BTO Research Report No. 428

The production of population trends for UK mammals using BBS mammal data: 1995-2004 update

Authors

Stuart E. Newson & David G. Noble

A report by the British Trust for Ornithology under contract to
the Joint Nature Conservation Committee

February 2006

BBS is funded by a partnership of the British Trust for Ornithology, the Joint Nature Conservation Committee (on behalf of English Nature, Scottish Natural Heritage and the Countryside Council for Wales, and also on behalf of the Environment and Heritage Service in Northern Ireland) and the Royal Society for the Protection of Birds. Mammal monitoring within the BBS is part of a wider suite of schemes looking at the changing fortunes of our mammal populations. These schemes are coordinated through the Tracking Mammals Partnership.

British Trust for Ornithology, The Nunnery, Thetford, Norfolk, IP24 2PU
Registered Charity No. 216652

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Published in April 2005 by the British Trust for Ornithology
The Nunnery, Thetford, Norfolk IP24 2PU, UK

ISBN No 1-904870-54-6

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1. EXECUTIVE SUMMARY

1 Since 1995, BTO/RSPB/JNCC Breeding Bird Survey (BBS) participants have been voluntarily recording mammals as well as birds on their 1-km squares, making it the first multi-species, annual mammal survey to be carried out in the UK. BBS mammal recording focuses on large-sized easily identifiable species, although observers record any species seen or for which evidence of its presence was found. In this report we update Newson & Noble (2005) to generate estimates of population change for 1995-2004.

2 Annual indices of relative abundance are produced at a national scale for nine mammal species – Brown Hare, Mountain/Irish Hare, Rabbit, Grey Squirrel, Red Fox, Red Deer, Fallow Deer, Roe Deer and Reeves's Muntjac. Counts of Rabbit, Red Fox, Red Deer and Fallow Deer were significantly lower in 2004 than in 1995, whereas counts of Grey Squirrel were significantly greater. In new work, trends for Fallow and Red Deer are tested for reliability by exploring the effects of a small number of sites with particularly large counts. We recommend that counts from deer parks be excluded from future analyses of deer data.

3 Where data were sufficient, regional indices of relative abundance were produced for English Government Office Regions (GOR) and for the four countries that constitute the UK. Trends 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 separate trends for Red Deer in Scotland and for Fallow Deer and Reeves's Muntjac in England.

4 Population trends are produced for Environmental Zones for the most commonly seen species. Environmental Zones are categories of landscapes found in Great Britain 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 makes results comparable with other mammal surveys associated with the Tracking Mammals Partnership that use the same approach.

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 evidence such as field signs, dead animals or gamekeeper knowledge could be used to record occurrence. These data were used to examine change in presence/absence on BBS squares between 1996 and 2004. We discuss reasons why these trends should be treated with caution. Since 2002 observers have recorded the criteria that they used for assessing 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.

6 Data for species seldom detected by sight or other evidence provide important information on their distribution. There is also the potential for combining these data with those from other surveys and with records in the National Biodiversity Network to provide a better understanding of 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 1995-2004. 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	1063	-30 *	522	-1	43	-13	472	12	221	-43 *	49	-75 *	38	-87 *	235	0	44	6
COUNTRIES																		
England	854	-14 *	449	15 *	-	-	421	8	178	-43 *	-	-	36	-90 *	174	8	44	6
Scotland	98	-57 *	52	-41 *	-	-	-	-	-	-	38	-74 *	-	-	61	-16	-	-
Wales	73	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ENGLISH REGIONS																		
North West England	89	-43 *	52	-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yorkshire & The Humber	75	11	44	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
East Midlands	71	-51 *	60	55 *	-	-	-	-	-	-	-	-	-	-	-	-	-	-
East of England	154	17	119	28 *	-	-	71	24	-	-	-	-	-	-	-	-	-	-
West Midlands	89	-22 *	-	-	-	-	56	-44	-	-	-	-	-	-	-	-	-	-
South East England	207	-30 *	72	-9	-	-	126	9	49	-15	-	-	-	-	61	86 *	-	-
South West England	133	37 *	50	52 *	-	-	62	-5	38	-44	-	-	-	-	60	17	-	-
ENVIRONMENTAL ZONES																		
Easterly lowlands (Eng./Wales)	467	18 *	281	16 *	-	-	235	19 *	95	-41 *	-	-	-	-	98	11	39	-13
Westerly lowlands (Eng./Wales)	360	3	138	18	-	-	192	5	80	-34 *	-	-	-	-	65	8	-	-
Uplands (Eng./Wales)	103	-23 *	50	-33 *	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lowlands (Scotland)	57	-67 *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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 (see the discussion). Because there are relatively few sites in the model to start with, a small number of sites not recording large herds in subsequent years, has had a large influence on the apparent relative abundance of these species.

2. INTRODUCTION

Although national surveys of some UK mammal species are carried out periodically, these surveys are generally not repeated frequently enough to separate underlying population change from natural between-year variation. Large gaps in the availability of reliable monitoring data is highlighted in a review of population estimates and the conservation status of British species (Harris *et al*. 1995) and more recently by Macdonald & Tattersall (2001).

