if there was one, (0-1m, 1-2m, >2m), and the presence of gaps large enough to let mammals as big as hedgehogs/rabbits, cats/foxes or deer pass through. Lastly, it was asked which habitats occurred within 100m of the survey area (gardens, woodland, common with rough grass or scrub, pasture/grass fields, arable fields, wasteland/derelict land, park/mown village green/residential square, pond/lake, stream/river).

Sheet B was used to record mammals each week for a period of 13 consecutive weeks. Mammals could be recorded in groups of one, two, and three or more individuals. Sheet C was used to record the effort. People were asked to estimate the approximate observation length during dawn, day, dusk and night each week. Time slots were defined as follows: 0 min, 1-10 min, 11-30 min, 31-60 min, and >60 min. Sheet D was used for the recording of mammal signs such as droppings and paw prints, and sheet E was used to record the scarcer mammal species.

5.2.2 Analyses

Analysis of the LWM dataset was limited to the hedgehog and two of its main wild predators: the badger, and the fox. The survey used the average for each of the time slots (5, 20 and 45 min) used for approximate observation length as an index for effort. For the last category (>60 min) it was assumed that the length of observation did not exceed 120 min, the average therefore was set at 90 min. The success of the observation depends on the activity pattern of the animal. Hedgehogs are generally nocturnal (Reeve, 1994). The probability of sighting a hedgehog during the day was therefore estimated at 0.10 (dawn), 0.00 (day), 0.20 (dusk) and 0.70 (night) based on findings regarding their activity pattern (Reeve, 1994). The effective recorder effort per time of day was calculated by using the following equation.

$$EE = \sum(SP_i \cdot AE_i) \qquad \textbf{Equation 5.1}$$

Where *EE* is the effective recorder effort, *SP* is the sighting probability for a species during each survey period *i* (dawn, day, dusk, and night), and *AE* is the actual effort defined as the total number of minutes spent surveying during each survey period *i*.

Four categories of the number of mammal sightings were defined in the survey: 0, 1, 2 or 3+. To calculate the total number of hedgehog sightings the values of the categories were summed. The category 3+ was classified as 3. The total number of hedgehogs recorded per site over the 13-week survey period divided by the *total effective recorder effort* represented the number of hedgehogs sighted per minute per site, and was used to provide an index of relative density. Unfortunately it was impossible to account for double counting of hedgehogs. The assumption has been made that the likelihood of seeing a hedgehog has a positive and linear correlation with their relative density; a fixed amount of recording effort will result in seeing a fixed proportion of the population. This implies that it is assumed that the relative density is proportional to the actual density and that the rate of proportionality is constant (Schwarz & Seber, 1999). Examples of surveys that use the point count method to estimate population densities are the ‘Common Birds Census’, and the ‘Constant Effort Sites Ringing Scheme’ in Great Britain.

In order to obtain an estimate of the minimum number of sites that have to be surveyed to gain confidence in the estimated relative density of hedgehogs, the mean number of hedgehogs observed per site was calculated using random sub-samples (ranging from 0-1700 with steps of 100). The mean relative density of badgers and foxes was calculated in a similar way. The probability of sighting a badger in the course of the day was estimated at 0.25 (dawn), 0.00 (day), 0.25 (dusk) and 0.50 (night), and for a fox at 0.30 (dawn), 0.10 (day), 0.30 (dusk) and 0.30 (night) based on their general activity pattern (Harris & Yalden, 2008). Relative abundance of badgers, foxes, and hedgehogs was estimated for built-up areas in the countryside (henceforth called countryside) (built-up <50%; derived from CS2000 [DEFRA & NERC, 2007]), urban areas (built-up >50%), and both areas together. This gives an indication of the relative abundance of the different species in different surroundings.

To estimate the area occupied by grass, shrubs, trees, concrete, sheds and wild areas within the individual survey sites, the log ratios of the five categories (0%, 1-25%, 26-50%, 51-75%, 76-100%) were taken (Aitchison, 1982; Kucera & Malmgren, 1998). The mean from each of the categories established for the age and size of the site (see section 5.2.1) was used as an index of the actual age and size of the site. If the site was established before 1900, it was assumed that it was established between 1800 and 1900 and therefore estimated to be, on average, 156 years old at the time of the survey in 2006. Sites greater than $200m^2$ were assumed to be between 200 and $400m^2$ and therefore, on average, $300m^2$. Only the variables that might have an impact on the presence of hedgehogs were included in the database (Table 5.1). Therefore, variables such as the presence of cats and birdbaths were discarded. Data about the density of built-up area were derived from CS2000 (DEFRA & NERC, 2007)

The Chi-square Test and Pearson Correlation Test have been used in SPSS to study whether the presence of hedgehogs was significantly related to the variables. The t-Test and nonparametric Kruskal-Wallis Test have been used to study the differences in population means. Similar to chapter 2 and 3, generalized linear modelling (GLM) of binomial proportions by transformation logit was used in GenStat (for windows 8th edition, VSN International Ltd, Lawes Agricultural Trust, Oxford, UK) to explain the variation in relative hedgehog density. The backward stepwise method was used in a similar fashion to the procedure used in chapter 2 and 3 to select the models of best fit. The effective recorder effort was used as a weight factor to correct for differences in effort. Different models were built for different environmental zones within Great Britain (Figure 2.1) in order to analyse hedgehog abundance on a smaller scale. Models were built for the sites located in the arable-dominated and the pasture-dominated lowlands in England and Wales only. No minimum adequate model could be obtained for the other environmental zones. Since 75% of the surveys occurred in gardens, no comparisons between all types of sites could be made due to lack of data. There was no strong collinearity between the predictor variables ($r \leq 0.60$, Graham, 2003).

Table 5.1 Variables obtained from participants of the LWM dataset and used for the analyses

Variable	***Description***
Arable in surrounding	Arable fields in surroundings (yes/no)
Box on site	Presence of hedgehog nest box (yes/no)
Built-up	Density of built-up area in 2000 (ha · 100km-2)
Common in surrounding	Commons with rough grass or scrub in surroundings (yes/no)
Compost on site	Presence of compost heap (yes/no)
Concrete percentage	Percentage of concrete/gravel/pavings (logratio transformed)
Density badgers	The average number of badgers per min observation
Density foxes	The average number of foxes per min observation
Density hedgehogs	The average number of hedgehogs per min observation
Feeder on site	Presence of pet feeder (non bird) (yes/no)
Fence	Site fenced (yes/no)
Gaps	Gaps in the boundary large enough for hedgehogs (yes/no)
Garden in surrounding	Garden in surroundings (yes/no)
Grass percentage	Percentage of grass (logratio transformed)
Hedgerow	Hedgerow as site boundary (yes/no)
Open	No site boundary (yes/no)
Park in surrounding	Park/ village green/ residential square in surroundings (yes/no)
Pasture in surrounding	Pasture/ grass fields in surroundings (yes/no)
Pile on site	Presence of pile of dead wood (yes/no)
Pond in surrounding	Pond/ lake in surroundings (yes/no)
Pond on site	Presence of pond (yes/no)
Presence badgers	Presence badger (yes/no)
Presence dogs	Presence of dog (yes/no)
Presence foxes	Presence foxes (yes/no)
Presence hedgehogs	Presence hedgehogs (yes/no)
River on site	Presence of river (yes/no)
Shed on site	Presence of shed (yes/no)
Shed percentage	Percentage of shed/ hut/ building (logratio transformed)
Shrubs percentage	Percentage of shrubs (logratio transformed)
Site	Type of site
Site age	Approximate age of site (4/33/82/157 years)
Site size	Approximate size of the site (13/38/126/300 ha)
Stream in surrounding	Stream/ river in surroundings (yes/no)
Trees percentage	Percentage of trees (logratio transformed)
Wasteland in surrounding	Wasteland/ derelict land in surroundings (yes/no)
Wild percentage	Percentage of wild untended areas (logratio transformed)
Woodland in surrounding	Woodland in surroundings (yes/no)

5.2.3 Site selection

Whether hedgehogs preferred or avoided a site can be estimated by their relative density per type of site in proportion to the availability of that type of site. The total number of hedgehogs seen per minute observing was summed for the different types of sites and the site availability was based on the total size as given by the surveyors. The method for habitat selection of Manly *et al.,* (1993) as previously used in chapter 2 (section 2.2.4) was used to estimate the selection of the different types of sites by hedgehogs. The significance of differences was tested with the nonparametric Kruskal-Wallis Test in SPSS. Since many types of sites were rarely selected by surveyors, and several type of sites resembled each other in habitat terms it was decided to amalgamate them in three groups: gardens, amenity grassland types (park/mown village green/residential square, churchyard/cemetery, playground, golf course), and other sites that were more varied (common with rough grass or scrub, wasteland/derelict land, allotment, railway embankment/roadside verge, river bank/stream bank, arable land, pasture, woodland).

5.2.4 Connectivity and presence of wildlife friendly features

The main variables that might prove important for connectivity between sites for hedgehogs are the habitat present in the surrounding area and in the survey site, the presence of roads and waterways in the surroundings of the survey site, and the presence of obstacles such as fences. Other features at the site that might be attractive to hedgehogs are feeders (other than those meant for birds), piles of dead wood, compost heaps, sheds, hedgehog nest boxes, and ponds or lakes. The individual effects of these variables upon presence and relative density of hedgehogs were investigated using the Chi-square Test in SPSS.

5.2.5 Predators

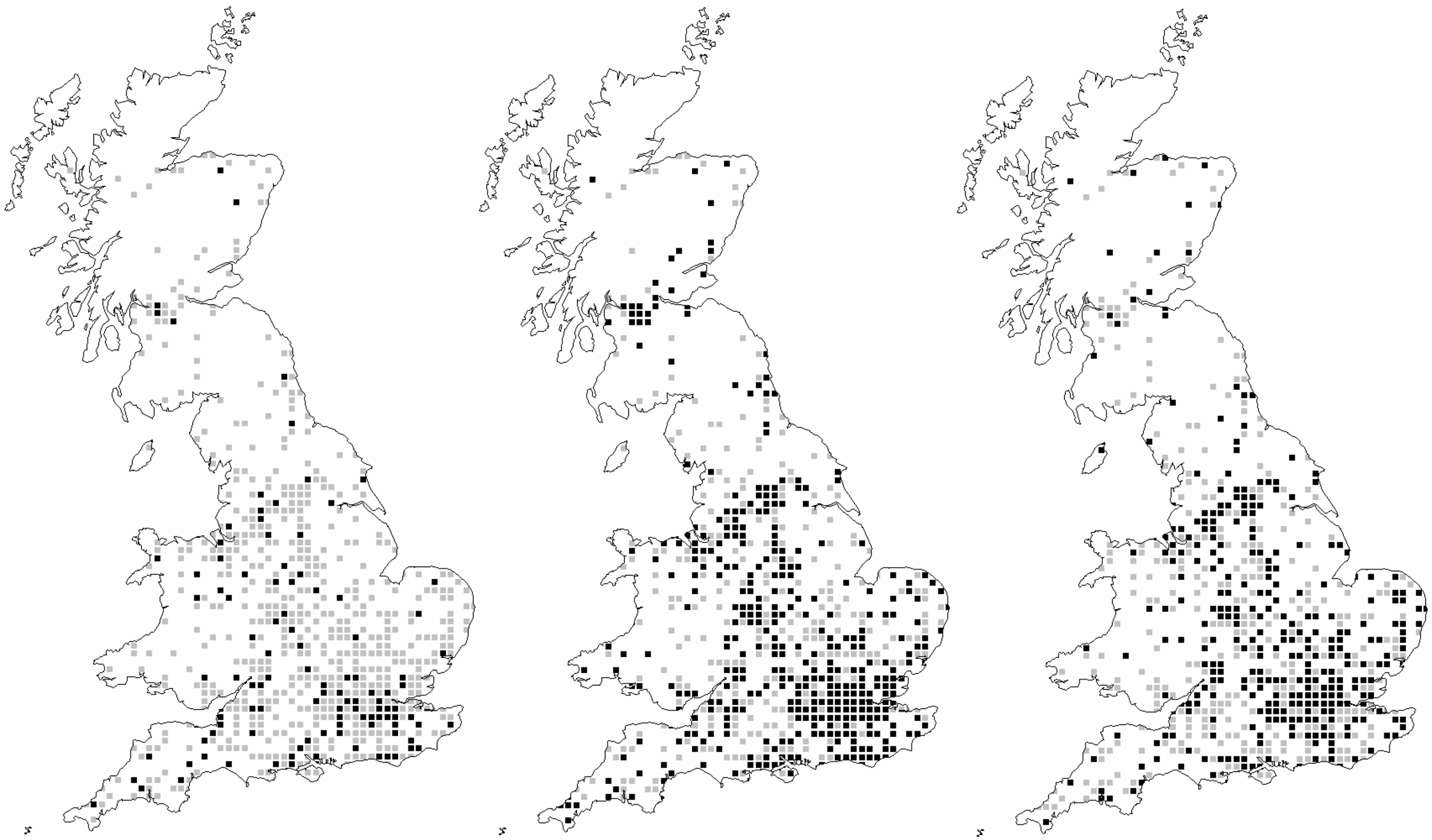
Badgers predate on hedgehogs and can negatively affect local hedgehog populations (see chapter 4 and Doncaster, 1992; Doncaster, 1994; Micol *et al.,* 1994; Young *et al.,* 2006). In addition, the previous chapters reveal a negative relation between badgers and hedgehogs nationwide. Foxes and dogs are however also known to predate hedgehogs occasionally (Doncaster *et al.,* 1990; Doncaster, 1994; Reeve, 1994) and may have negative effects on the abundance of hedgehogs as well. The individual and combined relationship between the presence and relative density of the predators upon hedgehogs was analysed using the Chi-square Test in SPSS.

5.3 Results

5.3.1 The presence of badgers, foxes and hedgehogs

In total 1711 sites were surveyed. The highest number of sites (377) was surveyed in southeast England whilst the lowest number was surveyed in the northeast (27 sites). The majority of sites (75%) were gardens, followed by commons with rough grass or scrub (6%), and by parks, mown village greens and residential squares (5%). Figure 5.1 shows the distribution of the sites throughout Great Britain and shows on which sites badgers, foxes and hedgehogs have been found and on which sites these species have not been found. The mean relative density of badgers, foxes and hedgehogs per region is shown in Figure 5.2. Differences in the mean relative density of a species between regions were significant for badgers (Kruskal-Wallis Test, χ^2=25.115, df=10, p=0.005), foxes (Kruskal-Wallis Test, χ^2=84.716, df=10, p=0.001), and hedgehogs (Kruskal-Wallis Test, χ^2=39.158, df=10, p=0.001). Hedgehogs were relatively more abundant in the eastern regions, whereas badgers were relatively more abundant in the southwest of England and in Scotland. Foxes were relatively most abundant in Greater London and in southeast England.

Figure 5.3a, b and c show the mean number of badgers, foxes and hedgehogs seen per minute observing in the countryside, urban areas, and both areas together. A clear distinction can be seen for foxes. The average relative density for foxes was significantly lower in the countryside than in the urban areas (t-Test, t=-2.106, df=1192, p=0.035), whilst this trend was reversed regarding the average relative density of badgers and hedgehogs. These differences however were not statistically significant (badgers: t-Test, t=1.262, df=1332, p=0.207, hedgehogs: t-Test, t=-0.257, df=1331, p=0.797). Also no significant trend in the relative density of hedgehogs occurred between the different years (Kruskal-Wallis Test, χ^2=2.495, df=3, p=0.476). It can be seen from Figure 5.4 that with the advancing season hedgehogs were seen on a larger number of sites.



