BTO Research Report No. 404

The production of population trends for UK mammals using BBS mammal data: 1995-2003 update

Authors

Stuart E. Newson & David G. Noble

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1. The BTO/RSPB/JNCC Breeding Bird Survey (BBS) was expanded in 1995 to record mammals as well as birds. This was the first multi-species, annual mammal survey to be carried out in the UK. It focuses on large-sized easily identifiable species, although observers record any mammal species seen or known to be present. In this report we update Newson & Noble (2005) to generate estimates of population change for 1995-2003.

2. Annual indices of relative abundance are produced at a national scale for nine mammal species for 1995-2003 - Brown Hare, Mountain/Irish Hare, Rabbit, Grey Squirrel, Red Fox, Red Deer, Fallow Deer, Roe Deer and Reeves's Muntjac. Comparing the abundance of these species in 2003 relative to 1995, Grey Squirrel and Roe Deer were significantly higher in 2003, whilst Rabbit, Mountain/Irish Hare, Red Fox, Red Deer and Fallow Deer were significantly lower. It is important to interpret change in abundance between 1995 and 2003 in relation to the underlying trend over this period.

3. Where data were sufficient, regional indices of relative abundance were produced for the nine English Government Office Regions (GOR) and the four countries that constitute the UK. In total indices of relative abundance could be produced for five mammal species (Brown Hare, Rabbit, Grey Squirrel, Red Fox and Roe Deer) for two or more regions. Additionally, data were sufficient to produce trends for Red Deer in Scotland and for Fallow Deer and Reeves's Muntjac in England.

4. Population trends are produced for government Environmental Zones for the most commonly sighted species. Environmental Zones are categories of landscapes found in the UK from the lowlands of the south and east, to the uplands and mountains of the north and west. The resolution of these analyses is at the 1 km square level, and hence this approach is comparable with other mammal surveys associated with the Tracking Mammals Partnership, such as the BTO/MS Winter Mammal Monitoring.

5. There are six mammal species (Badger, Mole, Hedgehog, Brown Rat, Stoat and Weasel) for which there were insufficient count data to produce indices of abundance, but for which observers collected a large amount of information on presence/absence from field signs, dead animals or local knowledge. These data were used to examine their change in presence/absence on BBS squares over time. As discussed in previous work (e.g. Newson & Noble 2005) interpreting the data from the first few years may be difficult because they may reflect increasing awareness by the observer of the presence of a particular species. With existing data, it is not possible to assess the significance of this potential bias. However, since 2002 observers have recorded the criteria that they used for reporting presence (live animals, field signs, dead animals, local knowledge of presence from that season or live animals seen on additional visits), which should aid interpretation in the future. We present information on the change in presence on BBS squares of these six species from 1996 to 2003 and discuss reasons why caution is needed in interpreting these trends.

   Using geostatistical methods trialed in Newson & Noble (2005), we examine finer scale spatial patterns in relative abundance for two mammal species Grey Squirrel and Roe Deer by interpolating maps of relative abundance for 1995 and 2003, and producing maps of change for these species between years. CEH landcover data is used to improve the model fit. Because these analyses are time-consuming for the analyst as well as computationally, it is suggested that we continue to produce maps for two species per year as we have done here, until methodology for automating maps of this type can be developed.

6. Data for a large proportion of mammal species recorded by the BBS are insufficient to calculate robust indices of relative abundance or occurrence. However, these data still provide important

information on the distribution of species, which in many cases are not properly monitored by any existing scheme. For most of these species, it would not be useful to produce annual maps of distribution, but distribution maps of species presence over intervals of perhaps five or ten-year blocks might be considered as more data are collected. There is also the potential for combining these data with those from other surveys and perhaps with incidental records through the National Biodiversity Network to provide a better understanding of species distribution and if temporal data were available, identify changes in distribution over time.

Table 1.1 Summary of temporal trends in relative abundance. Mean number of BBS squares with counts of each of nine mammal species and percent change in relative abundance for these species for the period 1995-2003. An asterisk denotes a significant difference between the first and last years of the survey at the 5% level or more. See Appendices 2a-c for raw data and Figures 4.1.1-4.1.9 for a visual representation of temporal trends for the UK.

	RABBIT		BROWN HARE		MOUNTAIN HARE		GREY SQUIRREL		RED FOX		RED DEER [1]		FALLOW DEER [1]		ROE DEER		REEVES'S MUNTJAC	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
UNITED KINGDOM	1057	-27 *	526	-9	44	-34 *	472	20 *	227	-44 *	51	-73 *	39	-82 *	239	31 *	45	21
COUNTRIES																		
England	849	-11 *	452	4	-	-	422	14 *	183	-42	-	-	38	-85 *	175	28 *	45	22
Scotland	99	-60 *	52	-51 *	-	-	39	37	-	-	40	-73 *	-	-	64	34	-	-
Wales	73	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ENGLISH REGIONS																		
North West England	88	-46 *	52	-29 *	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yorkshire & The Humber	75	14	45	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
East Midlands	70	-47 *	60	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-
East of England	154	40 *	122	20	-	-	73	-4	-	-	-	-	-	-	-	-	-	-
West Midlands	90	-29 *	-	-	-	-	57	-16	-	-	-	-	-	-	-	-	-	-
South East England	206	-17 *	71	-29 *	-	-	127	3	50	-43	-	-	-	-	60	65 *	-	-
South West England	135	16	51	65 *	-	-	63	-1	41	-43	-	-	-	-	62	78 *	-	-
ENVIRONMENTAL ZONES																		
Easterly lowlands (Eng./Wales)	465	-6	292	4	-	-	235	5	98	-45 *	-	-	-	-	99	8	40	-12
Westerly lowlands (Eng./Wales)	357	-6	145	19	-	-	192	23 *	81	-33 *	-	-	-	-	65	53 *	-	-
Uplands (Eng./Wales)	103	-19	53	-43 *	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowlands (Scotland)	58	-70 *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1] Temporal trends do not relate to underlying declines in these species, but instead relate to a steep decline in 1996, due to a small number of sites not recording large herds in this year and in subsequent years. Because there are relatively few sites in the model to start with, a small number of sites not recording large herds in subsequent years, can have a large influence on the apparent relative abundance of these species.

2. INTRODUCTION

Few UK mammal surveys have been carried out in a standardized manner to allow comparisons to be made between surveys, and surveys are often not repeated frequently enough to separate the underlying population change from natural between-year variation. This lack in reliable monitoring data is highlighted in a review of population estimates and conservation status of British mammals (Harris *et al*. 1995) and more recently by Macdonald & Tattersall (2001). Annual monitoring data of this type are important for a number of reasons, including the setting of conservation priorities, the management of pest species and sustainable use of game species and for examining the effect of change in land-use, habitat or climate (Battersby & Greenwood 2004).

In response to the scarcity of reliable mammal monitoring data, in 1995 the British Trust for Ornithology (BTO), with the agreement from its partners, the Royal Society for the Protection of Birds (RSPB) and the Joint Nature Conservation Committee (JNCC), expanded the scope of the national bird-monitoring scheme, the Breeding Bird Survey (BBS) to also collect information on British mammals. BBS observers, who are almost all volunteers, were asked to provide information on any mammals detected or known to be present whilst carrying out bird surveys on randomly allocated 1-km squares or during any other visits to these sites. This was the first multi-species, annual mammal survey to be carried out in the UK and although the focus was on medium to large sized easily identifiable species, observers have the opportunity to record any mammal species.

This report updates analyses of BBS mammal data for 1995-2002 (Newson & Noble 2005) to produce population trends (trends in relative abundance) from count data for the most commonly sighted species of British mammal (Brown Hare, Mountain Hare, Rabbit, Red Fox, Grey Squirrel, Roe Deer, Red Deer, Fallow Deer and Reeves's Muntjac) for the period 1995-2003. Where data are sufficient, we present trends at a regional level (nine English Government Office regions and four countries of the UK) and for different landscape types (six Environmental Zones within Great Britain). Northern Ireland has its own set of Environmental Zones that have been devised on a different basis to those used for Great Britain. Because the number of sites surveyed in Northern Ireland is small, we do not consider it worth examining the production of separate trends for this region. There are several species for which there are seldom sufficient count data to produce reliable indices of abundance. However, a large amount of indirect information on their occurrence from field signs, dead animals or local knowledge is collected and with which it may be possible to examine the change in presence over time. In this report we examine the change in presence on BBS squares for six species (Badger, Mole, Hedgehog, Brown Rat, Stoat and Weasel). A distribution map is produced for each of the fifteen species for which we examine the change in abundance or presence on BBS squares from information that demonstrates the presence of that species in one or more years of the survey. Using geostatistical methods, maps of abundance are produced for two species, Grey Squirrel and Roe Deer for 1995 and 2003. A further change map is produced to highlight areas of greatest population change between these two years.

3. METHODS

3.1 Survey methods

The BBS uses a stratified random sampling design, with 1 km squares from the National Grid assigned randomly within BTO regions (Noble *et al*. 2004). The survey is coordinated at BTO headquarters through a network of volunteer Regional Organisers, who are responsible for the volunteer observers in their region. All recording forms, including the mammal data are returned to the BTO after the field season for input and analyses over the winter. Mammal recording is carried out during the course of the bird surveys. In total BBS fieldwork involves three visits to each survey square per year. On the first visit, a transect route through the allocated 1 km square is determined comprising two roughly parallel lines, ideally 500 m apart and 250 m from the edge of the square and divided into ten equal sections of 200 m in length. Habitat is recorded for each transect section according to an established system, common to a range of BTO schemes (Crick 1992), although these data are not examined here. All mammals detected from the transect lines during the two bird counts are counted and recorded. The first BBS visit is made between April and mid-May and the second at least four weeks later between mid-May and the end of June. BBS visits are timed to start at between 0600 and 0700 hours and to last less than two hours. Visits during heavy rain, strong winds or poor visibility are discouraged. Unlike the BBS bird data, data for mammals are recorded within a single distance category. In order to collect information on widespread but seldom seen species such as Mole and Badger, observers are asked to record the presence of mammal species on the basis of counts of live and dead animals, counts made on any additional visits to the square, from field signs (e.g. tracks, droppings, molehills) or known to be present that season from local knowledge (e.g. from a gamekeeper or landowner). Prior to 2002, observers did not record the method or methods by which the species was known to be present, while since 2002 observers have recorded this information. The location of BBS squares recording mammals during the period 1995-2003 is shown in Figure 3.1.

3.2 Temporal trends in abundance

For the species for which counts are made, the maximum number of each species of mammal sighted over the two visits (early and late) was determined for each 1 km square in each year from 1995 to 2003. Survey work was severely affected by foot-and-mouth restrictions in 2001, resulting in a heavy bias towards particular areas of the country. For this reason, we exclude survey data for 2001 from all analyses. Using these data, log-linear Poisson regression was used to model site counts, with site and year effects (ter Braak *et al*. 1994) for the UK, where the year effect is an index of the change in numbers relative to 1995, the first year of the survey. This year, (1995) is set to an arbitrary index value of 1 from which all other years are measured. Counts of animals can violate the assumption of a Poisson distribution, so corrections for over-dispersion are made using the 'dscale' option in SAS (SAS 2001).

As with many long-term surveys these data include many missing values, where a particular site was not surveyed in a particular year. The model is estimated using the observed counts to predict the missing counts and calculate the indices from a full data set, including the observed and predicted counts. The model requires that two points in the time series are available to estimate parameters, so squares counted in one year only are excluded from the analysis. If the data contain too many missing values, the model parameters cannot be estimated. Because the stratified random sampling design results in unequal representation of regions across the UK, annual counts are weighted by the inverse of the proportion of each region that is surveyed in that year. Only results for species occurring on a mean of 40 or more squares in two or more years over the seven years for which survey data are available are presented, because of the low precision associated with small sample sizes (Joys *et al*. 2003). The significance of the trends were examined by making a comparison between the first and last years of the survey. Because non-overlapping of 95% confidence intervals provides a crude means of assessing significance at the 5% level or more, separate formal analyses to examine differences between indices were not performed.

To examine whether the UK trends are representative within different regions and landscape types, annual indices were produced in the same way as above, where data allowed, for the nine English Government Office Regions and for England, Scotland, Wales and Northern Ireland and for six Environmental Zones of Great Britain, shown graphically in Figures 3.2 & 3.3. The six Environmental Zones produced from the Land Cover Map 2000 data (Haines-Young *et al*. 2000), are based on combinations of CEH land classes which cover the range of environmental conditions that we find in Great Britain, from the lowlands of the south and east, through to the uplands and mountains of the north and west. Northern Ireland has its own set of Environmental Zones that have been devised on a different basis to those used for Great Britain. Because the number of sites surveyed in Northern Ireland is small, we do not consider it worth examining the production of separate trends for this region.

3.3 Temporal trends in presence

For six species that are not counted in sufficient numbers for trend analysis, but which leave obvious field signs or which are known to be present within a BBS square, we examined the change in presence/absence on surveyed squares. Species presence is defined here as information demonstrating that the species is present on a BBS square in a particular year. This may include counts of live animals as used in the above analyses, dead animals, field signs (e.g. tracks, scats, mole-hills), local knowledge of presence for that year from a gamekeeper or landowner or live animals seen on additional visits to the square during that season. Previous analyses of BBS mammal data suggests that of those species that cannot be monitored through counts of live animals, it may be possible to monitor changes in presence of Badger, Brown Rat, Mole, Hedgehog, Stoat and Weasel (Newson & Noble 2005).