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. 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 this report we update analyses of BBS mammal data for 1995-2003 (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 1995-2004. 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).

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.

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 1995-2004 is shown in Figure 3.1.

Figure 3.1 The location of 1 km BBS squares surveyed for mammals (1995-2004).

3.2 Trend analyses of count data

The maximum number of each of these species of mammal sighted over the two visits (early and late) was determined for each 1 km square in each year from 1995 to 2004. 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 nine 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 3.2.1 & 3.2.2. 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.

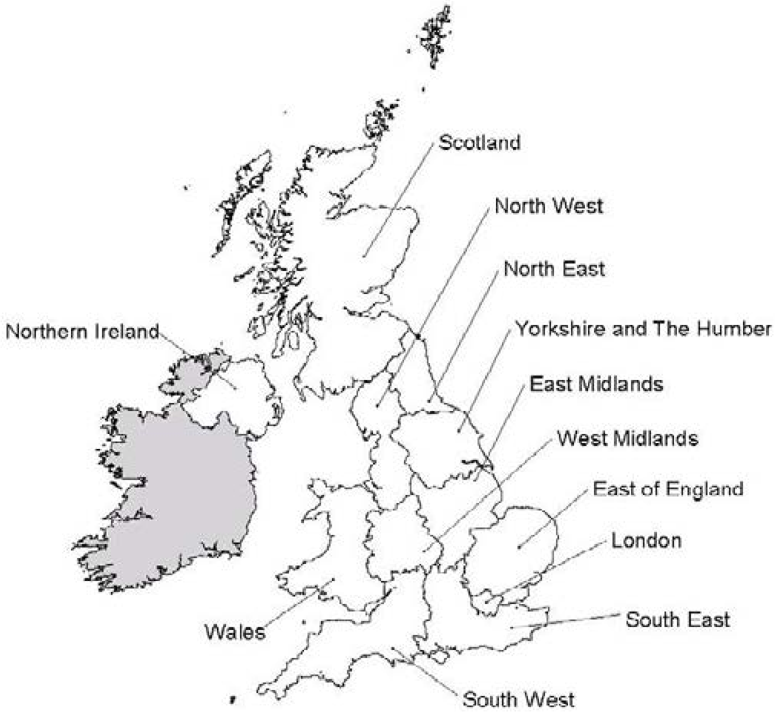


Figure 3.2.1 English Government Office Regions and Country boundaries used in the regional analyses.

Figure 3.2.2 The six Environmental Zones of Great Britain used in the analyses of landscape types.

3.3 Analyses of changes in occurrence

For species that are not counted in sufficient numbers during BBS visits for trend analysis, but for which other evidence can be used to assess presence (see Appendix 1b), we analysed the change in presence/absence on surveyed squares. Previous analyses (Newson & Noble 2005) have shown that it is possible to monitor changes in the occurrence of Badger, Brown Rat, Mole, Hedgehog, Stoat and Weasel using these methods. 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 during BBS visits, 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.

To test whether there had been a significant change in the presence of these species on BBS squares between 1996 and 2004, 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. A change was inferred if the odds ratio in 2004 was significantly different from the odds ratio in 1996.

4. RESULTS

4.1 UK trends in abundance

During 2004 mammal data were collected from a total of 2083 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. 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 the analyses here covered a relatively short time period (1995-2004), it is already apparent that there have been a number of substantial changes within these populations during this time. Comparing abundance of the above species at a UK level in 2004 relative to 1995, Rabbit, 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 2004 in relation to the these fluctuations, seen in the plots of the annual indices.

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).

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 and 2004. The reason for the apparent fall in abundance is not known. In addition, we have concerns for the reliability of trends produced for Red and Fallow Deer because of the influence of large counts at a small number of sites. The influence of large counts on the trends is explored further in Section 5.2.

In Figures 4.1.1-4.1.9, we pool the results of analyses of sightings data and distribution information to present a species by species account of what the BBS tells us about population change for these species for 1995-2004.

Figure 4.1.1 RABBIT ***Oryctolagus cuniculus***

Summary

Widespread. Numbers in the UK peaked in 1997, and have declined, almost continuously since then to 2004.

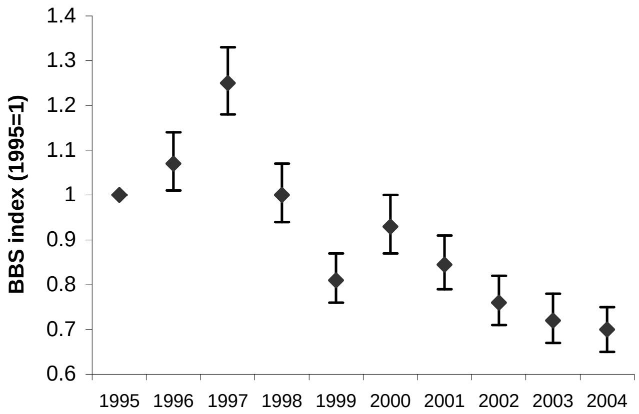
Largest significant decline in Scotland and to lesser extent England, in which East Midlands and North West have shown the greatest detectable declines.