Badgers Foxes Hedgehogs

Figure 5.1 Locations of the participants (n=1711) of the LWM survey 2003-2006. Black dots show where the species has been found and grey dots show where the species has not been found. Badger presence n=153, absence n=1558. Fox presence n=823, absence n=888. hedgehog presence n=515, absence n=1196

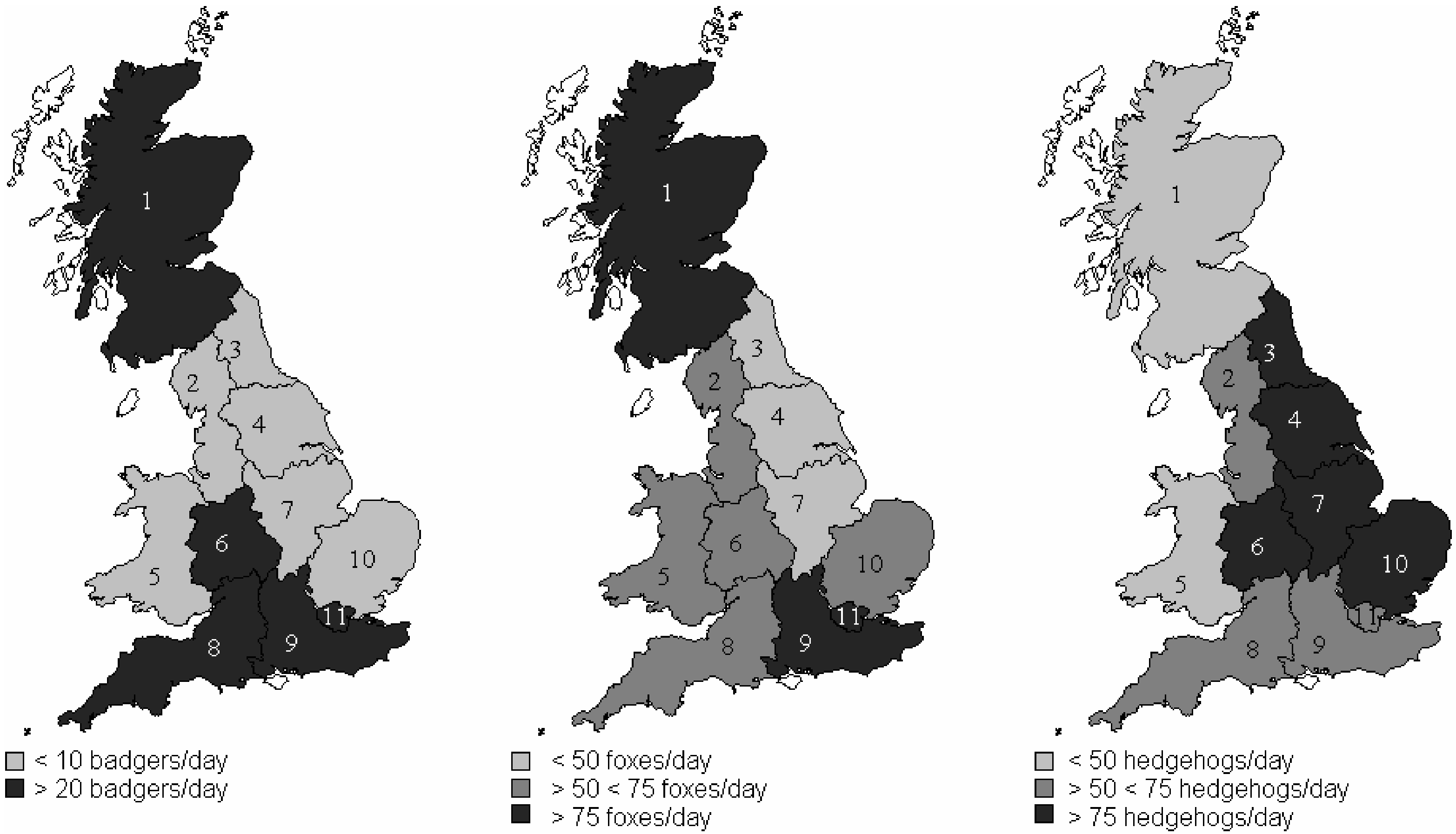
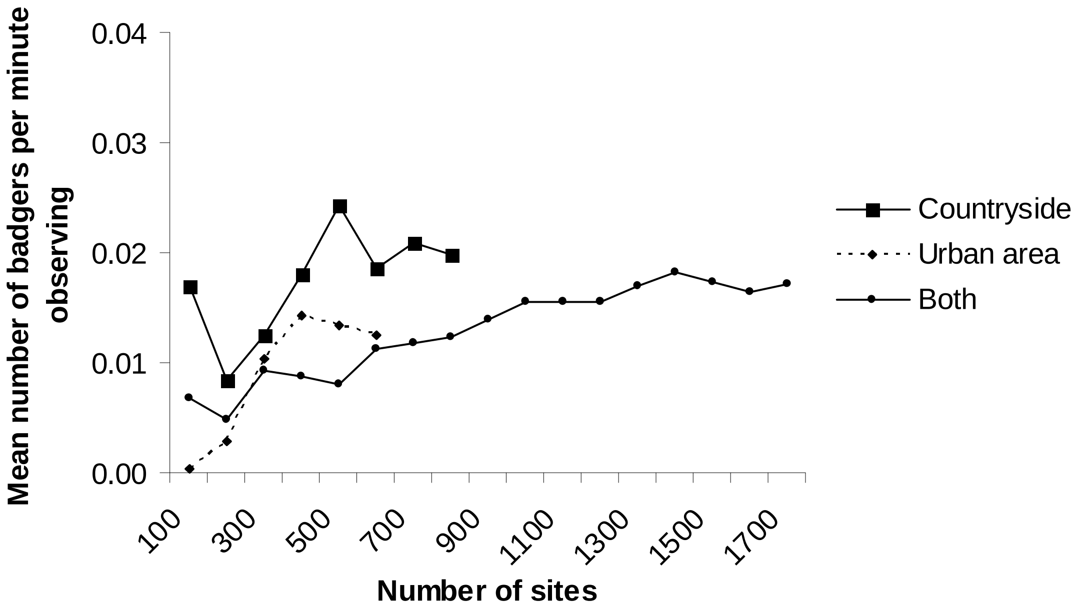
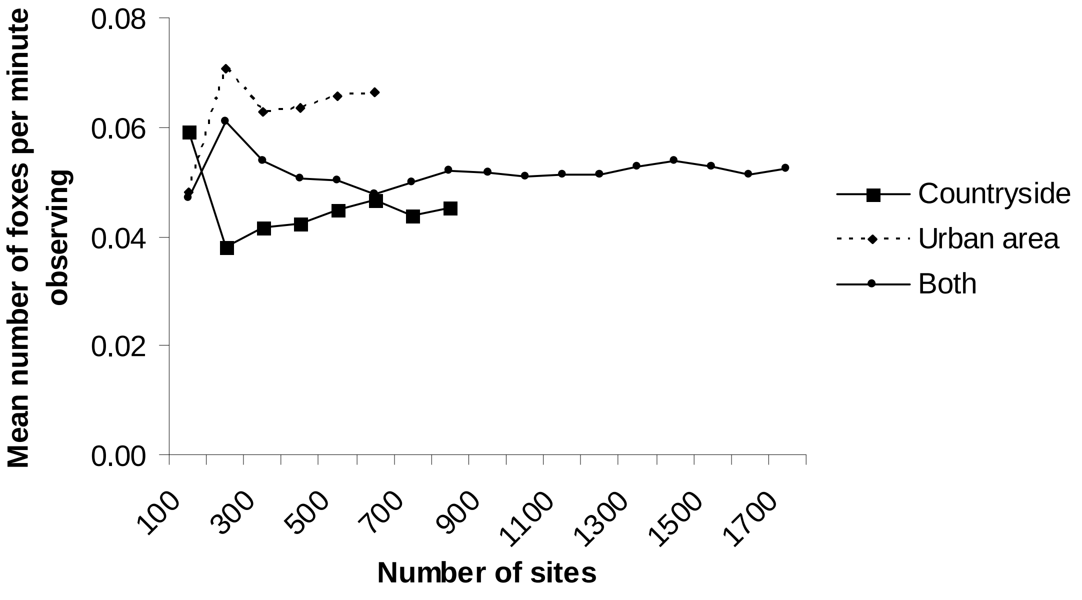


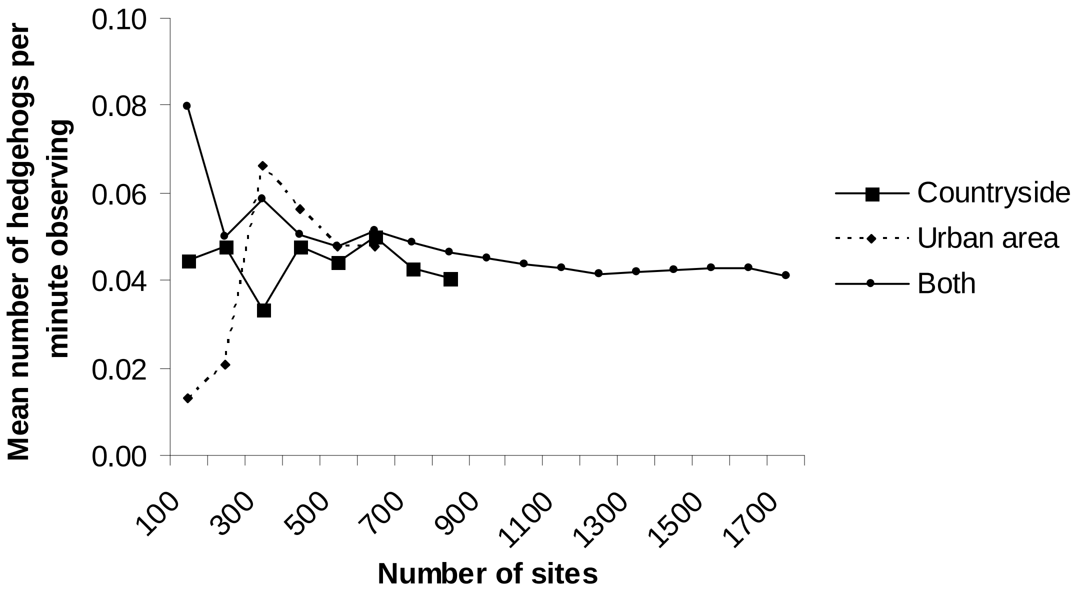
Figure 5.2 Mean relative density of badgers, foxes and hedgehogs seen per day of continuous observation per region of Great Britain, with 1) Scotland, 2) North West of England, 3) North East of England, 4) Yorkshire and The Humber, 5) Wales, 6) West Midlands, 7) East Midlands, 8) South West of England, 9) South East of England, 10) East of England, and 11) Greater London


Mean number of badgers per minute observing
0.04
0.03
0.02
0.01
0.00
100
300
500
700
900
1100
1300
1500
1700
Number of sites
Countryside
Urban area
Both

A


Mean number of foxes per minute observing
0.08
0.06
0.04
0.02
0.00
100
300
500
700
900
1100
1300
1500
1700
Number of sites
Countryside
Urban area
Both

B



C

Figure 5.3a, b, c Mean number of badgers, foxes and hedgehogs per minute observing versus the number of sites in the countryside, in the urban areas and in both areas, in the period 2003-2006. Standard errors are not shown for clarity. (Mean standard error badger: countryside se=0.005, urban se=0.004, both se=0.003, fox: countryside se=0.005, urban se=0.007, both se=0.04, hedgehog: countryside se=0.005, urban se=0.010, both se=0.005).

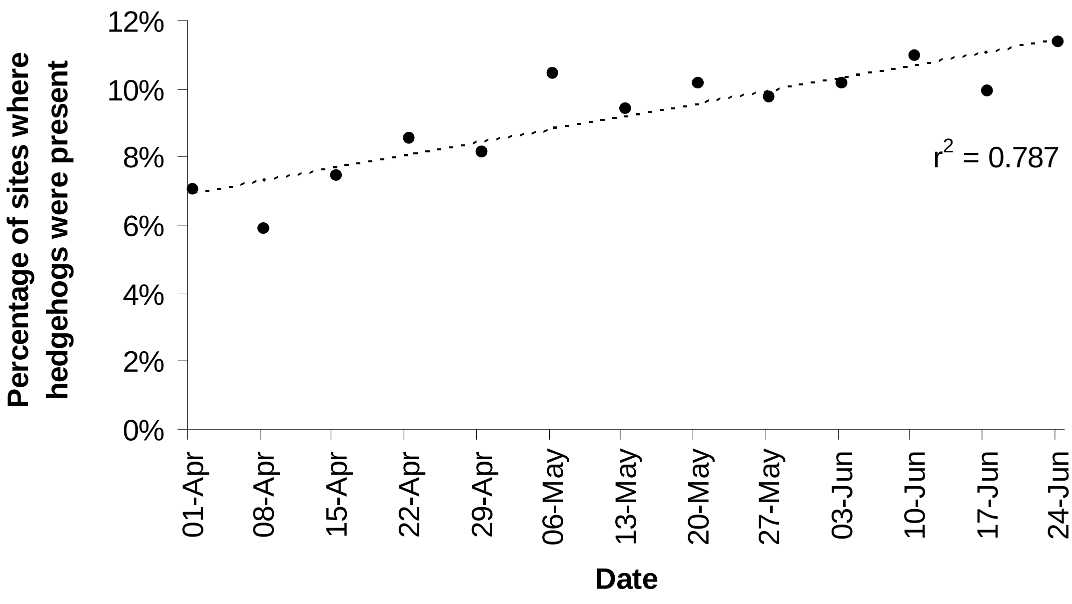


Figure 5.4 The percentage of sites where hedgehogs were seen in relation to the date of observation.

The GLMs (Table 5.2) were able to explain 42% of the variance in presence of hedgehogs in gardens in the pasture-dominated lowlands and 54% in gardens situated in the arable-dominated lowlands of England and Wales. The variable *pasture in the surroundings* explained the highest percentage of variance in hedgehog presence (21%) in the arable-dominated lowlands and was positively related to the presence of hedgehogs. Hedgehogs were less often present at sites also frequented by badgers. Furthermore, the presence of a large number of shrubs and/or a pond or lake at the site or in the surroundings of the site and the presence of a feeder at the site, were positively correlated with hedgehog presence. The presence of a hedgehog nest box had the highest explaining power (10%) in the pasture-dominated lowlands. A hedgehog nest box, feeders on site, a large percentage of grass on the site, gaps in the boundary, and a common, woodland or a park in the surrounding of the site were all positively related to hedgehog presence. In this environmental zone, hedgehogs were less often present in gardens that had arable land in the surroundings, high densities of built-up areas, or dogs and/or badgers frequenting the site. A river running through the site was also negatively related to hedgehog presence.

Table 5.2 Summary of the GLMs of hedgehog presence in sites surveyed by the participants of the LWM survey

Hedgehog presence in gardens 2003-2006	***Variable***	***Estimate***	***Partial r^2***	***p.***
Arable-dominated lowlands of England and Wales Explained: 42%, n=380, p<0.001	Constant	-5.370		<.001
	Pasture in surrounding	3.043	0.205	<.001
	Pond in surrounding	2.607	0.104	<.001
	Presence badgers	-3.557	0.091	<.001
	Pond on site	1.986	0.076	<.001
	Feeder on site	1.699	0.037	<.001
	Shrubs percentage	1.544	0.023	<.001
Pasture-dominated lowlands of England and Wales Explained: 54%, n=285, p<0.001	Constant	-2.498		<.001
	Box on site	3.611	0.097	<.001
	Arable in surrounding	-3.927	0.092	<.001
	River on site	-4.897	0.086	<.001
	Built-up	-2.282	0.059	<.001
	Common in surrounding	1.648	0.043	<.001
	Woodland in surrounding	1.735	0.041	<.001
	Park in surrounding	1.980	0.035	<.001
	Feeder on site	1.997	0.034	<.001
	Gaps	3.122	0.030	<.001
	Presence dogs	-1.625	0.030	<.001
	Presence badgers	-2.816	0.027	<.001
	Grass percentage	1.200	0.023	<.001

5.3.2 Site selection

The average number of hedgehogs seen per minute observing on amenity grassland sites was 0.115 (n=115, se=0.012) versus 0.037 (n=1095, se=0.004) in gardens and 0.036 (n=209, se=0.009) on the remainder of the sites. Differences were significant (Kruskal-Wallis Test, χ^2=8.502, df=2, p=0.014). If the effective recorder effort was not taken into account and the relative density of hedgehogs was merely defined by the average total of hedgehogs seen per week, hedgehogs appeared to be more abundant in gardens (on average 1.84 hedgehogs per week) than on amenity grasslands (on average 1.24 hedgehogs per week). This demonstrates the importance of considering the effective recorder effort.

The selection probabilities did not significantly differ from 1; they do however suggest that amenity type grasslands were preferred by hedgehogs, and gardens were avoided (Table 5.3). Badgers and foxes on the other hand seemed to prefer gardens.

Table 5.3 The selection probability per type of site for badgers, foxes and hedgehogs. Selection probabilities that show positive selection (> 1.0) are given in bold. Selection probabilities do not differ significantly from 1.

