BTO Research Report No. 598

UK Hedgehog Datasets and their Potential for Long-Term Monitoring

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Evidence of serious decline in abundance led to hedgehogs being added to the government priority species list for conservation action in 2007. As well as being a popular, beneficial and distinctive native mammal, hedgehogs are a flagship species: what's good for hedgehogs is good for many other species too. Like the miner's canary, its demise is a warning of a failing environment. People's Trust for Endangered Species (PTES) and the British Hedgehog Preservation Society (BHPS) are working together on a conservation strategy for this species and leading a public campaign to help hedgehogs.

Understanding the extent and nature of the decline and changes in hedgehog populations are critical to addressing the problem. A number of wildlife monitoring surveys, some of them quite long running, have data variously on hedgehog distribution and abundance. But no analysis had previously been done across the different data sets to see exactly what they are telling us and how this might inform what we do. With funding from PTES and BHPS, a significant part of which emanated from a bequest by wildlife television producer Dilys Breese, the British Trust for Ornithology (BTO) was commissioned to compare survey information and to advise on which of the surveys, or combination of surveys, are producing the most useful data in detecting population changes. This report summarises BTO's findings and provides valuable insight into how to go forward.

Our strategy has four main elements that offer scope for scientists, conservationists, land managers and the public to assist in many different ways. The BTO report will enable us to ensure that there is a robust ongoing system for monitoring hedgehog abundance nationally. In addition PTES and BHPS have commissioned further research into finding reliable ways of locating hedgehogs for monitoring purposes; establishing the likely minimum, viable populations size; assessing the threats posed by population fragmentation; understanding better how hedgehogs use their habitat, particularly on different types of farmland to assess the threats posed, and support offered, by different farming systems. Householders, farmers and landowners will be offered advice on hedgehog habitat management and on what can be done to reduce some of the more easily avoidable threats to hedgehogs. *Hedgehog Street* has been launched and 'hedgehog champions' recruited nationwide to create hedgehog-friendly neighbourhoods in urban and suburban landscapes. Training courses are in development for local authorities, ecologists and developers on how to include hedgehogs in environmental surveys associated with major land developments and on how to maintain an environment suitable for hedgehogs to thrive. And the many hedgehog carers who look after thousands of sick, injured and orphaned hedgehogs will be helped to gather information about the dangers hedgehogs face and their survival and dispersal after release back into the wild, using identification tags that the public can report when found.

For more information visit
www.ptes.org/hedgehogs ,
www.britishhedgehogs.org and
www.hedgehogstreet.org

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EXECUTIVE SUMMARY

In order to assess the feasibility of generating national and regional population trends for hedgehogs, we obtained data from seven national surveys. Following extensive data clean-up and handling, we carried out analyses to estimate trends in hedgehogs (in practice – occupancy rates) and determine the statistical power of each survey to detect population declines between 10% and 50% over periods of 10 and 25 years, the latter being a commonly-used time period for assessing population status for red-listing species.

Five surveys were conducted using a sufficiently repeatable sampling protocol over enough years to generate a national (UK) population trend. Additionally, for two of these surveys, we were able to carry out additional analyses with another measure of hedgehog presence or abundance derived from the same survey.

Of the seven measures assessed, five measures of hedgehog presence or abundance (from four surveys) showed a significant decline over the period of sampling, which varied from four to 14 years between 1996 and 2010. The other two measures declined but not significantly so. Hence, surveys of the wider countryside as well as for those focused on gardens and other human-dominated areas, showed evidence of declines.

Two additional surveys also targeted mainly at gardens and human dwellings (RSPB's Making Your Nature Count in 2009 and 2010, and PTES/BHPS's Hogwatch, conducted largely between 2005 and 2007) although involving a large number of volunteers, do not currently employ a sufficiently repeatable sampling design and/or protocol to reliably assess change in the same way. Tests for differences between years suggested very small increases in occupancy rates of hedgehogs, but the participant-driven sampling protocols may have resulted in slight bias towards increases.

We carried out power analyses for the seven measures (from five surveys) for which there were repeat visits to sites. All surveys had sufficient power (78 or greater) to detect red-level declines over 25 years (equivalent to red-listing for birds) or ten years but the WBBS and BBS records of dead hedgehogs only, were insufficient for reliably detecting 25% declines over 10 or 25 years. Two surveys (Garden BirdWatch, and Mammals on Roads) had >80% power to detect changes of 10% over 10 or 25 years, whereas Living with Mammals and BBS (all records) had slightly less power (70% to 80%) to detect population changes of 10%.

Power analyses were undertaken to determine the annual sample of Living with Mammals or Mammals on Roads sites required to detect modest levels of change (5% or 10%) over shorter time periods (five and ten years) with a power of at least 80%.The Living with Mammals results suggest that 300 sites (well within current scope) would have sufficient power to detect a 10% decline as long as these were resurveys of the same sites each year. To achieve this power if different sites were surveyed each year, almost five times the sample would be required, i.e. in excess of 1300 sites and considerably more than have been monitored in the last few years. The Mammals on Roads results suggest that 200-250 sites would provide enough power to detect a national decline of 10% over 5-10 years, if the same routes are revisited. More than 800 routes would need to be surveyed if the routes differed each year.

1. BACKGROUND

Within the UK the hedgehog (*Erinaceus europaeus*) is considered to be widespread and locally common (Harris & Yalden 2008). However, the species was included in the UK Biodiversity Action Plan because of concerns that it had undergone a significant population decline (UK BAP 2007; Hof 2009).

Although data on hedgehogs has been gathered by a number of organisations for varying numbers of years, the potential role that such information might play in the long-term monitoring of hedgehog populations has not been fully assessed (Toms *et al*. 1999; Toms & Newson 2006). Data on hedgehogs are currently collected through national surveys coordinated by organisations including the People's Trust for Endangered Species (PTES), the British Hedgehog Preservation Society (BHPS), the Game and Wildlife Conservation Trust (GWCT), the British Trust for Ornithology (BTO) and the Royal Society for the Protection of Birds (RSPB). Some of these surveys have been running for more than a decade. Given the increased value of this information as the time periods become longer, a review of existing datasets containing information on hedgehogs, coupled with statistical examination of their suitability for long-term monitoring, was considered timely.

1.1 Aims and Scope

The project's original aims were to examine each of eight identified surveys (PTES Living with Mammals, PTES Mammals on Roads, PTES/BHPS Hogwatch, BTO Garden BirdWatch, BTO/RSPB/JNCC Breeding Bird Survey, Waterways Breeding Bird Survey, GWCT's National Gamebag Census and RSPB's Make Your Nature Count) to determine the potential for long-term monitoring, the production of trends to date, and to identify the best means of monitoring Hedgehogs at national and regional levels.

This report encompasses three separate outcomes of the work. In the Methods we provide an overview of the key datasets on Hedgehogs held by different organisations. This includes descriptions of key meta-data such as survey timing and frequency, geographical scope, temporal considerations, duration of time series, sampling strategy, habitat coverage, as well as encounter rates and the parameter measured (*e.g.* occupancy, presence/absence or relative abundance).

Secondly, for each dataset, we also carry out an analysis of changes in abundance of Hedgehogs, at the national level and where possible, regionally. Note that we did not have access to GWCT's National Gamebag Census data, and we therefore analyse and report on the remaining seven surveys. The published Gamebag Census trends are cited as appropriate in the discussion.

Lastly, for all hedgehog surveys with a repeatable sampling protocol, we assessed the likelihood of being able to detect red-level or amber-level declines (50% or 25% over 25 years) by using power analyses. Where possible, we also assessed the likelihood of detecting such declines of 10 years.

2. SURVEYS and METHODS

2.1 Mammals on Roads

2.1.1 General information about the survey

Mammals on Roads (MoR), an annual volunteer-based survey of mammal carcasses, and live mammals, observed during reasonably long car journeys, is organised by the People's Trust for Endangered Species (PTES). The survey started in 2001 and is still ongoing, with results of the first few years of the survey initially summarised by Bright et al. (2005). Volunteers were asked to record dead (daytime only) and live (day and night-time) mammals when driving distances longer than 20 miles during the months July, August and September. Data was not recorded from motorways, dual carriageways or from urban areas. To minimise the risk that the same mammal was counted more than once, at least 30 days should pass before the same journey was surveyed. For the purpose of this study, we used data from 2001 and 2009 (i.e. data that had been submitted up to November 2010).

2.1.2 Data issues and scope

The datasets provided did not initially permit easy identification of repeat journeys, for example between years. Therefore, datasets were manipulated so that journeys between the same start and end points (and similar routes) could be coded with a unique identifier. In total, 7965 unique journeys were identified from 10947 submissions from sites in Great Britain. The geographical distribution of the journeys is shown in Figs 1 and 2, showing, respectively, the geographical pattern of occupied sites, and sites with the greatest numbers of hedgehogs. The number of journeys where at least one mammal was observed are summarised in Table 1. Overall, the proportion of routes where any hedgehogs were detected averaged about 50% and the mean number of hedgehogs detected was fairly constant at about two animals per journey. Turnover of sites is small, partly reflecting the fact that the number of routes surveyed has declined from over 2000 in the first year to about a quarter of that (ca 500) by 2009. For the power and trend analyses analysis (see Results), all journeys were included.

Of the surveys considered here, the MoR dataset is the best source of information to model abundance (i.e. counts) of hedgehogs, because volunteers count the number of hedgehogs, as well as all other mammals seen. Although BBS observers also count live hedgehogs, very few are detected during the daylight. Hence, the MoR dataset provides two measures of the status of hedgehogs for analysis, one being the overall occurrence (presence or absence of hedgehogs per journey) and the second the count of hedgehogs per journey. Because of the low detection rates of hedgehogs in other surveys where they are counted (e.g. BBS), this quantitative measure of abundance from MoR is unique among the data sources explored for this work.

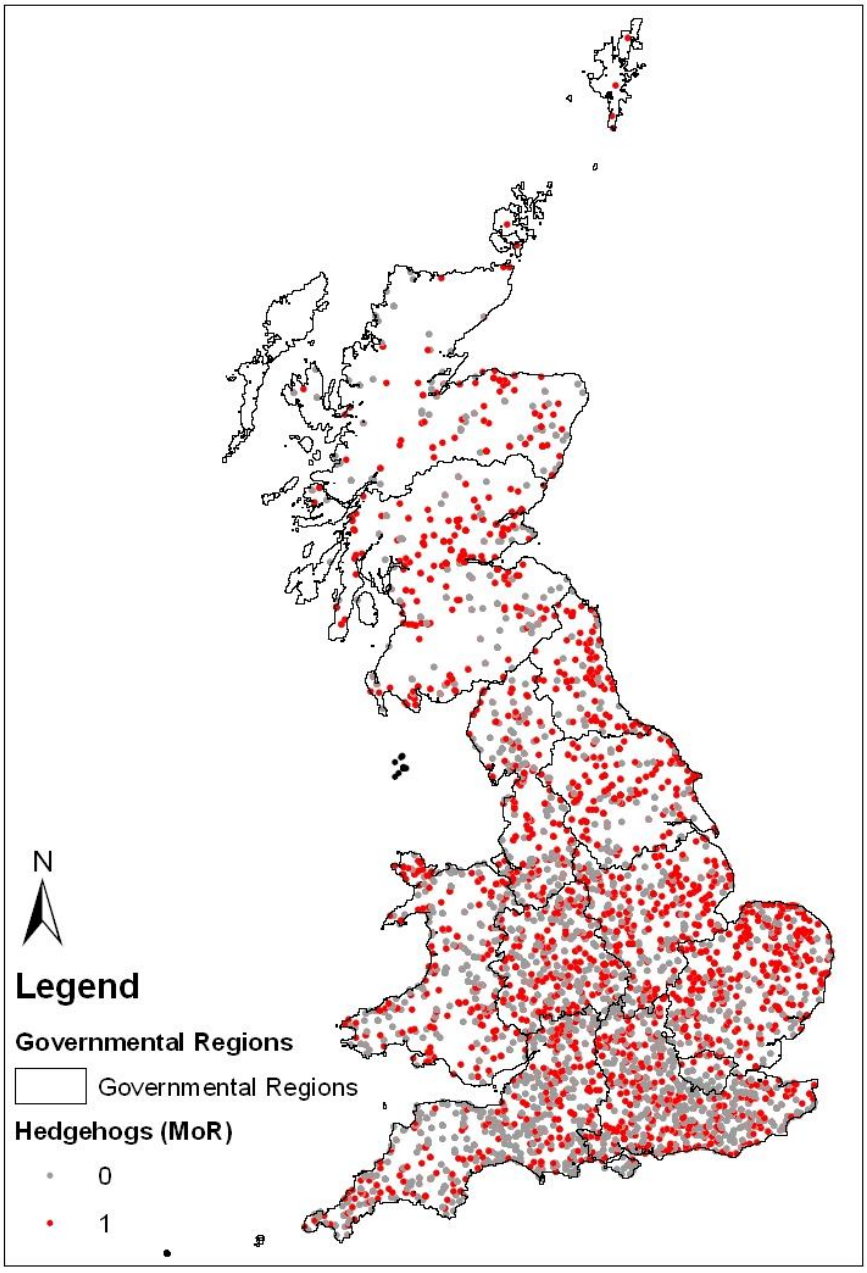

Fig 1. **Hedgehog presence at Mammals on Roads journey locations 2001-2009: t**he geographical distribution of starting points for journeys reported to the survey Mammals on Roads, with red dots denoting hedgehog 'presence' and grey dots 'absence'.

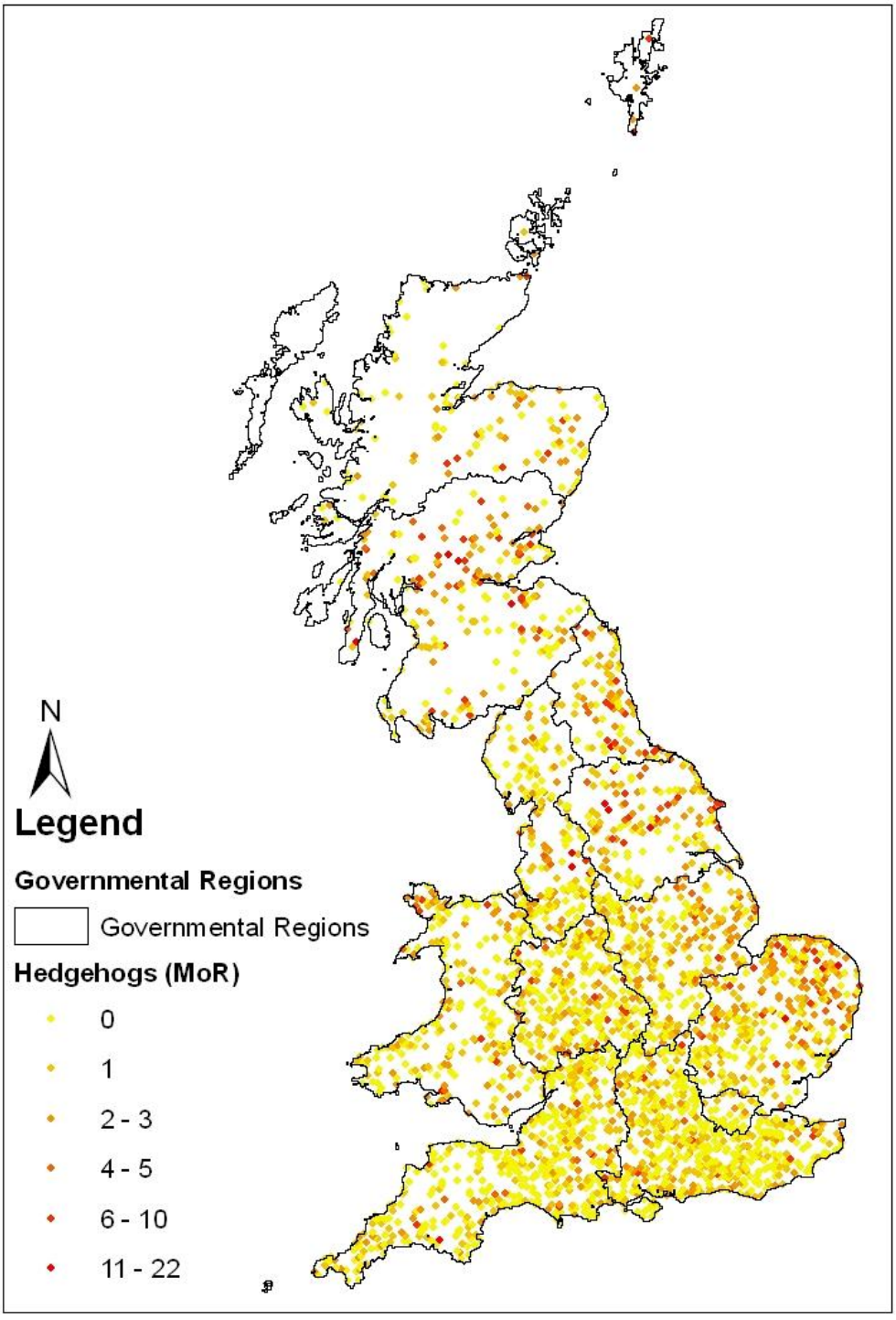

Fig 2. **Hedgehog numbers at Mammals on Roads journey locations 2001-2009: t**he geographical distribution of starting points for journeys reported to the survey Mammals on Roads, with the abundance categories of hedgehogs found coded using a colour gradient from yellow (none) to dark red (11 to 22 carcasses).