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) Percentage change (and no. of squares) in Rabbits (1995-2004). See Appendices 2a-c for indices.

	Mean squares	Percent change	$P \leq 0.05$
UNITED KINGDOM	1063	-30	*
COUNTRIES			
England	854	-14	*
Scotland	98	-57	*
Wales	73	-19	
ENGLISH REGIONS			
North West England	89	-43	*
Yorkshire & The Humber	75	11	
East Midlands	71	-51	*
East of England	154	17	*
West Midlands	89	-22	*
South East England	207	-30	*
South West England	133	37	*
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	467	-18	*
(Zone 2) Westerly lowlands (England/Wales)	360	-3	
(Zone 3) Uplands (England/Wales)	103	-23	*
(Zone 4) Lowlands (Scotland)	57	-67	*

b) Change in relative abundance from counts in the UK from 1995-2004. Error bars represent 95% confidence intervals.



c) Distribution from recorded presence in one or more year, 1995-2004.

Figure 4.1.2 BROWN HARE *Lepus europaeus*

Summary

Widespread. No significant change in abundance overall in the UK between 1995 and 2004.

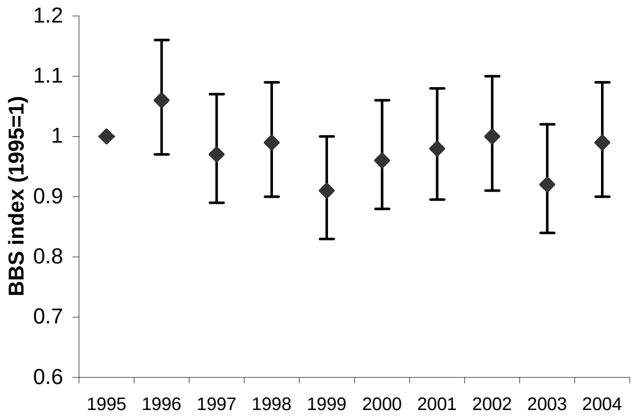
However, abundance has fallen in Scotland, whilst increased significantly in England, with significant increases detected specifically in East Midlands, East of England and South West England and more generally in the Easterly lowlands of England/Wales. Abundance of Brown Hare appears to have declined significantly in the Uplands of England/Wales.

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) Percentage change (and no. of squares) of Brown Hare (1995-2004). See Appendices 2a-c for indices.

	Mean squares	Percent change	$P \leq 0.05$
UNITED KINGDOM	522	-1	
COUNTRIES			
England	449	15	*
Scotland	52	-41	*
ENGLISH REGIONS			
North West England	52	-20	
Yorkshire & The Humber	44	14	
East Midlands	60	55	*
East of England	119	28	*
South East England	72	-9	
South West England	50	52	*
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	281	16	*
(Zone 2) Westerly lowlands (England/Wales)	138	18	
(Zone 3) Uplands (England/Wales)	50	-33	*

b) Change in relative abundance from counts in the UK from 1995-2004. Error bars represent 95% confidence intervals.



c) Distribution from recorded presence in one or more year, 1995-2004.

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

Summary

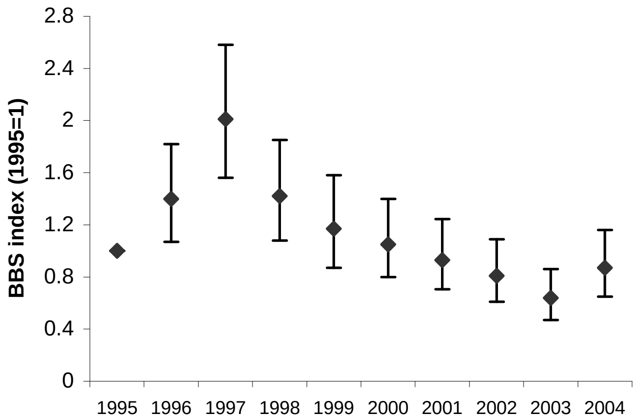
Restricted mainly to Scotland and NI. No significant change in abundance was detected between 1995 and 2004.

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) Percentage change (and no. of squares) of Mountain Hare (1995-2004). See Appendices 2a-c for indices.

	Mean squares	Percent change	P ≤ 0.05
UNITED KINGDOM	43	-13	

b) Change in relative abundance from counts in the UK from 1995-2004. Error bars represent 95% confidence intervals.



c) Distribution from recorded presence in one or more year, 1995-2004.

Figure 4.1.4 GREY SQUIRREL *Sciurus carolinensis*

Summary

Widespread but southerly distribution. No significant change in abundance overall in the UK between 1995 and 2004, with a large peak in 1996, perhaps related to high productivity in this year.