Species	***Type of site***	***Selection probability***	χ^2	***Confidence interval***	
				Lower	*Upper*
Badger	Amenity type grasslands	0.340	0.403	-0.397	1.913
	Garden	**1.170**	2.424	0.839	1.500
	Other type sites	0.758	3.759	-0.691	1.371
Fox	Amenity type grasslands	0.670	0.618	-0.414	1.832
	Garden	**1.129**	1.244	0.779	1.479
	Other type sites	0.709	0.496	-0.748	2.089
Hedgehog	Amenity type grasslands	**1.884**	0.818	-0.426	1.770
	Garden	0.941	0.190	0.532	1.351
	Other type sites	0.672	1.494	-0.308	4.075

5.3.3 Connectivity and presence of wildlife friendly features

Gaps in the boundary of the site large enough to allow hedgehogs through, rivers or streams through or in the surroundings of the site, gardens near the site, and arable land in the neighbourhood were all significantly related to the presence of hedgehogs. The presence of a river or stream at the site or in the surroundings was the only variable with a negative influence on the presence of hedgehogs and appeared to restrict connectivity. The presence of the following features potentially attractive for hedgehogs were recorded in the survey sites: garden-shed, pond or lake, hedgehog nest box, compost heap, piles of dead wood and animal feeders other than those meant for birds. The presence of a feeder, a pile of dead wood, a garden-shed and a hedgehog nest box were positively related to the presence of hedgehogs at the site (Table 5.4). The presence of a pond or lake and a compost heap did not have a significant influence. Figure 5.5 shows on which percentage of the sites particular wildlife attracting features were present.

Table 5.4 Summary of the Chi-square Test showing the variables significantly related to the presence/absence of hedgehogs in sites surveyed by the participants of the LWM survey. All tests have df=1

Variable	χ^2	*Sig. (2-tailed)*	*Relation*
Arable in the surroundings	6.889	0.009	Positive
Feeder	23.846	<0.001	Positive
Gaps in the boundary	9.683	0.002	Positive
Garden in the surroundings	4.081	0.043	Positive
Hedgehog nest box	12.486	<0.001	Positive
Pile of dead wood	12.063	0.001	Positive
River or stream in the site	5.194	0.023	Negative
River or stream in the surroundings	4.445	0.035	Negative
Shed	12.289	<0.001	Positive

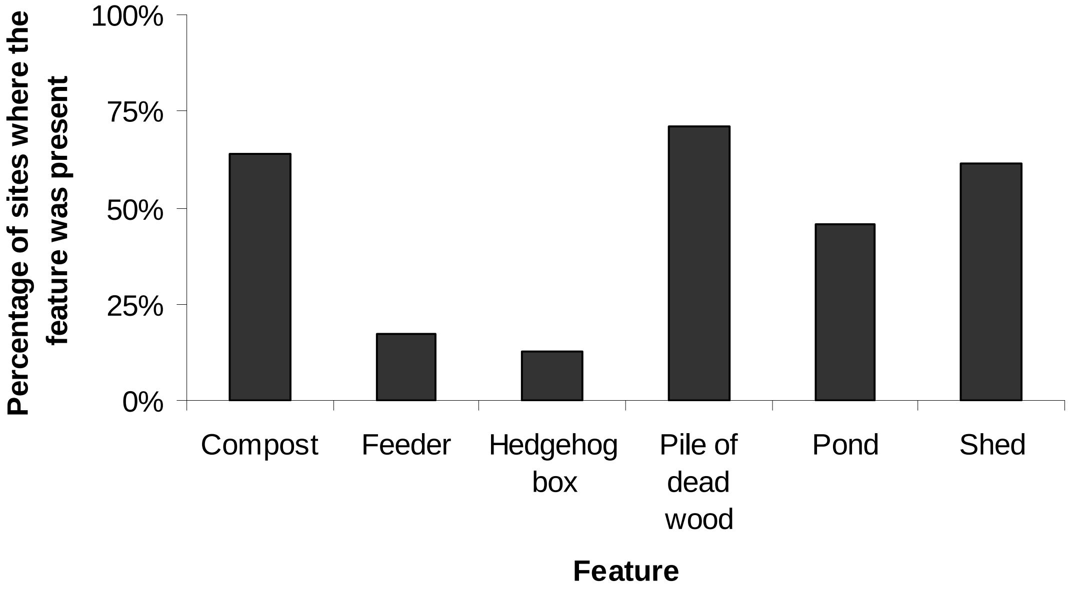


Figure 5.5 Percentage of sites with wildlife attracting features.

5.3.4 Predators

Hedgehogs were found on 30% (n=513) of all sites, whilst foxes were found on 48% (n=821) and badgers only on 9% (n=154). Dogs regularly frequented 36% (n=616) of the sites. In countryside areas, hedgehogs were only seen on 21% of the sites where badgers were present, opposed to on 32% of the sites where badgers were not seen. In urban areas, hedgehogs visited 27% of the sites where badgers were seen, opposed to 30% where badgers were not seen. The negative relation between the presence of badgers and the presence of hedgehogs was significant in survey sites classified as countryside areas (Chi-square Test, χ^2=4.447, df=1, p=0.035), but not in survey sites classified as urban areas (Chi-square Test, χ^2=0.168, df=1, p=0.682). A similar situation arose with the presence of dogs. A significant negative relation occurred in the countryside (Chi-square Test, χ^2=4.533, df=1, p=0.033), where hedgehogs were seen on 27% of the sites with dogs, versus 34% of the sites without dogs. In urban areas no significant relation was seen (Chi-square Test, χ^2=0.210, df=1, p=0.360); hedgehogs were seen on 28% of sites with dogs, and on 30% of the sites without dogs. The presence of foxes both in the countryside and in urban areas was not significantly related to the presence of hedgehogs (countryside: Chi-square Test, χ^2=0.009, df=1, p=0.923, urban: Chi-square Test, χ^2=0.593, df=1, p=0.441). They were seen on 31% of the sites also frequented by foxes both in countryside and in urban areas, versus 31% and 28% on sites not frequented by foxes in the countryside and in urban areas respectively. If badger, fox and dog all frequented the site in the countryside, hedgehogs were significantly less often present than if no predators would visit the site (Chi-square Test, χ^2=5.862 df=1, p=0.009). Hedgehogs were only seen on 10% of the sites frequented by badgers, foxes and dogs, whilst they were seen on 31% of the sites without those predators. Only a few sites (n=11) in the urban areas were visited by all three predators. Hedgehogs were only seen on 9% of the sites frequented by badger, fox and dog, whilst they were seen on 30% of the sites without any signs of these predators. Nevertheless, the presence of all three predators did not significantly relate to the presence of hedgehogs in these areas (Chi-square Test, χ^2=2.269 df=1, p=0.132). Table 5.5 summarises the findings.

Table 5.5 The percentage of sites in countryside area and in urban area where hedgehogs have been seen in relation to the presence of one or more species of predators. Figures in bold signify significant differences (p<0.05).

Area	***Species of predator***	***predator absent***	***predator present***
countryside	Badger	**32%**	**21%**
	Dog	**34%**	**27%**
	Fox	31%	31%
	Badger, dog, fox	**31%**	**10%**
urban	Badger	30%	27%
	Dog	30%	28%
	Fox	28%	31%
	Badger, dog, fox	30%	9%

5.4 Discussion

5.4.1 Predators

From this chapter it can be concluded that hedgehogs are likely to be present at a higher density in the eastern regions of England and in the West Midlands than in other areas of Great Britain, which is largely in agreement with findings in earlier chapters. In contrast, the eastern regions of England were characterized by a low relative density of badgers, and largely as well by a low relative density of foxes. This relation also appeared in terms of site selection: although not significantly, hedgehogs avoided the sites (gardens) which were preferred by badgers and foxes. It thus seems straightforward to suggest that a negative relation exists between the relative density of predators and the relative density of hedgehogs. Although the presence of foxes was not significantly related to that of hedgehogs, this was not the case for badgers and dogs. The presence of badgers was negatively correlated with the presence of hedgehogs in both the arable and the pasture-dominated lowlands of England and in survey sites in built-up areas in the countryside. This is in agreement with conclusions drawn from earlier chapters. However, this was not the case in urban areas. The presence of hedgehogs was not significantly related to badgers, dogs or foxes in these areas, which adds to the belief that urban areas might act as refugia for hedgehogs (Young *et al.,* 2006; Dowding, 2007).

Dogs are one of the other predators that might have partly caused gardens to be less attractive for hedgehogs than amenity type grasslands. They frequently roam freely in gardens, probably especially in more rural areas. Dogs are known to inflict injuries upon hedgehogs and occasionally kill them (Doncaster, 1994; Reeve, 1994). Hedgehogs were indeed less often seen on sites that were frequented by dogs. The GLM for the pasture-dominated lowlands showed a negative impact of dogs on hedgehog presence. Although no statistically significant relationship existed in urban areas, a negative relation between dogs and hedgehogs was visible in rural areas, where the prevalence of dogs was higher in the present survey.

The present study suggests that the presence of predators can indeed have a significant negative impact on the presence of hedgehogs. Increasing numbers of predators both in rural and in urban areas might lead to local extinctions of prey species (Holyoak & Lawler, 1996). But predator control, particularly of 'well liked' species, can meet resistance from the general public; it requires a considerable amount of time and money; and its effectiveness is questioned (Côté & Sutherland, 1997; Harding *et al.,* 2001; Schneider, 2001; Jackson, 2003). The control of the numbers of pets such as dogs might be even more prone to difficulties. Non-invasive mitigation measures might prove more time and cost efficient.

5.4.2 Wildlife attracting features

People in general like to have wildlife in their gardens and therefore often try to increase the attractiveness of their garden for wildlife. Features in gardens that seemed to be attractive to hedgehogs in the present study were piles of dead wood, the presence of a shed, the presence of a hedgehog nest box, and the availability of extra food sources. It is likely that some of the people decided to place a hedgehog nest box in their garden after first seeing a hedgehog there. It therefore cannot be concluded from these data that a hedgehog nest box itself will attract hedgehogs in gardens. Nevertheless, a hedgehog nest box does provide shelter and a suitable nest site location which might indeed encourage hedgehogs to return to those sites that include one. Sheds and piles of dead wood are able to provide shelter and suitable nest sites for hedgehogs as well (Morris, 2006). Compost heaps however did not seem to attract hedgehogs to gardens. Although they might provide an extra source of food due to edible remains, they offer fewer possibilities for nest sites than loose piles of wood or piles of dead leaves. Compost heaps are also regularly enclosed which limits access. Hedgehogs can often be found at food bowls put out in gardens to feed pet and feral cats or other mammals (Morris, 2006); it is therefore not surprising that hedgehogs were more often seen in gardens by people that provide food for wildlife. It has also been shown by other studies that wildlife-friendly features may favour the presence of other taxa (Baker & Harris, 2007). Raising awareness amongst the general public and stressing the importance of wildlife friendly features in private gardens is therefore likely to benefit wildlife in general.

The presence of hedgehogs was not only influenced by the features present in the site, but also by the area surrounding the site. In the arable-dominated lowlands of England and Wales a pasture in the surroundings of the site attracted hedgehogs to the site, whilst in the pasture-dominated lowlands of England and Wales sites with arable fields nearby were avoided by them. This is in agreement with the expectations that grassland in general is favoured over arable land due to differences in food availability (Doncaster, 1992; Doncaster, 1994; Huijser, 2000; Riber, 2006).

5.4.3 Connectivity

Many gardens are at least partly fenced which limits the accessibility for large and medium sized mammals. Gaps in boundaries of gardens did indeed have a significant positive effect on the presence of hedgehogs, provided they were large enough, and will enhance the connectivity between suitable habitats, thereby enlarging the area available for hedgehogs. It was therefore not surprising that the occurrence of green-spaces such as parks, commons, and woodlands in the surroundings of the site positively related to the presence of hedgehogs. Streams and rivers were significantly related to a low presence of hedgehogs; although hedgehogs are able to swim and are known to have crossed large water bodies (Doncaster, 1992; Morris *et al.,* 1993), the latter do seem to reduce connectivity by creating partial barriers.

Unfortunately the density of roads in the direct surroundings of the site could not be included in the GLM, since these data were not requested from the surveyors. However, possible effects of roads on hedgehog populations should not be ignored. Especially large roads were infrequently crossed by hedgehogs in an experiment by Rondinini & Doncaster (2002). Nevertheless, work by Doncaster *et al., (*2001) has shown that road verges can work as movement corridors for hedgehogs and thus roads as such do not form impenetrable barriers to them. Bergers & Nieuwenhuizen (1999) also state that the viability of hedgehog populations decreased dramatically as a result of fencing roads. Roads on the other hand can form a barrier to hedgehogs because of the risk of death caused by traffic. Large numbers of hedgehogs die every year on roads (Huijser, 2000; Morris, 2006), and Huijser (2000) suggests that roads and traffic may reduce hedgehog populations by up to 30%.

The results from this study emphasize the necessity to take connectivity into account in (new) development plans, not only in urban areas, but also in less urbanized regions. The lack of connectivity on a small scale by impenetrable fences and on a larger scale by inhospitable habitats or roads and waterways can be overcome not only by sound planning, but also by providing safe passageways, and by the (re)establishment of green-spaces.

Chapter 6

Distribution of hedgehogs in Greater London and changes in the population over time

Chapter 6

Distribution of hedgehogs in Greater London and changes in the population over time

6.1 Introduction

Urbanization poses a major threat to biodiversity. Many examples of (local) species extinction or declining species richness due to urbanization can be found in the literature (e.g. Czech *et al.,* 2000; Marzluff, 2001; Marzluff, 2005). Urbanization levels worldwide are expected to increase even more (United Nations, 2006), which inevitably leads to changes in the landscape structure and further pressure upon the countryside and protected areas (Antrop, 2004; McDonald *et al*, 2008). This highlights the necessity of incorporating ecological issues in urban landscape planning (Niemelä, 1999). Although urbanization promotes homogeneity in biota (Blair, 2001; McKinney, 2002), urban areas are still able to support a relatively high species richness (Eversham, 1996; McKinney, 2002; Araujo, 2003; Deutschewitz, 2003). Species such as the Norway rat (*Rattus norvegicus*) and feral pigeon (*Columba livia*) are well known for their high abundances in urbanized areas, but also species such as coyote (*Canis latrans*) (Atkinson & Shackleton, 1991), raccoon (*Procyon loto*) (Prange *et al.,* 2003) and red fox (*Vulpes vulpes*) (Harris, 1986; Gloor, 2002) are abundant in these areas. Nevertheless, even for species that are thought to be common and widespread in human inhibited areas, the risk exists that thresholds are reached and populations become less viable. The recent decline of house sparrows (*Passer domesticus*) in Britain is a well known example (Siriwardena *et al.,* 2002, Robinson *et al.,* 2005; De Laet & Summers-Smith, 2007). Species can often cope with or adapt to a certain level of stress factors such as limited habitat availability and fragmentation, but populations might decline because of higher levels of stress and once common species may become locally extinct (Bright, 1993; Hanski *et al*, 1996; Fahrig, 2002).

London is one of the greenest cities in the world with two thirds of its surface area covered with green-space or water according to the Greater London Authority & London Assembly (2005b). The Greater London area covers about 1579 km-square land, of which approximately 32% is protected by the Green Belt or by the Metropolitan Open Land status and is part of the strategic network of open space in Greater London (Greater London Authority, 2003). However, new targets for housing development which are reflecting social, economic and demographic changes, lead to the loss of valuable green-spaces as a result of suburban infill or back-land development. About 100ha of green-space in London was estimated to be lost each year to development between 1989 and 1999 (Greater London Authority & London Assembly, 2001), between 2001 and 2005 the average loss was 70ha per year (Greater London Authority & London Assembly, 2005b). Private gardens, for instance, are subject to loss. Although people increasingly see the value of a house with a private garden, a reduction in the size of gardens is becoming a trend due to the pressure of new development (London Biodiversity Partnership, 2005). A decline was not only seen in gardens; there was also a significant loss of playing fields in London since the 1980s, and over 30 allotment sites across London have been lost over the last ten years (Greater London Authority & London Assembly, 2006a; Greater London Authority & London Assembly, 2006b).