To examine whether there has been a significant change in the presence of these species on BBS squares, we modelled presence/absence as a function of site and year using logistic regression. The year effect here is the relative odds ratio, which is the odds of being present on a particular BBS square in a particular year *relative* to the odds of being present on that square in the first year in the time series. In these analyses we treat 1996 as if this were the first year in the series, because most species of interest appeared for the first time on the survey form in this year. To illustrate the concept of the odds ratio, if in the first year, the probability of being present is 0.2, the probability of being absent is 0.8. The odds of being present would therefore be 0.2/0.8 = 0.25. If, five years later, the probability of being present was 0.8 and the probability of being absent was 0.2, the odds of being present would be 4, and the odds ratio relative to the first year would be 4/0.25 = 16. Unlike the analyses of count data, the change in odds ratio described above is not intuitive. For this reason, we present simple figures showing the percentage change in the presence of these species on BBS squares, although use logistic regression to test the significance of this change.

3.4 Mapping the spatial distribution of British mammals

Distribution maps that demonstrate the presence of that species on BBS squares could be produced for all species recorded on BBS squares. Whilst maps of this type provide useful information on the distribution of species, and are likely to highlight the strongholds of particular species, these may be biased towards areas of higher observer density if, as in the case of the BBS the survey is not strictly random (the BBS is stratified by region). Using sightings data for Grey Squirrel and Roe Deer for 1995 and 2002, we interpolate statistically valid maps of relative abundance using geostatistical methods, specifically using the Geostatistical Analyst extension of ArcGIS (Johnston *et al*. 2001). Geostatistical methods are based on statistical models that model autocorrelation (statistical relationship among measured points). Not only do these techniques have the capability of producing a prediction surface, but they can also provide some measure of the accuracy of the predictions.

A number of geostatistical interpolation techniques have been developed, of which kriging is the most applicable to this work. Kriging weights the surrounding measured values to derive a prediction for unsurveyed locations. In these, the weights are based on the distance between measured sites and the prediction location, but also on the overall spatial arrangement in the weights (the spatial

autocorrelation). For a full discussion of geostatistics and geostatistical methods see Chiles & Delfiner (1999). Because mammal species show some form of habitat preference, we examine the extent to which habitat may improve our predictions. For this we use Centre for Ecology and Hydrology (CEH) 2000 land cover data for simple co-kriging. CEH land cover data provides information on the proportions of each square that are of each of 27 habitat classes. In these analyses, we use data classified into seven aggregate classes as defined in Table 3.1. Information for sea and estuary, coastal and inland water and unclassified habitat are not used in the analyses here. In these analyses we use each habitat in turn as a predictor of relative abundance. Once the best predictor habitat has been determined, a second habitat variable can be added to the model to examine whether this improves the reliability of predictions further. For the predictions to be unbiased (centered on the measurement values), the prediction errors should be close to zero. This depends on the scale of the data, which we standardize by dividing the prediction error by their prediction standard errors to give standardized mean prediction errors, which should also be close to zero. The predictions should also be as close as possible to the measurement values. To examine this we compute the root-mean-square prediction errors (the square root of the average of the squared distances between the predictions and their true values), for which the smaller the value the closer the model predicts the measured values.

Because the BBS employs a stratified sampling design that results in unequal representation of coverage in different areas of the UK, we need to control for this in the analyses. For this we use the method of declustering, which preferentially weights the count data, with counts in densely sampled areas receiving less weight and counts in sparsely sampled areas receiving greater weight (see Isaaks & Srivastava 1989 for a further discussion of this method). This effectively decides how much the data at each site contributes to the calculation of autocorrelation functions across the entire data set. In Geostatistical Analyst there is a choice of two declustering methods that can be used: cell declustering, which arranges rectangular cells over BBS squares in a grid and weight attached to each BBS square is inversely proportional to the number of BBS squares in its cell; or polygonal declustering, which weights each BBS square in proportion to the areas that it represents. We choose the first method in preference to the second, because with the second, it is likely to be difficult to define weights towards the coastline of Britain. It should be noted that although several geostatistical methods require that the data be normally distributed, prediction maps do not require this assumption to be met. BBS count data is unlikely to ever be normally distributed because there are a substantial proportion of zero counts.

Figure 3.1 The location of 1 km BBS squares surveyed for mammals (1995-2003).

Figure 3.2 English Government Office Regions and Country boundaries used in the regional analyses.

Figure 3.3 The six Environmental Zones of Great Britain used in the analyses of landscape types.

Table 3.1 Definition of seven aggregate habitat classes and associated subclasses.

Aggregate class definition	Subclass definition
Mountain, heath, bog	Bog (deep peat), open and dense dwarf shrub heath, montane habitats, inland bare ground
Broad-leaved / mixed woodland	Broad-leaved / mixed woodland
Coniferous woodland	Coniferous woodland
Improved grassland	Improved grassland
Semi-natural grassland	Neutral grass, set-aside grass, bracken, calcareous grass, acid grassland, fen, marsh and swamp
Arable and horticulture	Arable cereals, arable horticulture and arable non-rotational
Built up areas and gardens	Suburban / rural development, continuous urban

4. RESULTS

During 2003 mammal data were collected from a total of 1916 1 km BBS squares. The number (and percentage) of squares with counts for each species are shown in Appendix 1a. This highlights those species for which data are sufficient to produce trends from sightings data. Additional species that are not counted in sufficient number for trend analyses, but which leave obvious field signs or which are known to be present within a BBS square for which we can examine the change in presence on BBS squares are highlighted in Appendix 1b. This was only the second year in which observers were asked to record the method by which they report species presence. Prior to this, we have information on number of squares reporting sightings of each species, whilst the category presence is a combination of counts of live animals, dead animals, field signs (e.g. tracks, scats, mole-hills), local knowledge of presence for that year from a gamekeeper or landowner and live animals seen on additional visits to the square during that season.

To examine 2003 in relation to other years, we present the number (and percentage) of BBS squares reporting sightings and presence of all species in Appendices 1a and 1b. When interpreting these tables, it is important to highlight a number of changes to the BBS mammal survey form, which have influenced the apparent abundance (and presence) on BBS squares of some mammal species. Whilst observers have always been asked to record all mammal species sighted or known to be present, the survey form lists a number of the most regularly recorded species with space for recording count and presence information. Following the first year of the survey, a number of species were added to this list, including Hedgehog, Brown Rat, Badger, Mole, Stoat and Weasel. Additionally in 2000, Feral Cat and Sika Deer were added to the standard list of species and Common Shrew removed because of the difficulty in validating sightings of this species. In most of these cases, the addition of a species to the standard list resulted in an apparent increase in the number and proportion of squares reporting these species, and the removal of Common Shrew in 2000, a fall in the apparent abundance. The only species from this list that appeared little affected by these survey changes include Stoat, Weasel and Sika Deer. Another change to the survey form in 2000 was intended to improve the clarity but it also may have increased the scope for observers to record presence as well as counts and species presence on the survey form. Prior to this, the relatively high proportion of squares reporting sightings of Mole may reflect known presence from molehills rather than sightings of live animals. A number of problems discussed above have no particular consequence, because data are not sufficient to produce trends in abundance or presence/absence. For example, we do not produce trends for Feral Cat, small mammals (e.g. Common Shrew) and Sika Deer. We also do not use sightings data to produce trends in abundance for Mole and other species rarely sighted. Species for which changes in survey form could potentially have an important influence are those for which trends in presence/absence are produced including Hedgehog, Badger, Brown Rat, Mole, Stoat and Weasel.

4.1 Temporal changes in abundance

In the following section (Figures 4.1.1-4.1.9), we pool the results of analyses of sightings data and distribution information described in the method section above to present a species by species account of what the BBS tells us about population change for these species for 1995-2003.

Figure 4.1.1 RABBIT *Oryctolagus cuniculus*

Summary

Significant continuous decline in the UK from 1997 to 2003

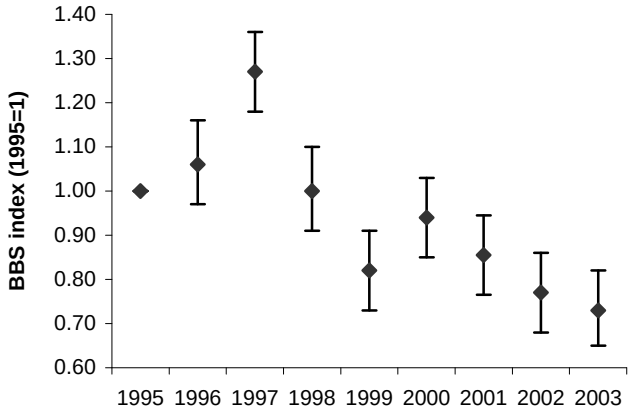
Largest significant decline in Scotland and to lesser extent England, in which East Midlands and North West have shown the greatest detectable declines

Past analyses has shown that it would be possible to detect at least a 25% decline at a UK level between any two years with power of 80% or more with the existing sample size.

a) Mean number of squares with Rabbit counts (1995-2003). See Appendices 2a-c for raw data.

	Mean squares	Percent change	$P \leq 0.05$
UNITED KINGDOM	1057	-27	*
COUNTRIES			
England	849	-11	*
Scotland	99	-60	*
Wales	73	11	
ENGLISH REGIONS			
North West England	88	-46	*
Yorkshire & The Humber	75	14	
East Midlands	70	-47	*
East of England	154	40	*
West Midlands	90	-29	*
South East England	206	-17	*
South West England	135	16	
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	465	-6	
(Zone 2) Westerly lowlands (England/Wales)	357	-6	
(Zone 3) Uplands (England/Wales)	103	-19	
(Zone 4) Lowlands (Scotland)	58	-70	*

b) Change in relative abundance from counts in the UK from 1995-2003. Error bars represent 95% confidence intervals (see Appendix 2a for raw data).



c) Distribution from recorded presence in one or more year, 1995-2003.

Figure 4.1.2 BROWN HARE *Lepus europaeus*

Summary

No significant change in abundance overall in the UK between 1995 and 2003.

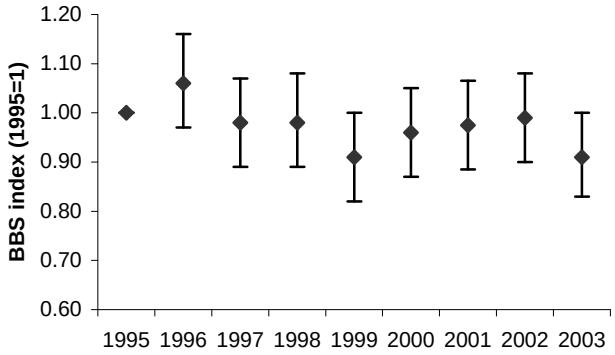
However, regional differences suggest that abundance has fallen significantly in Scotland, South East England, North West England and generally in the Uplands of England/Wales, whilst abundance appears to have increased significantly in South West England.

Past analyses has shown that it would be possible to detect at least a 25% decline at a UK level between two years with power of 80% or more with the existing sample size.

a) Mean number of squares with Brown Hare counts (1995-2003). See Appendices 2a-c for raw data.

	Mean squares	Percent change	P ≤ 0.05
UNITED KINGDOM	526	-9	
COUNTRIES			
England	452	4	
Scotland	52	-51	*
ENGLISH REGIONS			
North West England	52	-29	*
Yorkshire & The Humber	45	20	
East Midlands	60	21	
East of England	122	20	
South East England	71	-29	*
South West England	51	65	*
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	292	4	
(Zone 2) Westerly lowlands (England/Wales)	145	19	
(Zone 3) Uplands (England/Wales)	53	-43	*

b) Change in relative abundance from counts in the UK from 1995-2003. Error bars represent 95% confidence intervals (see Appendix 2a for raw data).



c) Distribution from recorded presence in one or more year, 1995-2003.

Figure 4.1.3 MOUNTAIN HARE (IRISH HARE) *Lepus timidus*

Summary

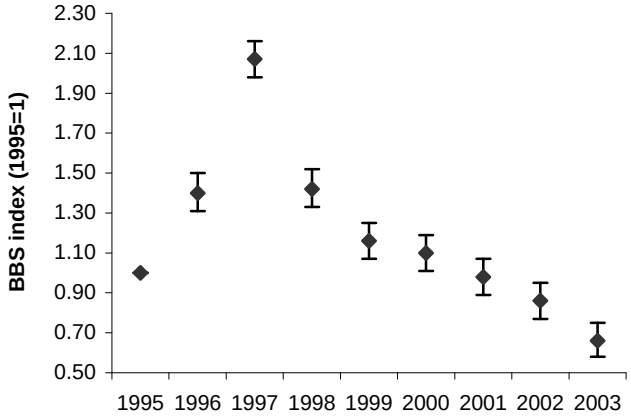
Significant decline in abundance in the UK between 1995 and 2003. However, large fluctuation in abundance between years suggests that this may not be an underlying trend.

Past analyses has shown that it would be possible to detect at least a 50% decline at a UK level between any two years with power of 80% or more with the existing sample size.

a) Mean number of squares with Mountain Hare counts (1995-2003). See Appendices 2a-c for raw data.

	Mean squares	Percent change	$P \leq 0.05$
UNITED KINGDOM	44	-34	*

b) Change in relative abundance from counts in the UK from 1995-2003. Error bars represent 95% confidence intervals (see Appendix 2a for raw data).



c) Distribution from recorded presence in one or more year, 1995-2003.

Figure 4.1.4 GREY SQUIRREL *Sciurus carolinensis*

Summary

Significant increase in abundance overall in the UK between 1995 and 2003, with a large peak in 1996, perhaps related to high productivity in this year.