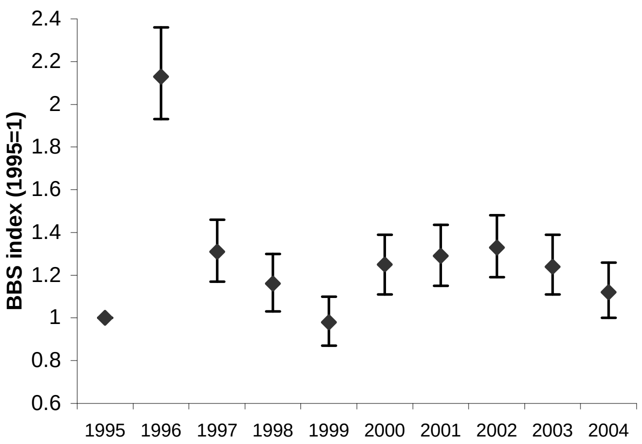
Abundance has increased significantly in the Easterly lowlands of England and a significant decline was detected in the West Midlands.

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) Percentage change (and no. of squares) of Grey Squirrels (1995-2004). See Appendices 2a-c for indices.

	Mean squares	Percent change	P ≤ 0.05
UNITED KINGDOM	472	12	
COUNTRIES			
England	421	8	
Wales	38	-10	
ENGLISH REGIONS			
East of England	71	24	
West Midlands	56	-44	*
South East England	126	9	
South West England	62	-5	
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	235	19	*
(Zone 2) Westerly lowlands (England/Wales)	192	5	

b) Change in relative abundance from counts in the UK from 1995-2004. Error bars represent 95% confidence intervals.



c) Distribution from recorded presence in one or more year, 1995-2004.

Figure 4.1.5 RED FOX *Vulpes* ***vulpes***

Summary

Widespread. Significant decline in abundance in the UK between 1995 and 2004, with the decline occurring between 2000 and 2003.

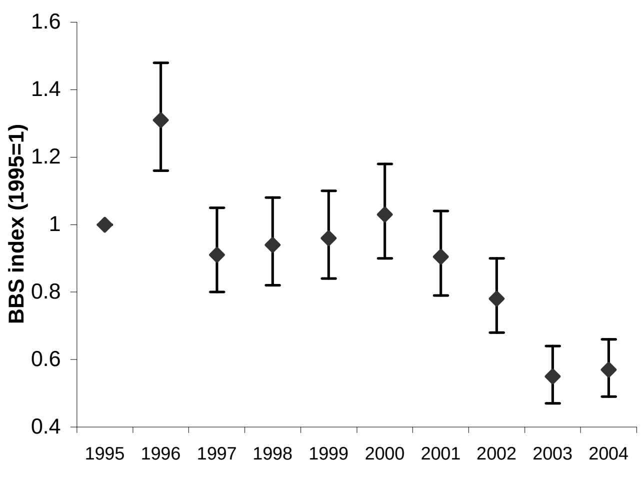
A significant decline was further detected in England between 1995 and 2004 and in The Easterly and Westerly lowlands of England/Wales and specifically a significantly decline was detected in South West England.

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

a) Percentage change (and no. of squares) of Red Fox (1995-2004). See Appendices 2a-c for indices.

	Mean squares	Percent change	P ≤ 0.05
UNITED KINGDOM	221	-43	*
COUNTRIES			
England	178	-43	*
ENGLISH REGIONS			
South East England	49	-15	
South West England	38	-44	*
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	95	-41	*
(Zone 2) Westerly lowlands (England/Wales)	80	-34	*

b) Change in relative abundance from counts in the UK from 1995 -2004. Error bars represent 95% confidence intervals.



c) Distribution from recorded presence in one or more year, 1995-2004.

Figure 4.1.6 RED DEER *Cervus* ***elaphus***

Summary

Apparent significant decline in abundance in the UK between 1995 and 2004. Much of this can be attributed to the steep drop in 1996, due to a small number of sites recording large herds in 1995 but not so often in subsequent years. Because relatively few sites were found to have Red Deer present, a small number of sites recording large herds can have a large influence on the apparent relative abundance of this species. For this reason trends for this species should be interpreted with caution (see discussion in Section 5.2).

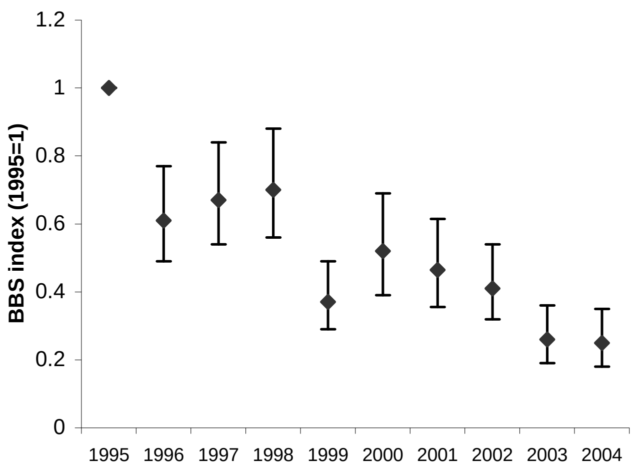
The majority of BBS squares reporting Red Deer are in Scotland.