Green-spaces in urban areas such as parks, road verges and gardens are able to support numerous populations of wildlife (Harris, 1984; Harris & Rayner, 1986; Mason, 2000; Bland *et al.,* 2004). A reduction in the availability and/or connectivity of such green-spaces can have a marked impact upon wildlife (Dickman, 1987; Baker & Harris, 2007). Hedgehogs have always been associated with urban areas and are thought to be able to withstand substantial levels of urban pressure (Morris, 2006). Nonetheless they seem to have disappeared from the majority of the big parks in Greater London (Nigel Reeve, personal communication, 2008). The presence of hedgehogs in Greater London has been well documented before the 1980s. Morris (1966) analysed distribution records collected by the London Natural History Society, and mapped the animal's occurrence as seen in the 1950s and 1960s based upon a 20 mile radius around St Paul's cathedral in central London. Plant (1979) did a similar survey in several north-eastern boroughs of London a decade later. This well-documented presence of hedgehogs provides an ideal starting point to quantify the implications of urbanization upon the viability of hedgehog populations in Greater London. The objective of this chapter was to get a more in-depth understanding of the extent of decline in hedgehog presence in urban areas, using London as an example, and to identify the main drivers behind this decline.

6.2 Methods

6.2.1 Study area

The study encompassed the entire administrative district of Greater London. Currently, buildings, waterways and hard surfaces not available to hedgehogs such as roads and car parks, cover about 40% of the area (Greater London Authority, 2003), largely as a result of the more than 7.5 million people living in Greater London (National Statistics & Greater London Authority, 2007). The remainder comprises water bodies and green-spaces such as parks, gardens, playing fields and golf courses. Private gardens constitute nearly one fifth of the total land area i.e. 20% (Greater London Authority, 2003). Larger areas of farmland, woodland, heath and downland are mainly found in the outer boroughs. A substantial reduction of green-spaces in Greater London took place between 1960-1980 and the 2000s (Clark, 2006). Unfortunately the extent of this change is, with the exception of a few periods, largely unknown (Greater London Authority & London Assembly, 2001).

6.2.2 Data collection

Data on hedgehog presence in Greater London in the 2000s were obtained from the Hogwatch survey 2005-2006 (see chapter 2). Additional records from 2007 and 2008 were received after targeting members of the ‘People’s Trust for Endangered Species’ and from the ‘British Hedgehog Preservation Society’ who lived in the Greater London area. Previous hedgehog distribution in Greater London was based on Morris (1966) and Plant (1979). The report by Morris is based on records of hedgehogs received by the London Natural History Society in the period from 1956 to 1964 inclusive. Since a large proportion of the records were from sites south of the river Thames it was generally felt that the research by Plant (1979), who collected records of hedgehogs in a similar manner north of the Thames (from 1971-1977 inclusive) provided a useful addition to the data, so the historical baseline consists of a joint data set from the period approximating to 1960-1980

6.2.3 Data analyses

Habitat selection was calculated following the methodology of Manly *et al., (*1993) as set out in chapter 2. Kriging (see chapter 2) was used to visualize an index of current relative hedgehog abundance in Greater London at the 1km^2 level (Surfer 8, Golden Software, Inc., Colorado, USA). As in chapter 2, a variogram model was integrated in the kriging method to account for spatial correlation and cross validation was used to select the best kriging model as is recommended (Isaaks & Srivastava, 1989; Meyers, 1997). Maps were produced in a Geographic Information System (Mapinfo Professional Version 8, MapInfo Corporation, New York, USA). The data obtained from the kriging method were analysed with generalized linear modelling (GLM) in GenStat (for windows 8th edition, VSN International Ltd, Lawes Agricultural Trust, Oxford, UK), using the normal distribution and identity link function at the 1km^2 level. Similar to earlier chapters, the backward stepwise method has been used to select the models of best fit. Variables that were used for the GLM included the environmental data obtained from CS2000 (DEFRA & NERC, 2007), and the soil data obtained from the National Soil Research Institute (NSRI) as used in previous chapters (2 and 3). The availability of green-spaces in the Greater London area was based upon data provided by 'Greenspace Information Greater London' (GIGL). Data included the location of green-spaces larger than 1ha. These green-spaces were grouped into 7 different types:

1) agricultural land
2) amenity grassland
3) semi-natural areas
4) wasteland/verges
5) wetland
6) woodland
7) other: e.g. hospital grounds and hills

The presence of green-space types per 1km$^{\mathbf{2}}$ and the distance from the centre of every 1km^2 grid-cell to the nearest green-space was determined using a Geographic Information System (Mapinfo Professional Version 8, MapInfo Corporation, New York, USA). The number and the area of private gardens per borough were provided by GIGL. The presence of red foxes (*Vulpes vulpes*) in

Greater London in the 2000s was obtained from the ‘National Biodiversity Network’ (NBN) (CEH & JNCC, 2007), from GIGL and from the ‘Living with Mammals’ (LWM) dataset used in chapter 5. The first two datasets only provided presence data. Therefore, the absence data of the LWM dataset was ignored. Badgers are rarely seen in Greater London according to databases from LWM (chapter 4), NBN and GIGL. Badgers were therefore neglected in the modelling. Variables such as the garden area per borough, the human population density and the number of dwellings per borough (Hollis, 1983; Office for National Statistics, 2008a) showed strong collinearity ($r \geq 0.60$, Graham, 2003) and could not be used in the model simultaneously. Human population density ($r=-0.769$), number of dwellings ($r=-0.759$), and the area of private gardens ($r=0.626$) were highly correlated with the distance from central London (set at St Paul’s Cathedral), which was therefore used as a surrogate for these variables. In order to be able to directly compare the estimates of the variables included in the model, the variables were standardized using equation 2.1 (chapter 2). Table 6.1 states the variables used for the modelling.

The stability of hedgehog populations between 1960-1980 and the 2000s was analysed on the 1km^2 level. Changes in the environment were based upon changes in the density of arable and horticulture, broadleaved woodland, built-up area, coniferous woodland, hedgerows, improved grasslands, number of dwellings and neutral grasslands between 1984 and 2000, and were obtained from CS2000 (DEFRA & NERC, 2007). Environmental data from the period before 1984 or after 2000 were not available. The data of 1984 were represented by the mean density of the habitat types per land class as defined by the ITE Merlewood land classification of Great Britain (Bunce *et al.,* 1996). To be able to compare the density of 1984 with the density of 2000, the mean density of the habitat types per ITE class was also used for 2000, instead of the more detailed data available. Table 6.2 shows the variables used for the GLM model of the probable loss of hedgehogs in Greater London between 1960-1980 and the 2000s. Statistical analyses, other than GLM and those used for the habitat selection, were conducted using SPSS (for windows 14th edition, SPSS Inc., Chicago, USA).

Table 6.1 Explanation of the variables used for the GLM of relative hedgehog abundance in Greater London in the 2000s.

Variable	***Explanation***
Arable	Density of arable and horticultural area in 2000 (ha)
Broadleaf	Density of broadleaved woodland in 2000 (ha)
Built-up	Density of built-up area in 2000 (ha)
Conifer	Density of coniferous woodland in 2000 (ha)
Distance from centre	Distance from St. Paul's Cathedral in City of London (km)
Drainage	Drainage (freely/ impeded/ naturally wet/ slightly impeded)
Fox	The presence of foxes (yes/ no)
Hedgehogs	Relative hedgehog abundance estimated by kriging (index)
Hedgerow	Length of hedgerows in 2000 (km)
Improved grass	Density of improved grassland in 2000 (ha)
Major roads	Coverage of major roads in 2000 (km)
Minor roads	Coverage of minor roads in 2000 (km)
Nearest area	Size of the nearest green-space (ha)
Nearest distance	Distance to the nearest green-space (km)
Nearest green-space	Nearest green-space type: agricultural land, amenity grassland, semi-natural areas, wasteland/ verges, wetland, woodland, other
Neutral grass	Density of neutral grassland in 2000 (ha)
Private gardens	Mean number of private gardens (#gardens)
Semi-natural	Density of semi-natural grassland (an amalgamation of neutral, calcareous, and acid Grassland, bracken and fen, marsh and swamp) in 2000 (ha)
Soil fertility	Soil fertility (lime-rich/ lime rich to moderate/ very low/ low/ moderate/ moderate to high/ high)
Texture	Soil texture (loamy/ sandy)
Traffic flow	Mean Annual traffic flow (#vehicles)
Upland	Density of dwarf shrub heath, bog, montane, inland rock in 2000 (ha)

Table 6.2 Explanation of the variables used for the GLM of probable hedgehog loss in Greater London between 1960-1980 and the 2000s.

Variable	***Explanation***
Change in arable	Change in density of arable and horticultural area (ha)
Change in broadleaf	Change in density of broadleaved woodland(ha)
Change in built-up	Change in density of built-up area (ha)
Change in conifer	Change in density of coniferous woodland (ha)
Change in number of dwellings	Change in number of dwellings (ha)
Change in hedgerow	Change in length of hedgerows (ha)
Change in improved grass	Change in density of improved grassland (ha)
Change in neutral grass	Change in density of neutral grassland (ha)
Change in population	Change in population density (ha)
Drainage	Drainage (freely/ impeded/ naturally wet/ slightly impeded)
Hedgehogs	Probable loss of hedgehogs estimated by kriging (index)
Soil fertility	Soil fertility (lime-rich/ lime rich to moderate/ very low/ low/ moderate/ moderate to high/ high)
Texture	Soil texture (loamy/ sandy)

6.3 Results

6.3.1 Hedgehog distribution and relative abundance 2000s

In total 895 people, representing 38% of the 1km^2 grid-cells in Greater London, reported seeing or not seeing hedgehogs in the Greater London area in the 2000s. Hedgehogs were seen by 35% of the respondents (n=311). Figure 6.1 shows the location of the people who recorded hedgehog presence and/or absence. The mean distance from hedgehog presence to the nearest green-space was 258m (n=311, se=18). Vicinity to green-spaces however was not significantly related to the presence of hedgehogs (t-Test, t=1.005, df=858, p=0.660). Hedgehogs seemed to prefer amenity grassland, semi-natural areas, and wastelands and verges as shown by the standardised selection ratio. Wastelands and verges favoured significantly. Agricultural land, wetlands, woodland and other green-spaces such as hospital grounds and hills, all seemed to be avoided (Table 6.3), of which the last significantly so.

Figure 6.1 Hedgehog presence (black dots, n=311) and absence (grey dots, n=584) in Greater London in the 2000s according to the public.

Table 6.3 The habitat selection by hedgehogs in Greater London based on the data from the 2000s. * denotes significant positive or negative selection.

Habitat type	***Selection probability***	χ^2	***Confidence interval***	
			Lower	*Upper*
Agricultural land	0.963	0.029	0.396	1.530
Amenity grassland	1.058	1.149	0.917	1.199
Other	0.638*	28.497	0.462	0.814
Semi-natural	1.043	0.180	0.779	1.307
Wasteland/verges	3.169*	53.740	2.399	3.938
Wetland	0.835	5.261	0.647	1.022
Woodland	0.801	4.770	0.565	1.038

An index of relative hedgehog abundance in Greater London is shown in Figure 6.2. The data are presented at the 1km^2 scale. Large parts of the area, mainly the central and southern areas, showed low relative hedgehog abundances. The GLM explained 47% of the variance in relative hedgehog abundance on the 1km^2 level. The distance from central London explained 27% of the variance observed in the relative hedgehog abundance, and had a positive impact upon the relative hedgehog abundance. Soil fertility explained 20% of the variance. Lime rich soils were negatively correlated, while the other soil types were positively correlated with the relative hedgehog abundance. The only other variable that was positively correlated with relative hedgehog abundance was the coverage of minor roads. Broadleaved woodlands, foxes and the number of private gardens were negatively correlated. Table 6.4 shows the summary of the model.

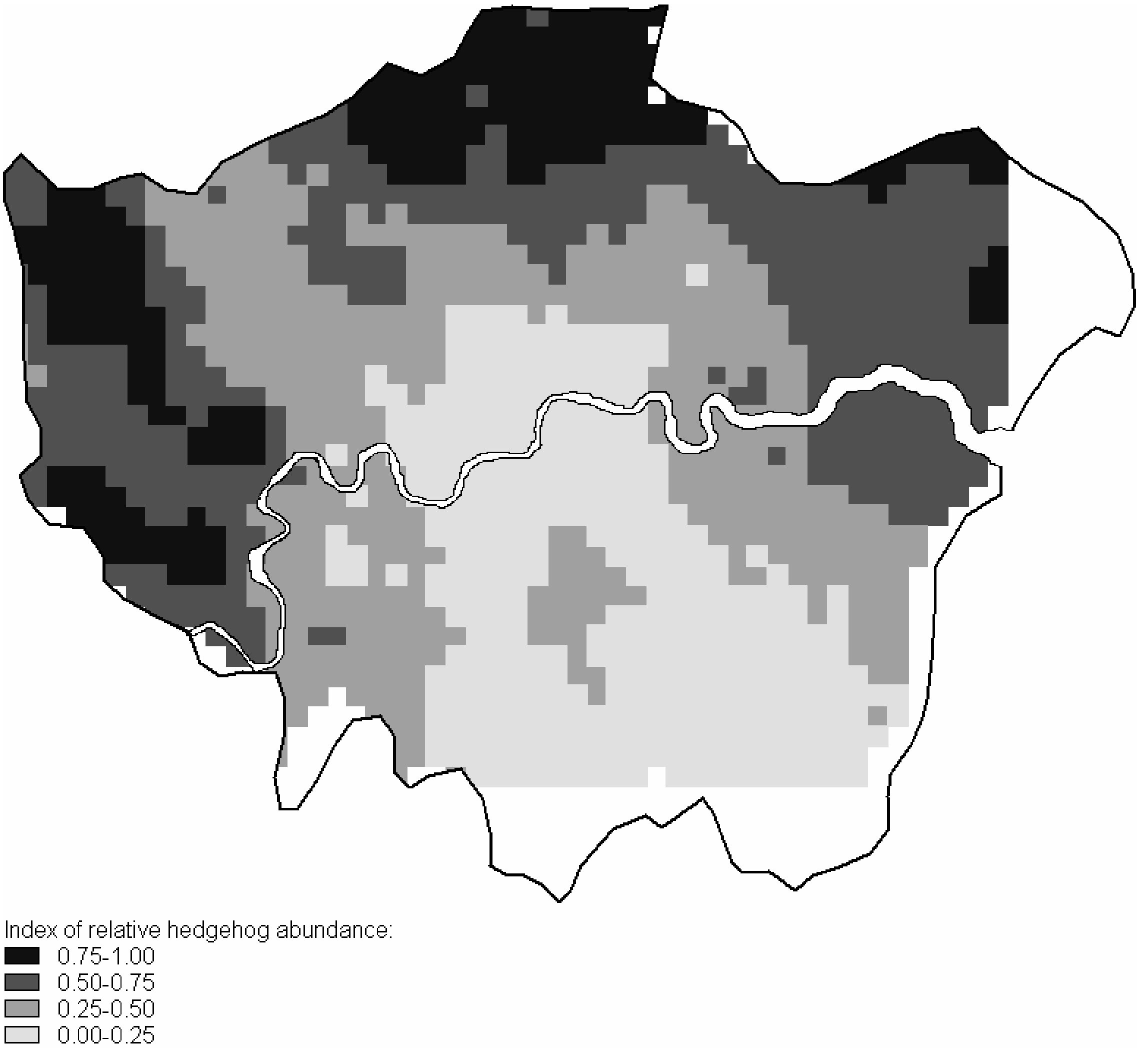


Figure 6.2 Index (0=low, 1=high) of relative abundance of hedgehogs in Greater London at a 1km^2 scale estimated by kriging. Blank areas did not produce sufficient data.

Table 6.4 Summary of the GLM of relative hedgehog abundance in Greater London in the 2000s.

Model summary	***Variable***	***Estimate***	***Partial r^2***	***p.***
	Constant	0.136		<.001
	Distance from centre	0.098	0.266	<.001
	Soil Fertility		0.201	
	- lime-rich	-0.071		0.009
	- lime-rich to moderate	0.232		<.001
Explained: 47%, n=1502, p. <0.001	- low	0.236		<.001
	- moderate	0.277		<.001
	- very low	0.135		<.001
	Fox	-0.087	0.021	<.001
	Number of private gardens	-0.021	0.013	<.001
	Minor roads	0.015	0.008	<.001
	Broadleaf	-0.011	0.004	<.001

6.3.2 Hedgehog distribution 1960-1980 versus the 2000s

Data were obtained from the public from a total of 459 1km^2 grid-cells in Greater London in 1960-1980, of these 295 grid-cells (64%) also returned records in the 2000s. In 45% of the grid-cells where hedgehogs were present in the period 1960-1980, hedgehogs were not found in the 2000s. Figure 6.3 shows the location of the surveyed 1km^2 grid-cells and the presence and absence of hedgehogs in the 2000s.