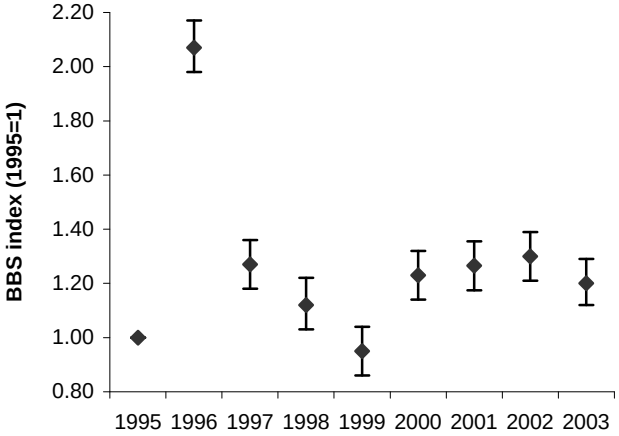
Abundance has increased significantly in England and generally in the Westerly lowlands of England/Wales.

Past analyses has shown that it would be possible to detect at least a 25% decline at a UK level between any two years with power of 80% or more with the existing sample size.

a) Mean number of squares with Grey Squirrel counts (1995-2003). See Appendices 2a-c for raw data.

	Mean squares	Percent change	P ≤ 0.05
UNITED KINGDOM	472	20	*
COUNTRIES			
England	422	14	*
Wales	39	37	
ENGLISH REGIONS			
East of England	73	-4	
West Midlands	57	-16	
South East England	127	3	
South West England	63	-1	
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	235	5	
(Zone 2) Westerly lowlands (England/Wales)	192	23	*

b) Change in relative abundance from counts in the UK from 1995 –2003. Error bars represent 95% confidence intervals (see Appendix 2a for raw data).



c) Distribution from recorded presence in one or more year, 1995-2003.

Figure 4.1.5 RED FOX *Vulpes vulpes*

Summary

Significant decline in abundance overall in the UK between 1995 and 2003, although this relates to declines in 2002 and 2003, rather than an underlying trend over the entire period.

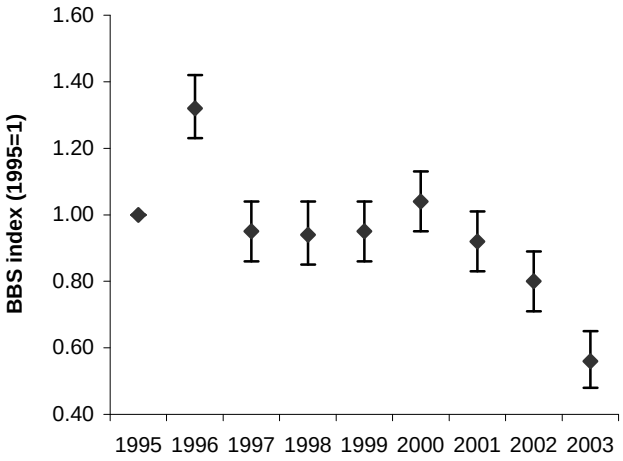
The Easterly and Westerly lowlands of England/Wales have shown a similar decline between 1995 and 2003.

Past analyses has shown that it would be possible to detect at least a 25% decline at a UK level between any two years with power of 80% or more with the existing sample size.

a) Mean number of squares with Red Fox counts (1995-2003). See Appendices 2a-c for raw data.

	Mean squares	Percent change	$P \leq 0.05$
UNITED KINGDOM	227	-44	*
COUNTRIES			
England	183	-42	
ENGLISH REGIONS			
South East England	50	-43	
South West England	41	-43	
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	98	-45	*
(Zone 2) Westerly lowlands (England/Wales)	81	-33	*

b) Change in relative abundance from counts in the UK from 1995 -2003. Error bars represent 95% confidence intervals (see Appendix 2a for raw data).



c) Distribution from recorded presence in one or more year, 1995-2003.

Figure 4.1.6 RED DEER *Cervus elaphus*

Summary

Significant decline in abundance between 1995 and 2003. This does not relate to an underlying decline in this species, but instead relates to a steep decline in 1996, due to a small number of sites not recording large herds in this year and in subsequent years. Because there are relatively few sites in the model to start with, a small number of sites not recording large herds in subsequent years, can have a large influence on the apparent relative abundance of this species.

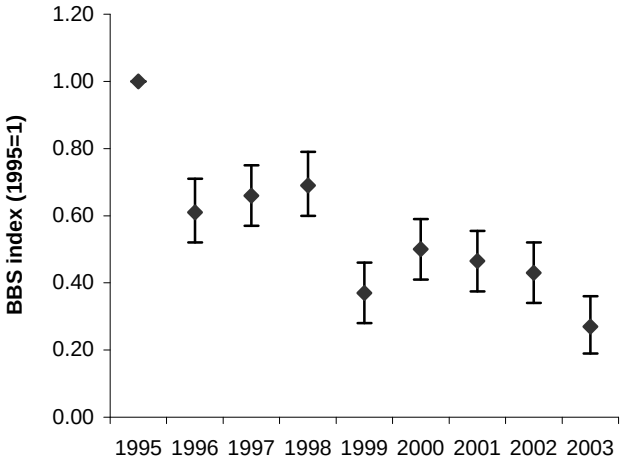
The majority of BBS squares reporting Red Deer are in Scotland.

Past analyses has shown that it would be possible to detect at least a 50% decline at a UK level between any two years with power of 80% or more with the existing sample size.

a) Mean number of squares with Red Deer counts (1995-2003). See Appendices 2a-c for raw data.

	Mean squares	Percent change	$P \leq 0.05$
UNITED KINGDOM	51	-73	*
COUNTRIES			
Scotland	40	-73	*

b) Change in relative abundance from counts in the UK from 1995-2003. Error bars represent 95% confidence intervals (see Appendix 2a for raw data).



c) Distribution from recorded presence in one or more year, 1995-2003.

Figure 4.1.7 FALLOW DEER *Dama dama*

Summary

Significant decline in abundance between 1995 and 2003. This does not relate to an underlying decline in this species, but instead relates to a steep decline in 1996, due to a small number of sites not recording large herds in this year and in subsequent years. Because there are relatively few sites in the model to start with, a small number of sites not recording large herds in subsequent years, can have a large influence on the apparent relative abundance of this species.

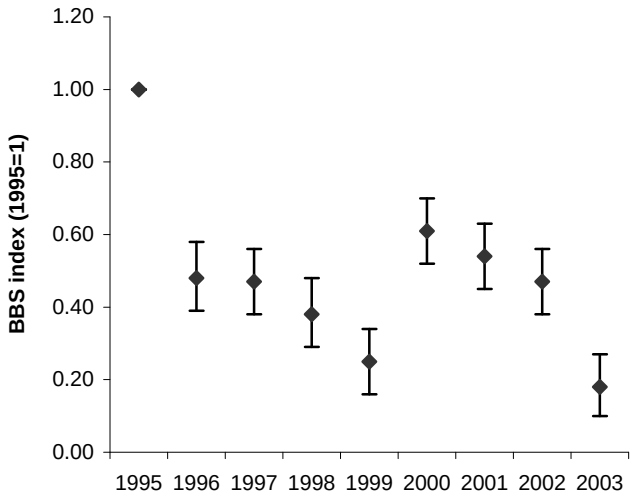
The majority of BBS squares reporting Fallow Deer are in England.

Past analyses has shown that it would be possible to detect at least a 50% decline at a UK level between any two years with power of 80% or more with the existing sample size.

a) Mean number of squares with Fallow Deer counts (1995-2003). See Appendices 2a-c for raw data.

	Mean squares	Percent change	$P \leq 0.05$
UNITED KINGDOM	39	-82	*
COUNTRIES			
England	38	-85	*

b) Change in relative abundance from counts in the UK from 1995-2003. Error bars represent 95% confidence intervals (see Appendix 2a for raw data).



c) Distribution from recorded presence in one or more year, 1995-2003.

Figure 4.1.8 ROE DEER *Capreolus capreolus*

Summary

Significant continuous increase in the UK from 1995 to 2002 although there is an apparent fall in abundance in 2003, also observed in Reeves's Muntjac.

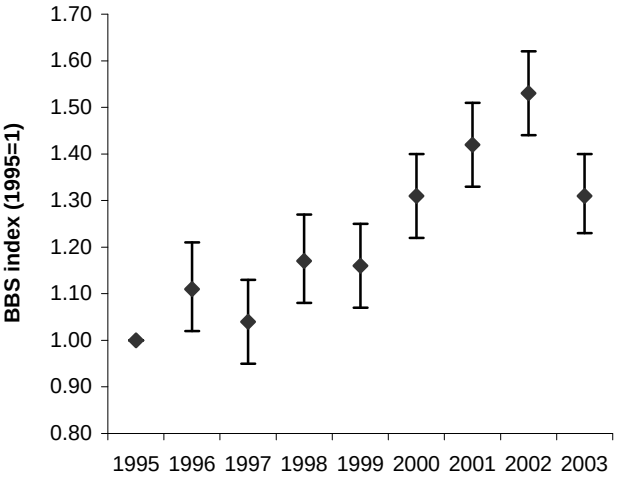
Significant increase in England in the South East and South West and generally in the westerly lowland of England/Wales.

Past analyses has shown that it would be possible to detect at least a 25% decline at a UK level between any two years with power of 80% or more with the existing sample size.

a) Mean number of squares with Roe Deer counts (1995-2003). See Appendices 2a-c for raw data.

	Mean squares	Percent change	P ≤ 0.05
UNITED KINGDOM	239	31	*
COUNTRIES			
England	175	28	*
Scotland	64	34	
ENGLISH REGIONS			
South East England	60	65	*
South West England	62	78	*
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	99	8	
(Zone 2) Westerly lowlands (England/Wales)	65	53	*

b) Change in relative abundance from counts in the UK from 1995-2003. Error bars represent 95% confidence intervals (see Appendix 2a for raw data).



c) Distribution from recorded presence in one or more year, 1995-2003.

Figure 4.1.9 REEVES'S MUNTJAC *Muntiacus reevesi*

Summary

Continuous increase in the UK from 1995 to 2002, although there is an apparent fall in abundance in 2003, also observed in Roe Deer. The change in abundance between 1995 and 2003 is not significant.

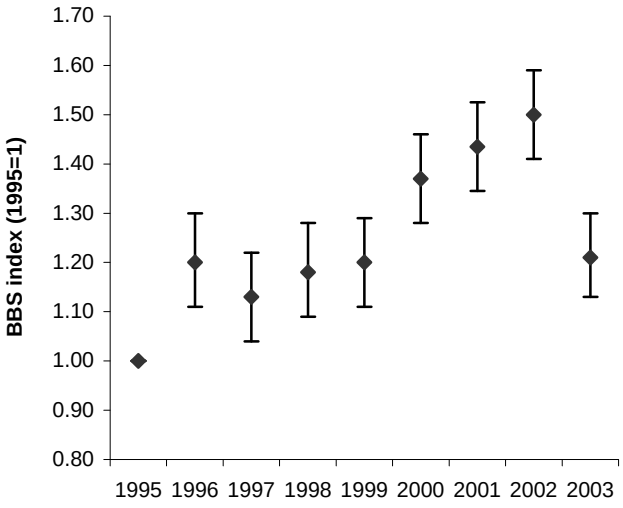
No evidence for a significant change in abundance in England.

Past analyses has shown that it would be possible to detect at least a 50% decline at a UK level between any two years with power of 80% or more with the existing sample size.

a) Mean number of squares with Reeves's Muntjac counts (1995-2003). See Appendices 2a-c for raw data.

	Mean squares	Percent change	$P \leq 0.05$
UNITED KINGDOM	45	21	
COUNTRIES			
England	45	22	
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	40	-12	

b) Change in relative abundance from counts in the UK from 1995-2003. Error bars represent 95% confidence intervals (see Appendix 2a for raw data).



c) Distribution from recorded presence in one or more year, 1995-2003.

4.2 Temporal changes in presence

The number of BBS squares reporting the presence of mammals from counts of live animals, dead animals, field signs (e.g. tracks, scats, mole-hills), local knowledge of presence for that year from a gamekeeper or landowner or live animals seen on additional visits to the square during that season for all species recorded in 1995-2003 are shown in Appendix 1b. This shows that 52 species were recorded on BBS squares during this period. For the six species for which we examine the change in presence on BBS squares (Badger, Brown Rat, Mole, Hedgehog, Stoat and Weasel), the apparent presence on BBS squares increased significantly for all these species from 1996-2003. The significance of the change in presence over time is examined using logistic regression, the results of which are shown in Appendix 3. However, because the change in odds ratio is difficult visually interpret, we present below simple figures showing the percentage change in the presence of these species on BBS squares. This information is summarised in Figure 4.2.1. (See section 5.3 for a discussion of the reliability of these trends).

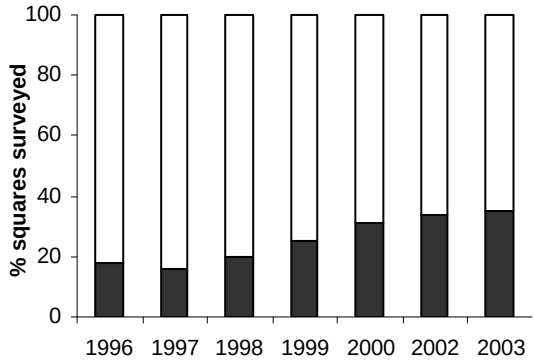
Figure 4.2.1 Summary of the change in presence on BBS squares of six mammals species.

Summary

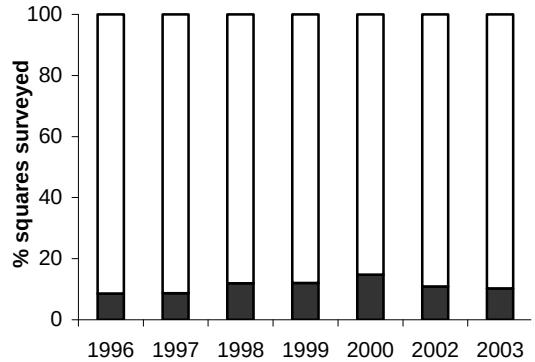
Apparent increase in presence of Mole, Hedgehog, Badger, Brown rat, Stoat and Weasel on BBS squares ($P \leq 0.05$) between 1995 and 2003.