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) Percentage change (and no. of squares) of Red Deer (1995-2004). See Appendices 2a-c for indices.

	Mean squares	Percent change	P ≤ 0.05
UNITED KINGDOM	49	-75	*
COUNTRIES			
Scotland	38	-74	*

b) Change in relative abundance from counts in the UK from 1995-2004. Error bars represent 95% confidence intervals.



c) Distribution from recorded presence in one or more year, 1995-2004.

Figure 4.1.7 FALLOW DEER *Dama dama*

Summary

Apparent significant decline in abundance in the UK between 1995 and 2004. Much of this can be attributed to the steep drop in 1996, due to a small number of sites recording large herds in 1995 but not so often in subsequent years. Because relatively few sites were found to have Fallow Deer present, a small number of sites recording large herds can have a large influence on the apparent relative abundance of this species. For this reason trends for this species should be interpreted with caution (see discussion in Section 5.2).

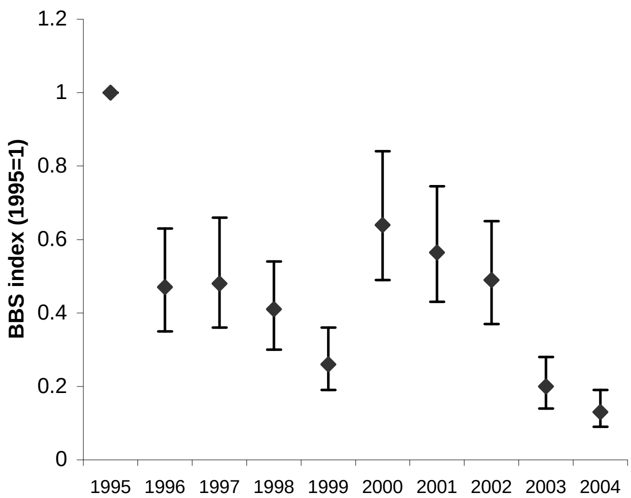
The majority of BBS squares reporting Fallow Deer are in England.

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) Percentage change (and no. of squares) of Fallow Deer (1995-2004). See Appendices 2a-c for indices.

	Mean squares	Percent change	$P \leq 0.05$
UNITED KINGDOM	38	-87	*
COUNTRIES			
England	36	-90	*

b) Change in relative abundance from counts in the UK from 1995-2004. Error bars represent 95% confidence intervals.



c) Distribution from recorded presence in one or more year, 1995-2004.

Figure 4.1.8 ROE DEER *Capreolus capreolus*

Summary

Widespread except in Northern Ireland, and also absent from much of central England and Wales. Continuous increase in the UK from 1995 to 2002 although there is an apparent fall in abundance since then, also observed in Reeves's Muntjac.

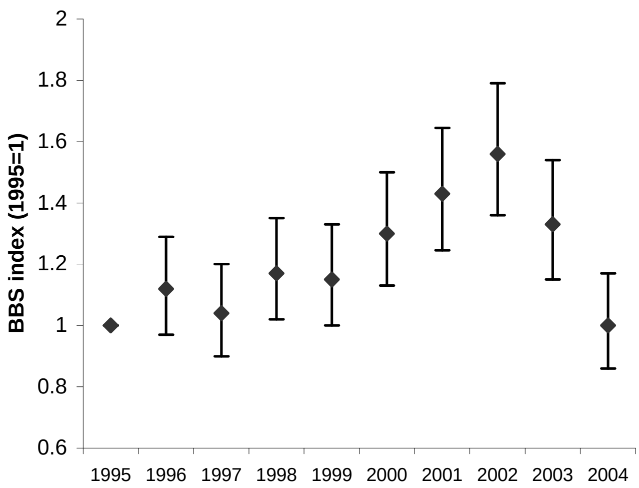
No significant change overall in England, although a significant increase in South East England.

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) Percentage change (and no. of squares) of Roe Deer (1995-2004). See Appendices 2a-c for indices.

	Mean squares	Percent change	P ≤ 0.05
UNITED KINGDOM	235	0	
COUNTRIES			
England	174	8	
Scotland	61	-16	
ENGLISH REGIONS			
South East England	61	86	*
South West England	60	17	
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	98	11	
(Zone 2) Westerly lowlands (England/Wales)	65	8	

b) Change in relative abundance from counts in the UK from 1995-2004. Error bars represent 95% confidence intervals.



c) Distribution from recorded presence in one or more year, 1995-2004.

Figure 4.1.9 REEVES'S MUNTJAC ***Muntiacus reevesi***

Summary

Restricted primarily to southeastern England. Continuous increase in the UK from 1995 to 2002, although there is an apparent fall in abundance since 2003, also observed in Roe Deer. The change in abundance between 1995 and 2004 is not significant.