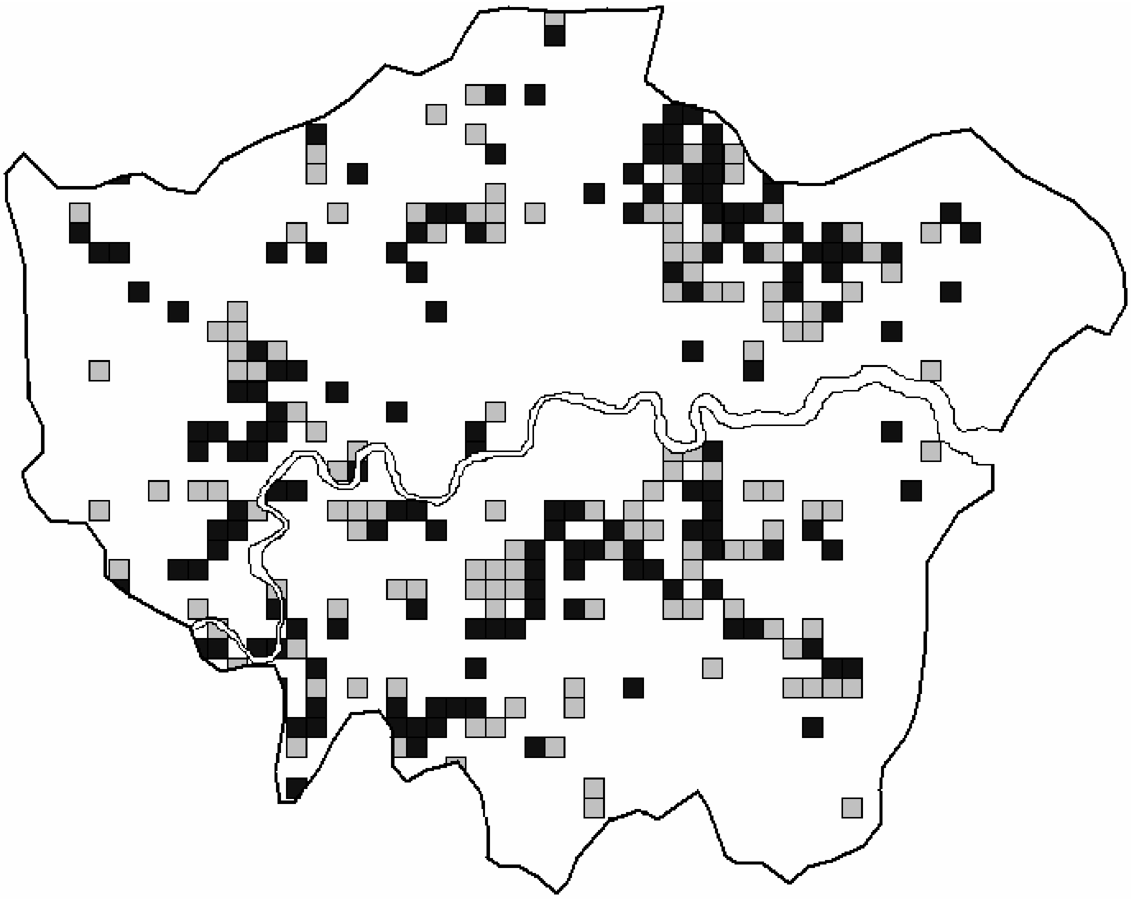


Figure 6.3 Map of Greater London showing sites surveyed in 1960-1980 where hedgehogs remained present (black) and where they were absent (grey) in the 2000s

Figure 6.4 shows the index of mean stability of hedgehog populations per green-space type on a scale from 0 (loss from the site) to 1 (still present at the site). Hedgehogs were significantly more often still present in areas where there are currently agricultural lands, and wetlands available than where there are currently woodlands available (Kruskal-Wallis Test, χ^2=49.709, df=6, p<0.001). Hedgehogs were more frequently lost from sites where there is currently 5 to

25ha of green-space available then from sites where there is currently less than 5 or more than 25ha of green-space available (Kruskal-Wallis Test, χ^2=22.222, df=3, p<0.001) (Figure 6.5).

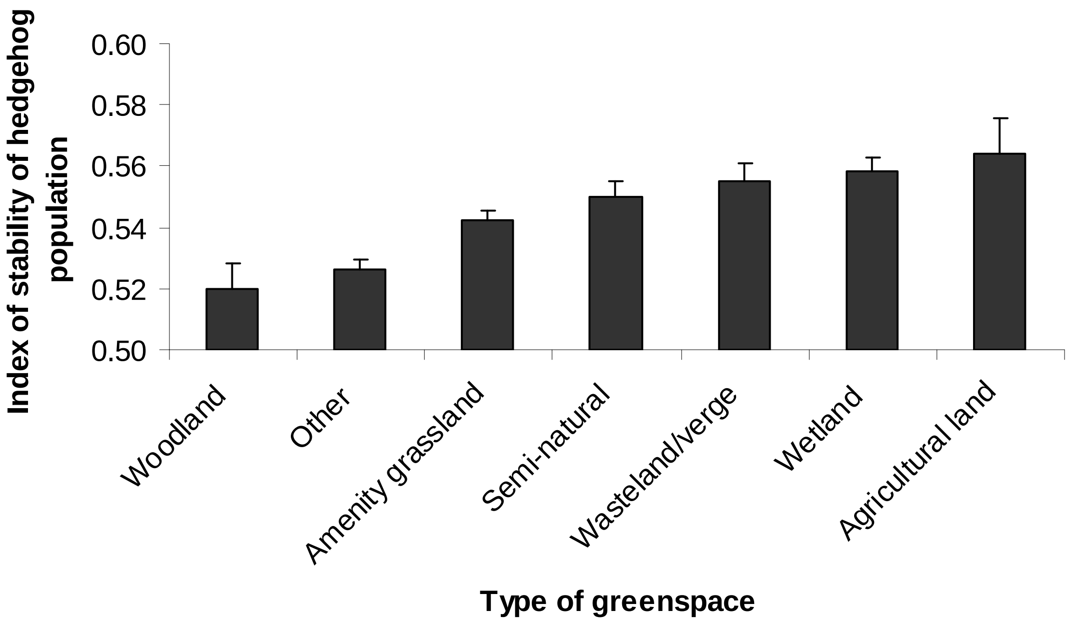


Figure 6.4 The stability of the hedgehog population on a scale from 0 (loss) to 1 (still present) in 1km^2 grid-cells versus the presence of green-space types (+se).

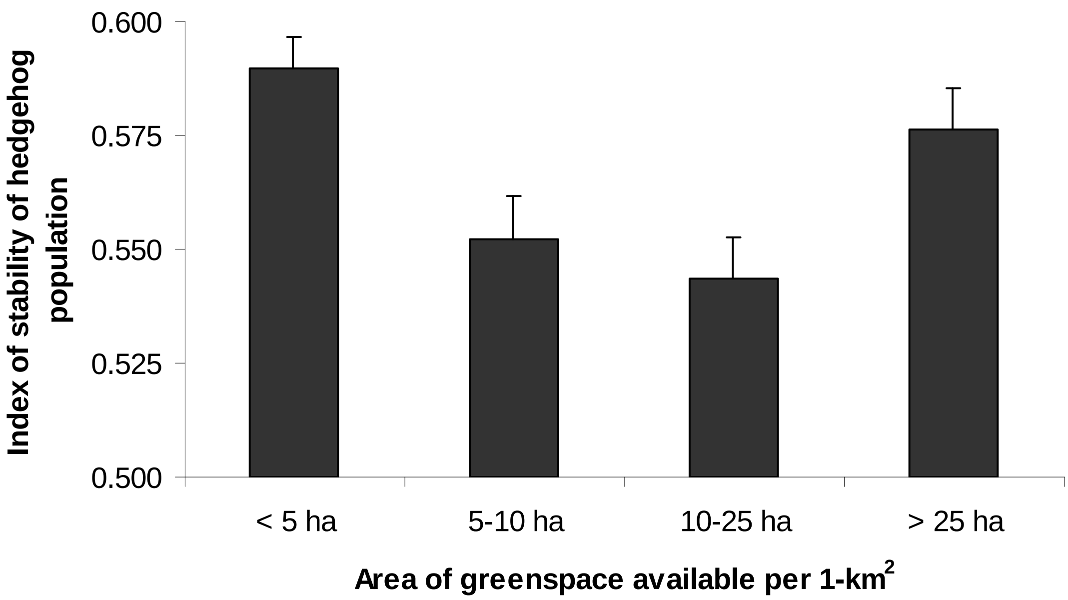


Figure 6.5 The stability of hedgehog populations on a scale from 0 (loss) to 1 (still present) versus the availability of green-space (+se).

Figure 6.6 shows the probable loss of hedgehogs between 1960-1980 and the 2000s. Between 1984 and 2000 the mean area of built-up land and neutral grassland increased, while the mean area of arable and horticulture, broadleaved woodland, coniferous woodland, improved grassland, and hedgerow declined in Greater London. Furthermore, the human population density of Greater London declined, while the number of dwellings increased during the same period. The GLM for the probable loss of hedgehogs between 1960-1980 and the 2000s explained 38% of the variance (Table 6.5). Soil fertility explained 21% of the variance. Hedgehogs were lost from lime rich soils and soils with a very low fertility, but less so from soils with a low to moderate fertility. Other variables explained a minor proportion of the variance in probable loss of hedgehogs. Table 6.5 shows the summary of the model.

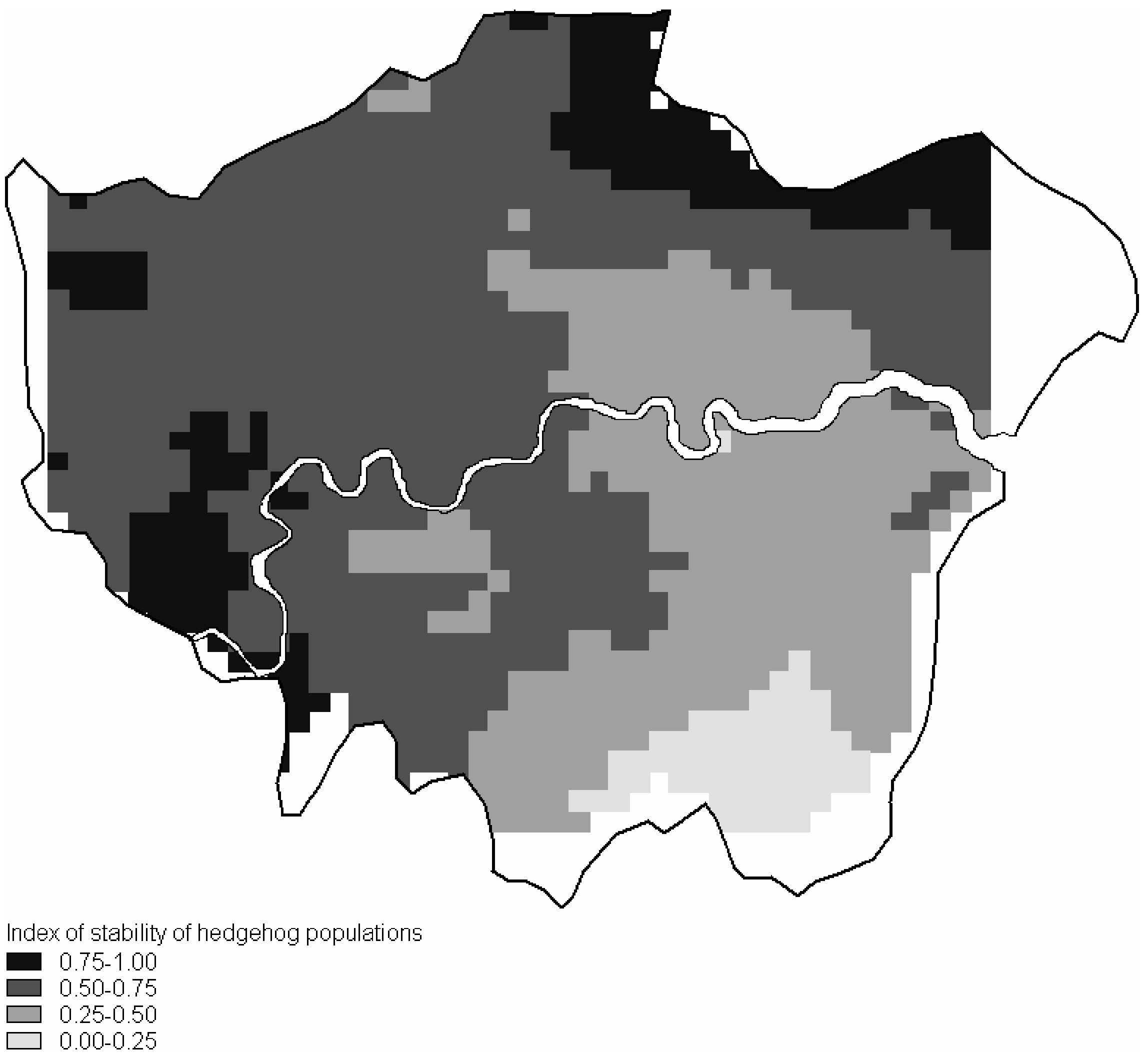


Figure 6.6 Index of stability (0=low, 1=high) of hedgehog populations in Greater London at a 1km^2 scale estimated by kriging. Blank areas did not produce sufficient data.

Table 6.5 Summary of the GLM of stability in hedgehog populations in Greater London between 1960-1980 and the 2000s.

Model summary	***Variable***	***Estimate***	***Partial r^2***	***p.***
Explained: 38%, n=1482, p. <0.001	Constant	0.485		<.001
	Soil fertility		0.207	
	- lime-rich	-0.067		<.001
	- low	0.070		<.001
	- moderate	0.069		<.001
	- very low	-0.024		0.008
	Change in hedgerow	-0.014	0.023	<.001
	Change in number of dwellings	-0.012	0.023	<.001
	Change in arable	-0.012	0.021	<.001
	Change in population	0.009	0.014	<.001
	Change in improved grass	0.009	0.010	<.001
	Change in neutral grass	0.009	0.009	<.001
	Change in broadleaf	-0.004	0.003	0.010

6.3.3 Predictions

As stated before, the variable ‘distance from central London’, was used as a surrogate for the number of dwellings, the population density and the area of private gardens due to strong collinearity. Of these the first two were negatively correlated and the latter was positively correlated with the distance to central London. It could therefore not be predicted with the use of the GLM model in section 6.3.1 how the relative hedgehog abundance would be affected by changes in, for instance, the population density by itself. Consequently predictions have been based upon the distance to central London (Figure 6.7). It can be concluded that if the population density will increase to the level in the 500m surrounding central London, the predicted relative abundance of hedgehogs will be approximately 0.20 on a scale of 0 (absence) to 1 (presence), whilst the mean for Greater London currently is 0.45 (se<0.01).

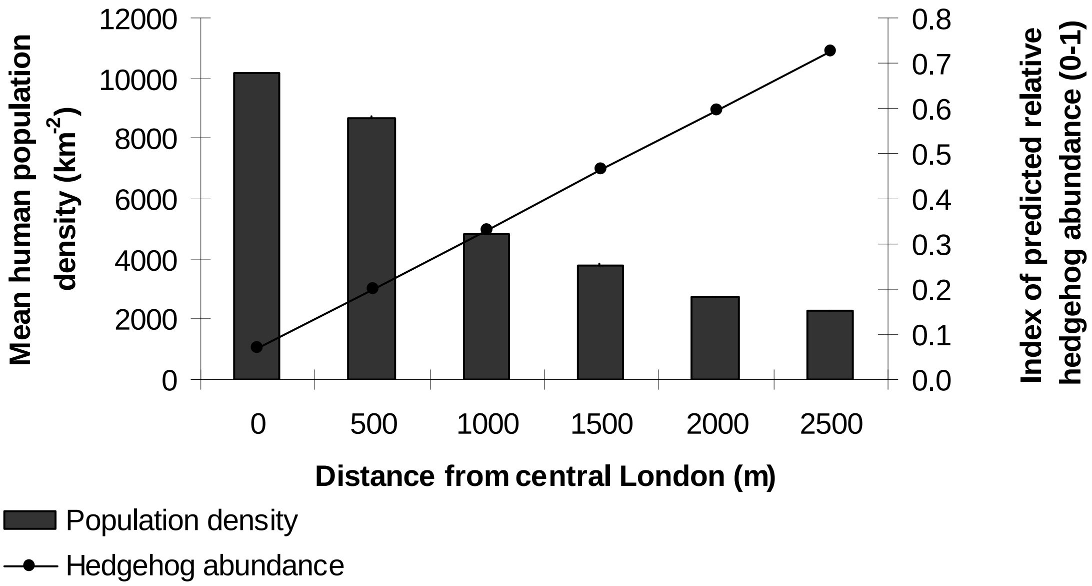


Figure 6.7 Predicted relative abundance of hedgehogs on a scale of 0 (absence) to 1 (presence) and mean human population density versus the distance from central London, based on the GLM of section 6.3.1.