Table 1 Summary hedgehog statistics[1] from Mammals on Roads, 2001-2009.

Year	Tot. no. of journeys	Tot. no. of mammals	Mean no. of mammals per journey	Max. no. of mammals per journey	Tot. no. of journeys with HHs	Tot. number of HHs	Mean no. of HHs per journey	Max. no. of HHs per journey	% of all journeys with HHs	% HHs of all mammals
2001	2081	10689	5.14	202	1205	2607	2.16	21	57.9	24.39
2002	1767	9629	5.45	122	939	2048	2.18	22	53.14	21.27
2003	1011	6843	6.77	71	508	1092	2.15	14	50.25	15.96
2004	1364	7748	5.68	118	643	1233	1.92	17	47.14	15.91
2005	768	4647	6.05	53	370	804	2.17	18	48.18	17.3
2006	806	5252	6.52	103	399	933	2.34	18	49.5	17.76
2007	868	6844	7.88	60	468	1086	2.32	23	53.92	15.87
2008	731	4125	5.64	55	385	813	2.11	17	52.67	19.71
2009	448	2542	5.67	54	215	424	1.97	10	47.99	16.68
Total	**9844**	**58319**		**838**	**5132**	**11040**		**160**		

[1] Number of journeys submitted to Mammals on Roads (MoR) where at least one mammal was observed, the total number of mammals recorded, and the mean and maximum number of mammals recorded per journey. In addition, the table shows the annual total number of dead hedgehogs (HHs) observed, the mean and maximum number of dead hedgehogs observed per journey, the percentage of journeys where at least one dead hedgehog was found, and the percentage of mammal roadkills that were hedgehogs..

2.2 Living with Mammals (LwM)

2.2.1 General information about the survey

Living with Mammals, coordinated by the People Trust for Endangered Species, is a survey that focuses on mammals in green spaces (gardens, parks, churchyards, allotments and similar spaces) in built-up areas. It was launched in 2003 and is still ongoing. Volunteers select their site themselves, and they are encouraged to visit their site on at least a weekly basis during 13 weeks per year (April to June). All green spaces surveyed have to be located within 200m of buildings, but sites more than 200m from buildings, but wholly within towns or cities could also be surveyed (e.g. large city parks). Suitable survey sites include gardens, parks, playing fields, allotments, derelict land, commons, churchyards, river banks and cemeteries.

The number of sites monitored annually in the UK varied annually from ca 450 (in 2008) to ca 750 (in 2004) but has been relatively constant in recent years (Table 2). The vast majority of sites are in England and about 84% are in gardens. Given that the total number of sites in the scheme is ca 2500, the mean rate of site turnover is about 45%. In practice, turnover is likely to be higher with newer and later-joining sites; more than 130 sites have been in the scheme since it began.

A high proportion of sites, ca 40%, reported either sightings or signs of hedgehogs (Table 2). The proportion of sites with hedgehogs varied between countries from 32.4% in Scotland to 37.5% in Wales and 40% in England, in all cases mostly based on sightings.

Table 2 Summary hedgehog statistics[1] from PTES Living with Mammals, 2003-2010**.**

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Country	Year	Total number of records	Number of sites with Hedgehog sightings	Proportion of sites where hedgehogs were seen	Number of sites with signs, including sightings, of hedgehogs	Proportion of sites where hedgehogs were detected
England	2003	566	129	0.23	233	0.41
England	2004	694	195	0.28	284	0.41
England	2005	637	193	0.30	288	0.45
England	2006	607	169	0.28	238	0.39
England	2007	544	131	0.24	198	0.36
England	2008	414	118	0.29	168	0.41
England	2009	430	117	0.27	164	0.38
England	2010	513	123	0.24	193	0.38
Scotland	2003	17	4	0.24	4	0.24
Scotland	2004	35	9	0.26	10	0.29
Scotland	2005	34	7	0.21	10	0.29
Scotland	2006	34	5	0.15	11	0.32
Scotland	2007	24	5	0.21	8	0.33
Scotland	2008	21	7	0.33	9	0.43
Scotland	2009	16	4	0.25	5	0.31
Scotland	2010	21	3	0.14	8	0.38
Wales	2003	13	2	0.15	6	0.46
Wales	2004	30	7	0.23	10	0.33
Wales	2005	32	7	0.22	16	0.50

Country	Year	Total number of records	Number of sites with Hedgehog sightings	Proportion of sites where hedgehogs were seen	Number of sites with signs, including sightings, of hedgehogs	Proportion of sites where hedgehogs were detected
Wales	2006	26	7	0.27	10	0.38
Wales	2007	23	4	0.17	7	0.30
Wales	2008	23	6	0.26	7	0.30
Wales	2009	20	5	0.25	6	0.30
Wales	2010	21	6	0.29	9	0.43
Total		**4795**	**1263**		**1902**	

[1] Information from People's Trust for Endangered Species' survey Living With Mammals (LWM) of hedgehog presence in green spaces in built up areas. The table shows the total number of LWM submissions by country, the number of submissions that reported hedgehogs as present, either based on sightings or based on signs of hedgehogs

2.3 Make Your Nature Count (MYNC)

The Royal Society for the Protection of Birds (RSPB) runs a week-long survey in early June called Make Your Nature Count (MYNC). The survey was launched in 2009, was repeated in 2010 and is intended to continue. Participating volunteers are asked to count birds, mammals and other taxa during one hour on any day during the week that the survey runs, in the early part of June. Hedgehogs are seldom reported during this diurnal survey hour but volunteers are also asked to describe how often they encounter any of a list of eight mammals and other mainly nocturnal wildlife species, using an ordinal frequency scale from daily to never.. For the purpose of this study we determined rates of occupancy from the frequency information that was submitted, combining all entries of daily, weekly, monthly and less than monthly as 'present' and categorising 'never seen' as absent.

The number of participating gardens increased between 2009 and 2010 (Table 3). As with many other surveys, the majority of records come from England, but at least 750 records from each of Scotland and Wales are also submitted annually (Fig 3, Table 3). Although a relatively high proportion (ca 70%) of sites recorded hedgehogs, the identity of individual sites is currently difficult to quantify for the short period covered by this dataset, and site turnover may be high. However, the percentage of records in each category was very similar between years, within each country.

Table 3 Summary hedgehog statistics from RSPB Make Your Nature Count, 2009-2010.

Country	Year	Total number of records	Daily	Weekly	Monthly	Less than monthly	Never	% of sites with Hedgehogs
England	2009	15558	2824	2211	1458	5431	3500	77.31
England	2010	30032	5756	4413	2558	10503	6376	78.46
Scotland	2009	1167	142	107	99	488	319	72.38
Scotland	2010	1887	210	217	144	791	504	72.99
Wales	2009	768	124	85	67	300	186	75.59
Wales	2010	1477	207	207	145	573	329	77.48
Total		**50889**	**9263**	**7240**	**4471**	**18086**	**11214**	

Note: Information from RSPB's survey Make Your Nature Count (MYNC) on the frequency that hedgehogs were observed in gardens in Scotland, England and Wales. The table shows the total number of MYNC records, the number of records that reported hedgehogs encountered daily, weekly, monthly, less than monthly and never, and the percentage of gardens in each year that observed hedgehogs.

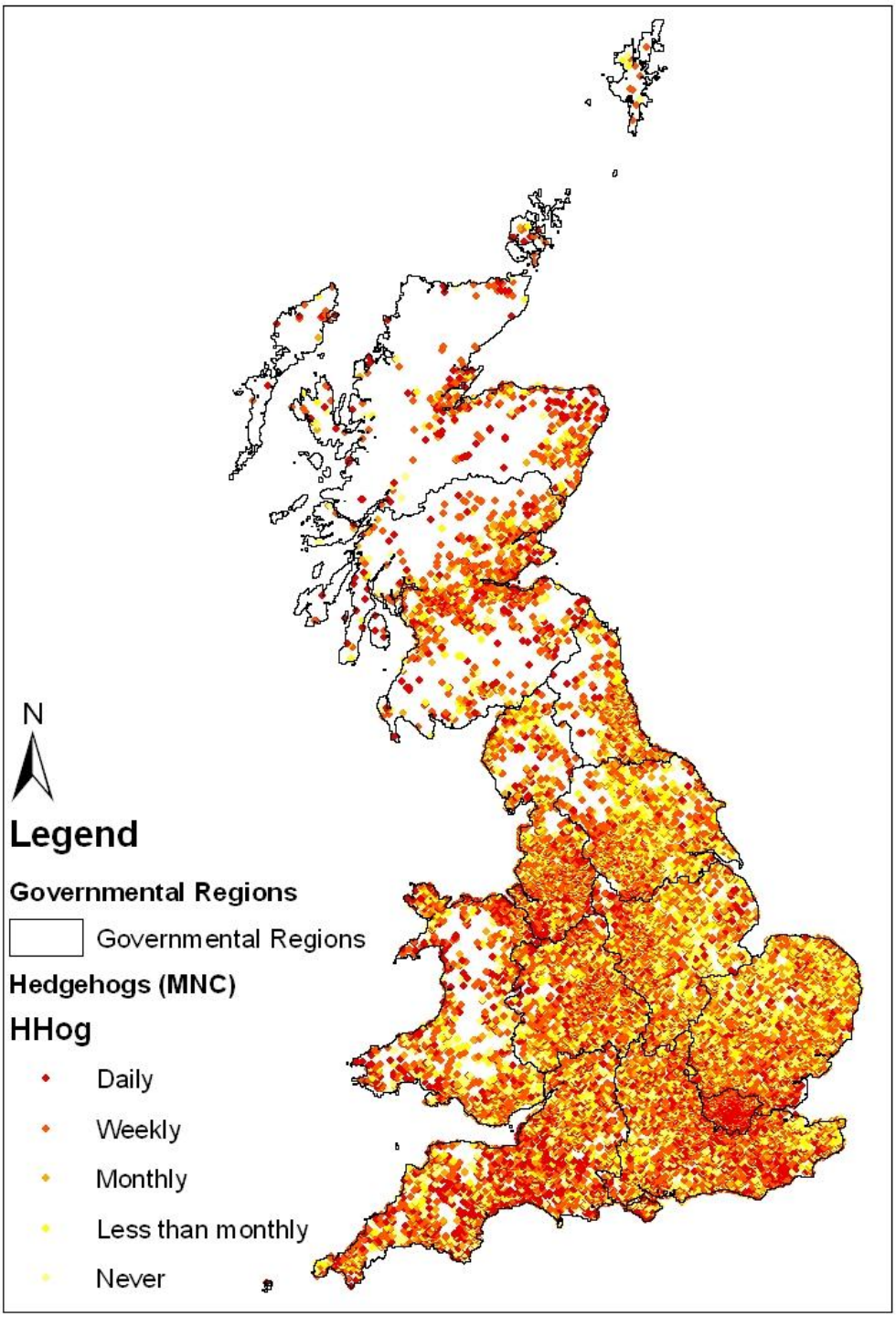


Figure 3 Hedgehog presence on Make Your Nature Count sites, 2009-2010: the location of sites that submitted data to Make Your Nature Count (MYNC). The sites are shown with a yellow to red scale of increasing frequency of hedgehog observations.

2.4 HogWatch (HW)

2.4.1 General information about the survey

The People's Trust for Endangered Species (PTES) and the British Hedgehog Preservation Society (BHPS) ran a hedgehog survey, *HogWatch*, between 2005 and 2007 (the main focus was on the years 2005 and 2006). For the basic level of this survey (HogWatch A), volunteer recorders in Britain and Ireland were asked to submit records on whether they had observed one or several hedgehogs in their own garden during the last year. They could also send in records from encounters with hedgehogs from locations other than from their own garden. The spatial identifier used in this survey was the postcode of the garden. The recorders were finally asked to give their opinion about the population changes in hedgehog numbers over the last 5 and 10 years, respectively. They could answer "Don't know", "Hedgehogs are equally common", "Hedgehogs are less common now than five years ago" and "Hedgehogs are more common now than five years ago".

In a more detailed questionnaire (HogWatch B) volunteer recorders were asked whether they had observed a hedgehog in their garden, the maximum number of hedgehogs seen, the presence of hedgehog nests (with counts and broad age classification of the young). The recorders were also asked to submit records from encounters with hedgehogs from locations other than their own garden with a habitat description from these non-garden sites. The spatial identifier used in this survey was the grid reference.

2.4.2 Data issues and scope

To link individual observations to a geographic location we converted postcodes to a grid reference. For HogWatch A this was done by merging the HogWatch A dataset (N= 19411 records) with the official postcode database (obtained from the Ordnance Survey at https://www.ordnancesurvey.co.uk/). However, many records did not contain a valid postcode. Substantial "cleaning" of postcodes (i.e. correcting obvious miss-spellings such as the use of the letter "O" instead of the number "0") increased the number of useable postcode locations. After merging the two datasets and only retaining records from Great Britain (i.e. excluding records from the Republic of Ireland, Northern Ireland and even New Zealand), 18951 records remained in the dataset (Table 4). Although recorders were instructed to only send in one record form for each garden and year, it was clear that around 900 records had used the same postcode and address (i.e. compare the number of submitted records and the number of unique locations submitting records in Table 4).

HogWatch A data suggests that hedgehogs were observed in approximately 60% of locations (Table 4; Fig. 4). However, HogWatch may suffer from a lack of negative reporting, that is, recorders are probably less likely to submit their forms if they did not observe hedgehogs.