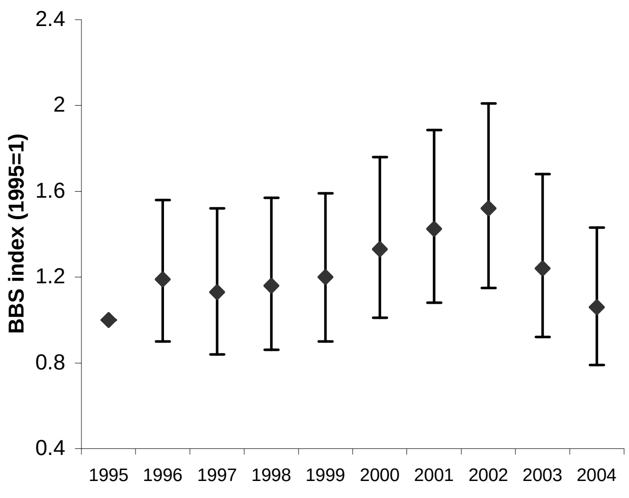
No evidence for a significant change in abundance in England.

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) Percentage change (and no. of squares) of Reeves's Muntjac (1995-2004).See Appendices 2a-c for indices.

	Mean squares	Percent change	P ≤ 0.05
UNITED KINGDOM	44	6	
COUNTRIES			
England	44	6	
ENVIRONMENTAL ZONES			
(Zone 1) Easterly lowlands (England/Wales)	39	-13	

b) Change in relative abundance from counts in the UK from 1995-2004. Error bars represent 95% confidence intervals.



c) Distribution from recorded presence in one or more year, 1995-2004.

4.2 Trends by region and Environmental Zone

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. Separate analyses of mammal data within Environmental Zones provides trends for a broad range of environmental conditions found in the UK and makes them potentially comparable with other mammal surveys, such as the BTO/Mammal Society Winter Mammal Monitoring Survey (Noble *et al*. 2002).

4.3 Analyses of changes in occurrence

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 1995-2004 are shown in Appendix 1b. For all six species tested (Badger, Brown Rat, Mole, Hedgehog, Stoat and Weasel), the odds of being present on BBS squares increased significantly between 1996 and 2004. The annual estimates of the odds ratio, and confidence intervals are shown in Appendix 3.

Unlike the analyses of count data, the change in odds ratio interpretation is not as intuitive because we are measuring a change in ratio where it is not possible to ascribe the same percent change measure to the probability of presence at all sites. It is however essential to model the data in this framework, to ensure that estimated probabilities of presence/absence remain in the range 0-1. Consider two sites which, in a particular year, have a probability of presence = 0.2 and 0.8. While it is clearly possible for the former to increase threefold over time to 0.6, an increase of this type for the second site because a probability of 2.4 is meaningless. The odds-ratio is a convenient means of dealing with this problem; the log of the odds can be multiplied by any constant rate of increase and yet the corresponding probabilities remain sensible (see McCullagh & Nelder 1989). To extend the example to changes in the odds ratio, if in the first year, the probability of being present was 0.2 and the probability of being absent was 0.8, the odds of being present would be 0.2/0.8 = 0.25. If, eight 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. To avoid misinterpretation of graphs of the odds ratio, we therefore present simple figures showing the percentage occurrence for each of the species tested in Figure 4.3.1.

The apparent increases in the occurrence of these species should be interpreted with caution for a number of reasons. The first is the reliability of criteria other than visual observations or dead animals. Recorded since 2002, the breakdown of criteria for assigning presence in Appendix 1 confirms that moles are detected almost exclusively from field signs (mole-hills), whereas a large proportion of hedgehog records are from sightings of dead animals. Although these measures should be reliable, at least since 2002, the majority of Badger records are based on field signs, and to a lesser extent local knowledge. It should be noted that Badger field signs here include setts and latrines, and there is no certain way of distinguishing between them, or between active and unused setts in the 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. Brown Rat is another species for which local knowledge contributes a significant proportion of the records (and these could also be used for Red Fox). Further analyses to examine the influence of excluding records based solely on local knowledge on the resulting trends might be advisable.

A second important point is that there have been a number of changes to the survey form that may affect the recording of presence of species on BBS squares during the survey period. Many species, including Badger, Hedgehog, Brown Rat, Mole, Stoat and Weasel, were first added to the recording form in 1996 and for this reason, trends are calculated from 1996. Additional changes to the form were made in 2000, the most important being a clarification in the instructions that the 'presence' column should include the recording of dead animals, information from personal communication with landowners/gamekeepers and signs such as mole-hills and Badger latrines. For further discussion of the implications of changes to the survey form see Newson & Noble (2005). A further change to the survey form in 2002 to record the criteria for presence 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. Perhaps two distinct time series should be considered. Excluding 1995, the first series covers the period 1996-99, during which there were no obvious changes to the survey form that would result in a change in the recording presence. The second covers the period 2000 to the present, assuming that the additional recording of the criteria for presence begun in 2002 had no effect on the way presence was assessed by BBS participants. Data for 2001, when coverage was biased by foot and mouth restrictions on access to the countryside, are excluded from these trend analyses.