6.4 Discussion

6.4.1 Current hedgehog distribution

In the 2000s hedgehogs were more common in the suburbs of London (e.g. Barnet, Enfield, Hillingdon, and Hounslow) than in the centre (e.g. City of London, Lambeth, and Southwark); except for southern Greater London (e.g. Bromley, Croydon, and Sutton), where the relative hedgehog abundance was also low. Nonetheless, the distance from central London (St. Paul's Cathedral) was strongly related to differences in relative hedgehog abundance. This was likely caused by the correlation between distance from central London and variables such as human population density, number of dwellings, and the area of private gardens per hectare. Both the density of the human population and the number of dwellings were higher in central London than in the suburbs. However, in the suburbs private gardens are less numerous, but, on average, larger than in central London, resulting in a higher area of private gardens per hectare. It is therefore not surprising that the number of private gardens per hectare was negatively correlated with the relative abundance of hedgehogs. In this respect, the size of the green-space proves to be of higher importance than the number of green-spaces, which illustrates the value of connectivity for hedgehogs.

Connectivity between patches of habitat in fragmented landscapes by good quality dispersal routes is frequently deemed essential for the prevalence of viable populations of various taxa (Fahrig & Merriam, 1985; Fahrig & Merriam, 1994; Beier & Noss, 1998). Green-spaces in heavily urbanized areas are, however, frequently not interconnected and also lack good quality dispersal routes. It is predicted that the loss of green-spaces in Greater London will continue due to pressure of an expanding human population and new developments (Greater London Authority & London Assembly, 2006c), which will doubtlessly further decrease habitat connectivity. The viability of populations of various taxa will be jeopardized by ongoing habitat loss and fragmentation if their critical thresholds in habitat connectivity are reached (Mönkkönen & Reunanen, 1999; Fahrig, 2002; Ovaskainen *et al.,* 2002). Local population extinctions are not uncommon, and are part of normal metapopulation dynamics due to demographic and environmental stochasticity (Foley, 1997). However, continuing habitat loss and fragmentation may reduce the change of successful reoccupation of otherwise suitable areas and the loss of local populations may have significant effects on the dynamics of a metapopulation, possibly resulting in extinction (Murphy *et al.,* 1990; Harrison, 1994).

6.4.2 Habitat selection

Consistent with conclusions from earlier chapters and other studies (e.g. Doncaster, 1992; Doncaster, 1994; Dowie, 1993; Huijser, 2000) agricultural land seemed to be avoided by hedgehogs. Wasteland and verges and amenity grasslands on the other hand were significantly most favoured by hedgehogs in Greater London. Hedgehogs are likely to be more visible in wastelands and along verges which might have over-expressed the selection ratio to some extent. Amenity grassland is commonly reported as favoured by hedgehogs in other studies (e.g. Micol *et al.,* 1994; Zingg, 1994). Nevertheless, amenity grasslands were, together with green-spaces such as hospital grounds and woodlands, amongst the green-spaces where hedgehog populations appeared to have been lost most frequently over the past decades. Existing hedgehog populations in 1960-1980 situated on agricultural land, wetland, and wastelands were often still present in the 2000s. This leads to the belief that the quality of, amongst others, amenity grasslands has been deteriorating for hedgehogs. This could be due to possible loss of suitable nesting sites, food availability, accessibility, or due to the increasing abundance of predators in these sites; the red fox (*Vulpes vulpes*) is thriving in urban areas (Harris, 1986; Gloor, 2002). Other factors not investigated such as the presence of dogs might also have had their impact. Although hedgehog remains are infrequently found in the diet of foxes (e.g. Harris, 1986; Doncaster *et al.,* 1990), it is not unlikely that hedgehogs respond in a similar avoiding way to fox odour as to badger odour (Ward *et al*, 1996; Ward *et al*, 1997). The results reported in this chapter do suggest a negative impact of fox densities upon the presence of hedgehogs. This is however not confirmed by the results in chapter 5. Although various hedgehog carers in England have reported increasing incidences of injuries inflicted by foxes (Sue Kidger, personal communication, 2008; Epping Forest Hedgehog Rescue, 2009), direct evidence of foxes regulating or even severely impacting on hedgehog populations is currently lacking.

Surprisingly, the vicinity of green-spaces was not significantly related to the abundance of hedgehogs in Greater London. The exact location of private gardens where hedgehogs were seen was not known and might have influenced this lack of correlation considerably, since the variable ‘number of gardens’ was significantly related to hedgehog abundance. It was also surprising that the soil fertility had such a large impact upon the relative hedgehog abundance and upon the probable loss of hedgehogs throughout Greater London; lime rich soils being negatively related to both the current hedgehog abundance and the stability of hedgehog populations. Soils with a very low fertility were also negatively related to the change in hedgehog distribution whilst other soils were positively related to both the current hedgehog abundance and the change in hedgehog distribution. Lime rich soils are known to be very dry and to have poor nutrient levels. Invertebrate life, hence food available to hedgehogs, is less abundant in soils with a low fertility (Stork & Eggleton, 1992), which is likely to be reflected in hedgehog abundances.

6.4.3 Loss of hedgehogs

By the 2000s hedgehogs appeared to have been lost from about 45% of the sites where they were present in 1960-1980. Unfortunately it was not recorded in 1960-1980 where hedgehogs were absent. Possible establishments of hedgehog populations between the two periods were therefore not recognised. The apparent loss from sites where hedgehogs used to be present was mainly related to soil fertility, as mentioned before. Hedgehogs were also lost from sites where the number of dwellings had increased. In the period from 1996 to 2001 the overall density of residential development in England was 25 dwellings per hectare. This is compared with the average of 23 dwellings per hectare in 1971 (Office for National Statistics, 2008b) – not a large increase. However, the mean density of new developments in London has been estimated at 71 dwellings per hectare in 2003 (Office of the deputy prime minister, 2005). The change in the housing figures between 1984 and 2000 that was used for the GLM of the probable loss of hedgehogs might therefore have underestimated the impact of the increased number of dwellings. The expected increase in the density of dwellings poses a threat to urban green-spaces and will inevitably lead to an increase in habitat fragmentation and a loss of habitat suitable for hedgehogs and other wildlife, which is also suggested by the predictions from this chapter.

It proved difficult to obtain accurate information concerning the amount of green-space in Greater London in the period from 1960 to 1980. The ‘Green-spaces Investigative Committee’ from the Greater London Authority quotes its consultant (Steve Osborn, SNU) in a report: “There are major gaps in information on green-spaces in London: there is no data to show how much green-space is being lost in London through residential and business development” (Greater London Authority & London Assembly, 2001). Clark (2006) states that massive suburban expansion brought a noticeable reduction in open space in the expanding periphery of London, which resulted amongst other effects in an 18% increase in total number of dwellings between 1981 and 2005 (Office for National statistics, 2008a). Many green-spaces might already have been lost to development prior to 1967 when the classification of Metropolitan Open Lands was introduced in Greater London as a protective designation for green-spaces that might be vulnerable to building development

(Clark, 2006). Indeed, Morris (1966) already mentioned in his report that 'many old houses standing in large gardens are now being pulled down so that a greater number of small houses can be erected in their place', which will inevitably result in habitat loss and fragmentation. Data about differences in the size of gardens between the 1960s and the 2000s were not available and largely anecdotal. It is believed that more green-spaces have been lost for wildlife due to development, fragmentation and loss of accessibility than is documented. The impact of this loss is therefore likely to be bigger even than is estimated from the present study.

Chapter 7

General Discussion

Chapter 7
General discussion

7.1 The hedgehog in Great Britain: a résumé

The aim of this thesis was to assess the current distribution of hedgehogs throughout Great Britain, and to investigate whether, and to what extent, they are declining. Additionally, correlates of geographical variations in hedgehog distribution and changes in relative abundances of hedgehogs over time were identified, on both a national and a local scale in rural and in urban areas. Whilst chapter 2 focused on the wider geographical distribution and changes in relative abundance of hedgehogs over time, chapter 3 and 4 concentrated on rural areas and the impact of agricultural management, including possible benefits of agri-environment schemes. Chapters 5 and 6 focused on urban areas; drivers behind the apparent decline of hedgehogs were identified.

The results of various surveys indicate that although hedgehogs were still widespread, they were more prevalent in the northern and eastern arable-dominated lowlands of Great Britain than in the southern and western pasture-dominated lowlands. Especially the Hogwatch survey (chapter 2) and the Questionnaire survey (chapter 3) gave similar results. The indices for relative hedgehog abundance per region correlated significantly (Pearson Correlation Test, $r=0.868$, $n=9$, $p=0.002$). The Living with Mammals survey (chapter 5) gave different results for the West Midlands. However, the relative hedgehog abundance per region correlated significantly with the results from the Hogwatch survey when this region was discarded (Pearson Correlation Test, $r=0.801$, $n=8$, $p=0.017$).

Although several determining factors appeared in the various statistical models built for different areas in Great Britain, a few variables were frequently identified as an explaining factor and consistently appeared to be more important than others in explaining the distribution and abundance of hedgehogs. On average the strongest and most frequent negative indicator was the presence of badgers. Not only did the variable '*presence of badgers*' appear in the majority of models, the radio-tracking study in chapter 4 also showed a high mortality of hedgehogs caused by badger predation. In addition to the impact of badger abundance, the coverage of major roads was frequently identified as one of the negative factors affecting hedgehog presence and/or abundance. Woodlands, both coniferous and broadleaved, also regularly had a significant impact on the presence and/or abundance of hedgehogs. The impact of woodlands however was not consistent. Grasslands were in general positively related to the presence and/ or abundance of hedgehogs, although improved grassland frequently had a negative effect, whilst other types of grassland were more often positively related to them. Other factors frequently showing a positive impact on hedgehogs were the density of arable land, the coverage of minor roads and the amount of hedgerows present in the area. The impact of the various aspects is extensively discussed in the individual chapters.

Although hedgehogs are present in higher abundances in arable landscapes, mainly due to the relative absence of badgers, it can be deduced from the movements of hedgehogs (chapter 4) and their habitat selection that they do not frequently use arable land itself. Radio tracking showed that hedgehogs appeared to be concentrated on the agri-environment field margins and in the hedgerows surrounding the arable fields, which they were reluctant to cross, or they (females especially) retreated within the village boundaries. It is thus thought likely that, in the absence of badgers, hedgehogs would be more numerous in landscapes dominated by pastures than is currently the case. Increasing the coverage of agri-environment field margins in arable landscapes would also benefit hedgehogs.

Hedgehogs were not abundant in heavily urbanized areas such as Greater London (chapters 2 and 6), due to high population densities, high numbers of dwellings and a small area of private gardens. Lack of connectivity between sites, due to large water bodies and impenetrable fences, also seemed to hamper hedgehogs in built-up areas. In Greater London, fox abundance negatively influenced the presence of hedgehogs as well. When hedgehogs were present in built-up areas they preferred amenity or semi-natural grasslands, wastelands and verges, and/or sites with wildlife friendly features such as a feeder, a pile of dead wood, a garden shed and a hedgehog nest box. The type of soil was also frequently correlated with the presence and/or relative abundance of hedgehogs, which is likely to be related to food availability.

Another conclusion that can be drawn from various chapters is that hedgehog numbers have been falling over the past few decades. I estimated that, although hedgehogs still occur throughout Great Britain, the relative abundance had fallen by about 16% in the past 30 to 40 years (chapter 2). Additionally, the people taking part in the Hogwatch survey and respondents to the questionnaire also more often perceived a decline in hedgehog abundance than an increase over the last 10 years. This was particularly noteworthy in the southern and western parts of Great Britain, and especially so in Greater London, where the perceived abundance of hedgehogs declined by an estimated 45% in the past 30 to 40 years. Factors affecting the decline of hedgehogs were largely the same as the factors affecting the current differences in the presence and/ or relative abundance of hedgehogs.

7.2 Conservation strategies

The results reported in this thesis indicate that the abundance of badgers, of which numbers have been increasing over the last few decades in both rural and urban regions partly due to increased legislative protection (Wilson *et al.,* 1997; Battersby, 2005; Delahay *et al.,* 2009), was one of the principal negative factors affecting hedgehog populations. It seems straightforward, and most beneficial for the conservation of hedgehogs, to suggest predator control, which is frequently practised in order to protect prey species (Reynolds & Tapper, 1996). However, both practical, the badger is protected by law under the Protection of Badgers Act 1992, and ethical issues are likely to arise in culling one species in order to protect another, especially for ‘popular’ species. Furthermore, it is generally found that although predation might be an important limiting factor in prey populations, it is unlikely to drive populations to extinction on a wide scale (MacDonald *et al.,* 1999). Moderate or low levels of predation generally have little influence if population growth rates remain high (MacDonald *et al.,* 1999). It is however debatable whether the level of predation from badgers experienced by hedgehogs is only low or moderate and not high. Evidence from various studies, including the present one, suggests that levels can be high (Doncaster, 1992; Doncaster, 1994; Morris & Warwick, 1994; Strøm Johansen, 1995). On the other hand, a high proportion of hedgehogs (*Erinaceus spp*) is rarely found in the diet of badgers, if found at all (e.g. Kruuk

& Parish, 1981; Ashby & Elliot, 1983; Canova & Roasa, 1993; Neal & Cheeseman, 1996; Goszczyński *et al.,* 2000; Del Bove & Isotti, 2001). However, this may be due to the relatively low population density of hedgehogs resulting in a low probability of encounters and hence a low probability of occurrence in a limited sample of stomachs or faecal samples studied. The great exception found in the literature is a study by Middleton (1935), who identified four hedgehogs in the stomach of a single badger.

The behaviour of the predator towards its prey is an important factor that should be taken into account. Although badgers may specialize on a particular food item (Kruuk & Parish, 1981; Fedriani *et al.,* 1998), they are generally regarded as generalists (Roper, 1994; Neal & Cheeseman, 1996; Revilla & Palomares, 2002). The occurrence of predation by badgers upon hedgehogs is therefore thought to be strongly related to the availability of hedgehogs. However, it seems likely that the loss of suitable and/or connected habitat due to increasing levels of development, human population densities, road coverage and intensified agriculture, reduced the number of suitable sites that are able to provide hedgehogs with protection from badgers. It is therefore thought that predator control is not a guaranteed successful mitigation measure to stabilize/increase numbers of hedgehogs. It seems imperative to seek more effective and non-lethal methods to preserve hedgehogs. Moreover, despite the answers this thesis provides, the current abundance of hedgehogs is not known. Estimates of both the current hedgehog abundance and badger abundance are necessary in order to assess the direct risk of local extinctions of hedgehogs due to badger predation, before such a strong measure as a badger cull can be considered. It is likely that, without further habitat loss and fragmentation, a new equilibrium will be reached at some point in time with hedgehogs mainly persisting in areas less suitable for badgers.

Habitat management in order to reduce the impact of predators can be beneficial for prey species (Carter, 2002; Finke & Denno, 2002; Janssen *et al.,* 2007) and should therefore be considered as a conservation strategy for the hedgehog. Increasing the number and availability of sites that offer coverage by increasing the complexity of the habitat structure may be beneficial to hedgehogs. This can be done by establishing more and denser hedgerows in rural areas, dense shrubbery and undergrowth in urban areas, and by increasing the connectivity between suitable habitats. The likelihood of success of increasing the habitat structure is uncertain. It is currently not known if complex and dense habitat structures provide hedgehogs with the level of protection necessary to escape the risk of predation. An additional advantage of increasing the number of hedgerows, shrubs and undergrowth could be an increase in the abundance of macro-invertebrates, prey items of both hedgehogs and badgers, which could potentially lessen the predation pressure of badgers on hedgehogs.

As discussed before, agricultural intensification had a detrimental impact on biodiversity. Ongoing habitat loss and fragmentation of the landscape and the continued use of pesticides and other toxins are amongst those factors of agricultural intensification that will undoubtedly put more species at risk. It however needs to be stressed that the rapid agricultural intensification after the Second World War has mainly been fed by the policy framework and the demand for low cost high quality food products, rather than by individual farmers. Much could be gained by environmental awareness among the general public and by their willingness to change their consumption habits and focus on those products produced under more wildlife-friendly circumstances.