Key Black = present: White = absent (species not recorded)

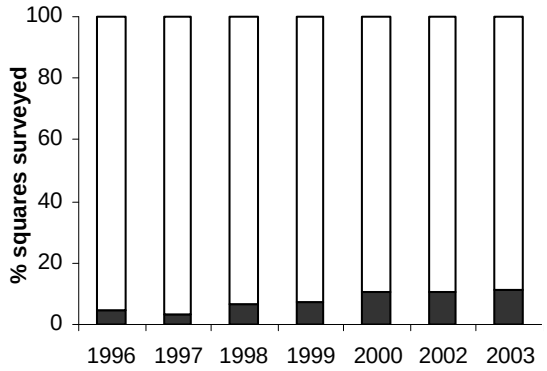
a) Mole



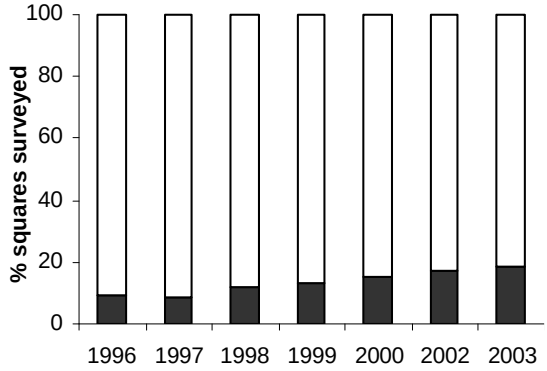
b) Hedgehog



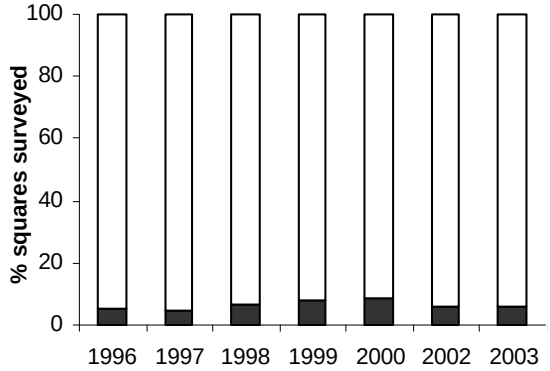
c) Brown Rat



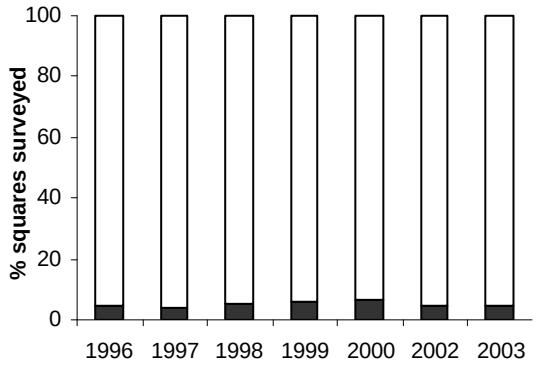
d) Badger



e) Stoat



f) Weasel



4.3 Interpolated maps of abundance

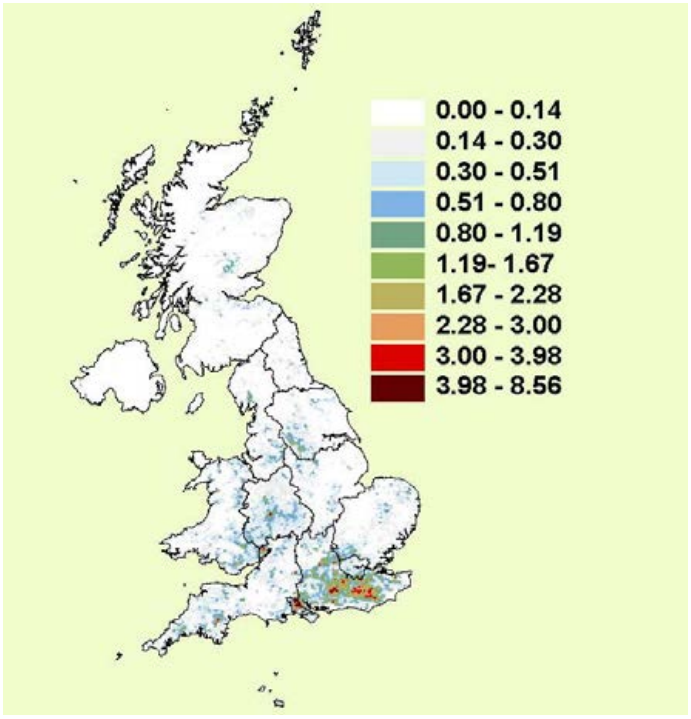
Comparing the root-mean-square prediction errors (measures how close the model predicts measured values) and standardized mean prediction errors (the extent to which the predictions are centered on the measurement values) between models in Table 4.3.1, it is clear that the addition of habitat as the predictor can improve the resulting predictions of relative abundance across the UK. For Grey Squirrel, broad-leaved woodland in 1995 and broad-leaved woodland and human habitat in 2003, provided the best predictive variables (Figure 4.3.1), whilst for Roe Deer, the combination of broad-leaved woodland and improved grassland in both 1995 and 2003 produced the best predictions of abundance (Figure 4.3.2). A change map is shown for both species is shown in Figure 4.3.3.

Table 4.3.1 Comparison of model fit and error associated with the prediction of Grey Squirrel and Roe Deer abundance across the UK from BBS sightings data for 1995 and 2003 and CEH landcover data aggregated into seven habitat categories. For the predictions to be unbiased (centered on the measurement values), the prediction errors should be close to zero. This depends on the scale of the data, which we standardize by dividing the prediction error by their prediction standard errors to give standardized mean prediction errors, which should also be close to zero. The predictions should also be as close as possible to the measurement values. To examine this we compute the root-mean-square prediction errors (the square root of the average of the squared distances between the predictions and their true values), for which the smaller the value the closer the model predicts the measured values. The best models are highlighted in bold. The chosen model is marked with an asterisk.

Model: 1995	Root-mean-square prediction errors	Standardized mean prediction errors	Model: 2003	Root-mean-square prediction errors	Standardized mean prediction errors
GREY SQUIRREL			GREY SQURRIEL		
No habitat: Simple kriging	1.187	-0.3927	No habitat: Simple kriging	1.489	-0.3026
Moorland, heath & bog	1.190	-0.3908	Moorland, heath & bog	1.491	-0.2938
Broadleaved woodland*	**1.198**	**-0.2673**	Broadleaved woodland	**1.514**	**-0.1667**
Coniferous woodland	1.190	-0.4183	Coniferous woodland	1.492	-0.3325
Improved grassland	1.189	-0.4377	Improved grassland	1.495	-0.3740
Semi-natural grassland	1.188	-0.4260	Semi-natural grassland	1.492	-0.3557
Arable	1.214	-0.4250	Arable	1.531	-0.3309
Human	**1.282**	**-0.2873**	Human	**1.637**	**-0.1829**
Broadleaved woodland + Human	**1.54**	**-0.2012**	Broadleaved woodland + Human*	**1.422**	**-0.07768**
ROE DEER			ROE DEER		
No habitat: Simple kriging	1.04	-0.5528	No habitat: Simple kriging	1.131	-0.3840
Moorland, heath & bog	1.048	-0.5687	Moorland, heath & bog	1.134	-0.3605
Broadleaved woodland	**1.045**	**-0.5195**	Broadleaved woodland	**1.130**	**-0.3406**
Coniferous woodland	1.042	-0.5546	Coniferous woodland	1.133	-0.3640
Improved grassland	**1.043**	**-0.5382**	Improved grassland	**1.133**	**-0.3589**
Semi-natural grassland	1.044	-0.5408	Semi-natural grassland	1.133	-0.3669
Arable	1.044	-0.546	Arable	1.133	-0.3654
Human	1.043	-0.5591	Human	1.132	-0.3772
Broadl woodland + improved grass*	**1.045**	**-0.5189**	Broadl woodland + improved grass*	**1.133**	**-0.3223**

Figure 4.3.1 Interpolated relative abundance of Grey Squirrel from BBS mammal data.

a) 1995



b) 2003

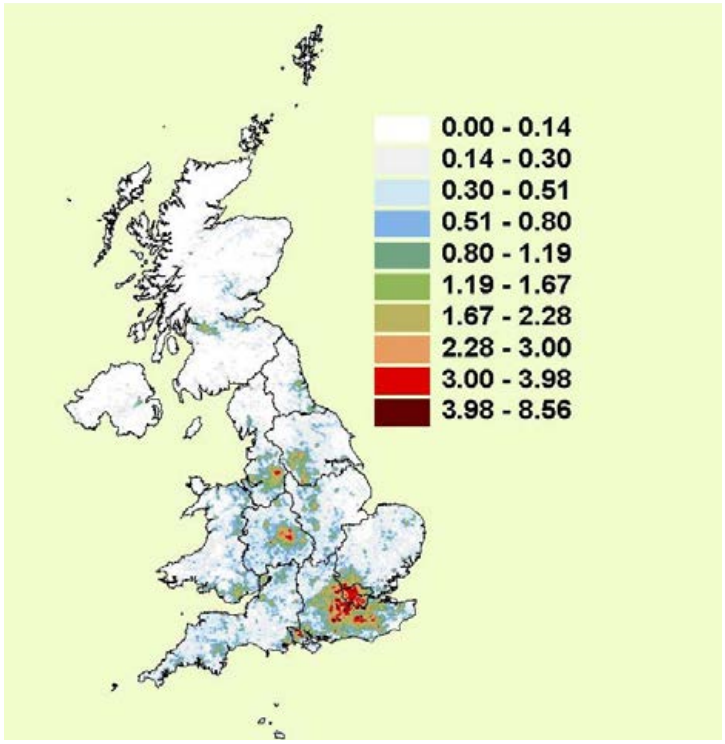
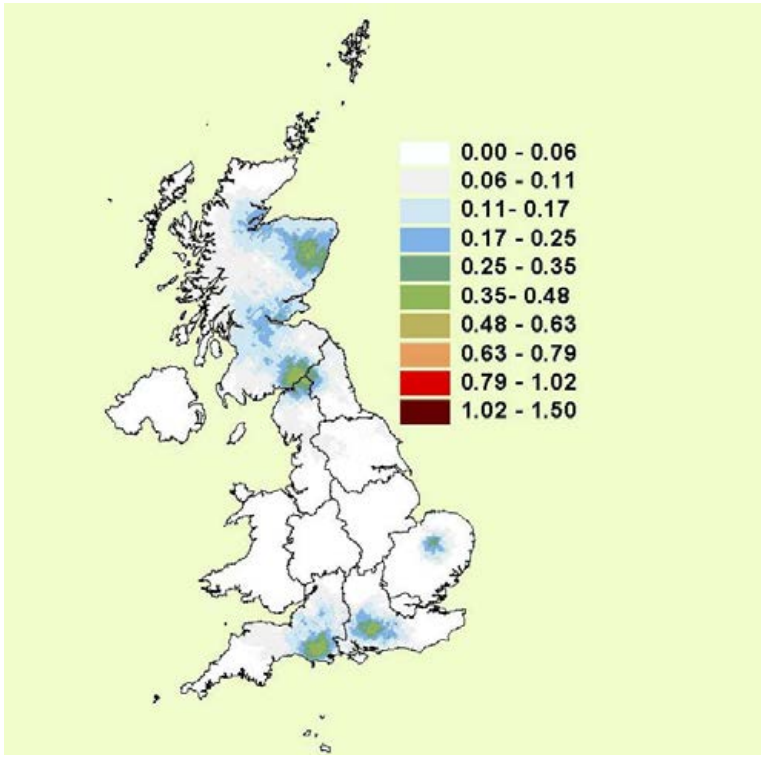


Figure 4.3.2 Interpolated relative abundance of Roe Deer from BBS mammal data.