Lastly, it is possible that increasing observer awareness of the presence of a species in a square (e.g. in the years after a badger sett is first detected, or after first being informed of the presence of their presence by gamekeepers) could result in more search effort and/or higher rates of detection in subsequent years. With further years of data collection on presence and the criteria used to assess it, we hope to be more confident in our estimates of change in populations of these species. It may, for example, be sensible in the future to join trends for the periods 1996-99 to the index for 2000 onwards without including the change from 1999 to 2000. This discussion also demonstrates that although improvements to the way mammals are recorded by the BBS can be suggested, unless it is absolutely essential to do so, there should be no further changes to the survey form.

In addition to the six species discussed earlier, BBS observers collect sufficient data to model trends in presence/absence for some of the nine species for which we produce trends from count data. In most cases, however the additional information adds very few additional squares, and the 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.

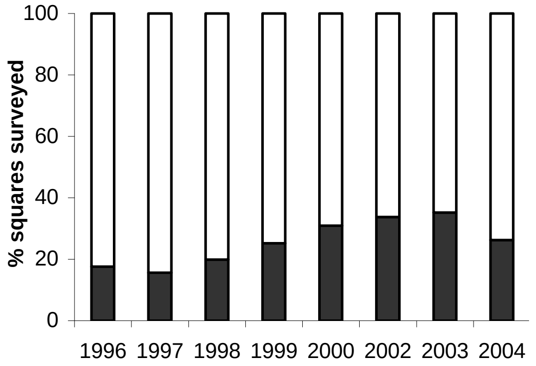
Figure 4.3.1 Summary of the change in presence on BBS squares of six mammal species. Values are the percentage of BBS squares in which the species occurred, in each year.

Summary

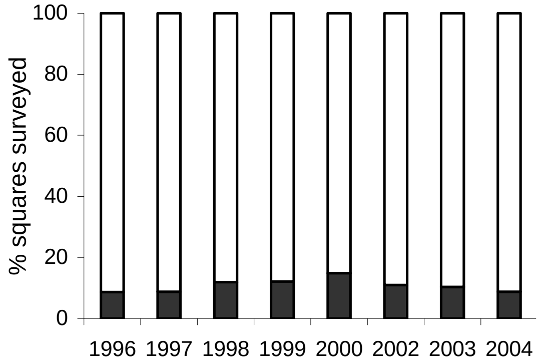
Apparent increase in presence of Mole, Hedgehog, Badger, Brown Rat, Stoat and Weasel on BBS squares (P ≤ 0.05) between 1996 and 2004.

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

a) Mole



b) Hedgehog



c) Brown Rat

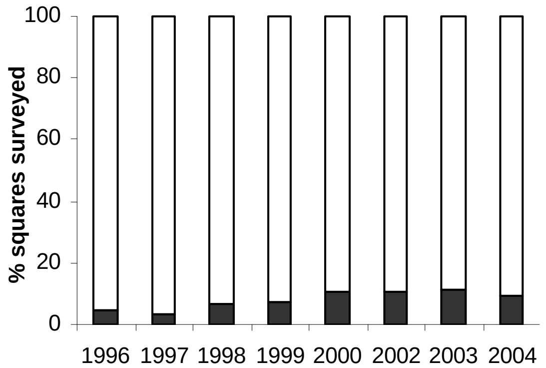
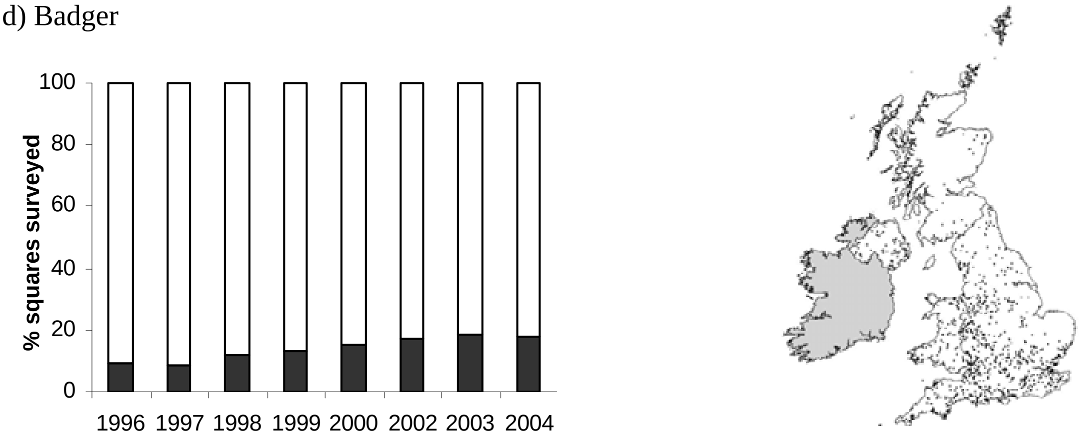
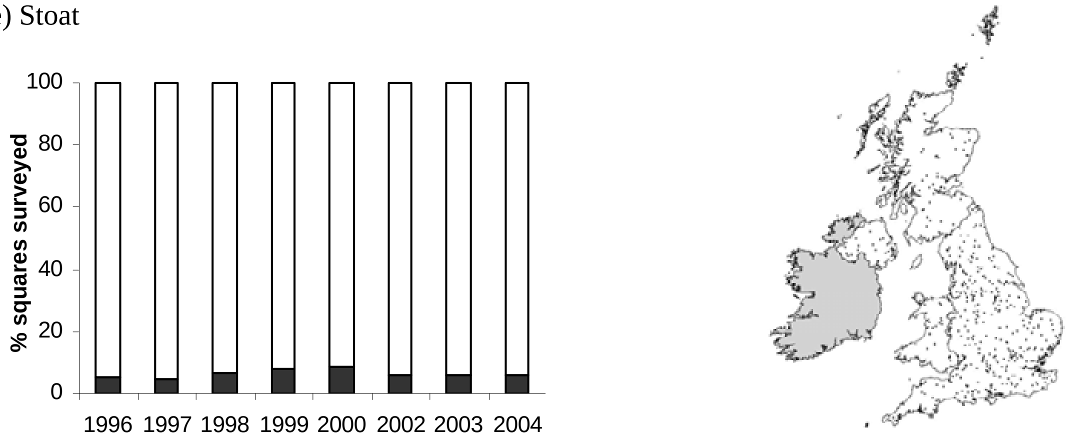