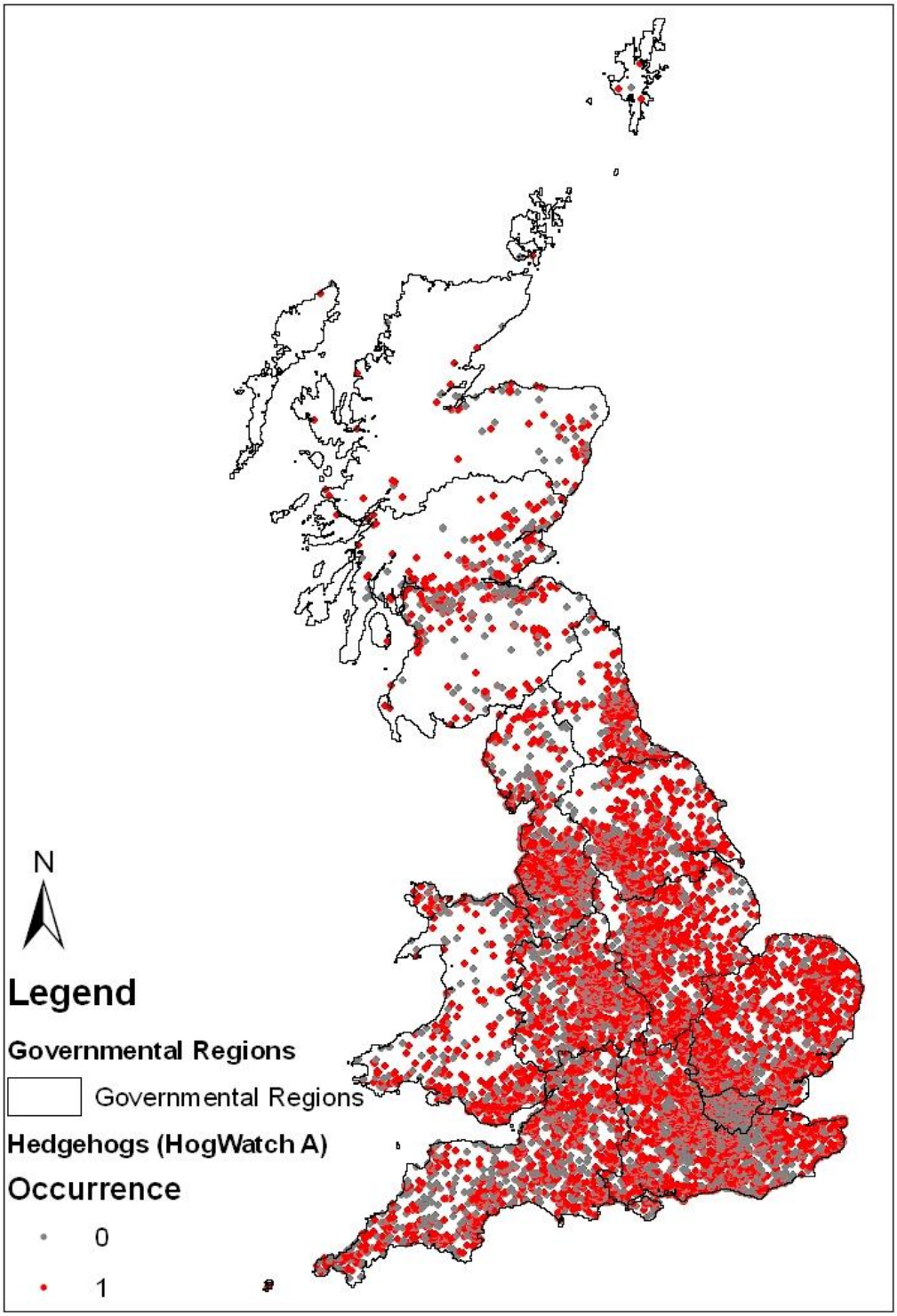


Figure 4 Hedgehog presence on HogWatch A sites, 2005-2007: the location of sites that submitted data to HogWatch A. Sites are shown as either having recorded the presence of hedgehogs (red) or absence (grey).

Table 4 Summary statistics from PTES HogWatch A, 2005-2007**.**

Year	Country	No. of submitted records	No. of unique locations submitting records	Live Hedgehogs	% locations with Hedgehogs	Recorders view of Hedgehog population changes the last 5 years				
						No answer	Do not know	Equally common	Less common	More common
2006	England	17448	16565	11005	66.4	12886	986	1325	1597	654
2006	Scotland	584	562	325	57.8	414	48	48	52	22
2006	Wales	748	722	488	67.6	536	38	71	70	33
2007	England	155	149	102	68.5	55	24	22	32	22
2007	Scotland	6	6	3	50	2	2	1	1	0
2007	Wales	9	9	4	44.4	1	3	0	2	3
2008	England	1	1	1	100	1	0	0	0	0
Total		**18951**	**18014**	**11928**		**13895**	**1101**	**1467**	**1754**	**734**

Note: Number of records submitted to HogWatch A as well as the number of unique locations, the number of live sightings of hedgehogs, the percentage of locations with live sightings of hedgehogs and the recorders opinion on hedgehog population changes in their local neighbourhood the last five years.

A total of 6477 records were submitted to the detailed HogWatch B survey. Eight records referred to sightings made before 2005, and were therefore excluded from further analyses, leaving a total of 6469 records. A majority of the records refer to observations made in 2006 (i.e. 86.8%; Table 5).

For Hogwatch B the spatial information was already available in the form of a grid reference, so no merging with the postcode database was needed. However, 600 records out of the total of 6469 (i.e. 9.3%) lacked a grid reference, and for some future analyses these records may have to be excluded.

The summary of the HogWatch B data suggest that Hedgehogs were observed in around 89% of the locations in 2006 (Table 5). This probably suggests that HogWatch B suffers even more from a lack of negative reporting than HogWatch A. The mean maximum number of Hedgehogs seen in a year was more or less constant between 2006 and 2010. The number of nests found in different stages were relatively low, but it seems likely that the detection of nests with large young is higher than the detection of nests with small young (Table 5).

In HogWatch B 6098 (i.e. 94.3%) of the records (i.e. including also records without hedgehog sightings) were submitted with a habitat. For the records with hedgehogs sightings with a habitat description (N=4921) the data suggest that a vast majority of the observations were made in gardens (73.0%; Table 6).

Table 5 Summary statistics from HogWatch B, 2005 to 2010.

Year	No. of submitted records	No. of unique locations submitting records	No. of gardens with live Hedgehogs	No. of records with live Hedgehogs observed outside gardens	The mean maximum no. of Hedgehogs observed	No nest found	Nests with small young found	Nests with large young found
2006	5614	4745	4217	786	1.47	5089	10	130
2007	607	463	494	76	1.49	580	0	5
2008	105	80	86	13	1.53	102	0	0
2009	58	39	52	5	1.47	57	0	1
2010	85	43	73	8	1.39	81	0	1
Total	**6469**	**5370**	**4922**	**888**		**5909**	**10**	**137**

Note: Number of records submitted to HogWatch B, as well as the number of unique locations, the number of live sightings of Hedgehogs in and outside gardens, the mean maximum number of hedgehogs observed and the number of nests in different stages found.

Table 6 Number of live sightings of hedgehogs in different habitat types submitted to HogWatch B, by year.

Year	Garden	Park	Churchyard or cemetery	School ground	Road or road verge	Deciduous woodland	Coniferous woodland	Arable farmland	Pastoral grazed farmland	Lowland heathland	Rough unfarmed downland	Rough unfarmed grassland	Rough unfarmed moorland
2006	3046	87	53	81	271	122	23	145	190	16	8	162	11
2007	374	6	0	11	39	10	1	15	15	1	1	19	0
2008	69	1	0	2	3	0	1	6	1	0	0	3	0
2009	41	0	0	2	3	1	3	3	2	0	0	0	0
2010	62	1	0	1	3	0	0	2	1	0	0	3	0
Total	**3592**	**95**	**53**	**97**	**319**	**133**	**28**	**171**	**209**	**17**	**9**	**187**	**11**

2.5 Breeding Bird Survey (BBS)

2.5.1 General information about the survey

The BTO/JNCC/RSPB Breeding Bird Survey (BBS) was launched in 1994, and continues under the partnership. The sampling design involves 3000 volunteer birdwatchers carrying out standardised annual bird counts on up to ca 3500 randomly located 1-km sites every year. Analyses of these annual counts enable BTO to calculate representative population trends for over 100 bird species. The field methods are that volunteers make three visits to randomly located 1-km squares. The first visit is to record habitat and to set up a suitable survey route (i.e. two roughly parallel 1 km long transects approximately 500 m apart). The second and third visits are to record birds and mammals that are seen or heard while walking along the route.

Mammal recording was first introduced to the BBS in 1995 with a view to help improve the knowledge of the distribution and population trends of some of the commoner and easily identified diurnal mammals. Even though mammal recording has always been a voluntary option in the scheme, more than 80% of BBS observers regularly record them during their bird-count visits. The information on species detected more often by signs of their presence than by sightings (e.g. badger, hedgehog and mole) can also be used to estimate trends, although these require more careful interpretation.

2.5.2 Data issues and scope

As the BBS was primarily developed for bird monitoring, not all volunteers monitor mammals when walking their BBS transects. However, when submitting their data, volunteers are asked to tick a box to show whether they monitored mammals or not. For the purpose of this study, we excluded records where the volunteer had indicated that they did not record mammals (approximately 15%, making the total number of useable transects 30140). This procedure gives us great confidence to say that a submitted record with no hedgehogs recorded means that the volunteer did not observe any Hedgehogs (i.e. there is no risk for "false negatives" in the BBS data).

For all years since mammal recording was introduced in BBS in 1995 it has been possible to enter the number of Hedgehogs recorded on both the first and second visit to the BBS square. However, the recording system for recording the presence of a species without counting the number of individuals has changed slightly over the years. For the years 1995-1999 a volunteer could indicate that the species was present, but that no count was made by submitting a "1" in the "presence" column. To indicate that the species was present and a count of the species was submitted the volunteer entered a "0" in the "presence" column. For the years 2000-2001 the system was made easier, so that the volunteer could only enter a "1" in the "presence" column for mammals species that were observed, regardless of whether a count was submitted or not. Finally, for the years 2002-2009 the presence code changed to indicate how the volunteer observed the mammal.

The codes for "presence" for these years were:

S = Seen on non-BBS visit (e.g. when walking the dog in the BBS square),

L = Local knowledge (e.g. when you know from field experience in the area that the species occur there),

D = Found dead in the BBS square,
F = Field signs (e.g. tracks, pellets, nests, dens and similar signs found in the BBS square),
C = Counted on BBS visit.

These changes in the way that mammals were recorded over the years put constraints on how the hedgehog data from the BBS survey can be used. Since 2002, when the more detailed presence codes have been in use, it is clear that "Local knowledge" is the most common type of presence code used for hedgehogs (N=577 site-season combinations; Table 7). Volunteers also often found dead hedgehogs (N=413) and observed (and counted) live hedgehogs on their transects (N=256; Table 7). It is however possible to use the full dataset from 1995 (or 1996, as the number of hedgehog records was so low that it is likely that volunteers were not effective mammal observers the first year; Table 7), if one considers using a composite number of transect where any sign of hedgehogs was reported (N=2594 for the years 1995-2009; Table 7).

BBS observers are asked to resurvey the same squares each year but for many reasons observers drop out and new squares are taken up, resulting in a rate of site turnover of about 10% per annum (Risely, unpublished). Hedgehogs are seldom seen during morning bird surveys (on just over 1% of squares) but other signs or information about their presence, including dead animals (on just over 2% of sites), results in an overall detection rate of 8.6%.

Table 7 Summary hedgehog statistics from the Breeding Bird Survey, 1995 to 2009.

Year[1]	Number of transects	Live Hedgehogs	Dead Hedgehogs	Field signs of Hedgehogs	Local knowledge suggest presence of Hedgehogs	Additional visits revealed presence of Hedgehogs	Total presence of Hedgehogs[2]
1995	1333	8	.	.	.	.	25
1996	1615	27	.	.	.	.	138
1997	1882	43	.	.	.	.	162
1998	1959	29	.	.	.	.	233
1999	2033	35	.	.	.	.	244
2000	1901	.	.	.	.	.	284
2001	518	.	.	.	.	.	106
2002	1824	15	52	33	77	33	196
2003	1942	10	55	36	78	22	192
2004	2098	7	48	35	79	24	182
2005	2429	13	34	36	66	14	153
2006	2755	13	59	28	92	14	194
2007	2915	26	68	34	79	24	216
2008	2516	14	56	16	67	13	156
2009	2420	16	41	15	39	13	113
Total	**30140**	**256**	**413**	**233**	**577**	**157**	**2594**

[1] In year 2001 the number of surveyed transects was reduced due to an outbreak of foot and mouth disease that restricted access to many sites.
[2] The 'total presence of Hedgehogs' comprises the number of transects where *any* sign of Hedgehogs was observed. At some transects several different types of signs were observed

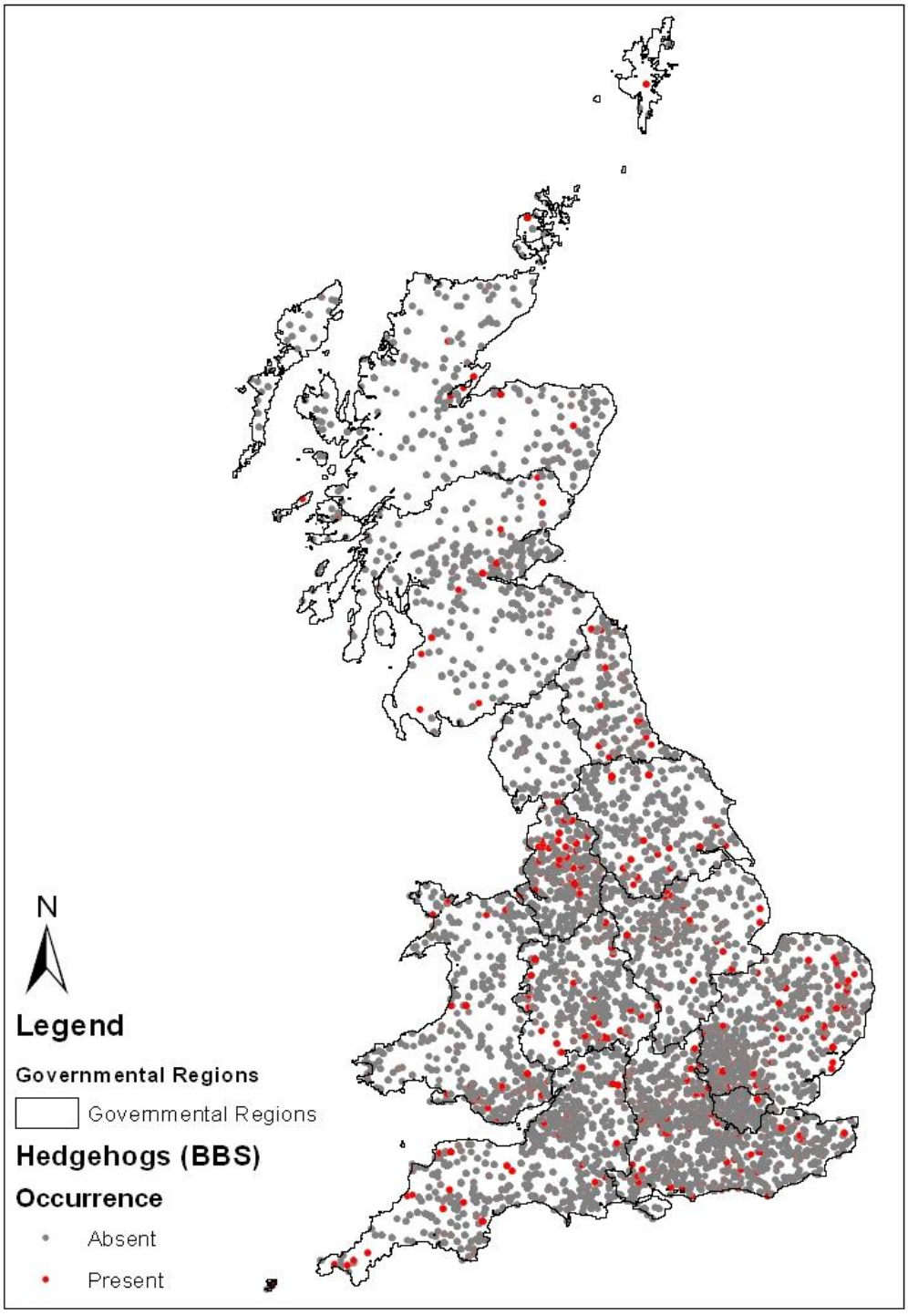


Figure 5 Hedgehog presence on BBS squares, 1996-2009: the location of sites where the Breeding Bird Survey (BBS) has been conducted at least once between the years 1996 and 2009. Sites are shown as either having recorded the presence of hedgehogs (red) or absence (grey).