a) 1995



b) 2003

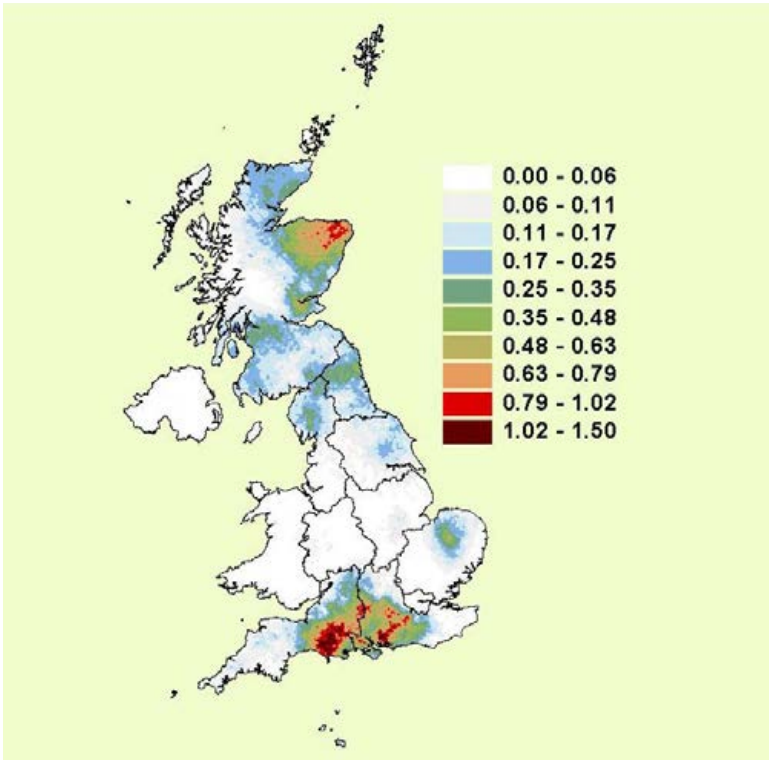
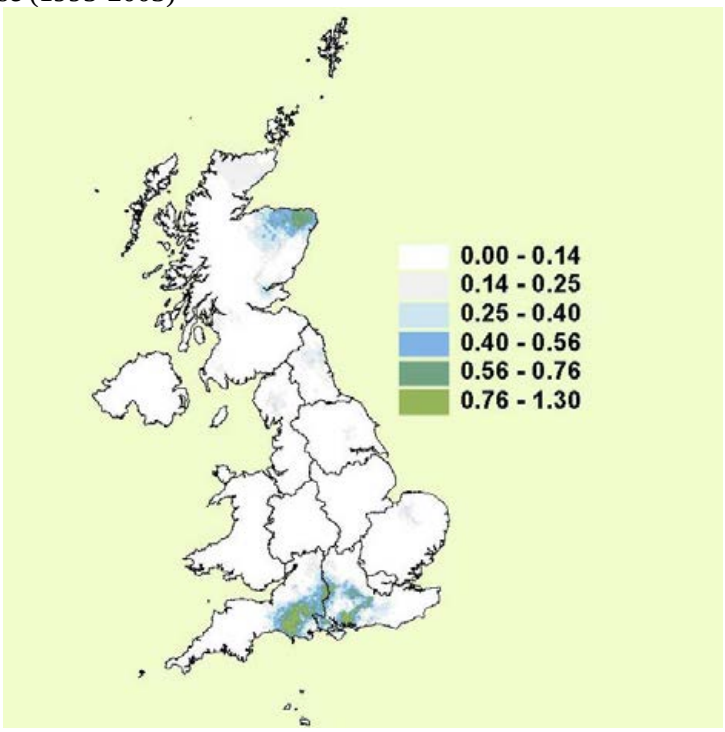
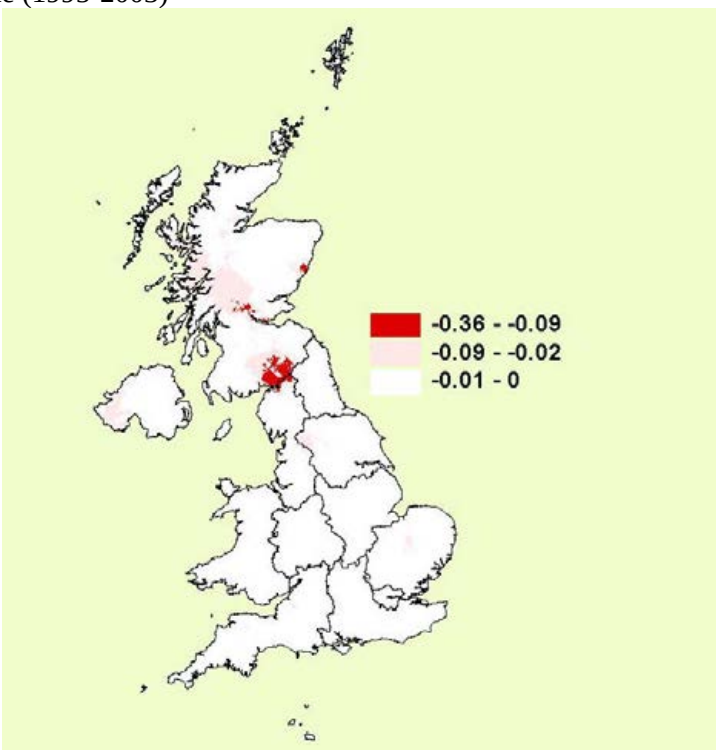


Figure 4.3.3 Change in relative abundance of Roe Deer and Grey Squirrel between 1995 and 2003.

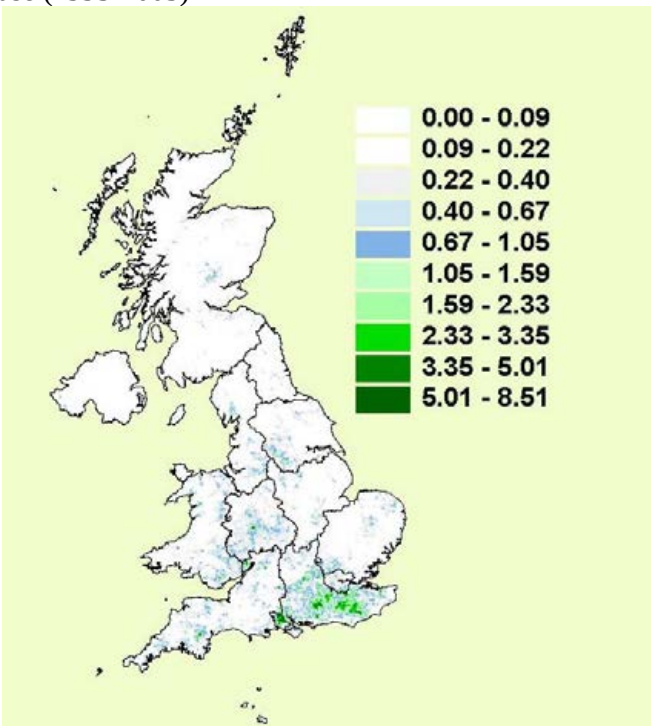
a i) Roe Deer increase (1995-2003)



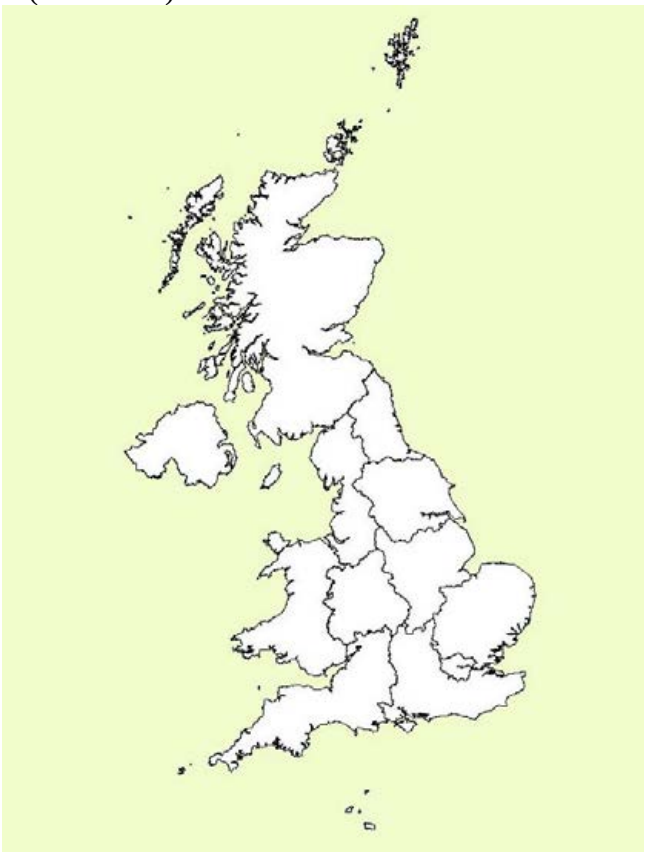
a ii) Roe Deer decline (1995-2003)



b i) Grey Squirrel increase (1995-2003)



b i) Grey Squirrel decline (1995-2003)



5. DISCUSSION

5.1 UK population trends from sightings

This report highlights the importance of the BBS for annual monitoring of a number of terrestrial mammals in the UK. Data were sufficient to produce population trends based on count data at a UK level for nine species of mammal (Brown Hare, Mountain/Irish Hare, Grey Squirrel, Red Fox, Red Deer, Fallow Deer, Roe Deer, Reeves's Muntjac and Rabbit). Whilst annual indices of this type are important for identifying annual variation in abundance at various scales, comparing abundance between the first and last years in the series could be misleading if the species fluctuates widely in abundance between years.

Fitting linear trends as in Newson & Noble (2003) could be used to examine the significance of the underlying trend, although, as the time series becomes more extensive, the potential of generalized additive models (GAMs) for reducing noise resulting from annual fluctuations in abundance should be considered. Unlike conventional generalised linear models (GLMs), which allow change in mean abundance over time to follow a linear form or sequence of unrelated estimates, GAMs allow mean abundance to follow any smooth function, the formulation of which is described in detail by Hastie & Tibshirani (1990).

Whilst the analyses here covered a relatively short time period (1995-2003), it is already apparent that there have been a number of important changes within these populations during this time. Comparing abundance of the above species at a UK level in 2003 relative to 1995, Grey Squirrel and Roe Deer were significantly higher in 2003, whilst Rabbit, Mountain Hare, Red Fox, Red Deer and Fallow Deer were significantly lower in this year. Most species show significant fluctuations in abundance between years, so it is important to interpret a significant difference in abundance between 1995 and 2003 in relation to the underlying trend between these years.

5.2 Factors affecting population change

Grey Squirrel showed a particularly large fluctuation in abundance in 1996. It is encouraging to observe that trends for Grey Squirrel based on independent game bag data for this species show a similar peak in this year (Whitlock *et al*. 2003). Examining the proportion of BBS squares reporting the presence of Grey Squirrels in this year (see Appendix 1b) there is no evidence of an increase in the distribution of this species, so this fluctuation perhaps reflects high productivity in 1996. In a similar way there is no evidence from presence data for a contraction in the range of Rabbits from 1997, although there is an observed decline in relative abundance on recording squares from 1997 onwards, which is also seen in independent analyses of game bag data for this species (Whitlock *et al.* 2003). For Roe Deer there is a significant increase in relative abundance and an increase in the proportion of BBS squares reporting this species. This suggests that the increase in relative abundance may have occurred through expansion of its existing range during the survey period. Interestingly both Roe Deer and Reeves's Muntjac showed a drop in abundance in 2003, following a period of population growth. The reason for the apparent fall in abundance in this year is not known.

The decrease in the proportion of squares reporting the presence of Red Deer and Fallow Deer could reflect contraction in the range of this species, although examination of the raw count data suggests that the drop in abundance in 1996 is mainly the result of a small number of sites reporting large herds in 1995 but not in following years. Because there are relatively few sites in the model to start with, a small number of sites not recording large herds after 1995 is having a proportionally large influence on the apparent, but not real abundance of these species.

5.3 Population trends from presence/absence data

BBS observers collect sufficient data to model trends in presence/absence (based on counts and other information indicating presence) for some of the nine core species for which we produce trends from

count data. In most cases, however the additional information adds very few additional squares. Moreover, some additional information may be less reliable than count data, for example using field signs for deer, which are difficult to assign correctly to species without experience and training.

This report examines the change in presence, using evidence of species presence from field signs, dead animals, local knowledge of presence, counts of live animals made during the survey or any additional visits, for six species, which are rarely seen. Change in the populations of these species should be interpreted with caution for a number of reasons. The first is related to the criteria for recording presence, data for which is currently available for 2002 and 2003 only. For example, Newson & Noble (2005) showed that the presence of moles in 2002 was exclusively recorded from field signs (mole-hills), whilst a large proportion of hedgehogs are reported from dead animals. In fact, hedgehog is the only species for which dead animals are likely to contribute significantly to analyses of presence/absence. The majority of Badger records are based on field signs, and to a lesser extent local knowledge. It should be noted that field signs here include setts and latrines, and there is no way of distinguishing between these in the current data.

The reliability of monitoring the presence of a species where a large proportion of the information is obtained through word of mouth (local information gained from landowner or gamekeeper) is difficult to assess without more supplementary information, but it is probably poor. For example the high similarity in UK trends of Stoat and Weasel, which are both gleaned mainly from local knowledge, should perhaps be treated with caution. Other species for which local knowledge contributes a significant proportion of the recorded presence includes Brown Rat and Hedgehog and to a lesser extent Red Fox. Now that the criteria for presence are recorded, further analyses could examine the influence of excluding records based solely on local knowledge on the resulting trends.

The second important point to make is that there have been a number of changes to the survey form that may affect the apparent presence of species on BBS squares during the survey period. In 1996, a number of species were added to the species list, including Badger, Hedgehog, Brown Rat, Mole, Stoat and Weasel. For this reason, data for 1995 may not be comparable with 1996 and for this reason, as we have done here, trends should be calculated from 1996 (see section 4.2). Furthermore additional changes to the form were made in 2000, the most important of which was to clarify what the category of presence should include, making it clearer in the instructions that this should include the recording of dead animals, information from personal communication with landowners/gamekeepers and stating specifically on the survey form examples of signs including mole-hills and Badger latrines. For further discussion of the implications of changes to the survey form see Newson & Noble (2005).

The change to the survey form in 2002 was intended to provide more detail and should in principle have little influence on rate of recording of presence, but it is not to possible to confirm this from the data collected. We perhaps have three distinct time series of data. The first year (1995) is excluded from all analyses of presence/absence because there may be a year effect resulting from observers acquainting themselves with mammal recording and the absence of Badger, Mole, Hedgehog and Brown Rat, from the form in 1995. The second series covers the period 1996-99, during which there were no obvious changes to the survey form that would result in a change in apparent presence, although increasing observer awareness of the presence of a species in a square (e.g. after a badger sett is found) could result in an apparent increase in the presence of these species during this period.