Farmland covers approximately 71% of the land area in Great Britain (DEFRA & National Statistics, 2008). The continued introduction of agri-environment schemes on existing farmland and the preservation of less disturbed areas are of high importance for a variety of species as extensively discussed in numerous studies (Kleijn *et al.,* 2001; Kleijn *et al.,* 2004; Kleijn *et al.,* 2006; Kleijn & Sutherland, 2003; Bengtsson *et al.,* 2005; Shore *et al.,* 2005; Knop *et al.,* 2006). Increasing the amount of set-aside, possibly resulting in intensification of the productive farmland, could have disadvantageous affects for avian wildlife (Tucker, 1997). The present study also offers no confirmation of the value of set-aside for wildlife, specifically hedgehogs. This thesis however does suggest that both agri-environment field margins and hedgerows could play a positive role in the conservation of hedgehogs. This adds to the urgency to encourage the implementation of agri-environment schemes that include wide agri-environment field margins and dense, well-established hedgerows on farmland, since it is vital that both the structural and biological quality of farmland is sufficient to maintain the viability of hedgehog populations and other wildlife.

Urban areas are suggested to be refugia for hedgehogs (Young *et al.,* 2006; Dowding, 2007). This thesis partly presents evidence in favour of this idea. Indeed, hedgehogs were seen to retreat to villages in the countryside, probably in order to escape the threat of predation; thus villages seemed to offer refuge. Unfortunately, more heavily urbanized areas appeared to offer less suitable environments. The high rate of urbanization has lead to extensive loss of urban green-spaces and loss of connectivity between remaining sites resulting in a harsher environment for hedgehogs, and probably other species that once were associated with human settlements. The city-centre of Greater London, for instance, is largely devoid of hedgehogs (chapter 6) and is likely low in biodiversity in general. A similar situation might occur in other heavily urbanized areas. It has already been shown that species composition in urban areas is more homogeneous than that in more natural environments (Blair, 2001; McKinney, 2006). Certain species such as the feral pigeon (*Columba livia*), the brown rat (*Rattus norvegicus.*), and mice (*Mus* spp) thrive in city centres. Other species such as the house sparrow (*Passer domesticus*) and the European starling (*Sturnus vulgaris*), but also the hedgehog, used to be frequent residents in more urbanized areas in Great Britain as well (Reeve, 1994; Crick *et al.,* 2002; Crick *et al.,* 2004; De Laet & Summers-Smith, 2007). It is likely that the number of species that have been reported to suffer declining numbers in human settlements reflects an increasingly inhospitable environment not only to those species but to wildlife in general.

In order to preserve wildlife in urbanized areas an increased effort in adopting conservation strategies aiming at increasing the complexity and connectivity of the habitat structure in urban green-spaces is vital. Additionally, a greater availability of potential nest and cover sites and an increased number of macro-invertebrates in these landscapes is likely to relate to such strategies. City authorities, for example that of Greater London, are recognizing the importance of urban green-spaces in respect of climate change, public health and biodiversity (Greater London Authority, 2008). However, it needs to be stressed that green-spaces need to reach a certain standard in quality, quantity *and* connectivity to be able to support healthy populations of wildlife. Frequently the lack of connectivity between urban green-spaces is one of the greatest problems, much reducing the value of those green-spaces that are preserved. Needless to say it is vital that with the establishment of new components of the built environment (e.g. roads, car parks and houses), the connectivity of green-spaces should be secured. It is however necessary to create new dispersal routes between currently isolated patches of otherwise suitable habitat, even if it is at the expense of existing structures, in order to conserve species such as the hedgehog.

One way of establishing connectivity between patches of green-space, already well used in countries throughout Europe, Australia, Canada and the United States, but so far largely unexploited in Great Britain, is the use of wildlife passes such as tunnels, "ecoducts" and other faunal passageways. These passageways proved beneficial to a number of species (Berris, 1997; Keller & Pfister, 1997; Clevenger & Waltho, 2000; Jackson & Griffin, 2000). Badgers may negatively affect the use of tunnels by hedgehogs due to the latter avoiding response to badger odour (Ward *et al.,* 1996; Ward *et al*, 1997; Doncaster, 1999). It might however be possible to adjust the size of tunnels to reduce their use by badgers.

Much can be gained by raising awareness of the public to the problems currently faced by a range of urban dwelling species. Practices such as the paving of gardens for convenience or to convert them into parking lots, creating highly obstructive barriers by means of the fencing of gardens, the tidying of gardens or replacing native plants by ornamental exotics, all mean a loss in suitable habitat for numerous species. The large public participation in surveys such as the ones used in this thesis shows that people are not ignorant of wildlife; so increasing the awareness of people to individual practices they can undertake to improve habitat suitability for wildlife is feasible, practical and potentially very beneficial. Figure 7.1 provides an overview of the problems hedgehogs might face, their possible mitigation measures and the likelihood of success of those mitigation measures.

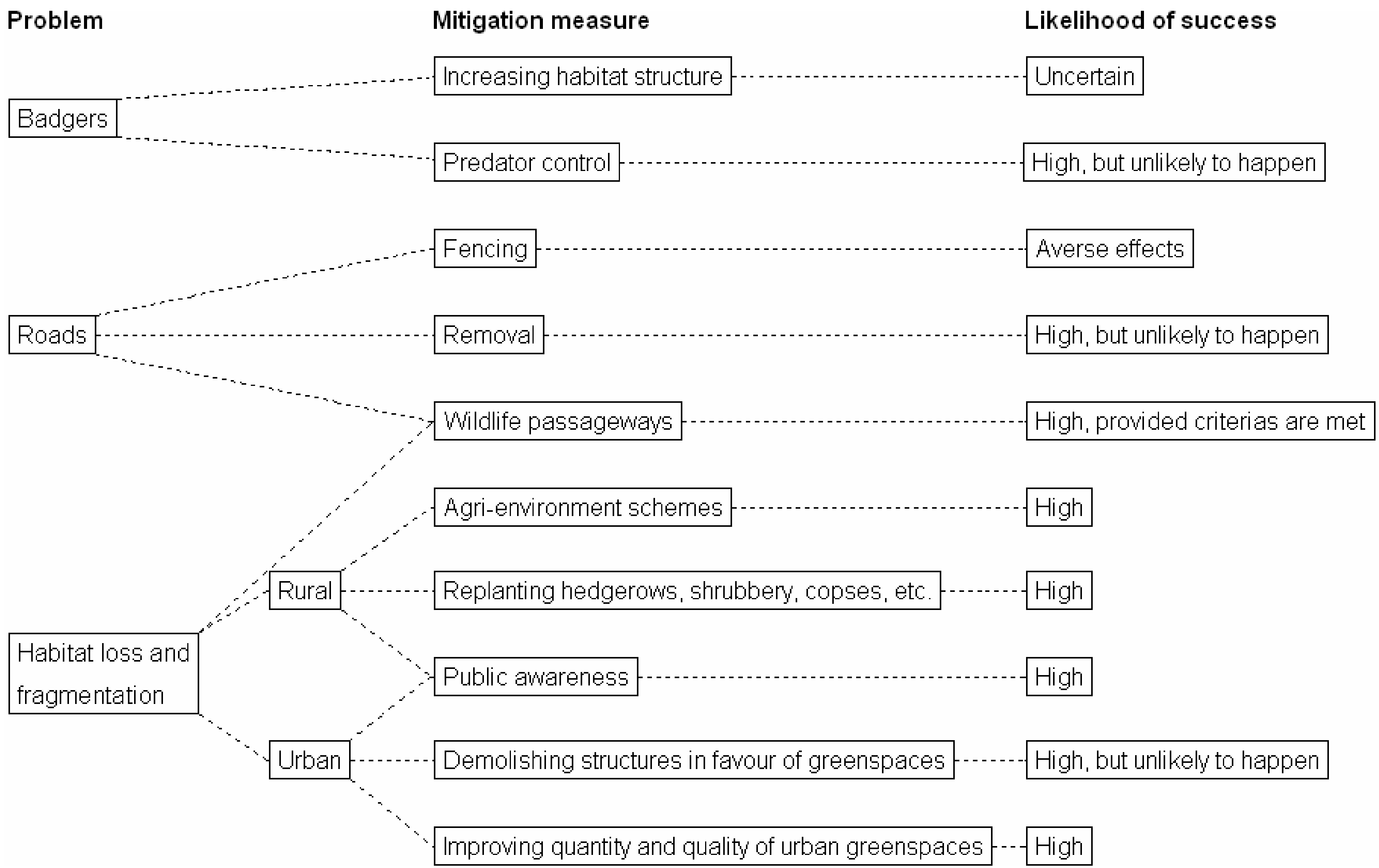


Figure 7.1. Graphic representation of problems hedgehogs face, possible mitigation measures and their likelihood of success.

7.3 Future research

Currently the most recent pre-breeding estimation of the number of hedgehogs in Great Britain is 1,555,000 individuals. This number was based on limited information, and is probably out of date (Harris *et al.,* 1995). Additionally, this thesis showed that the numbers of hedgehogs have been falling over the last few decades; it is thus probable that this estimate no longer holds. Based upon the average abundance of 7.5 hedgehogs·km^{-2} in the study site in Norfolk and 2 hedgehogs·km^{-2} in Kent (chapter 4), and based upon the relative abundance of hedgehogs throughout England as determined by kriging (chapter 2), I estimate the number of hedgehogs in England currently at 800,000 individuals. Since the estimated abundance of hedgehogs was on average lower for both Scotland and Wales than for England (chapters 3 and 5) I estimate that there are currently about 1,000,000 hedgehogs in Great Britain. Nevertheless, hedgehogs are still widespread (chapter 1), although it is not known how viable local isolated populations are.

For the conservation of the hedgehog it is important to identify the areas where hedgehogs are currently facing the greatest risks. These are most likely situated in urbanized areas and in the south-western regions of England. Areas commonly thought to be less suitable for hedgehogs, such as the arable-dominated regions in East Anglia (e.g. Reeve, 1994; Morris, 2006), still have a relatively large density of hedgehogs. However, when assessing the situation in the study site in Norfolk (see chapter 4) I think that if mitigation measures are not introduced, hedgehogs might face threats in the near future in this part of the country as well. The mean density of hedgehogs in the Norfolk study site was low in comparison to earlier research by others in Great Britain (Reeve, 1981; Micol *et al.,* 1994; Young *et al.,* 2006), but high when compared to work as part of this thesis in Kent (see chapter 4) . More research regarding the estimation of densities in areas throughout Great Britain will provide a better guidance regarding the current numbers of hedgehogs and might identify local regions currently at the highest risk.

Although I considered various possible causes for the decline in hedgehog numbers, there might be other factors possibly limiting hedgehog populations not yet fully investigated, such as loss of genetic diversity and susceptibility to diseases. Diseases can have a large negative impact on populations and may cause species extinction (Holmes, 1996; Daszak *et al.,* 2000; Altizer *et al.,* 2003; Wyatt *et al.,* 2008). An example in Great Britain is the parapox virus which is thought capable of driving the red squirrel (*Sciurus vulgaris*) to local extinction under certain circumstances (Rushton *et al.,* 2000b). Research with regard to the infestation pattern of hedgehogs with macro parasites and the likelihood that these are involved in population regulation of their host is currently underway at the University of Karlsruhe in Germany (Petney *et al.,* 2008). Also the role of climate change, as discussed in chapter 1, needs to be investigated further, especially with respect to food availability and hibernation ecology. The impact of food availability itself upon the distribution of hedgehogs remains largely unstudied. As it has been estimated that the hedgehog spends up to 84% of its active time foraging (Wroot, 1984), their movements might be largely dictated by the distribution and abundance of prey items. However, since numerous factors affect the abundance of an important food source for the hedgehog, earthworms (Lumbricidae), countrywide effects of food availability on the distribution of hedgehogs might be difficult to assess.

Anecdotal evidence provided by hedgehog carers and wildlife centres raises the question of whether high abundances of foxes in urban areas might pose problems for hedgehogs (Sue Kidger, personal communication, 2008; Epping Forest Hedgehog Rescue, 2009). It is uncertain from the present study what the impact of foxes upon hedgehogs is. Whereas the abundance of foxes was not statistically related to that of hedgehogs in green-spaces in built-up areas throughout Great Britain (chapter 5), the results from chapter 6 do suggest a negative impact of fox densities upon the presence of hedgehogs in Greater London. There is currently no research available that investigates this issue, but it might be necessary in order to gain a better understanding of which factors regulate hedgehog populations.

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Appendices

Appendix I

Appendix I The 'HogWatch' survey-sheet of 2006 used to assess the current hedgehog distribution

www.HogWatch.org.uk

When did you last see a hedgehog? For some time anecdotal evidence has pointed to the absence of hedgehogs from gardens and countryside. Results from PTES' Mammals on Roads survey is also showing direct evidence that hedgehogs in rural England, and probably Wales, are declining at a very rapid rate.

How serious is the decline and what's causing it? To find out PTES and BHPS are carrying out a nationwide public participation survey of hedgehogs called HogWatch. The aim of HogWatch is to create a map of the distribution of hedgehogs across the UK. Hedgehogs are not found everywhere. For example where conditions in the countryside appear unsuitable for them they seem to be clustered in and around villages. In some regions they are clearly found in more places than in others. Many of you get hedgehogs visiting your garden and we would like you to let us know if you do. We would also like you to look out for hedgehogs in the wider countryside.

To create an accurate distribution map it is just as important for us to know the location of where you haven't seen hedgehogs as where you have. Of course you can only say that you haven't seen a hedgehog in a place that you have regularly looked - therefore we would also like to know if you haven't had any hedgehogs visiting your garden all year. So please still submit your survey forms even if you have haven't had any hedgehogs visiting your garden all year.

We would like you to let us know whether or not you saw a hedgehog last year, in 2005. And we would also like you to record your sightings – or lack of them throughout the rest of 2006. The survey will run until the end of the year.

Points to remember when filling in the survey form

- Please only record each hedgehog ONCE, even if the same one (s) visits your garden on a regular basis *(However is you later see an adult hedgehog with babies or two adults when you only saw one then we would like you to tell us.)*
- Please only record LIVE hedgehogs we are not collecting road casualty sightings.
- Please let us know about each NEW LOCATION you see a hedgehog in 2006 - perhaps you saw one whilst walking you dog in the local park or along field verges.
- If you have a garden but by December 2006 you have not seen any hedgehogs during the year then please let us know. Remember – these 'null' records are just as important to enable us to create an accurate hedgehog map of the UK.
- Please do not record hedgehogs that have been deliberately released into your garden eg from a rehab unit.

PLEASE RECORD ONE SIGHTING PER FORM - for further sightings please either photocopy this form or call 020 7498 4533 for more copies. If you have any queries please call us on the same number.

Your details

Name..

Address..

....Postcode...

E-mail...

We would really like to know the grid reference of where you saw your hedgehog (s) - or of your garden if you haven't had a hedgehog there all year. It isn't difficult, if you have access to an OS map of your local area. Please fill in the 8 digit number.

GR:

1. Did you see a hedgehog in your garden last year? Yes ☐ No ☐

2. Did you see a hedgehog anywhere else last year? Yes ☐ No ☐

2a. Where? Street ....
Town/ village ....
County ....

3. Did you see a hedgehog in your garden this year? Yes ☐ No ☐

4. Did you see a hedgehog anywhere else this year? Yes ☐ No ☐

4a. Where? Street ....
Town/ village ....
County ....

5. Which best describes where you saw the hedgehog? (Please ring/ underline)

Garden	Park/ common	School grounds
Churchyard	Road or road verge	Lowland heathland
Arable farmland	Deciduous woodland	Coniferous woodland
Pastoral farmland i.e. grazing	Rough/ unfarmed grassland/ downland/ moorland	

6. What date did you see the hedgehog(s) ☐

7. How many hedgehogs did you see? ☐

8. Were they?
- ☐ 1 adult
- ☐ 2 adults
- ☐ Nest of babies with mother
- ☐ Nest of babies without mother
- ☐ An adult (mother) with young at

7. Did you see a nest with baby hedgehogs? Yes ☐ No ☐ If yes, how many babies? ☐

Where they pink, blind & helpless ☐ OR eyes open with brown spines ☐

8. Do you think that hogs are more common where you live now than 5 years ago?

More common ☐ Less common ☐ Don't know ☐

9. Do you think that hogs are more common where you live now than 10 years ago?

More common ☐ Less common ☐ Don't know ☐

Any other comments: *(please continue on extra sheet)*

HogWatch is being coordinated by Royal Holloway University of London and is funded by the People's Trust for Endangered Species & the British Hedgehog Preservation Society. Data will be held and used by all parties and will not be passed on to any other organisation for any purpose.