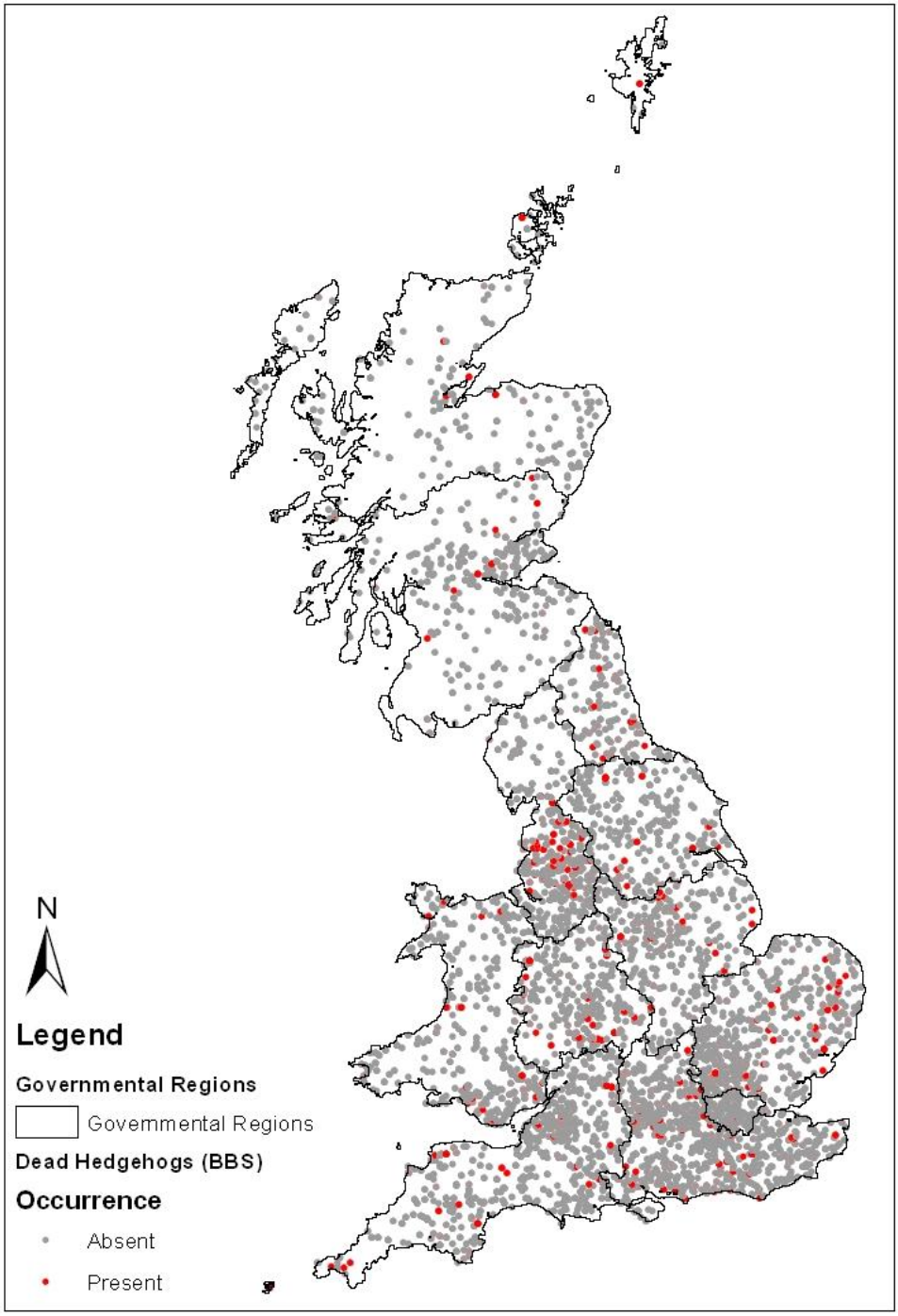


Figure 6 Hedgehog carcasses found on BBS squares, 2002-2009: the location of sites where the Breeding Bird Survey (BBS) has been conducted at least once between the years 2002 and 2009. Sites are shown as either having recorded the presence of dead hedgehogs (red) or absence (grey).

2.6 Garden BirdWatch (GBW)

2.6.1 General information about the survey

Garden BirdWatch, organised by the BTO, aims at collecting data on the use that birds and other wildlife make of gardens. It differs from other BTO schemes in that participants pay an annual fee to join the survey and in return receive feedback in the form of a regular newsletter *Bird Table* but otherwise the approach is quite similar to that used in many other long-running BTO surveys. Because it only requires observers to be able to identify common garden birds (and optionally other wildlife), it is suitable for relatively inexperienced participants and attracts a high level of participation.

GBW volunteers are asked to record the birds and other wildlife using their gardens, making records from the same garden at more or less the same time or times each week. Continuity of recording effort is more important than the quantity of recording, since this is a relative measure of garden use changing from week to week. Only species actively using the garden are recorded.

Volunteers record the maximum number of individuals of each species seen together at one point in time during the recording period. For taxa other than birds, volunteers can instead of maximum count data submit "presence" data (i.e. "1" for present). If maximum count data of a mammal species is submitted for a specific week the presence is automatically "1". The records can be submitted either on paper forms or online.

2.6.2 Data issues and scope

For these analyses, we used the data that had been submitted electronically between 1 January 2007 and 7 November 2010 (N=605,442 records). As the GBW was initially and primarily developed to survey birds, some volunteers do not record other taxa (e.g. mammals, butterflies, amphibians and reptiles). Thus, to make certain that we only analysed gardens where the observer recorded mammals, we excluded garden-year combinations where no mammal sightings were submitted. The rationale for this decision was that if observers are recording mammals they would be expected to detect and submit at least one mammal record per year. This exclusion reduced the number of useable records by about 33% (i.e. to 401,517 useable records). The geographical distribution of gardens that submitted mammal records is shown in Fig. 7.

As there were uncertainties whether a lack of a maximum count of hedgehogs for a specific week meant that the volunteer did not count mammals that particular week or whether it was because the volunteer looked out for but did not observe any mammals, we decided to only use the "presence" data and not the maximum count data.

In total, 24,942 hedgehog records were received between 2007 and 2010 (Table 8). Thus, on average 6.39% of all records from garden-year combinations where the observer was recording mammals was a hedgehog submission. The number of gardens participating in GBW mammal recording has increased from 1715 in 2007 to 3200 in 2010 (Table 8). On average, the percentage of GBW mammal recorders observing at least one hedgehog per year was 33.6%, but overall, the percentage has declined from 36.27 in 2007 to 30.63% in 2010. The overall rate

of annual turnover in Garden BirdWatch is about 15-20%, but those reporting mammals and other wildlife (possibly reflecting more biologically-rich gardens) may have an even higher retention rate.

Table 8 Summary hedgehog statistics from BTO Garden BirdWatch, 2007 to 2010.

Year	Total number of submissions	Number of Hedgehog submissions	% submissions reporting presence of Hedgehogs	Number of participating gardens	Number of gardens reporting presence of Hedgehogs	% gardens reporting presence of Hedgehogs
2007	65185	5155	7.91	1715	622	36.27
2008	113225	6527	5.76	2891	983	34.00
2009	119641	6950	5.81	3106	1039	33.45
2010	103466	6292	6.08	3200	980	30.63
Total	**401517**	**24924**	**6.39**		**3624**	**33.59**

Note: Information from BTO's GardenBirdWatch (GBW) on hedgehog presence and abundance. Only gardens that submitted at least one mammal record for the year of interest are included. The table shows the total number of GBW submissions, the number and % of submissions that reported hedgehogs as present. The table also shows the total number of participating gardens and the number and the percentage of gardens recording presence of hedgehogs.

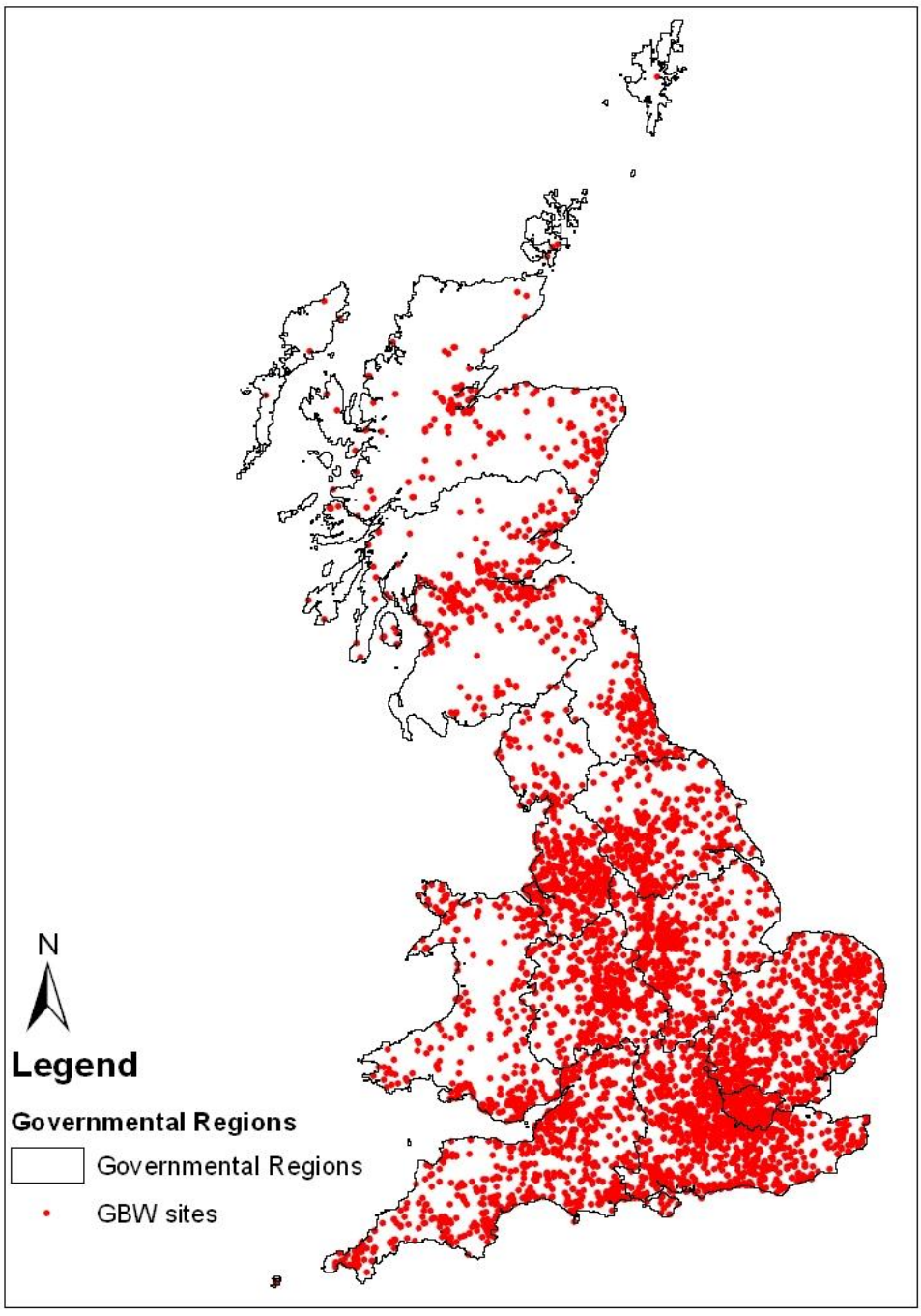


Figure 7 Location of GardenBirdWatch sites 2007 to 2010.

2.7 Waterways Breeding Bird Survey (WBBS)

2.7.1 General information about the survey

The Waterways Breeding Bird Survey (WBBS) is an annual survey of breeding birds and mammals along rivers and canals, organised by the BTO with funding from the BTO and the Environment Agency. It is a transect survey with many similarities to the Breeding Bird Survey (BBS). Volunteers walk along from just 500 metres to a maximum of 5 km of waterway, recording all birds and mammals that they see and hear using standardised protocols. The WBBS results supplement BBS by providing additional data on the birds and mammals of waterside habitats, particularly riparian bird specialists such as Common Sandpiper, Kingfisher and Dipper and riparian mammal specie such as American Mink, Water Vole and Otter.

The Waterways Breeding Bird Survey was started in 1998 and has become an annual survey. Around 200-300 river and canal sites are now surveyed each year for breeding birds by the BTO's volunteer observers (Fig. 8; Table 9). Site retention rate is similar to that of BBS, with about 10-15% turnover per year. Mammal recording has been optional since the start of the WBBS, with ca 80% participating annually. Relatively few live hedgehogs are seen but since 2002, the rate of occurrence of hedgehogs on routes, based on all evidence, has varied between ca 8% and 14% (Table 9).

Table 9 Summary hedgehog statistics from the Waterways Breeding Bird Survey, 1998 to 2009.

Year[1]	Number of transects	Live Hedgehogs	Dead Hedgehogs	Field signs of Hedgehogs	Local knowledge suggest presence of Hedgehogs	Additional visits revealed presence of Hedgehogs	Total presence of Hedgehogs[2]
1998	155	2	.	.	.	.	24
1999	171	2	.	.	.	.	36
2000	158	0	.	.	.	.	33
2001	46	1	.	.	.	.	8
2002	196	0	2	3	6	9	17
2003	217	6	5	2	14	5	31
2004	242	4	3	3	23	4	31
2005	231	1	4	6	16	5	27
2006	225	2	5	3	13	6	23
2007	214	0	1	2	13	6	21
2008	212	0	2	3	13	7	24
2009	210	0	3	4	16	4	23
Total	**2277**	**18**	**25**	**26**	**114**	**46**	**298**

Note: The number of Waterways Breeding Bird Survey (WBBS) transects recording the presence of hedgehogs, divided into encounters of live and dead hedgehogs, field signs of hedgehogs, additional information from local sources and additional field visits by the observer. For the years (1998-2001), the type of evidence was not specified.

[1] In year 2001 the number of surveyed transects was reduced due to an outbreak of foot and mouth disease that restricted access to many sites

[2] The total presence of hedgehogs presents the number of transects where *any* sign of hedgehogs was observed. At some transects several different types of signs were observed.

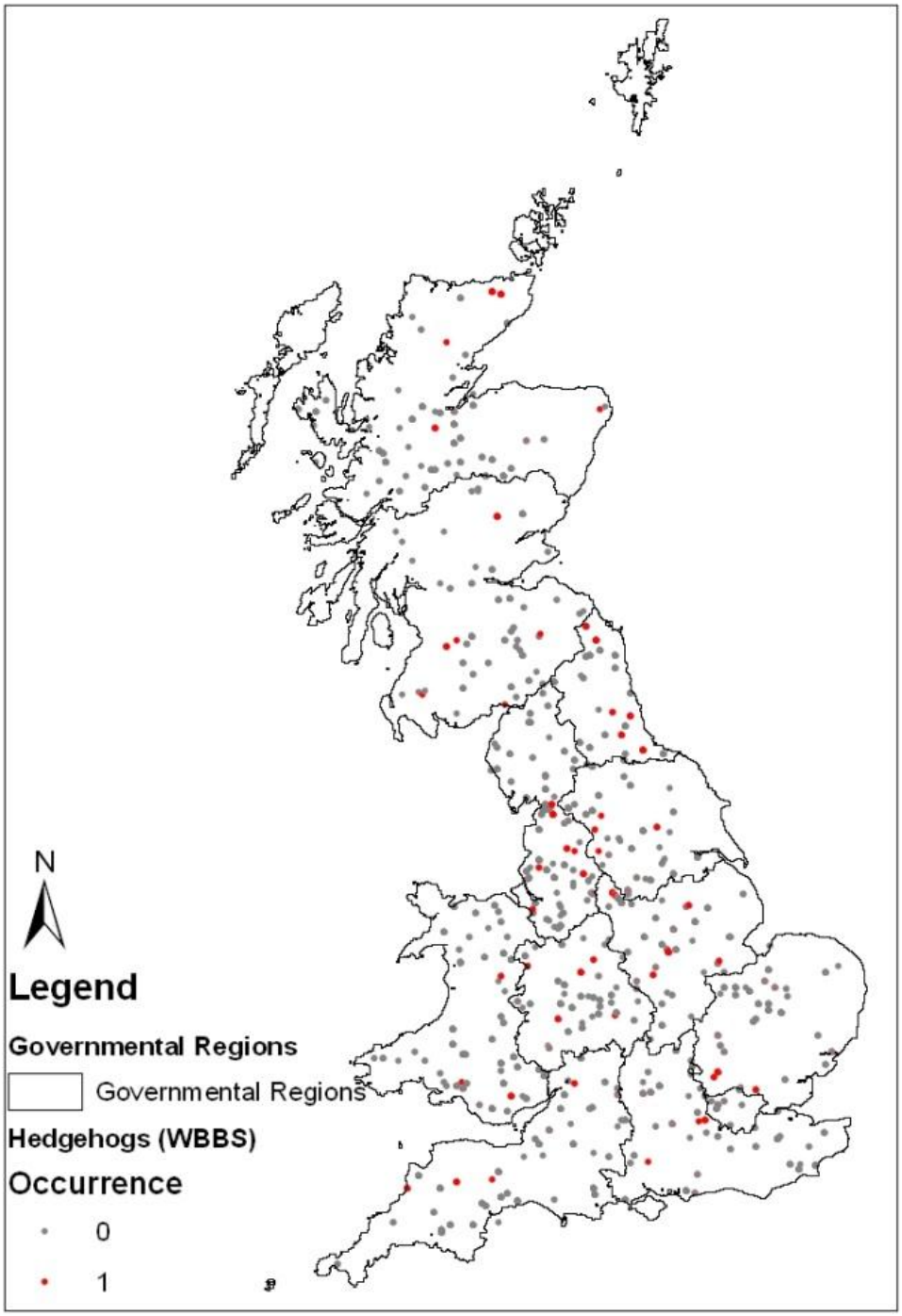


Figure 8 Hedgehog presence on WBBS sites, 1998-2009: the location and presence of hedgehogs on Waterways Breeding Bird Survey (WBBS) sites between 1998 and 2010.