The data for 2000 are likely to be comparable with data in 2002 and 2003, although the data form was changed in 2002 to record the criteria for recording presence (e.g. counts of live animals, dead animals etc.), although this should not change the incidence of reported presence on BBS squares. Data for 2001 are excluded because coverage in this year was severely biased by the influence of foot-and-mouth disease. With further years of data, it is hoped that it will be possible to be more confident in our estimates of change in populations of these species. It may be sensible in the future to continue to exclude all data for 1995, because of the potential year effect and exclusion of a number of key species and to join trends for the periods 1996-99 to the index for 2000 onwards without including the

change from 1999 to 2000. This also shows that unless it is absolutely essential to do so, there should be no further changes to the survey form.

5.4 Regional trends and trends by Environmental Zone

Where data were sufficient, annual indices were produced at a Government Office Region level, for countries of the UK and for Environmental Zones. Environmental Zones are based on groupings of CEH Land Cover Map 2000 broad habitat categories and cover a range of environmental conditions that we find in the UK from the lowlands of the south and east, through to the uplands and mountains of the north and west. As in Newson *et al*. (2005), trends in relative abundance could be produced for five mammal species (Brown Hare, Rabbit, Grey Squirrel, Red Fox and Roe Deer) for two or more regions and Environmental Zones and for Red Deer in Scotland, Fallow Deer and Reeves's Muntjac in England and Reeves's Muntjac in the Easterly lowlands of England/Wales.

Whilst habitat information is recorded by BBS observers for each 10 x 200 m transect section surveyed, counts of mammals are made at a broader 1-km square level. For this reason, analyzing BBS habitat information at this level has no apparent advantages over CEH land cover data which is also at the 1-km square level, but covers the entire UK, which has obvious advantages over BBS habitat data for predictive modeling purposes. Grouping CEH land cover categories into Environmental Zones provides trends for a broad range of environmental conditions found in the UK and importantly is comparable with other mammal surveys, such as the BTO/Mammal Society Winter Mammal Monitoring Survey (Noble *et al*. 2002), and will therefore be of utility. Although we do not make comparisons between the BBS, the Winter Mammal Monitoring Survey and other independent surveys in this report, but this would be a useful comparison.

5.5 Monitoring distribution

Whilst the above analyses cover a range of mammal species recorded on BBS squares, data for a large proportion of mammal species recorded by the BBS are still insufficient to calculate robust indices of relative abundance or occurrence. However, these data still provide important information on the distribution of species, which in many cases are not properly monitored by any existing scheme. Distribution maps of species presence combined over intervals of perhaps five or ten-year blocks, as more data are collected, might be considered. Trials in Newson & Noble (2005) examined the use of geostatistical methods for improving our understanding of finer scale spatial patterns in relative abundance or distribution, than is possible through the production of regional indices or visually through the production of distribution maps of species presence. In this report we apply these methods to sightings data for two species, Grey Squirrel and Roe Deer. Using similar methodology for binary data (indicator kriging), it should be possible to produce maps of species presence for species that are rarely seen, such as Badger, Mole, Hedgehog, Brown Rat, Stoat and Weasel and to make comparisons where more than one indicator of presence is recorded. An example would be to compare predicted presence for Red Fox from sightings and field signs. Results from the production of interpolated maps of abundance for Grey Squirrel and Roe Deer, demonstrate the importance of habitat requirements for this species, and how information of this type at a 1 km scale, such as the Land Cover Map 2000 data (Haines-Young *et al*. 2000) used here can improve our predictions. Although considerably time consuming for the analyst, predictions may be improved if models are produced and compared for each of the 27 separate landcover classes, rather than for the aggregated classes used here. Current research into the development of interpolated maps of this type at the BTO has focused on using the geostatistical analyst extension of ArcMap. Because of the increasing use of this methodology by bird monitoring organizations primarily across Europe, an international spatial modeling workgroup for birds was established in April 2005. This will compile and assess the different methodologies (including software) available for such a purpose and discuss their adequacy in different regions, and their general accessibility and usability, with the main aim of working towards a pan-European bird mapping initiative. Whilst mammal recording at a European level is not as well established as European bird monitoring, these discussions are likely to have a large influence on the direction of future work that examines the distribution and abundance of British mammals.

6. CONCLUSIONS

Although the majority of British mammal species are recorded on too few squares to be monitored effectively by this survey, this report demonstrates that we can monitor a core group of common medium to large-sized mammals using sightings data. Data on the presence/absence of an additional group of species provides potential for increasing the number of monitorable species further, but changes in recording protocols limit the conclusions from the first years of the BBS. Nevertheless, now that observers record the criteria that they use for reporting presence (e.g. live animals, field signs, dead animals, local knowledge of presence from that season or live animals seen on additional visits), the potential for reliability monitoring and interpreting change in the presence of these species improves greatly. For the remaining species reported on BBS squares, these are reported on too few squares to do little more than map presence. In isolation these data are of little importance, apart from perhaps identifying the strongholds of particular species. However, it is important to highlight the potential for combining these data with those from other surveys and perhaps with incidental records through the National Biodiversity Network to provide a better understanding of their distribution.

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Appendix 1a The number of BBS squares recording counts of mammals on BBS squares (percentage of total BBS squares surveyed in shown in parentheses). We excluded data here and in the analyses for 2001 due to the bias in survey coverage caused by the outbreak of foot-and-mouth disease. Species occurring on a mean of 40 or more squares over the seven years and for which we produce annual trends in relative abundance are highlighted in bold.

	Year							
Species	1995	1996	1997	1998	1999	2000	2002	2003
Hedgehog	8 (0.6)	27 (1.7)	43 (2.3)	29 (1.5)	35 (1.7)	29 (1.5)	14 (0.8)	9 (0.5)
Mole	18 (1.4)	76 (4.7)	56 (3)	30 (1.5)	45 (2.2)	6 (0.3)	0	0
Common Shrew	19 (1.4)	52 (3.2)	47 (2.5)	74 (3.8)	68 (3.3)	4 (0.2)	11 (0.6)	5 (0.3)
Pygmy Shrew	0	0	0	1 (0.1)	0	2 (0.1)	1 (0.1)	0
Water Shrew	0	0	1 (0.1)	2 (0.1)	0	0	0	0
Natterer's Bat	0	1 (0.1)	0	0	0	0	0	0
Pipistrelle Bat	0	0	1 (0.1)	0	2 (0.1)	0	0	0
Rabbit	827 (62)	980 (60.6)	1163 (61.8)	1177 (60.1)	1194 (58.8)	1169 (61.5)	1117 (61.6)	1027 (53.6)
Brown Hare	428 (32.1)	512 (31.7)	599 (31.8)	577 (29.4)	599 (29.5)	574 (30.2)	536 (29.5)	478 (24.9)
Mountain Hare	28 (2.1)	48 (3)	60 (3.2)	60 (3.1)	57 (2.8)	44 (2.3)	39 (2.1)	35 (1.8)
Red Squirrel	7 (0.5)	18 (1.1)	21 (1.1)	16 (0.8)	16 (0.8)	14 (0.7)	12 (0.7)	12 (0.6)
Grey Squirrel	301 (22.6)	501 (31)	500 (26.6)	517 (26.4)	509 (25.1)	542 (28.5)	523 (28.8)	452 (23.6)
Bank Vole	3 (0.2)	7 (0.4)	5 (0.3)	4 (0.2)	3 (0.1)	2 (0.1)	1 (0.1)	1 (0.1)
Field Vole	2 (0.2)	6 (0.4)	5 (0.3)	9 (0.5)	7 (0.3)	2 (0.1)	3 (0.2)	0
Orkney Vole	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	1 (0.1)	1 (0.1)	1 (0.1)
Water Vole	4 (0.3)	7 (0.4)	8 (0.4)	7 (0.4)	19 (0.9)	11 (0.6)	4 (0.2)	4 (0.2)
Wood Mouse	2 (0.2)	9 (0.6)	2 (0.1)	3 (0.2)	3 (0.1)	4 (0.2)	1 (0.1)	1 (0.1)
Harvest Mouse	0	1 (0.1)	0	0	0	0	0	0
House Mouse	0	0	0	0	0	1 (0.1)	0	0
Brown Rat	13 (1)	23 (1.4)	17 (0.9)	16 (0.8)	24 (1.2)	30 (1.6)	23 (1.3)	19 (1.0)
Red Fox	180 (13.5)	256 (15.8)	255 (13.5)	240 (12.2)	286 (14.1)	245 (12.9)	230 (12.7)	166 (8.7)
Pine Marten	2 (0.2)	2 (0.1)	0	1 (0.1)	1 (0.1)	3 (0.2)	0	0
Stoat	26 (2)	28 (1.7)	33 (1.8)	31 (1.6)	37 (1.8)	28 (1.5)	15 (0.8)	17 (0.9)
Weasel	9 (0.7)	14 (0.9)	22 (1.2)	22 (1.1)	20 (1)	15 (0.8)	10 (0.6)	10 (0.5)
Polecat	0	1 (0.1)	3 (0.2)	1 (0.1)	2 (0.1)	0	0	0
Ferret	0	0	0	0	0	0	1 (0.1)	0
American Mink	3 (0.2)	1 (0.1)	3 (0.2)	2 (0.1)	1 (0.1)	6 (0.3)	0	2 (0.1)
Badger	5 (0.4)	21 (1.3)	14 (0.7)	14 (0.7)	13 (0.6)	5 (0.3)	8 (0.4)	8 (0.4)
Otter	1 (0.1)	3 (0.2)	3 (0.2)	3 (0.2)	1 (0.1)	4 (0.2)	3 (0.2)	8 (0.4)

Species	Year							
	1995	1996	1997	1998	1999	2000	2002	2003
Feral/Domestic Cat	2 (0.2)	1 (0.1)	2 (0.1)	3 (0.2)	4 (0.2)	194 (10.2)	250 (13.8)	236 (12.3)
Park Cattle	1 (0.1)	0	0	0	0	0	0	0
Minke Whale	0	0	0	0	0	0	1 (0.1)	0
Harbour Porpoise	1 (0.1)	0	0	0	0	0	0	0
Common Seal	2 (0.2)	0 (0)	1 (0.1)	1 (0.1)	2 (0.1)	2 (0.2)	2 (0.2)	2 (0.1)
Grey Seal	0	2 (0.1)	2 (0.1)	4 (0.2)	2 (0.1)	1 (0.1)	3 (0.2)	1 (0.1)
Red Deer	51 (3.8)	76 (4.7)	56 (3)	65 (3.3)	55 (2.7)	45 (2.4)	43 (2.4)	32 (1.7)
Sika Deer	4 (0.3)	4 (0.2)	3 (0.2)	5 (0.3)	4 (0.2)	8 (0.4)	9 (0.5)	7 (0.4)
Fallow Deer	30 (2.3)	34 (2.1)	40 (2.1)	45 (2.3)	36 (1.8)	51 (2.7)	51 (2.8)	29 (1.5)
Roe Deer	182 (13.7)	214 (13.2)	228 (12.1)	249 (12.7)	277 (13.6)	270 (14.2)	300 (16.5)	235 (12.3)
Reeves's Muntjac	40 (3)	35 (2.2)	40 (2.1)	47 (2.4)	58 (2.9)	49 (2.6)	57 (3.1)	41 (2.1)
Chinese Water Deer	1 (0.1)	1 (0.1)	0	0	3 (0.1)	2 (0.1)	3 (0.2)	2 (0.1)
Feral Goat	4 (0.3)	2 (0.1)	1 (0.1)	3 (0.2)	3 (0.1)	3 (0.2)	3 (0.2)	2 (0.1)

Appendix 1b The number of BBS squares recording the presence of mammals on BBS squares from counts of live animals, as used in the above analyses, dead animals, field signs (e.g. tracks, scats, mole-hills), local knowledge of presence for that year from a gamekeeper or landowner or live animals seen on additional visits to the square during that season (percentage of total BBS squares surveyed in shown in parentheses). We excluded data here and in the analyses for 2001 due to the bias in survey coverage caused by the outbreak of foot-and-mouth disease. Species for which analyses to examine the change in species presence on BBS squares is carried out are highlighted in bold.