Appendix II

Appendix II The questionnaire send to a random selection of landowners in order to assess the impact of farm management practices on hedgehog distribution throughout Great Britain

Hedgehogs Questionnaire

1. How often did you see hedgehogs on your farm during 2006?

❑ None seen
❑ Seen less than 3 times
❑ Seen 3-6 times
❑ Seen more than 6 times

2. Ten years ago did you see on your farm (Please tick only ONE box):

❑ About the same number of hedgehogs as in 2006?

❑ More hedgehogs than in 2006, because of (Please circle ALL the relevant options):
- Increase of suitable habitat (e.g. hedgerows, pasture)
- Increase of available food (e.g. slugs, worms, beetles)
- Less intensive farm management (Please specify): …………………
- Decreasing numbers of badgers
- Other (Please specify): ………………………………………………

❑ Fewer hedgehogs than in 2006, because of (Please circle ALL the relevant options):
- Decrease of suitable habitat (e.g. hedgerows, pasture)
- Decrease of available food (e.g. slugs, worms, beetles)
- Intensification of farm management (Please specify): ………………
- Increasing numbers of badgers
- Other (Please specify): ………………………………………………

3. Where do you usually see hedgehogs on your farm? (Please tick ALL the relevant boxes)

❑ Garden
❑ Rough (unfarmed) grassland/ downland/ moorland
❑ Lowland heathland e.g. with gorse, heather
❑ Arable farmland
❑ Pastoral farmland i.e. grazing
❑ Predominantly deciduous woodland
❑ Predominantly coniferous woodland
❑ Other (Please specify): ……………...

4. What is your opinion of hedgehogs?

❑ I like to have them around my farm because: …………………………………………........
❑ I have no strong opinion about them
❑ I don't really like to have them around my farm because: ……………………………..

5. Is your farm MAINLY concerned with (Please tick ALL that apply):

❑ Rearing livestock ❑ Dairy
❑ Arable ❑ Poultry/eggs
❑ Market garden or horticulture
❑ Other (Please specify):…………………

6. How many hectares does your farm cover? …………………hectares

7. What percentage of your farm is arable land, grassland (including pasture and set aside), woodland? (Please tick only ONE box per line)

Arable land:	❑ 0%	❑ 1 - 25%	❑ 26 - 50%	❑ 51 - 75%	❑ over 75%
Grassland:	❑ 0%	❑ 1 - 25%	❑ 26 - 50%	❑ 51 - 75%	❑ over 75%
Woodland:	❑ 0%	❑ 1 - 25%	❑ 26 - 50%	❑ 51 - 75%	❑ over 75%

8. What is the <u>approximate</u> total length of hedgerows on your farm? ……………...metres

9. Is your farm certified as organic by a DEFRA approved body?

- ❑ Yes
- ❑ No

10. Is your farm, or part of your farm, in any agri-environment scheme(s)? (Please tick ALL that apply)

- ❑ I do not have any agri-environment scheme(s) on my farm
- ❑ Entry Level Stewardship
- ❑ Higher Level Stewardship
- ❑ Organic Entry Level Stewardship
- ❑ Other (Please specify): ……………..

11. If your farm has been in ANY agri-environment scheme(s), how long in total has it been in such scheme(s)?

- ❑ Just started
- ❑ Less then 5 years
- ❑ Between 5 and 10 years
- ❑ More then 10 years

12. Would you be willing to make changes on your farm to increase the number of hedgehogs?

- ❑ Yes I would
- ❑ Yes, but I would need to be subsidised
- ❑ No I would not

If you have any further comments, please state them below:

Thank you very much for completing this questionnaire. Your input is greatly appreciated.

Please send the questionnaire back using the enclosed pre-paid envelope to:

People's Trust for Endangered Species, 15 Cloisters House, 8 Battersea Park Road, London, SW8 4BG

www.ptes.org enquiries@ptes.org 020 7498 4533
Registered Charity Number 274206

Appendix III

Appendix III

ID	Sex	Tracking days (n)	Sightings (n)	Status	Weight at start (g)	Weight at end (g)
Wf1	female	17	54		1100	850
Wf2	female	13	50	Lost transmitter	650	
Wm3	male	13	48	Dead: badger predation	850	
Wm4	male	2	9	Dead: badger predation	900	
Wm5	male	12	35	Dead: badger predation	850	
Wf6	female	7	27	Lost transmitter	550	
Wf7	female	11	44		700	750
Wf8	female	15	65		700	550
Wm9	male	8	14	Dead: badger predation	850	
Wm10	male	13	63		600	550
Wm11	male	12	77		950	900
Wf12	female	12	51		850	750
Wf13	female	2	2	Lost	650	
Wm14	male	5	16	Lost	750	
Wf15	female	13	75	Dead: failed pregnancy	850	
Wm16	male	2	5	Dead: badger predation	600	
Wf17	female	11	98		750	750
Wm18	male	10	96		650	750
Wf19	female	11	85		700	700
Wm20	male	14	69		900	850
Wm21	male	10	61	Lost transmitter	650	
Wf22	female	14	66		900	750
Wf23	female	11	78		800	650
Wm24	male	12	52		900	800
Wm25	male	12	70		550	650
Wm26	male	10	59		850	800
Wm27	male	12	79		650	650
Wm28	male	3	7	Dead: badger predation	650	
Wm29	male	12	68		650	850
Wf30	female	11	67		800	700
Wm31	male	3	4	Lost	850	
Wm32	male	17	91		750	600
Wf33	female	2	11	Dead: badger predation	800	
Wm34	male	15	68		750	700
Wf35	female	14	63		600	500
Wf36	female	12	64		800	500
Wf37	female	13	73		750	650
Wf38	female	10	84		450	550
Wm39	male	2	7	Dead: badger predation	700	
Wm40	male	12	56		750	750
Wm41	male	12	56	Lost transmitter	750	
Wf42	female	10	67		650	800
Wf43	female	10	73		650	800
Wm44	male	2	12	Lost	600	

Appendix IV

Appendix IV The ‘Living with Mammals’ survey-sheet of 2003 used to assess the distribution of wildlife in (sub)urban green-spaces

Living with Mammals SURVEY 2003

Mammals Trust UK

FORM A REGISTERING YOUR SITE

Please refer to the separate instruction sheet when completing the forms.
Please use block capitals in black or blue ink and mark the boxes clearly with a cross like this

SURVEY No. ☐

1. YOUR DETAILS

YOUR NAME ☐

YOUR ADDRESS ☐

YOUR POSTCODE ☐

If you are under 18 years old, please mark this box ☐

2. YOUR SURVEY SITE

2a) Site Location

SITE NAME ☐

SITE ADDRESS ☐

COUNTY ☐

SITE POSTCODE or GRID REF* ☐

* To ensure accuracy, it's very important that you provide us with either the postcode or grid reference of your chosen survey site.

FOLD

2b) Type of site*

- Garden ☐
- Park / mown village green / residential square ☐
- Common with rough grass or scrub ☐
- Wasteland / derelict land ☐
- Churchyard / cemetery ☐
- Playing field ☐
- Golf course ☐
- Allotment ☐
- Railway embankment / roadside verge ☐
- River bank / stream bank ☐

* Remember not to record on nature reserves.

2c) When was your site established?

Pre 1900s ☐ 1901-1949 ☐ 1950-1999 ☐ Since 2000 ☐

2d) Approx. area of your site: Please refer to the instruction sheet for help on how to work out the area of your site.

Less than 25m² ☐ 26-50m² ☐ 51-200m² ☐ Greater than 200m² ☐

3. DESCRIPTION OF YOUR SITE

3a) Indicate the percentage of your site that consists of the following:

	0%	1-25%	26-50%	51-75%	76-100%
Grass	☐	☐	☐	☐	☐
Shrubs	☐	☐	☐	☐	☐
Trees	☐	☐	☐	☐	☐
Concrete / gravel / pavings	☐	☐	☐	☐	☐
Shed / hut / building	☐	☐	☐	☐	☐
Wild untended areas	☐	☐	☐	☐	☐

Please ensure that your figures add up to 100%.

3b) Please indicate the presence of the following on your site:

- Garden shed ☐
- Pond / lake ☐
- Bat box ☐
- Hedgehog box ☐
- Bird box ☐
- Compost heap ☐
- Piles of dead wood ☐
- Bird table ☐
- Bird bath ☐
- Bird feeder ☐
- Other animal feeder ☐

3c) Do any of the plants on your site produce:

- Fruit / berries ☐
- Nuts / seeds / cones ☐
- Bulbs / root vegetables ☐
- Vegetables (above ground) ☐

3d) Do any domestic animals regularly use the survey site?

Dogs ☐ Domestic / feral cats ☐ Other ☐ *(Please specify below)*

3e) Does your site have artificial illumination at night?

Yes ☐ No ☐

4. BOUNDARY DESCRIPTION

FOLD

4a) What type of boundary surrounds your survey area?

- None, it's all open ☐
- All fenced ☐
- Partially fenced ☐
- All hedged ☐
- Partially hedged ☐
- All walled ☐
- Partially walled ☐
- All trees ☐
- Partially trees ☐

4b) If your site is enclosed, please indicate the height of the boundary:

0-1m ☐ 1-2m ☐ Higher than 2m ☐

4c) If your site is enclosed, please indicate if the boundary has:

- Any gaps large enough to let mammals as big as hedgehogs pass through? ☐
- Any gaps large enough to let mammals as big as rabbits or cats pass through? ☐
- Any gaps large enough to let mammals as big as foxes and deer pass through? ☐

5. DETAILS OF THE SURROUNDING AREA

Which of the following occur within 100 metres of your survey area?

- Gardens ☐
- Woodland ☐
- Common with rough grass or scrub ☐
- Pasture / grass fields ☐
- Arable fields ☐
- Wasteland / derelict land ☐
- Park / mown village green / residential square ☐
- Pond / lake ☐
- Stream / river ☐

We will send you a report when the survey is complete. We will not pass your personal details on to a third party. The information that you send will be held on a database and may be shared with other conservation bodies. If you do not wish to receive any further correspondence from MTUK, please mark this box ☐

Mammals Trust UK is a restricted fund of PTES, registered charity number 274206.

Living with Mammals SURVEY 2003

Mammals Trust UK

FORM B YOUR MAMMAL SIGHTINGS

PLEASE USE BLOCK CAPITALS IN BLACK OR BLUE INK.

YOUR NAME	
SITE NAME	
COUNTY	
SITE POSTCODE or GRID REF*	

* To ensure accuracy, it's very important that you provide us with either the postcode or grid reference of your chosen survey site.

At the end of each week, please record the size of the LARGEST group of each species that you have seen TOGETHER at your site at any one time during that week. For example, if you see 2 hedgehogs together on Monday, then **2** is your record for the week. But if you see 3 hedgehogs together on Friday, the record for that week changes to become 3+.

SURVEY No.	

WEEK NUMBER		1	2	3	4	5	6	7	8	9	10	11	12	13
Mark the box if you have surveyed that week WEEKS SURVEYED ▸		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hedgehog	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Fox	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Grey squirrel	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Badger	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Roe deer	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Muntjac deer	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bats	1-2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3-10	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	10+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Rabbit	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Mice	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Voles	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Brown rat	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Shrews	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Domestic / feral cats	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Did you put out food for:	Mammals	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Birds	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

FOLD

HOW TO MARK THE BOXES

Because these forms are to be read electronically, please ensure that you use black or blue ink and that you mark the boxes clearly with a cross like this: ☒

FOLD

WEEK 1 *Monday 31 March - Sunday 6 April*

WEEK 2 *Monday 7 April - Sunday 13 April*

WEEK 3 *Monday 14 April - Sunday 20 April*

WEEK 4 *Monday 21 April - Sunday 27 April*

WEEK 5 *Monday 28 April - Sunday 4 May*

WEEK 6 *Monday 5 May - Sunday 11 May*

WEEK 7 *Monday 12 May - Sunday 18 May*

WEEK 8 *Monday 19 May - Sunday 25 May*

WEEK 9 *Monday 26 May - Sunday 1 June*

WEEK 10 *Monday 2 June - Sunday 8 June*

WEEK 11 *Monday 9 June - Sunday 15 June*

WEEK 12 *Monday 16 June - Sunday 22 June*

WEEK 13 *Monday 23 June - Sunday 29 June*

Living with Mammals SURVEY 2003

Mammals Trust UK

FORM C WHEN AND HOW LONG YOU OBSERVED

SURVEY No.

At the end of each week, please record the TOTAL amount of time you have spent watching your site at each different time of day.

Please refer to the instruction sheet for further details.

Remember to record even very short lengths of time that you spent observing your site e.g. glancing out of a window overlooking your site.

WEEK NUMBER 1	Monday 31 March - Sunday 6 April				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 2	Monday 7 April - Sunday 13 April				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 3	Monday 14 April - Sunday 20 April				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 4	Monday 21 April - Sunday 27 April				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 5	Monday 28 April - Sunday 4 May				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

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WEEK NUMBER 6	Monday 5 May - Sunday 11 May				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 7	Monday 12 May - Sunday 18 May				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 8	Monday 19 May - Sunday 25 May				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 9	Monday 26 May - Sunday 1 June				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 10	Monday 2 June - Sunday 8 June				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 11	Monday 9 June - Sunday 15 June				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 12	Monday 16 June - Sunday 22 June				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

WEEK NUMBER 13	Monday 23 June - Sunday 29 June				
Length of observation	0 mins	1-10 mins	11-30 mins	31-60 mins	1+ hours
Time of observation					
Dawn	☐	☐	☐	☐	☐
Daytime	☐	☐	☐	☐	☐
Dusk	☐	☐	☐	☐	☐
Nighttime	☐	☐	☐	☐	☐

HOW TO MARK THE BOXES

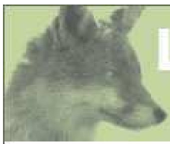
Because these forms are to be read electronically, please ensure that you use black or blue ink and that you mark the boxes clearly with a cross like this: ☒

Dawn
One hour before or after sunrise

Daytime
One hour after sunrise until one hour before sunset

Dusk
One hour before or after sunset

Nighttime
One hour after sunset until one hour before sunrise



Living with Mammals SURVEY 2003

Mammals Trust UK

FORM D MAMMAL SIGNS

PLEASE USE BLOCK CAPITALS IN BLACK OR BLUE INK.

YOUR NAME	
SITE NAME	
COUNTY	
SITE POSTCODE or GRID REF*	

* To ensure accuracy, it's very important that you provide us with either the postcode or grid reference of your chosen survey site.

Please record the presence of any FRESH signs left by mammals at your site within the last week by putting a cross in the relevant the boxes.

SURVEY No.

WEEKS NUMBER		1	2	3	4	5	6	7	8	9	10	11	12	13
Please mark the box if you have surveyed your site that week WEEKS SURVEYED		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hedgehogs	Droppings Pawprints	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Foxes	Droppings Food remains Pawprints	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Moles	Molehills	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Badgers	Fresh digging Droppings Hair	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Deer	Droppings Hoof prints	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bats	Droppings Sound	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Rabbits / hares	Droppings Scrapes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Mice / voles / shrews	Burrows Droppings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Rats	Burrows / runs Droppings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Squirrels	Food remains	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Unidentified signs		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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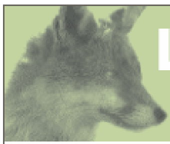
WEEK 10 *Monday 2 June - Sunday 8 June*

WEEK 11 *Monday 9 June - Sunday 15 June*

WEEK 12 *Monday 16 June - Sunday 22 June*

WEEK 13 *Monday 23 June - Sunday 29 June*



Living with Mammals SURVEY 2003

PROTECTING OUR NATIVE ANIMALS AND THEIR HABITATS
Mammals Trust UK

FORM E SCARCER SPECIES FORM

It is possible that you may see a mammal that is not listed on FORM B. If you are confident with your sighting, please record the information in the table below as for FORM B.

SURVEY No.

Please refer to the Spotting Wild Mammals guide for help with identification.

WEEK NUMBER		1	2	3	4	5	6	7	8	9	10	11	12	13
Mark the box if you have surveyed that week WEEKS SURVEYED ▶		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Species	1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	3+	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Did you put out food for:	Mammals	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Birds	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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WEEK 1
Monday 31 March - Sunday 6 April

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WEEK 12
Monday 16 June - Sunday 22 June

WEEK 13
Monday 23 June - Sunday 29 June