2.8 Analytical methods

2.8.1 Calculating current trends in occurrence

For appropriate metrics obtained from each of the available datasets from the different surveys that were run for three or more years, we modelled the occurrence of Hedgehogs (i.e. presence vs. absence) using year and site as independent variables. As the occurrence of hedgehogs at a site was binomially distributed, we used a binomial error distribution with a logit link function. All modelling was done using Generalized Linear Models (PROC GENMOD in SAS). Additionally, for the Mammals on Roads data, we also modelled the abundance of hedgehogs (as measured by the number of carcasses encountered during each trip) again using site and year as independent variables. For these analyses, we used a Poisson error distribution with a log link function. BBS and WBBS observers also count live hedgehogs but too few are seen on these diurnal surveys and data were too few to analyse. No other variables were included in the models although we tested for a possible influence of journey length by re-analysing some of the Mammals on Roads data with 'journey length' included in the model as an offset (see below).

2.8.2 Power analyses

To assess the likelihood of being able to detect 10%, 25% and 50% declines of Hedgehogs we needed to use a different approach. Estimation of power to detect change over a period of years is based upon repeated Monte-Carlo simulation techniques (Morgan, 1984). A survey is assumed to yield presence/absence data x_{it} at sites i=1,2…I over a number of years t=1,2….T. This process is simulated by generating repeated random variables from a Bernoulli distribution with probability of presence p_{it} defined by the sum of site (S_i) and year (Y_j) effects as follows:

(1) $$\text{logit}(Y_t * p_{it}) = S_i$$

where logit is the logit link transformation: logit(x) = log(x) - log(1-x). And S_i is drawn from a normal distribution with mean and variance informed by the data. Y_t is defined such that a linear trend over T years describes a set percentage reduction in the probability of a site being occupied. Thus the data match a Generalized Linear Model (GLM) widely adopted in producing trends from real survey data for birds, and many other taxa.

Within the simulations, the temporal trend Y_t is assumed to vary linearly over time, to an extent characterised by one of three conditions, namely a decline of 10%, 25% or 50% over a study of T years duration (T=10 or T=25 in these simulations). The decline in the probability of occupancy is assumed to apply at all sites (at which the changes therefore act in parallel, but for stochastic variation) and the null hypothesis of no change is tested.

In other words, by using randomly drawn values of how often individual sites were monitored in each survey, and the frequency that Hedgehogs were observed (based on the mean and variance from the real survey data), we created simulated datasets that spanned 10 or 25 years for each survey. Thus, every simulated dataset varied slightly in the occurrence of Hedgehogs, but as a whole the dataset contained as many "presences" and "absences" as the real survey. The "occurrence" of Hedgehogs in these simulated datasets was then modelled using Generalized Linear Mixed Models (GLMM) in Program R. Specifically we modelled the

occurrence of Hedgehogs as a response to the independent variables year and site, the latter being a random factor. By running the analyses on each of the simulated datasets, and comparing how often the population trends declined, we were able to calculate the power to detect such declines of 10 and 25 years.

As any survey is vulnerable to intermittent missing data due to volunteer turnover or temporary unavailability, or changes in land access, in all cases we have assumed that the pattern of surveys and duration of time over which individual sites are monitored was equivalent to that observed in the data. The form of the model means that such missing values are routinely accommodated in the fitting.

In summary, we produced sets of simulated data and fitted them with bionomial (or Poisson) models for each of the scenarios with differing:

(i) duration (T = 10 or 25 years)

(ii) overall rate of decline – a constant annual rate to year T of 10%, 25% or 50%

(iii) sample size, mean and variance based on the current situation nationally, within countries and within regions (unless otherwise specified).

The numbers of these simulations producing a decline significant at the conventional level $\alpha = 0.05$ are adopted and used, expressed as a proportion of the replicates, as estimates of the survey's power in the given set of conditions. For most power analyses, we used 50 iterations. This is low but necessary because of the complexity of the modelling approach and the computing capacity required. Using a larger number of iterations would tend to smooth out the estimates of power with increasing sample size.

3. RESULTS & DISCUSSIONS

3.1 Trends in Hedgehog occurrence and abundance

The results from all of the surveys analysed to date suggest that the presence of hedgehogs (i.e. presence-absence data) has declined over the past 3 to 13 years (the range of time series sampled). Of surveys for which data has been collected for more than two consecutive years, four reveal a significant decline in hedgehog presence (Table 10) and one (Living with Mammals) showed a non-significant decline. In addition to the measures of hedgehog presence extractable from all surveys, Mammals on Roads dataset provides a count of hedgehogs detected during each journey by the observer at a sufficiently high encounter rate to allow an analysis of changes in hedgehog relative abundance. The numbers of hedgehogs encountered on MoR also showed a significant decline, in agreement with the observed decline in occurrence (Table 10). Live hedgehogs are also counted during BBS and WBBS visits but too few are seen using this protocol to estimate a reliable trend.

Table 10 Trend analyses of Hedgehog occurrence, and numbers for MoR, using data from surveys where data were collected for more than two years. The estimates of slope (i.e. the values for *B*) are all negative, indicating that all surveys are detecting a decline .

Survey	Years	*B ± SE*	*z*	*p*
GardenBirdWatch	2007-2010	-0.079 ± 0.022	-3.61	<0.001
WBBS	1998-2009	-0.072 ± 0.032	-2.27	0.023
BBS (dead only)	2002-2009	-0.048 ± 0.026	-1.88	0.060 NS
BBS (any presence)	1996-2009	-0.060 ± 0.006	-10.74	<0.001
MoR (presence)	2001-2010	-0.034 ± 0.011	-3.23	0.001
MoR (counts)	2001-2010	-0.022 ± 0.007	-3.00	0.003
LWM	2003-2010	-0.026 ± 0.015	-1.66	0.097 NS

In the next table, the overall percentage change in occupancy, or abundance, for each survey was calculated by fitting a linear trend to the raw data, and calculating the percentage change over the survey duration. The annual percentage change was then calculated by taking the nth root of the overall change, where n is the number of inter-year intervals in the time series. For example, the Mammals on Roads survey suggests that between 2001 and 2009, hedgehog occupancy declined by 14.8%, equivalent to decline of 1.8% per year. Because fitting a linear trend to the data smooths out many of the between year fluctuations, the overall percentage change shown in the table is the best estimate of change over the time period of the survey. From these values, we were also able to generate an overall estimate of change in occupancy over ten years using the annual rate of growth figures for each survey and extrapolating to ten years, which is a slightly greater duration than the longer time series (the mean was just over 7 years). Using all measures except WBBS for which a linear trend could not be fitted, resulted in an average change of -40% over ten years. Restricting the averaging to one measure of occupancy per survey (the one considered most appropriate) resulted in a very similar estimate of -42% over ten years.

Table 11. Population changes in hedgehogs for each survey, estimated by fitting a linear trend

Survey	First year	Last year	Duration	Overall % change	Annual % change
MoR	2001	2009	9	-14.8	-1.8
MoR_counts	2001	2009	9	-21.5	-2.7
LwM	2003	2010	8	-32.1	-4.7
BBS	1996	2009	14	-66.4	-7.5
BBS.dead	2002	2009	8	-52.2	-8.8

GBW	2007	2010	4	-36.3	-10.7
WBBS	1998	2009	12	extremely non-linear trend so not fitted	

We also estimated overall change in another way, without assuming a linear trend and incorporating the annual fluctuations. Hence % change was calculated by averaging out the proportional change from the index in the first year of the survey, to the index in the last year. The figures are therefore sensitive to stochasticity in the index in these two years. For example, the Mammals on Roads survey suggests that from 2001 to 2010 hedgehog occupancy declined by 19.5%, an equivalent of 2.4% per year. We recommend using the linear trend approach as above but it should be noted that the annual fluctuations seen in the plots could be real.

Table 12. Population changes in hedgehogs for each survey, estimated using an annual model

Survey	First year	Last year	Duration	Overall % change	Annual % change
MoR	2001	2009	9	-19.5	-2.4
MoR_counts	2001	2009	9	-25.8	-3.3
LwM	2003	2010	8	-22.0	-3.1
BBS	1996	2009	14	-56.0	-5.7
BBS.dead	2002	2009	8	-52.0	-8.8
GBW	2007	2010	4	-30.1	-8.6
WBBS	1998	2009	12	-78.4	-12.0

For Mammals on Roads, we also considered the influence of possible changes in the distance travelled between years. The mean distance travelled per journey showed relatively little variation between years (even as the number of journeys per year diminished) varying from 41 miles in 2001 to 50 miles in 2006. Moreover, neither the counts of hedgehogs seen per journey or the estimated count of hedgehogs seen per 100 miles showed a marked trend. Over the period 2001 to 2009, the mean number of hedgehogs seen per 100 miles was 2.23 (based on an average of about one dead hedgehog per 40 to 50 mile journey), about 14% fewer than the 2.59 per 100 miles reported a decade earlier in the 1994 Hedgehog Roadkill Survey (unpublished results). Although a test of the mean distance per journey showed no significant effect of year, and indeed no evidence of a trend, we reanalysed the trends in the presence/absence of hedgehogs including journey length as an offset in the model. Using this model suggested greater oscillation in the trend between years but little overall difference (Figure 10).

Figure 9 Comparison of two analytical approaches to estimating hedgehog population trends using Mammals on Roads data, one including journey distance.

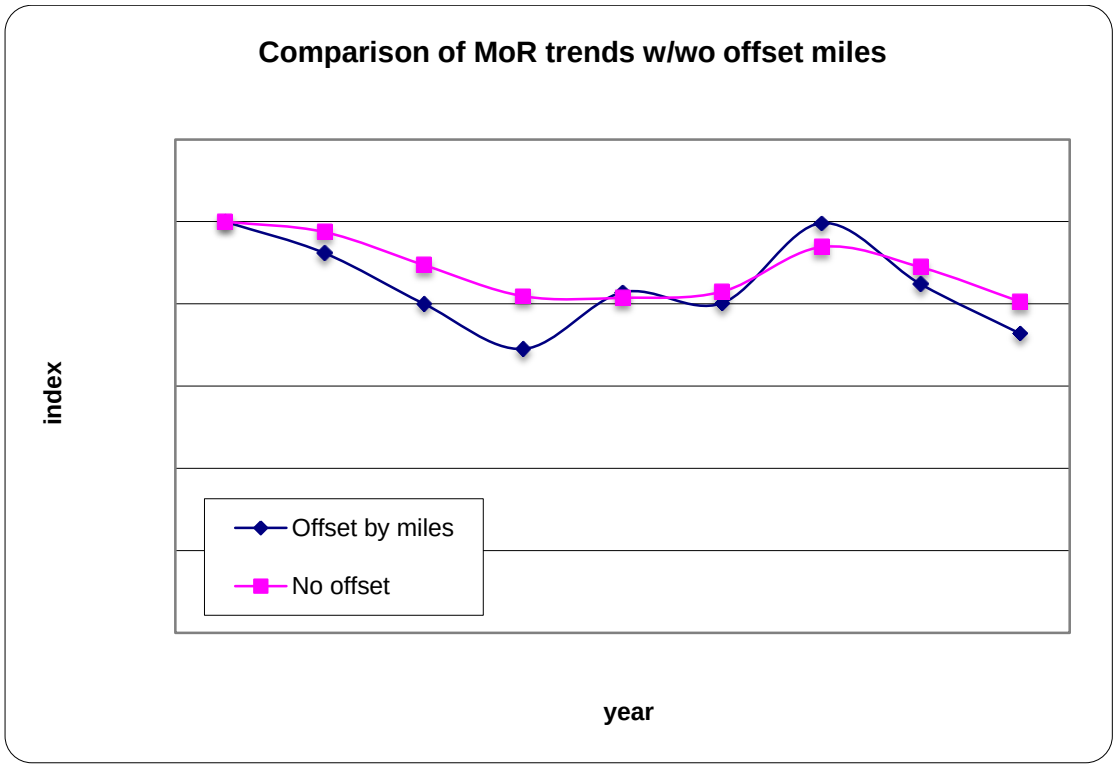
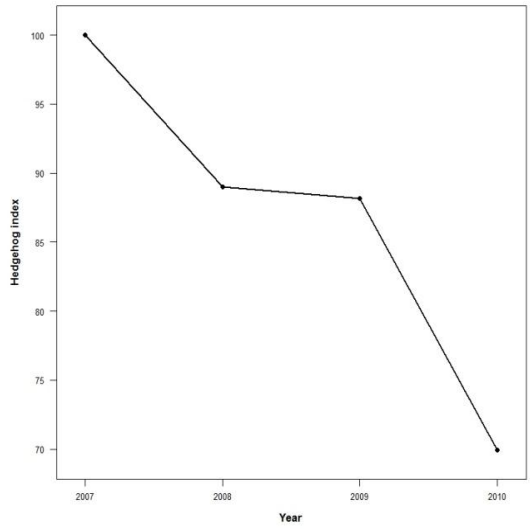


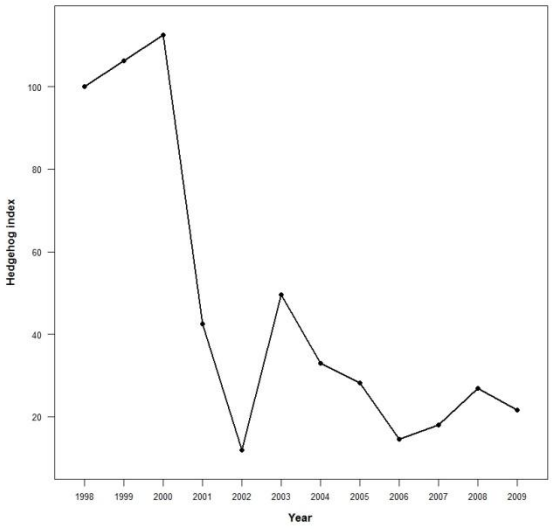
Figure 10 shows the pattern of trends in hedgehog occurrence revealed by the different surveys (or subsets of survey data) over the time series available for each survey. The index values in all figures are standardised to 100 in the first year, and reflect the probability of detecting a hedgehog in a particular year in relation to the probability of detecting a hedgehog in the first year in the time series. Hence, for example, a value of '50' in the last year for a given survey means that the index of occupancy is 50% lower than in the first year. But occupancy in the first year could have been ca 10% or up to 40% depending on the methodology for that survey.

Figure 10 Hedgehog trends based on: a) Garden BirdWatch, b) Waterways Breeding Bird Survey, c) Breeding Bird Survey (all records), d) Breeding Bird Survey (dead hedgehogs only), e) Mammals on Roads (occurrence of hedgehogs), f) Mammals on Roads (numbers of hedgehogs) and g) Living with Mammals.