	Year							
Species	1995	1996	1997	1998	1999	2000	2002	2003
Hedgehog	25 (1.9)	138 (8.6)	162 (8.7)	233 (11.9)	244 (12.1)	281 (14.8)	197 (10.9)	188 (9.8)
Mole	95 (7.2)	284 (17.6)	292 (15.6)	389 (19.9)	510 (25.2)	587 (30.9)	610 (33.7)	640 (33.4)
Common Shrew	27 (2.1)	100 (6.2)	89 (4.8)	157 (8.1)	171 (8.5)	16 (0.9)	19 (1.1)	11 (0.6)
Pygmy Shrew	1 (0.1)	2 (0.2)	2 (0.2)	4 (0.3)	3 (0.2)	3 (0.2)	4 (0.3)	2 (0.1)
Water Shrew	0	0	1 (0.1)	2 (0.2)	0	1 (0.1)	2 (0.2)	0
Lesser white-toothed Shrew	0	1 (0.1)	0	2 (0.2)	0	0	1 (0.1)	1 (0.1)
Greater Horseshoe Bat	0	0	0	0	0	0	1 (0.1)	0
Natterer's Bat	0	2 (0.2)	0	0	0	0	0	0
Noctule Bat	2 (0.2)	1 (0.1)	1 (0.1)	2 (0.2)	1 (0.1)	1 (0.1)	0	0
Leisler's Bat	0	0	0	0	1 (0.1)	0	0	0
Pipistrelle Bat	4 (0.4)	5 (0.4)	6 (0.4)	4 (0.3)	10 (0.5)	4 (0.3)	4 (0.3)	4 (0.2)
Long-eared Bat	0	1 (0.1)	0	1 (0.1)	1 (0.1)	0	0	1 (0.1)
Rabbit	962 (72.2)	1120 (69.4)	1304 (69.3)	1366 (69.7)	1438 (70.9)	1351 (71.1)	1294 (71.4)	1362 (71.0)
Brown Hare	493 (37)	583 (36.1)	651 (34.6)	642 (32.8)	679 (33.5)	646 (34)	605 (33.4)	664 (34.6)
Mountain Hare	40 (3.1)	65 (4.1)	71 (3.8)	76 (3.9)	66 (3.3)	51 (2.7)	53 (3)	64 (3.3)
Red Squirrel	15 (1.2)	30 (1.9)	32 (1.7)	35 (1.8)	29 (1.5)	28 (1.5)	27 (1.5)	27 (1.4)
Grey Squirrel	398 (29.9)	571 (35.4)	607 (32.3)	669 (34.2)	719 (35.5)	742 (39.1)	676 (37.3)	718 (37.5)
Bank Vole	3 (0.3)	15 (1)	10 (0.6)	8 (0.5)	5 (0.3)	4 (0.3)	5 (0.3)	4 (0.2)
Field Vole	15 (1.2)	25 (1.6)	14 (0.8)	16 (0.9)	16 (0.8)	11 (0.6)	12 (0.7)	7 (0.4)
Orkney Vole	2 (0.2)	1 (0.1)	0	3 (0.2)	3 (0.2)	2 (0.2)	2 (0.2)	2 (0.1)
Water Vole	5 (0.4)	8 (0.5)	12 (0.7)	14 (0.8)	24 (1.2)	18 (1)	13 (0.8)	10 (0.5)
Wood Mouse	9 (0.7)	15 (1)	6 (0.4)	6 (0.4)	12 (0.6)	11 (0.6)	8 (0.5)	6 (0.3)
Yellow-necked Mouse	0	0	1 (0.1)	0	0	1 (0.1)	0	1 (0.1)
Harvest Mouse	0	1 (0.1)	1 (0.1)	0	1 (0.1)	0	1 (0.1)	2 (0.1)
House Mouse	0	2 (0.2)	1 (0.1)	2 (0.2)	2 (0.1)	4 (0.3)	3 (0.2)	2 (0.1)
Brown Rat	23 (1.8)	78 (4.9)	64 (3.4)	129 (6.6)	154 (7.6)	196 (10.4)	187 (10.4)	209 (10.9)
Common Dormouse	1 (0.1)	1 (0.1)	2 (0.2)	1 (0.1)	1 (0.1)	0	0	0
Red Fox	423 (31.8)	527 (32.7)	476 (25.3)	592 (30.3)	686 (33.8)	701 (36.9)	632 (34.9)	671 (35.0)

Species	Year							
	1995	1996	1997	1998	1999	2000	2002	2003
Pine Marten	4 (0.4)	9 (0.6)	3 (0.2)	2 (0.2)	2 (0.1)	5 (0.3)	2 (0.2)	5 (0.3)
Stoat	37 (2.8)	86 (5.4)	85 (4.6)	123 (6.3)	162 (8)	159 (8.4)	111 (6.2)	112 (5.8)
Weasel	19 (1.5)	69 (4.3)	70 (3.8)	104 (5.4)	125 (6.2)	122 (6.5)	88 (4.9)	81 (4.2)
Polecat	0	1 (0.1)	3 (0.2)	3 (0.2)	6 (0.3)	4 (0.3)	0	0
Ferret	0	0	0	0	0	1 (0.1)	2 (0.2)	0
American Mink	7 (0.6)	8 (0.5)	7 (0.4)	10 (0.6)	9 (0.5)	28 (1.5)	25 (1.4)	29 (1.5)
Badger	82 (6.2)	152 (9.5)	156 (8.3)	235 (12)	273 (13.5)	287 (15.1)	305 (16.9)	337 (17.6)
Otter	6 (0.5)	13 (0.9)	12 (0.7)	14 (0.8)	8 (0.4)	18 (1)	16 (0.9)	28 (1.5)
Wild Cat	1 (0.1)	0	0	0	0	0	0	1 (0.1)
Feral/Domestic Cat	3 (0.3)	2 (0.2)	2 (0.2)	3 (0.2)	4 (0.2)	350 (18.5)	365 (20.2)	421 (22.0)
Chillingham Cattle	1 (0.1)	0	0	0	0	0	0	0
Wild Boar	0	0	0	0	0	0	1 (0.1)	0
Minke Whale	0	0	0	0	0	0	1 (0.1)	0
Harbour Porpoise	1 (0.1)	0	0	0	0	0	0	0
Common Seal	2 (0.2)		1 (0.1)	1 (0.1)	2 (0.1)	2 (0.2)	2 (0.2)	3 (0.2)
Grey Seal	1 (0.1)	2 (0.2)	2 (0.2)	4 (0.3)	2 (0.1)	1 (0.1)	4 (0.3)	2 (0.1)
Red Deer	84 (6.4)	100 (6.2)	98 (5.3)	108 (5.6)	93 (4.6)	71 (3.8)	75 (4.2)	78 (4.1)
Sika Deer	5 (0.4)	5 (0.4)	3 (0.2)	8 (0.5)	4 (0.2)	11 (0.6)	17 (1)	12 (0.6)
Fallow Deer	47 (3.6)	57 (3.6)	57 (3.1)	86 (4.4)	78 (3.9)	89 (4.7)	90 (5)	83 (4.3)
Roe Deer	245 (18.4)	296 (18.4)	301 (16)	356 (18.2)	394 (19.4)	385 (20.3)	408 (22.5)	436 (22.7)
Reeves's Muntjac	60 (4.6)	67 (4.2)	74 (4)	100 (5.2)	103 (5.1)	122 (6.5)	110 (6.1)	113 (5.9)
Chinese Water Deer	1 (0.1)	2 (0.2)	1 (0.1)	0	3 (0.2)	2 (0.2)	3 (0.2)	4 (0.2)
Feral Goat	5 (0.4)	3 (0.2)	1 (0.1)	3 (0.2)	3 (0.2)	2 (0.2)	3 (0.2)	3 (0.2)
Red-necked Wallaby	0	0	0	0	0	0	1 (0.1)	0

Appendix 2a UK temporal trends in relative abundance for nine mammal species for the period 1995-2003. 95% confidence intervals are shown in brackets. Indices are measured relative to the year 1995, which is set to one. Although we exclude data for 2001 from the analyses due to foot-and-mouth disease, we interpolate an index here for 2001. An asterisk denotes a significant difference between the first and last years of the survey at the 5% level or more. We present for each species whether a 25% or 50% decline would be detectable with 80% power. A visual representation of temporal trends in abundance for the UK are shown in Figure 2.3.

		Year								
Species	*n*	1995	1996	1997	1998	1999	2000	2001	2002	2003
Brown Hare	526	1	1.06 (0.97-1.16)	0.98 (0.89-1.07)	0.98 (0.89-1.08)	0.91 (0.82-1.00)	0.96 (0.87-1.05)	0.98 (0.89-1.07)	0.99 (0.90-1.08)	0.91 (0.83-1.00)
Mountain Hare*	44	1	1.4 (1.07-1.82)	2.07 (1.61-2.66)	1.42 (1.08-1.86)	1.16 (0.86-1.56)	1.10 (0.83-1.47)	1.34 (1.09-1.67)	0.86 (0.64-1.15)	0.66 (0.49-0.90)
Rabbit*	1057	1	1.06 (1.00-1.13)	1.27 (1.19-1.35)	1.00 (0.94-1.07)	0.82 (0.76-0.88)	0.94 (0.87-1.00)	0.98 (0.91-1.04)	0.77 (0.71-0.83)	0.73 (0.68-0.79)
Grey Squirrel*	472	1	2.07 (1.87-2.29)	1.27 (1.14-1.42)	1.12 (1.00-1.26)	0.95 (0.84-1.07)	1.23 (1.10-1.38)	1.32 (1.19-1.47)	1.30 (1.16-1.45)	1.20 (1.07-1.35)
Red Fox*	227	1	1.32 (1.16-1.49)	0.95 (0.83-1.09)	0.94 (0.82-1.08)	0.95 (0.83-1.09)	1.04 (0.90-1.19)	1.00 (0.88-1.14)	0.80 (0.69-0.92)	0.56 (0.48-0.65)
Red Deer*	51	1	0.61 (0.48-0.77)	0.66 (0.52-0.84)	0.69 (0.55-0.88)	0.37 (0.28-0.49)	0.50 (0.37-0.67)	0.54 (0.42-0.70)	0.43 (0.32-0.57)	0.27 (0.19-0.37)
Roe Deer*	239	1	1.11 (0.97-1.28)	1.04 (0.90-1.20)	1.17 (1.02-1.35)	1.16 (1.00-1.33)	1.31 (1.14-1.51)	1.22 (1.04-1.43)	1.53 (1.33-1.75)	1.31 (1.13-1.51)
Fallow Deer*	39	1	0.48 (0.36-0.64)	0.47 (0.34-0.64)	0.38 (0.28-0.51)	0.25 (0.18-0.35)	0.61 (0.46-0.80)	0.44 (0.31-0.61)	0.47 (0.35-0.62)	0.18 (0.13-0.26)
Reeves's Muntjac	45	1	1.2 (0.90-1.59)	1.13 (0.84-1.53)	1.18 (0.87-1.60)	1.2 (0.90-1.61)	1.37 (1.02-1.82)	1.26 (0.90-1.74)	1.5 (1.13-2.00)	1.21 (0.89-1.64)

Appendix 2b Regional temporal trends in relative abundance for eight mammal species for the period 1995-2003. 95% confidence intervals are shown in brackets. Indices are measured relative to the year 1995, which is set to one. Although we exclude data for 2001 from the analyses due to foot-and-mouth disease, we interpolate an index here for 2001. An asterisk denotes a significant difference between the first and last years of the survey at the 5% level or more.

		Year								
Species	*n*	1995	1996	1997	1998	1999	2000	2001	2002	2003
Brown Hare										
North West England*	52	1	1.17 (0.91-1.50)	0.94 (0.72-1.24)	1.01 (0.77-1.32)	0.74 (0.55-1.00)	0.99 (0.74-1.33)	0.95 (0.71-1.26)	0.82 (0.60-1.11)	0.71 (0.52-0.96)
Yorks & The Humber	45	1	1.47 (1.04-2.09)	1.29 (0.90-1.84)	1.05 (0.73-1.52)	0.96 (0.65-1.40)	0.93 (0.63-1.36)	1.18 (0.82-1.68)	1.35 (0.94-1.93)	1.20 (0.84-1.72)
East Midlands	60	1	1.17 (0.88-1.56)	0.84 (0.61-1.15)	0.84 (0.62-1.15)	1.15 (0.86-1.53)	1.15 (0.86-1.53)	1.09 (0.77-1.51)	1.40 (1.05-1.86)	1.21 (0.91-1.61)
East of England*	122	1	1.17 (0.98-1.40)	1.07 (0.89-1.28)	1.08 (0.89-1.30)	1.13 (0.94-1.35)	1.10 (0.91-1.32)	1.12 (0.93-1.36)	1.18 (0.98-1.43)	1.20 (1.00-1.46)
South East England*	71	1	0.96 (0.77-1.21)	0.91 (0.72-1.14)	0.86 (0.68-1.08)	0.81 (0.64-1.03)	0.75 (0.59-0.95)	0.84 (0.68-1.04)	0.74 (0.59-0.94)	0.71 (0.56-0.91)
South West England*	51	1	1.60 (1.19-2.16)	1.16 (0.85-1.58)	1.39 (1.02-1.88)	0.89 (0.64-1.23)	0.98 (0.70-1.36)	1.20 (0.89-1.63)	1.20 (0.86-1.67)	1.65 (1.19-2.27)
England	452	1	1.18 (1.07-1.30)	1.03 (0.93-1.14)	0.99 (0.89-1.09)	0.94 (0.85-1.04)	0.99 (0.90-1.10)	1.05 (0.95-1.16)	1.10 (1.00-1.22)	1.04 (0.94-1.15)
Scotland*	52	1	0.72 (0.54-0.95)	0.88 (0.66-1.17)	0.93 (0.71-1.22)	0.73 (0.55-0.99)	0.71 (0.53-0.95)	0.76 (0.59-0.99)	0.61 (0.44-0.82)	0.49 (0.36-0.68)
Rabbit										
North West England*	88	1	1.19 (0.95-1.48)	1.05 (0.84-1.32)	0.80 (0.63-1.02)	0.49 (0.37-0.67)	0.81 (0.62-1.05)	0.83 (0.66-1.05)	0.65 (0.49-0.85)	0.54 (0.40-0.72)
Yorks & The Humber	75	1	1.30 (1.02-1.65)	1.41 (1.11-1.79)	1.06 (0.82-1.36)	1.05 (0.82-1.35)	1.23 (0.96-1.58)	1.20 (0.94-1.53)	1.14 (0.89-1.46)	1.14 (0.88-1.46)
East Midlands*	70	1	0.55 (0.45-0.69)	0.70 (0.55-0.89)	0.56 (0.43-0.73)	0.37 (0.27-0.49)	0.55 (0.43-0.72)	0.53 (0.41-0.70)	0.45 (0.33-0.61)	0.53 (0.41-0.69)
East of England*	154	1	1.70 (1.45-2.00)	1.63 (1.38-1.93)	1.21 (1.01-1.45)	1.09 (0.90 -1.30)	1.11 (0.92-1.33)	1.32 (1.13-1.56)	1.22 (1.02-1.46)	1.40 (1.17-1.66)
West Midlands*	90	1	0.57 (0.45-0.71)	0.68 (0.54-0.84)	0.67 (0.54-0.83)	0.66 (0.53-0.82)	0.59 (0.47-0.74)	0.62 (0.51-0.77)	0.55 (0.44-0.70)	0.71 (0.57-0.88)
South East England*	206	1	1.09 (0.96-1.25)	1.16 (1.01-1.33)	0.95 (0.82-1.09)	0.91 (0.79-1.05)	0.81 (0.69-0.94)	0.95 (0.83-1.07)	0.76 (0.65-0.88)	0.83 (0.71-0.96)
South West England	134	1	0.86 (0.70-1.06)	1.56 (1.28-1.90)	1.08 (0.87-1.34)	1.32 (1.08-1.61)	1.49 (1.22-1.82)	1.22 (0.98-1.52)	1.03 (0.82-1.30)	1.16 (0.93-1.45)
England*	849	1	1.06 (0.99-1.14)	1.16 (1.08-1.25)	0.92 (0.85-0.99)	0.86 (0.80-0.93)	0.91 (0.84-0.99)	0.87 (0.81-0.95)	0.83 (0.77-0.90)	0.89 (0.82-0.96)
Scotland*	99	1	1.05 (0.87-1.27)	1.51 (1.25-1.82)	1.13 (0.93-1.37)	0.76 (0.61-0.95)	0.97 (0.79-1.19)	1.00 (0.85-1.19)	0.59 (0.47-0.75)	0.40 (0.30-0.52)
Wales	73	1	1.08 (0.86-1.36)	0.80 (0.61-1.05)	0.74 (0.56-0.98)	0.77 (0.59-1.01)	0.71 (0.52-0.96)	0.86 (0.64-1.14)	1.05 (0.81-1.37)	1.11 (0.86-1.44)
Grey Squirrel										
East of England	73	1	2.36 (1.85-3.02)	1.36 (1.05-1.78)	1.21 (0.92-1.60)	1.00 (0.75-1.34)	1.13 (0.85-1.49)	1.35 (1.08-1.71)	1.02 (0.76-1.37)	0.96 (0.71-1.31)
West Midlands	57	1	1.68 (1.32-2.13)	1.00 (0.77-1.32)	0.76 (0.56-1.01)	0.77 (0.58-1.04)	0.98 (0.74-1.30)	1.04 (0.80-1.37)	1.05 (0.80-1.38)	0.84 (0.63-1.12)
South East England	127	1	1.90 (1.58-2.27)	1.10 (0.90-1.35)	1.10 (0.90-1.35)	0.80 (0.64-1.00)	1.20 (0.98-1.47)	1.18 (0.98-1.43)	0.96 (0.78-1.19)	1.03 (0.83-1.26)
South West England	63	1	1.98 (1.51-2.61)	1.56 (1.18-2.08)	0.95 (0.69-1.31)	1.07 (0.79-1.46)	1.37 (1.00-1.87)	1.45 (1.04-2.01)	1.79 (1.34-2.41)	0.99 (0.71-1.38)
England*	422	1	1.99 (1.79-2.20)	1.25 (1.12-1.40)	1.05 (0.94-1.18)	0.89 (0.79-1.00)	1.18 (1.05-1.32)	1.19 (1.06-1.33)	1.19 (1.06-1.33)	1.14 (1.01-1.28)
Wales	39	1	2.84 (1.95-4.12)	1.50 (0.99-2.28)	1.75 (1.16-2.64)	1.32 (0.86-2.03)	1.41 (0.90-2.19)	1.76 (1.21-2.59)	1.73 (1.15-2.62)	1.37 (0.90-2.09)
Red Fox										
South East England*	50	1	1.20 (0.90-1.6)	1.17 (0.87-1.57)	1.25 (0.92-1.68)	1.16 (0.86-1.55)	1.56 (1.18-2.07)	1.19 (0.88-1.59)	0.78 (0.56-1.08)	0.57 (0.40-0.82)
South West England*	41	1	1.29 (0.95-1.76)	0.75 (0.53-1.07)	0.89 (0.63-1.24)	0.92 (0.66-1.28)	0.75 (0.53-1.08)	0.89 (0.67-1.23)	0.76 (0.53-1.10)	0.57 (0.38-0.84)
England*	183	1	1.35 (1.18-1.55)	1.06 (0.92-1.23)	0.96 (0.82-1.12)	0.90 (0.77-1.05)	0.90 (0.77-1.06)	0.88 (0.75-1.03)	0.85 (0.72-0.99)	0.58 (0.49-0.68)

Species	*n*	Year								
		1995	1996	1997	1998	1999	2000	2001	2002	2003
Red Deer										
Scotland*	40	1	0.61 (0.44-0.84)	0.66 (0.48-0.91)	0.66 (0.47-0.92)	0.37 (0.25-0.54)	0.48 (0.32-0.73)	0.54 (0.39-0.76)	0.43 (0.29-0.63)	0.27 (0.17-0.42)
Roe Deer										
South East England*	60	1	1.39 (1.01-1.92)	0.92 (0.65-1.31)	1.11 (0.79-1.57)	1.29 (0.93-1.80)	1.32 (0.95-1.83)	1.33 (0.89-1.93)	1.97 (1.45-2.66)	1.65 (1.21-2.26)
South West England*	62	1	1.11 (0.83-1.49)	1.08 (0.81-1.44)	0.90 (0.67-1.21)	0.81 (0.60-1.10)	1.56 (1.16-2.08)	1.245 (0.8-1.83)	2.01 (1.52-2.65)	1.78 (1.34-2.37)
England*	175	1	0.98 (0.82-1.16)	0.96 (0.81-1.13)	0.91 (0.76-1.08)	0.96 (0.81-1.14)	1.12 (0.95-1.33)	1.38 (1.17-1.62)	1.63 (1.39-1.91)	1.28 (1.08-1.52)
Scotland*	64	1	1.25 (0.95-1.65)	1.12 (0.84-1.51)	1.46 (1.10-1.93)	1.37 (1.03-1.82)	1.50 (1.12-2.00)	1.35 (0.98-1.84)	1.39 (1.04-1.87)	1.34 (1.00-1.80)
Fallow Deer										
England*	38	1	0.38 (0.28-0.52)	0.41 (0.30-0.56)	0.34 (0.25-0.46)	0.23 (0.16-0.32)	0.54 (0.41-0.71)	0.47 (0.36-0.63)	0.40 (0.30-0.54)	0.15 (0.11-0.22)
Reeves's Muntjac										
England	45	1	1.20 (0.91-1.59)	1.13 (0.84-1.52)	1.17 (0.86-1.59)	1.20 (0.90-1.60)	1.37 (1.03-1.82)	1.37 (1.02-1.82)	1.36 (1.01-1.82)	1.22 (0.90-1.66)

Appendix 2c Temporal trends in relative abundance for six mammal species for the period 1995-2003 within the six environmental zones in Great Britain. The six Environmental Zones are based on combinations of CEH land classes which cover the range of environmental conditions that we find in Great Britain, from the lowlands of the south and east, through to the uplands and mountains of the north and west (Haines-Young *et al.* 2000). 95% confidence intervals are shown in brackets. Indices are measured relative to the year 1995, which is set to one. Although we exclude data for 2001 from the analyses due to foot-and-mouth disease, we interpolate an index here for 2001. An asterisk denotes a significant difference between the first and last years of the survey at the 5% level or more.

		Year								
Species	*n*	1995	1996	1997	1998	1999	2000	2001	2002	2003
Brown Hare										
Zone 1	283	1	1.13 (0.99-1.27)	1.05 (0.93-1.20)	0.91 (0.80-1.04)	0.93 (0.82-1.06)	0.95 (0.83-1.08)	1.01 (0.88-1.15)	1.10 (0.96-1.25)	1.04 (0.91-1.18)
Zone 2*	138	1	1.42 (1.20-1.68)	1.01 (0.84-1.22)	1.23 (1.02-1.47)	1.07 (0.89-1.30)	1.20 (1.00-1.44)	1.19 (0.99-1.42)	1.18 (0.98-1.41)	1.19 (0.99-1.42)
Zone 3*	51	1	0.83 (0.64-1.07)	0.64 (0.48-0.84)	0.81 (0.62-1.07)	0.67 (0.51-0.88)	0.96 (0.73-1.27)	0.78 (0.57-1.07)	0.78 (0.59-1.04)	0.57 (0.41-0.77)
Rabbit										
Zone 1*	465	1	1.00 (0.91-1.10)	1.14 (1.04-1.26)	0.90 (0.81-1.00)	0.85 (0.76-0.94)	0.90 (0.81-0.99)	0.94 (0.85-1.03)	0.83 (0.75-0.92)	0.94 (0.85-1.04)
Zone 2*	357	1	1.16 (1.04-1.29)	1.20 (1.07-1.34)	0.95 (0.84-1.07)	0.89 (0.79-1.01)	0.94 (0.83-1.07)	1.00 (0.89-1.12)	0.86 (0.75-0.97)	0.94 (0.83-1.06)
Zone 3	103	1	0.97 (0.78-1.20)	1.00 (0.81-1.23)	0.88 (0.71-1.09)	0.86 (0.69-1.07)	0.90 (0.72-1.13)	0.93 (0.75-1.16)	0.94 (0.76-1.17)	0.81 (0.65-1.01)
Zone 4*	58	1	1.05 (0.83-1.32)	1.37 (1.09-1.73)	0.63 (0.49-0.82)	0.66 (0.51-0.85)	0.69 (0.52-0.90)	0.83 (0.67-1.03)	0.56 (0.42-0.76)	0.30 (0.20-0.44)
Grey Squirrel										
Zone 1	235	1	1.88 (1.64-2.16)	1.19 (1.02-1.38)	1.04 (0.89-1.21)	0.84 (0.72-0.99)	1.29 (1.11-1.50)	1.23 (1.06-1.43)	1.11 (0.95-1.30)	1.05 (0.90-1.23)
Zone 2*	192	1	2.06 (1.77-2.40)	1.36 (1.15-1.60)	1.19 (1.00-1.41)	1.03 (0.86-1.23)	1.17 (0.98-1.40)	1.37 (1.16-1.62)	1.43 (1.20-1.69)	1.23 (1.03-1.46)
Red Fox										
Zone 1	98	1	1.50 (1.24-1.81)	1.19 (0.97-1.46)	1.23 (1.00-1.51)	1.00 (0.82-1.24)	1.22 (0.99-1.51)	1.18 (0.97-1.43)	0.93 (0.75-1.15)	0.55 (0.43-0.70)
Zone 2*	81	1	1.13 (0.92-1.39)	0.78 (0.62-0.98)	0.77 (0.6-0.98)	0.90 (0.71-1.13)	0.73 (0.57-0.93)	0.84 (0.68-1.04)	0.72 (0.56-0.92)	0.67 (0.52-0.86)
Roe Deer										
Zone 1*	99	1	0.96 (0.76-1.21)	1.05 (0.83-1.32)	0.99 (0.79-1.26)	1.03 (0.81-1.29)	1.02 (0.81-1.30)	1.12 (0.85-1.46)	1.69 (1.36-2.09)	1.08 (0.85-1.38)
Zone 2*	65	1	1.00 (0.76-1.32)	0.85 (0.65-1.11)	0.70 (0.53-0.93)	0.86 (0.65-1.13)	1.37 (1.04-1.79)	1.09 (0.73-1.56)	1.77 (1.37-2.29)	1.53 (1.18-1.98)
Reeves's Muntjac										
Zone 1	40	1	0.81 (0.59-1.11)	0.89 (0.65-1.21)	0.96 (0.70-1.32)	0.96 (0.71-1.29)	1.14 (0.85-1.52)	0.97 (0.69-1.35)	1.07 (0.79-1.45)	0.88 (0.63-1.23)

Appendix 3 Change in the presence of six mammal species for the period 1995-2003. 95% confidence intervals are shown in brackets. Indices are measured relative to the year 1995, which is set to one. Although we exclude data for 2001 from the analyses due to foot-and-mouth disease, we interpolate an index here for 2001. An asterisk denotes a significant difference between the first and last years of the survey at the 5% level or more. For all species below, there is power of 80% or more to detect at a 25% decline in presence on BBS squares.

		Year							
Species	*n*	1996	1997	1998	1999	2000	2001	2002	2003
Mole*	451	1	0.58 (0.57-0.59)	1.29 (1.26-1.32)	2.41 (2.36-2.46)	6.30 (6.15-6.44)	5.96 (5.82-6.09)	5.61 (5.48-5.74)	6.80 (6.64-6.96)
Hedgehog*	191	1	0.65 (0.63-0.67)	1.80 (1.75-1.85)	1.39 (1.35-1.44)	3.94 (3.83-4.06)	3.06 (2.97-3.15)	2.17 (2.10-2.23)	1.65 (1.61-1.71)
Badger*	240	1	0.69 (0.67-0.71)	1.74 (1.69-1.79)	2.00 (1.94-2.06)	3.64 (3.53-3.75)	3.78 (3.67-3.90)	3.92 (3.80-4.04)	4.92 (4.77-5.07)
Brown Rat*	136	1	0.32 (0.31-0.34)	1.18 (1.14-1.22)	1.67 (1.61-1.74)	4.33 (4.17-4.49)	3.94 (3.80-4.09)	3.55 (3.42-3.68)	3.79 (3.65-3.93)
Stoat*	109	1	0.45 (0.43-0.46)	1.26 (1.21-1.30)	2.25 (2.17-2.33)	3.21 (3.1-3.33)	2.28 (2.20-2.37)	1.35 (1.30-1.40)	1.53 (1.47-1.58)
Weasel*	86	1	0.49 (0.47-0.52)	1.17 (1.12-1.22)	1.55 (1.48-1.61)	3.08 (2.95-3.21)	2.29 (2.19-2.38)	1.49 (1.43-1.55)	1.18 (1.13-1.23)