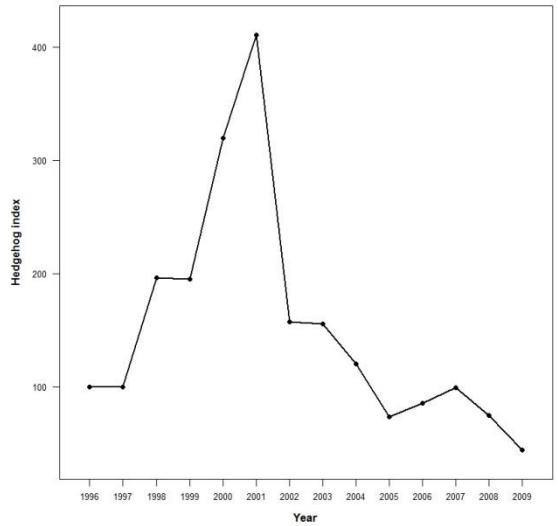
a) Garden BirdWatch



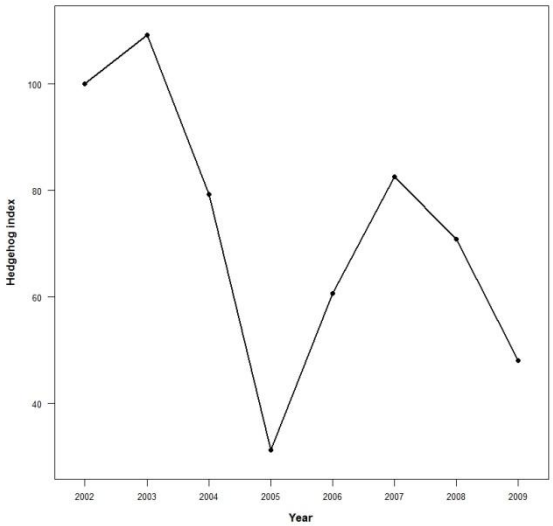
b) Waterways Breeding Bird Survey



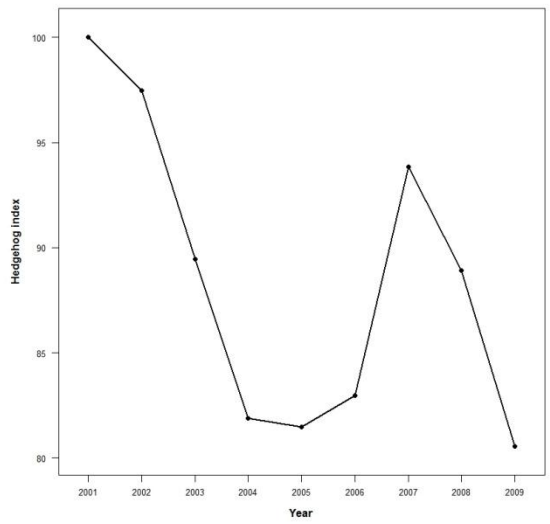
c) Breeding Bird Survey (all records)



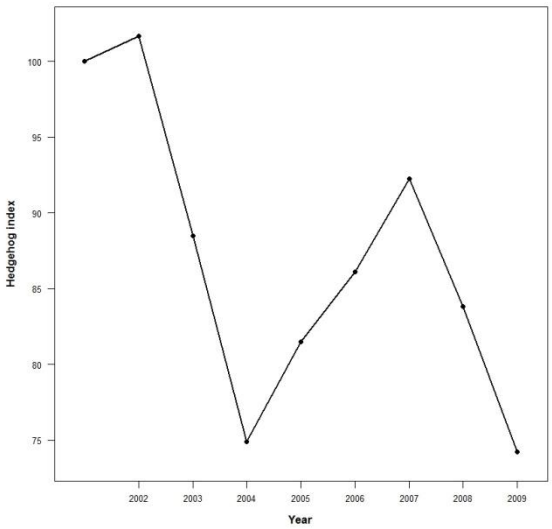
d) Breeding Bird Survey (dead hedgehogs)



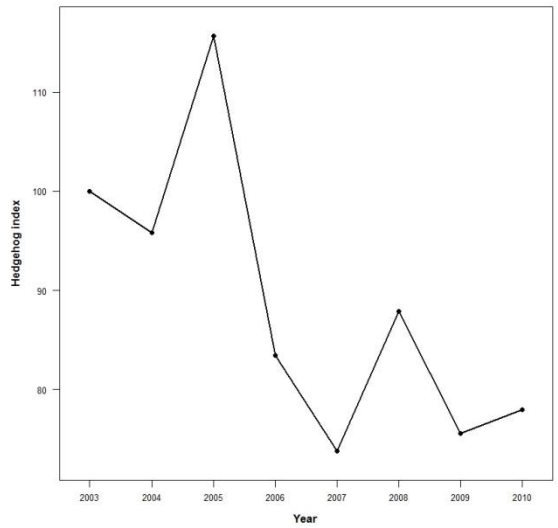
e) Mammals on Roads



f) Mammals on Roads (abundance)



g) Living with Mammals



Of surveys designed to be representative of the wider countryside, BBS, WBBS and MoR all show evidence of marked decline, particularly over the period 2002/2003 to 2009. Note that estimates for 2001 are unavailable because of unrepresentative sampling during this period of restricted access to the countryside, and hence estimates for that year are interpolated from estimates for 2000 and 2002. Although BBS (all records) and WBBS (all records) show evidence of increases between 1996 and 2000, and 1998 and 2000, respectively, volunteer interpretation of the protocols employed prior to 2002 may have contributed to this apparent increase. Changes in the wording of the instructions were introduced in 2002 and since that year records of presence of hedgehog on both BBS and WBBS have declined, roughly in parallel. The results from Mammals on Roads revealed a strikingly similar pattern of declines since 2003, with some variation in the pattern in 2004 and 2005 between measures of occurrence and measures of abundance.

Of the two surveys aimed largely at gardens and more human-dominated habitats (Garden BirdWatch and Living with Mammals), results revealed overall declines since 2007 and 2003, respectively. The inter-annual fluctuations in indices for LWM differed from the countryside surveys

over the period of overlap (2004 to 2009) but the downward trend in presence of hedgehogs in GBW gardens between 2007 and 2009 was supported by results from BBS and Mammals of Roads.

These results highlight a very important finding on the importance of repeat visits to sites in estimating changes in population status. It can be observed that the level of decline suggested by the summary tables for some schemes (e.g. Living with Mammals) are much less marked than those revealed by the trend analyses carried out in this study that account for repeat visits to sites in subsequent years. Firstly, such measures will differ because the modelling approach requires that all sites included are visited at least twice – whereas the summary data by year include all sites, including those just visited once. Secondly and more importantly, the trend analyses are strongly influenced by sites surveyed in the greatest number of years. In the case of Living with Mammals, although 2500 sites were surveyed in total, only 130 sites were surveyed every year. In surveys where observers are freely allowed to choose their sites, it seems quite possible that new participants entering the scheme each year are more likely to be those where hedgehogs are present than where they are absent. Such a bias in site turnover could easily result in the less marked declines revealed by the summary tables of occupancy per year, compared to those revealed by the trend analyses and highlights the importance of having participants revisit the same sites , the recording of absences as well as presences, and the need to account for site effects in surveys, especially where sites are freely selected by participants, and where the survey is focused on a single or very few species (e.g. Hogwatch).

3.2 Other measures of change in the status of hedgehog populations

Although we were not able to analyse GWCT game bag data for hedgehogs for this report, information on hedgehog population trends from game bags has been recently published by GWCT (Davey et al. 2010). This showed that in the UK, Hedgehog numbers had declined by 28% (albeit non-significantly) in NGC game bags between 1995 and 2008. Declines were least severe in England (-22%), intermediate in Scotland (-36%) and most severe in Wales (-65% and significant although based on a small sample). All regions within England showed evidence of hedgehog declines over this period with steepest declines in the Northwest, Southeast and East Midlands.

This is the only hedgehog dataset that goes back significantly more than a decade, and over the longer term since 1961, Hedgehogs in game bags have fallen by 49% across the UK. However, partial protection of the hedgehog by the 1981 Wildlife and Countryside Act is likely to have resulted in a reduction of numbers killed and/or recorded on estates since then, and complicates interpretation.

Trends derived from bags are unusual because the data represent numbers of animals killed rather than counts of live animals. Hence there are potential biases with bag data that do not occur with count data and that could obscure an underlying trend. Importantly, the number of animals killed is a function of their abundance on the ground and the amount of effort invested in culling them. For predatory/pest species such as Hedgehog, the number of gamekeepers per site, number of traps set, type of trap and duration of trapping will all influence effort and contribute to variation in the numbers killed. However, in practice, it appears that much of this variation adds noise to an underlying trend that reflects population density (Whitlock et al. 2003). Formal comparisons of NGC mammal trends with those derived from BBS were recently carried out jointly by BTO and GWCT but hedgehog trends could not be reliably compared because of differences in the measures recorded (numbers versus occupancy).

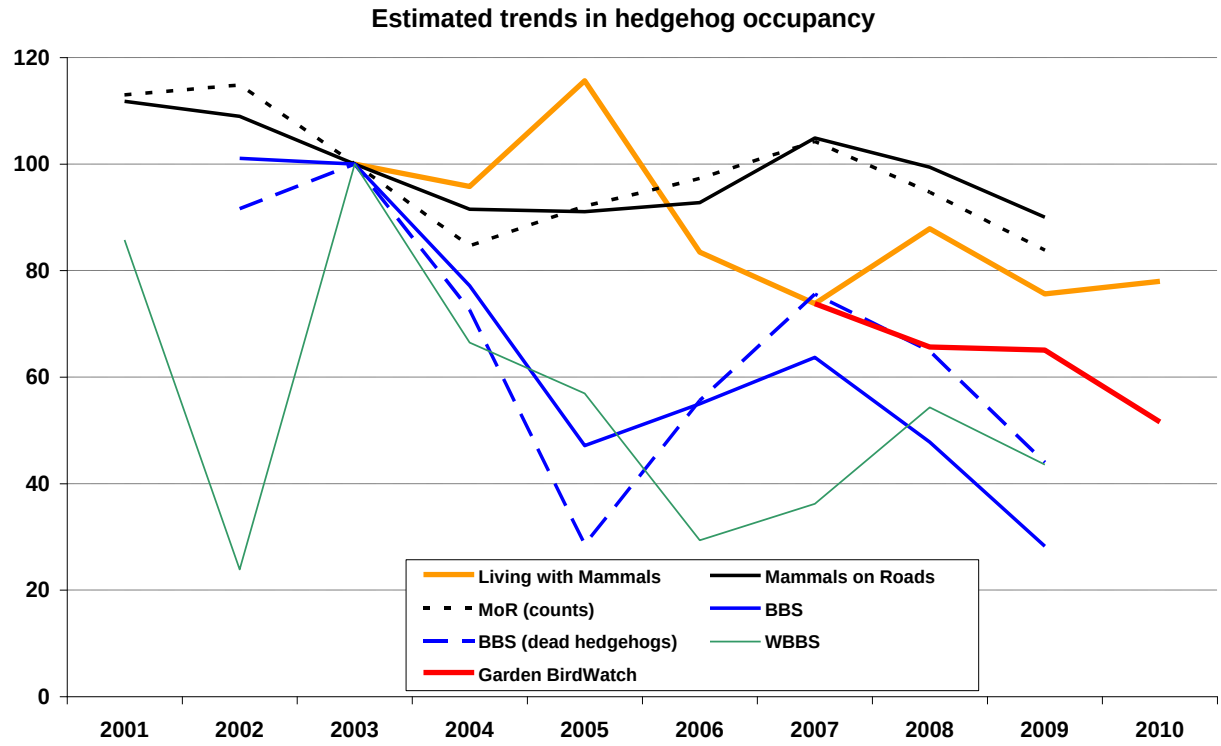
Two other surveys are comprised largely on observations made in garden and in urban areas (Making Your Nature Count and HogWatch). Due to the lack of a repeatable sample or the relatively short duration of these surveys, it was not possible to model changes in occupancy in the same way.

Instead, we calculated the proportion of sites occupied by hedgehogs (according to the criteria set in the survey protocols) and compared between years using contingency tests.

These analyses revealed a very small but significant increase from 76.9% to 78.1 % in the proportion of MYNC sites in Great Britain where hedgehogs were detected between 2009 and 2010 (Chi square = 7.84, p=0.005). Although this is largely due to the small but significant change in England (from 77.35 to 78.5%), similar non-significant increases were found in both Scotland (72.4% to 73.0%) and in Wales (75.6% to 77.5%). We do not feel that these increases are biologically important. The rates of occupancy derived from HogWatch B, which were already high, in excess of 90%, also exhibited a significant increase over the period 2006 to 2010, but due to the reduction of the sample over this period, it is highly likely that the apparent increase in occupancy reflects a bias towards increased response rates where hedgehogs continue to be detected.

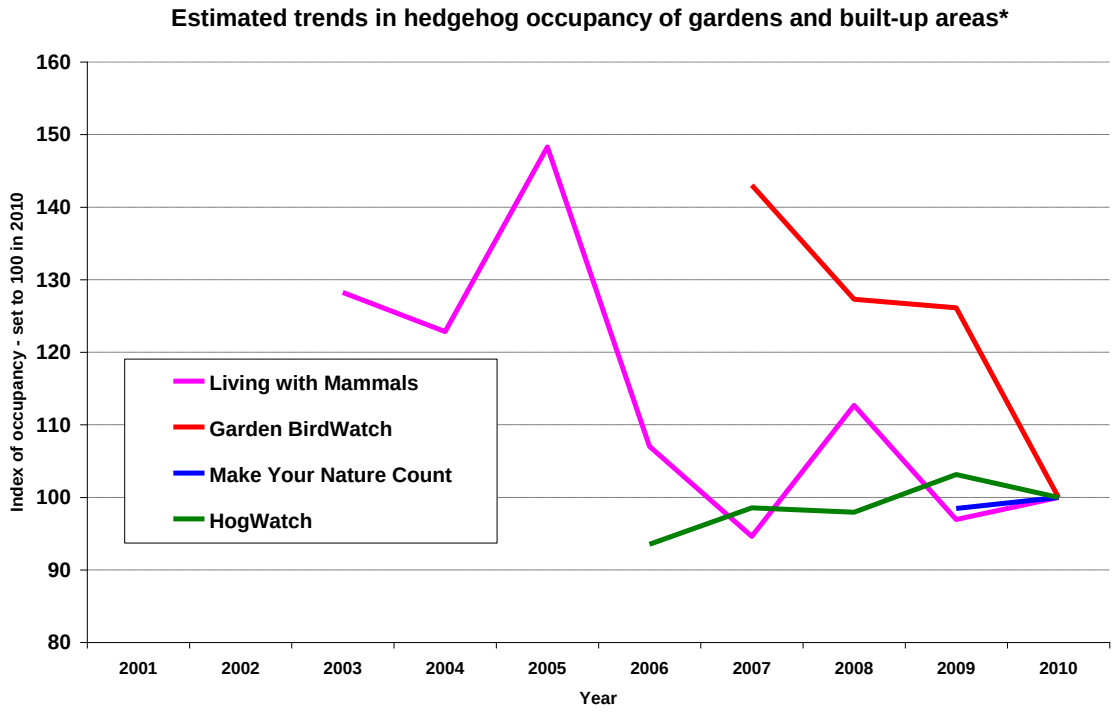
In order to compare patterns of change in occupancy revealed by these different surveys, we plotted them all on the same plot with the relative indices standardised by setting them all to '100' in 2003, the year where time series most frequently overlapped. Because the time series for GBW does not start until 2007, we added this trend to the plot by setting the GBW initial index to that of Living with Mammals in its year of entry (2007). For this purpose, we start in 2001 (the first year of Mammals on Roads) and exclude BBS and WBBS trends prior to 2001. In fact, 2002 is the starting year of current recording protocols for BBS and WBBS so values prior to 2002 are considered subject to bias.

Figure 11 Comparison of trends in occupancy and/or abundance of hedgehogs based on seven measures from five surveys, relative to a common year, 2003. Note that actual rates of occupancy vary considerably across surveys, due to differences in detectability in sampling and recording protocols.



We also provide below a plot showing the changes in occupancy revealed by four different surveys that are largely comprised of gardens, and hence not necessarily representative of the wider countryside, agricultural or woodland areas. For purposes of comparison, these four measures of change in occupancy (from Living with Mammals, HogWatch B, Garden BirdWatch and Making Your Nature Count) are standardised to a common index of 100 in their common ultimate year (2010).

Figure 12 Comparison of trends in occupancy or abundance of hedgehogs in gardens and other areas mainly near human dwellings, based on four different surveys, standardised to the same end point in 2010. Note that actual rates of occupancy vary considerably across surveys, due to differences in sampling and recording protocols, and that the index on the y-axis is a relative measure (in this case compared to the last year).



3.3 Results of power analyses

This section describes the findings of the power analyses. The following tables provide the results of the power analyses for the seven measures of hedgehog occupancy or abundance available from surveys with an easily repeatable sampling design. The first (Table 11) shows that at the national level, all of the assessed surveys would be sufficient to detect sustained red-level (50%) declines over a 25 year period, but only GBW, BBS (all records), Mammals on Roads and Living with Mammals, would reliably be able to detect less severe declines of 10% or 25%. Because 25 years is a long period, and biologically significant levels of decline would ideally be detected sooner, we also determined the power of each survey over a ten-year period (Table 12). Although powers were slightly reduced, there was no substantive change in the pattern and the same four surveys at the national level, all had sufficient power to detect declines of 10%, 25% or 50%.

Table 13. The power to detect hedgehog population changes of -10%, -25% and -50% in the UK over 25 years using simulated data based on hedgehog occurrence from each survey.

Survey	Population change and Power		
	-10%	-25%	-50%
GardenBirdWatch	1.00	1.00	1.00
WBBS	0.12	0.51	1.00
BBS (dead only)	0.02	0.24	0.88
BBS (any presence)	0.73	1.00	1.00
MoR (presence)	1.00	1.00	1.00
MoR (numbers)	1.00	1.00	1.00
LWM	0.82	1.00	1.00

Table 14. The power to detect hedgehog population changes of -10%, -25% and -50% in Great Britain over 10 years using simulated data based on observed hedgehog occurrence from each survey.

Survey	Population change and Power		
	-10%	-25%	-50%
GardenBirdWatch	1.00	1.00	1.00
WBBS	0.02	0.24	0.78
BBS (dead only)	0.06	0.31	0.98
BBS (any presence)	0.78	0.98	1.00
MoR	1.00	1.00	1.00
LWM	0.76	1.00	1.00

Table 15. The power to detect 5%, 10%, 25% and 50% population declines over 5 years

Survey	Population decline			
	5%	10%	25%	50%
GBW	1.00	1.00	1.00	1.00
BBS (any presence)	0.18	0.18	0.88	1.00
BBS (dead)	0.10	0.20	0.22	0.98
WBBS	0.02	0.10	0.27	0.92
LWM	0.31	0.71	1.00	1.00
MoR	0.51	0.92	1.00	1.00

In addition to determining the population status of hedgehogs at the UK level, a second question was whether current survey efforts would be able to detect significant declines in hedgehogs at the country or smaller regional level. The following tables provide the results of power analyses for the

same seven measures of hedgehog occupancy or abundance available from the five long-term surveys, but at the country level (Table 13) or regional level (Table 14) over 25 years.

Mammals on Roads and GBW performed best overall and, importantly, had sufficient power to detect 25% declines in Wales, the smallest country and with the lowest sampling effort. For comparing the power of different surveys to detect changes in occupancy at the regional level, we divided England into three regions. The western part of England (the Southwest, the West Midlands and the Northwest government office regions) were combined with Wales to create one region. The 'South / East England' region in Table 14 is comprised of the Southeast, the East Midlands and the East of England. , The 'East / North England' region is comprised of the East Midlands, Yorkshire and the Humber, and the Northeast. Using these divisions, there was sufficient power in most surveys (BBS – all records, Mammals on Roads, GBW and Living with Mammals (except in Scotland and southeast England) to detect regional declines of 25% or more.

Table 16. The power to detect hedgehog population changes of -10%, -25% and -50% over 25 years in Scotland, England and Wales using simulated data based on observed hedgehog occurrence from surveys where the sample sizes were large enough for breakdown by country. Shading denotes a power of 75% or greater.

Survey and Country	**Population change and Power**		
	-10%	**-25%**	**-50%**
BBS (any presence)			
Scotland	0.20	0.98	1.00
England	0.65	1.00	1.00
Wales	0.04	0.08	0.47
BBS (dead Hedgehogs)			
Scotland	0.02	0.02	0.16
England	0.12	0.49	1.00
Wales	0.06	0.35	0.98
GBW			
Scotland	0.67	1.00	1.00
England	1.00	1.00	1.00
Wales	0.29	1.00	1.00
MoR			
Scotland	0.86	1.00	1.00
England	1.00	1.00	1.00
Wales	0.63	1.00	1.00
LWM			
Scotland	0.14	0.37	0.98
England	0.29	0.94	1.00
Wales	0.06	0.20	0.76

Table 17 The power to detect hedgehog population changes of -10%, -25% and -50% over 25 years in regions of the UK (see text) using simulated data based on observed hedgehog occurrence from surveys where the sample sizes were large enough for breakdown by country. Shading denotes a power of 75% or greater.

Survey and Region	Population change and Power		
	-10%	**-25%**	**-50%**
BBS (any presence)			
Scotland	0.20	0.98	1.00
East / North England	0.12	0.94	1.00
West England and Wales	0.10	0.78	1.00
South / East England	0.10	0.76	1.00
BBS (dead Hedgehogs)			
Scotland	0.67	1.00	1.00
East / North England	0.02	0.14	0.61
West England and Wales	0.00	0.14	0.67
South / East England	0.00	0.12	0.94
GBW			
Scotland	0.67	1.00	1.00
East / North England	0.69	1.00	1.00
West England and Wales	0.90	1.00	1.00
South / East England	1.00	1.00	1.00
MoR			
Scotland	0.86	1.00	1.00
East / North England	1.00	1.00	1.00
West England and Wales	1.00	1.00	1.00
South / East England	1.00	1.00	1.00
LWM			
Scotland	0.14	0.37	0.98
East / North England	0.27	0.90	1.00
West England and Wales	0.27	0.96	1.00
South / East England	0.06	0.45	1.00

3.3.1 Relationship between power and number of sites

This section describes the results of power analyses carried out to determine the sample sizes required to achieve sufficient power to detect declines of 5% to 10% over five to ten years, for two different surveys (Living with Mammals and Mammals on Roads). These are the two volunteer surveys currently coordinated by PTES that provide annual data on the presence of hedgehogs, and hence could potentially be modified in scope (reduced or expanded) to provide the required extent of data. We explored this question using two different scenarios: (i) when the same sites are surveyed each year, and (ii) when different sites are surveyed each year. The approach and details of the models are described below.

Power was estimated using simulations, repeated over many iterations to determine the power of detecting a statistically significant level of change over a given period. The level of change and time period is set by the programmer, and the proportion of sites which have presences, and the variation of 'presences' within sites were replicated at similar levels to the real data. For simulations for both surveys, the number of sites tested was increased from 20, to 50, 100, 200, 300, 500, 1000 or 2000. The upper ranges of these sample sizes are also broadly equivalent to the range of sites monitored each year by the surveys (Mammals on Roads has declined from an initial sample of ca 2000 in 2001 to ca 500 in 2009; and annual coverage on Living with Mammals has averaged between 500 and 700). In practice, the number of sites for which simulations were run was increased for each scenario until either 2000 sites, or a power of 0.8 was reached, whichever was sooner. This was due to the long time taken to run the simulations with a high number of sites.

For each simulation, the number of sites being surveyed in each year is set. The proportion of presences are modelled to decline by a specified amount (5% or 10%) over a set number of years (five or 10) under each of the scenarios described above (same sites or different sites each year). The models are then run on the simulated data, and the coefficient and p-value of the year parameter are recorded. Following all repetitions of the simulation, the proportion of simulations in which the coefficient was negative and the p-value was less than 0.05 is taken as the power. The results are shown in the two figures below. It is important to note that due to the simulation nature of this procedure, there would be variation in another repetition of the simulations, but the broad patterns can expected to be similar.

For each set of analyses, the number of sites required to achieve 80% power to detect declines in occupancy probability was calculated by linear interpolation between the two points immediately adjacent to the simulations which achieved power nearest to 80% (i.e. the one above 80% and the one below 80%).

3.3.2 Living with Mammals

The power of the Living with Mammal survey was assessed in two ways. First, simulations were carried out in which the same LwM sites are surveyed every year, so site could be included in the model as a variable. The variance structure meant that this was best analysed with site as a random effect in a mixed model. The second approach was one in which different sites were surveyed every year. The analysis of change for these were done in a model with no site variable, i.e. assuming sites are independent. Therefore the model structures were:

For the same sites every year:

$$logit(P_{it}) = intercept + year_t + s_i$$

where P_{it} is 0 or 1, and describes whether a hedgehog presence was detected at site *i* in year *t*, year is a continuous covariate and s_i is a random site effect where $s_i \sim N(0, \sigma^2)$. This is a mixed model, with site as a random factor, a binomial error structure, and a logit link function.

For different sites in every year:

$$logit(P_{it}) = intercept + year_t$$

where P_{it} is 0 or 1, and describes whether a hedgehog presence was detected at site *i* in year *t* and year is a continuous covariate. This is a GLM with a binomial error structure, and a logit link function.

The results are shown in Figure 1, and it is important to note that due to the simulation nature of this procedure, there would be variation in another repetition of the simulations, but the broad patterns can expected to be similar.

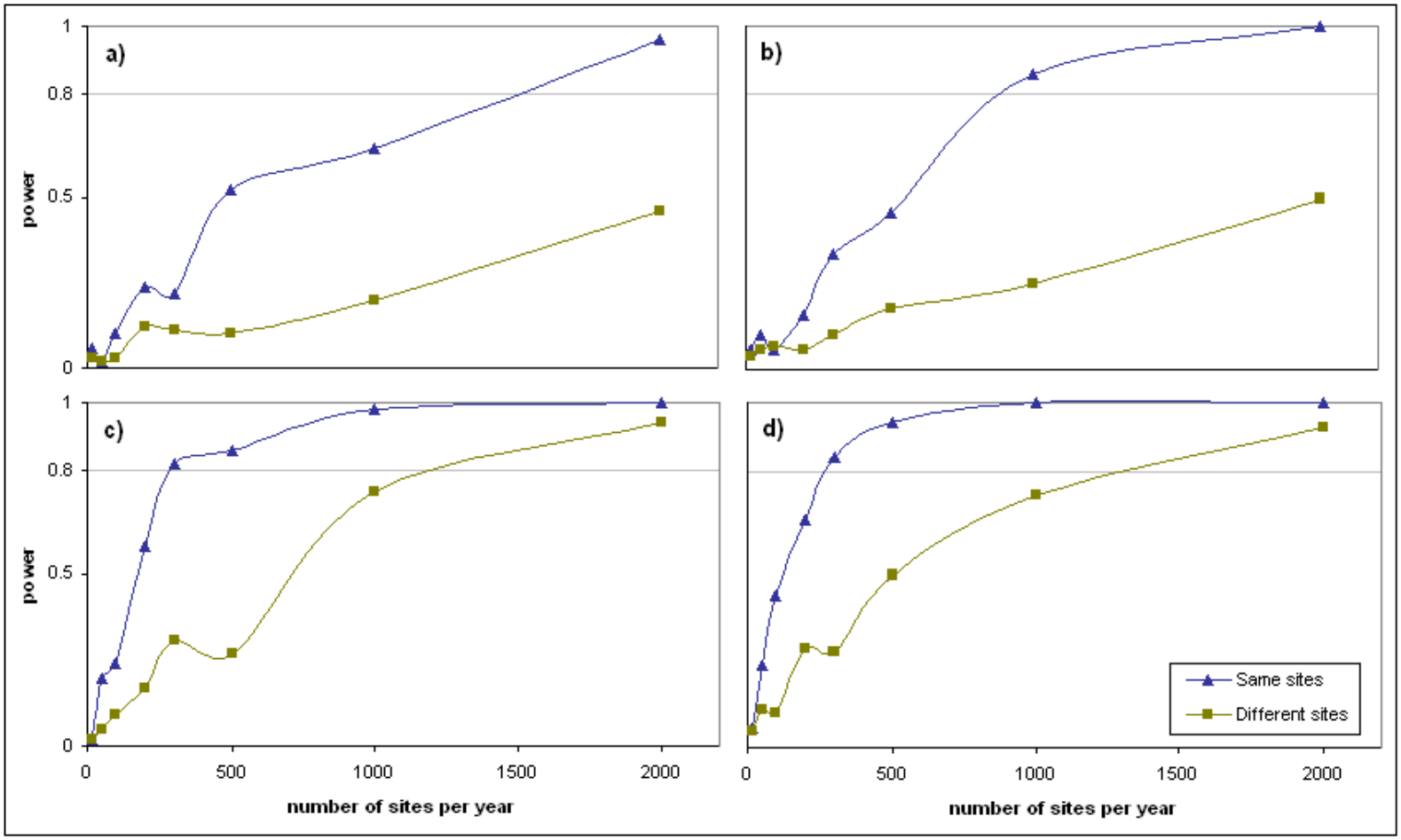


Figure 13 Plots indicate the power of detecting declines in relation to the number of sites using the Living with Mammals survey. Dots show the simulated data points, and lines fitted curves through the data points. a) 5% decline over 5 years; b) 5% decline over 10 years; c) 10% decline over 5 years; d) 10% decline over 10 years.

Table 18 The number of sites required to achieve 80% power under different simulated scenarios using the Living with Mammals survey.

Scenario	years	% decline	same sites each year	different sites each year
a)	5	5	1500	>2000
b)	10	5	925	>2000
c)	5	10	292	1300
d)	10	10	278	1350

For Living with Mammals, results showed that sufficient power could be achieved for a number of plausible scenarios. It is clear that when different sites are surveyed every year, a considerably larger sample size is required and even with 2000 sites, the power to detect a 5% decline is still less than 80%. From an examination of the graphs, it is likely these values would be substantially greater than 2000. At least 1300 sites are required to detect a 10% decline over 5 to 10 years. However, if the same sites are surveyed each year, much lower numbers would be required to detect either 5% (900-1500 sites) or 10% declines (ca 300 sites) with a power of 80%. This highlights the marked improvement in power to detect changes in occupancy rates by surveying the same sites between years.

3.3.3 Mammals on Roads

The power of the Mammals on Roads survey was also calculated in two ways, using similar data as for Living with Mammals, i.e. the presence or absence of hedgehogs per journey. First, simulations were carried out in which the same routes were surveyed every year, so 'route identity' could be included in the model as a variable. The variance structure meant that this was best analysed with route as a fixed effect in a GLM. Secondly, simulations were done in which different routes were surveyed every year. The analysis of change for these were done in a model with no site variable, i.e. assuming sites are independent.

The proportion of journeys where hedgehogs were detected, and the variation of presences within routes were replicated at similar levels to the real data. For each simulation, the number of journeys being surveyed each year is set. The proportion of journeys with hedgehogs are modelled to decline by 5% or 10% over the specified number of years (five or 10). The models are then run on the simulated data, and the coefficient and p-value of the year parameter are recorded.

Therefore the model structures for the same routes every year was:

$$logit(P_{it}) = intercept + year_t + s_i$$

where P_{it} is 0 or 1, and describes whether a hedgehog presence was detected on journey i in year t, year is a continuous covariate and s_i is a site effect. This is a GLM, with site as a fixed factor, a binomial error structure, and a logit link function.

And the model structure for different routes in every year:

$$logit(P_{it}) = intercept + year_t$$

where P_{it} is 0 or 1, and describes whether a hedgehog presence was detected on journey *i* in year *t* and year is a continuous covariate. This is a GLM with a binomial error structure, and a logit link function.

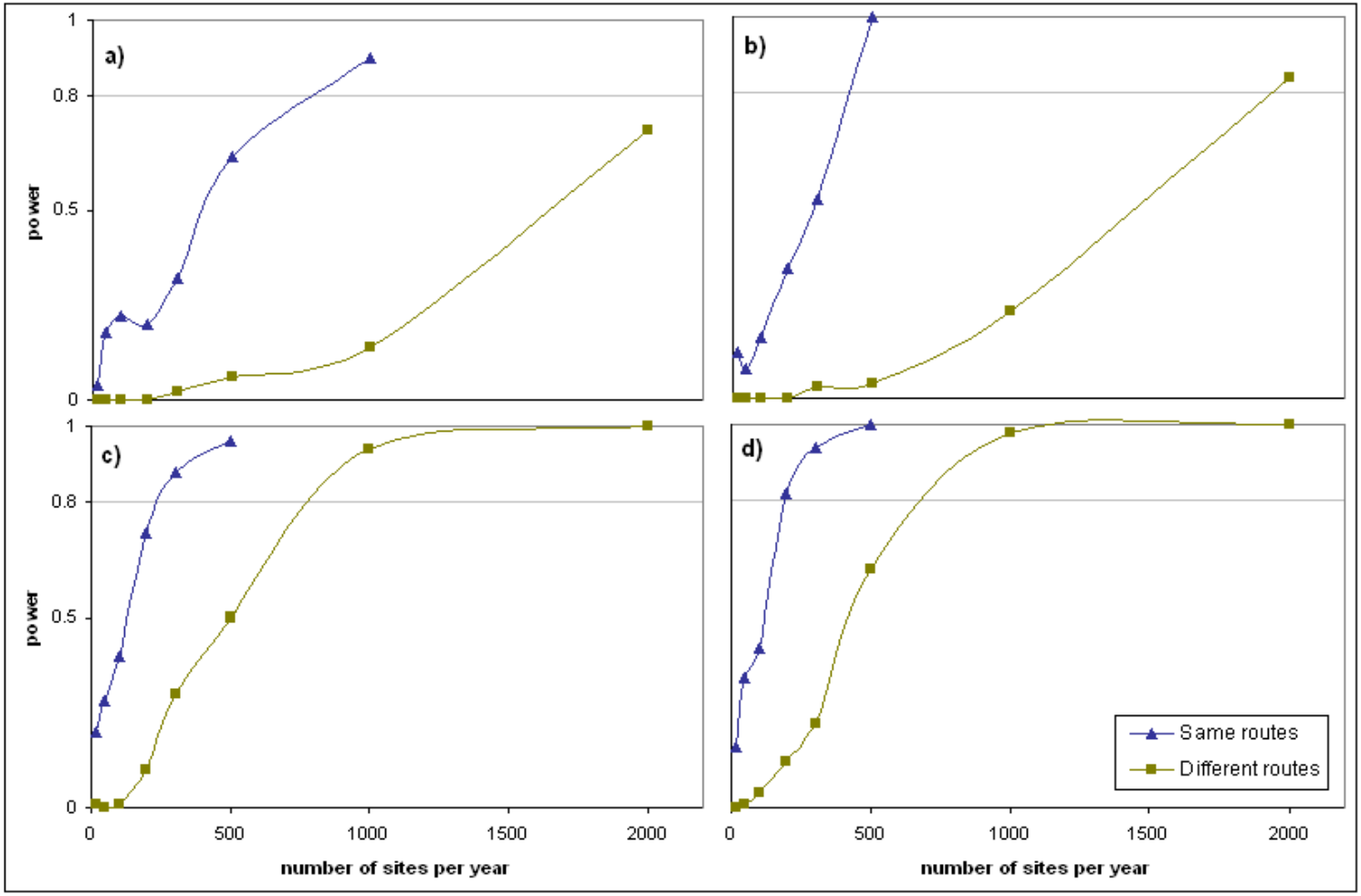


Figure 14 Plots indicate the power of detecting declines in relation to the number of sites using the Mammals on Roads survey. Dots show the simulated data points, and lines fitted curves through the data points. a) 5% decline over 5 years; b) 5% decline over 10 years; c) 10% decline over 5 years; d) 10% decline over 10 years

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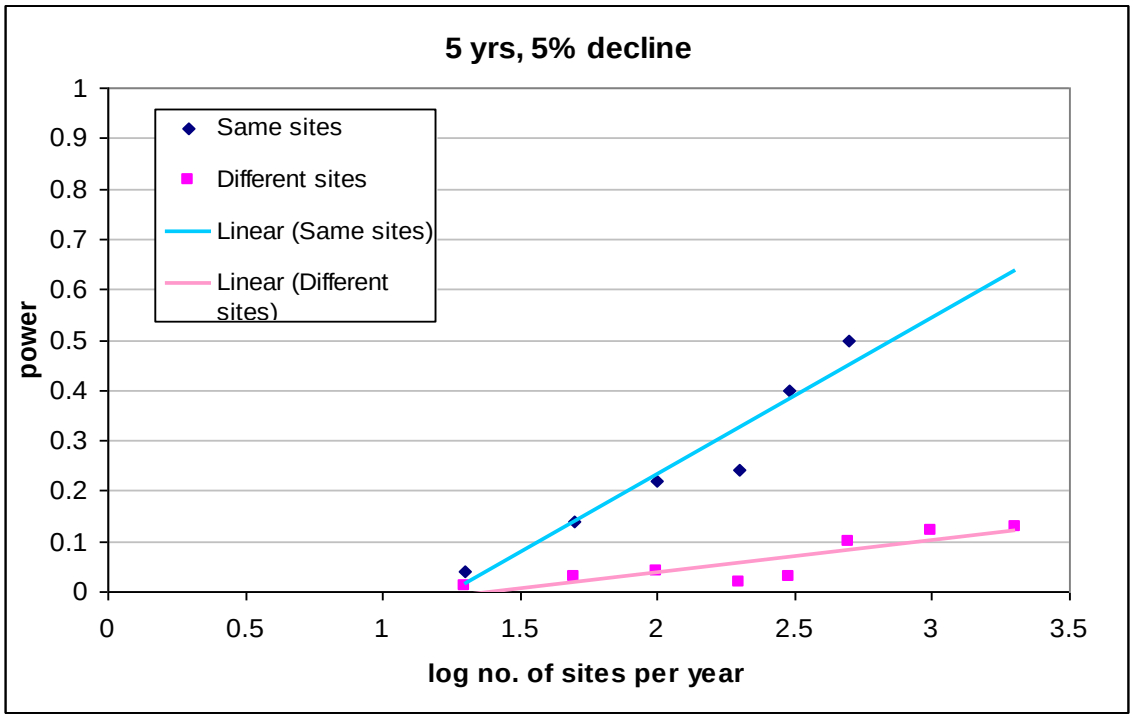
Table 19 The number of sites required to achieve 80% power under different simulated scenarios using the Mammals on Roads survey.

scenario	years	% decline	same routes each year	different routes each year
a)	5	5	808	>2000
b)	10	5	417	1934
c)	5	10	250	840
d)	10	10	195	750

The results from the Mammals on Roads analyses show that when different routes are surveyed every year, many more journeys are required per year to reach 80% power and even with 2000 routes there would be less than 80% power to detect a 5% decline over five years. Declines of 10% or more could be detected in five to ten years with samples of 750 to 850. However, if the same routes are surveyed every year, 10% declines could be detected with 195 to 250 sites and 5% declines could be detected with 400 to 800 routes. As with the Living with Mammals results, this difference reflects the low variance of counts within routes (or sites) and high variance between routes (or sites).

The graph below shows the results for Living with Mammals, but plotted on a log scale for the x-axis, and fitting a linear trend through the estimates of power to reveal the approximately linear relationship. This approach could be used to estimate the sample size needed for a given power (e.g. 80%).

Figure 15 The effect of sample size on power to detect declines with Living with Mammals, plotted on a log scale



3.3.4 Overview of findings of power analyses:

Altogether, these results provide some key pointers to survey design and power:

- Firstly, repeat surveys of the same sites or routes have a much greater power to detect change than surveying different sites or routes each year, whatever the survey methodology, time period or magnitude of decline. For example, to detect a 5% decline in the presence of hedgehogs with Mammals on Roads over 10 years with 80% power, a sample of 417 routes would be required if the same routes were surveyed each year, whereas 1934 routes would be required if they were different

- Second, it is clear that a larger decline can be detected with a smaller number of sites. Detecting a 5% decline over 10 years with 80% power requires more than twice as many sites as detecting a 10% decline over 10 years with 80% power, whether the sites are the same in each year or not.

- Thirdly, the same overall decline is easier to detect over longer periods (e.g. ten years rather than five years) even though the annual rate of decline is less steep. In other words, the additional information provided by the longer time series seems to have more influence on power than the annual rate of decline.

3.3.5 Implications for current survey planning

The Living with Mammals results suggest that 300 sites (well within current scope) would have sufficient power to detect a 10% decline as long as these were resurveys of the same sites each year. To achieve this power if different sites were surveyed each year, almost five times the sample would be required, i.e. in excess of 1300 sites and considerably more than have been monitored in the last few years. Even with the current sample of ca 550 nationally (500 just in England), there does not appear to be much power to detect a 10% decline in England and certainly not for other countries or smaller regions.

The Mammals on Roads results suggest that 200-250 sites would provide enough power to detect a national decline of 10% over 5-10 years, if the same routes are revisited. More than 800 routes would need to be surveyed if the routes differed each year. Simulations with the current samples in each country show that there is already sufficient power to detect 10% declines over ten years in England and Scotland, but in Wales only greater declines (for example 25%) could be detected.

Garden BirdWatch is one of the largest surveys assessed, and in general the same sites (gardens) are surveyed each year. In fact, most gardens are surveyed every fortnight, providing many opportunities during the year to detect hedgehogs.

Although many of the surveys do not have enough power individually to detect modest changes in numbers (i.e. 5 to 10% declines) at the country level other than in England, the effective sample size can potentially be improved by combining surveys. Strictly speaking, this is justified only: (i) where the sampling design of the surveys are similar (e.g. random sites or targeted at gardens) and (ii) where the variance structures are broadly similar, i.e. the relative degree of within-site variance compared to between-site variance. However, although the pattern of

variance within and between sites will always differ to some extent between surveys, assumptions of similarity could be made when methodologies are similar, for example if both surveys involved asking participants at the end of the season whether they had seen hedgehogs in their garden, or in their neighbourhood. Differences between surveys in detectability rates cause less of a problem, and combining surveys will simply result in an averaged 'annual proportion of sites occupied with hedgehogs'. Note that any measures using counts rather than presence – absence will have a very different variance structure and would not be combinable with surveys of presence/absence.

Clearly, it will always be necessary to interpret any trends or patterns from survey results in relation to the survey methods and scope. Any survey solely of gardens and other built-up areas can only provide information on the presence or abundance of hedgehogs in those habitats and cannot be used to infer patterns of abundance in the wider countryside. The previous caveats about variance aside, although surveys with a random design could be combined with a non-random or garden based survey, the unknown amount of bias provided by inclusion of the non-random survey means that the information from the random design survey is effectively downgraded, and the results would represent 'mostly gardens'.

Given the points above, we think it would be possible to combine some of the volunteer-based surveys amongst this set, thereby increasing sample size and improving capacity to generate trends at the country or smaller regional level.

1) Living with Mammals and Garden BirdWatch are both multi-species surveys mainly of gardens although a small proportion of these gardens may be in rural, lowland or upland areas or forests. These could be combined to provide information about changes in hedgehog occupancy of these habitats at smaller regional scales than would be individually possible. It would not be advisable to include Hogwatch because this is targeted specifically at hedgehogs and participation and subsequent reporting rates may be related to whether hedgehogs were detected or not. The RSPB's 'Make Your Nature Count' could be potentially be added to this list but would require some clarification of the recording period to be used by participants.

2) BBS, WBBS and Mammals on Roads are mainly rural surveys, but only BBS has a strictly random design. Mammals on Roads is not carried out in urban areas and also not along major roads which might result in bias away from other habitats. The WBBS is targeted specifically on linear waterways, and in any case currently provides relatively few data on hedgehogs. With certain assumptions about similarity in variance, results of MoR and BBS could be combined, possibly excluding urban BBS sites to provide better compatibility and focus on information about the population status of hedgehogs in the wider countryside. Given the amount of data and the relatively large scale of the sample sites (1-km squares or stretches of road), analyses at a broad regional scale or broad landscape type (easterly lowlands, etc) would be most informative.

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Appendix 1 Index values for estimated population trends, standardised to start year

Year	MoR	MoR_numbers	LwM	BBS	BBS dead	GBW	WBBS
1996				100			
1997				99.59597			
1998				196.0854			100
1999				194.9904			106.2939
2000				319.7862			112.5276
2001	100.00	100		410.497			42.47706
2002	97.47	101.6613		157.2732	100		11.83644
2003	89.46	88.50822	100.00	155.6215	109.1923		49.53299
2004	81.88	74.89474	95.80	120.0286	79.27417		32.93331
2005	81.48	81.50436	115.63	73.32798	31.20705		28.19554
2006	82.97	86.10378	83.46	85.57568	60.70189		14.53786
2007	93.82	92.24235	73.78	99.14598	82.5333	100	17.93751
2008	88.91	83.83481	87.86	74.39711	70.81553	88.99835	26.89249
2009	80.54	74.21057	75.59	43.95719	48.03299	88.16594	21.57585
2010			77.98			69.91289	

Appendix 2 Index values for estimated population trends, standardised to year 2003

Year	MoR	MoR_numbers	LwM	BBS	BBS dead	GBW	WBBS
1996				64.26			
1997				64.00			
1998				126.00			201.89
1999				125.30			214.59
2000				205.49			227.18
2001	111.78	112.98		263.78			85.76
2002	108.95	114.86		101.06	91.58		23.90
2003	100.00	100.00	100.00	100.00	100.00		100.00
2004	91.52	84.62	95.80	77.13	72.60		66.49
2005	91.07	92.09	115.63	47.12	28.58		56.92
2006	92.74	97.28	83.46	54.99	55.59		29.35
2007	104.87	104.22	73.78	63.71	75.59		36.21
2008	99.38	94.72	87.86	47.81	64.85		54.29
2009	90.03	83.85	75.59	28.25	43.99		43.56
2010			77.98				

The table below is to illustrate the feasibility of regional trend analyses in current surveys. Although we only show the tables for the BBS data, similar tables were produced for the other surveys. The BBS rule of thumb is that there should be more than 30 observations of a species per year within the designated geographic area to generate robust trends. Even when pooling all evidence of hedgehog presence, only two Governmental Regions had sufficient sample size. We therefore decided to pool Governmental Regions into larger Regions, so that trend analyses could be performed

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Appendix 3 The number of BBS squares surveyed in each Governmental Region per year where the occurrence of Hedgehogs was recorded. Regions with more than 30 presences of Hedgehogs are shaded grey.

REGION	Occurrence	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
East Midlands	Absence	115	122	119	118	108	35	104	113	137	166	199	200	185	168	1889
East Midlands	Presence	4	10	11	16	19	10	13	17	11	10	8	15	12	10	166
East of England	Absence	197	235	213	219	174	67	189	173	195	261	280	300	263	259	3025
East of England	Presence	29	31	39	41	39	24	32	27	29	15	32	35	22	13	408
London	Absence	38	38	47	43	44	37	46	51	73	75	88	85	82	76	823
London	Presence	4	3	6	10	14	11	7	7	5	2	2	5	0	0	76
North East	Absence	35	37	40	34	41	0	45	53	61	69	90	97	81	85	768
North East	Presence	3	5	6	3	7	0	5	5	7	6	8	9	8	6	78
North Scotland	Absence	125	129	126	106	82	29	73	87	81	96	105	122	88	77	1326
North Scotland	Presence	11	6	9	8	8	2	10	6	6	7	6	3	3	2	87
North West	Absence	133	155	147	154	143	25	145	168	179	205	226	221	196	189	2286
North West	Presence	17	14	17	23	27	11	16	16	24	20	22	27	26	20	280
South East	Absence	219	271	274	298	288	115	278	294	342	403	447	447	431	423	4530
South East	Presence	22	26	44	46	54	29	37	39	32	21	31	49	31	22	483
South Scotland	Absence	111	123	121	119	114	32	107	126	125	144	155	181	155	160	1773
South Scotland	Presence	3	4	9	12	6	5	11	7	8	10	10	10	5	2	102
South West	Absence	183	216	220	236	204	24	216	225	232	253	334	349	323	306	3321
South West	Presence	10	15	23	23	35	6	23	23	17	16	22	22	17	15	267
Wales	Absence	77	102	136	167	154	14	168	159	174	204	197	193	146	137	2028
Wales	Presence	9	9	17	16	20	4	11	10	13	11	12	8	9	7	156
West Midlands	Absence	95	135	129	127	116	21	105	109	120	154	167	171	150	153	1752
West Midlands	Presence	10	21	23	24	28	3	17	21	15	15	21	15	12	10	235
Yorkshire and The Humber	Absence	73	103	93	105	94	15	100	109	123	141	156	154	154	144	1564
Yorkshire and The Humber	Presence	13	11	26	22	23	3	8	10	8	5	7	12	9	2	159
Grand Total		**1536**	**1821**	**1895**	**1970**	**1842**	**522**	**1766**	**1855**	**2017**	**2309**	**2625**	**2730**	**2408**	**2286**	**27582**