Figure 4.3.1 (continued)

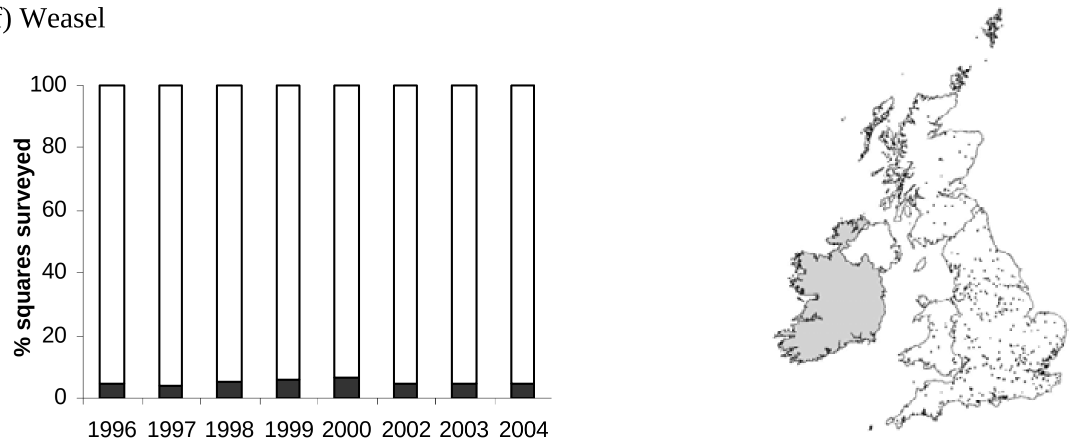
d) Badger



e) Stoat



f) Weasel



5. NEW DEVELOPMENTS

5.1 Options for producing habitat-specific trends

There are various approaches that could be taken for producing habitat-specific trends from BBS mammal data. One of these, trialed in the first report on the analysis of BBS mammal data (Newson & Noble, 2003) is to use habitat data collected by BTO observers for surveyed 1-km squares.

For this, surveyed BBS squares were categorised as belonging to a particular broad habitat if 5 or more of the 10 x 200 transect sections (i.e. 50% or more) belonged to a single broad habitat class. Squares with less than 5 x 200 transects of a single habitat were classified as being of mixed habitat. Choosing a 50% cut-off meant that a large proportion of squares were not assigned to any particular habitat, and effectively removed from the analyses. As a result, trends were produced for few (11) species x habitat combinations. It should be noted that whereas BBS habitat and bird data are recorded at the 200-m transect section level, mammals are recorded at the 1-km square level, and hence cannot be assigned to specific habitat sections.

A second approach is to use independent habitat data, of which the Land Cover Map 2000 data is most appropriate (Haines-Young *et al*. 2000). Like BBS mammal data, Land Cover Map 2000 data is recorded at the 1-km scale, so there is no difference in the resolution. Land Cover Map 2000 data have a number of important advantages over BBS habitat data. For one, it provides a measure of habitat on 1-km squares not surveyed for BBS. Secondly, habitat-specific trends based upon this method can be compared to trends from other sources using the same stratification. CEH have defined habitat as belonging to one of 26 classes, which CEH has further grouped into 10 aggregate habitat classes (see Table 5.1.1). Because of sample size restrains, it makes most sense to use the aggregate habitat classes for the production of habitat-specific trends as defined by CEH.

Table 5.1.1 Summary of CEH land Cover Map 2000 subclasses and aggregate classes.

Code	Subclass		Aggregate class	Code		% of Total
c01	Sea / Estuary	9744.373	Oceanic seas	D10	9744.373	3.6
c02	Water (inland)	2795.239	Standing open water	D8	2795.239	1
c03	Littoral rock	169.312	Coastal	D9	3378.064	1.3
c04	Littoral sediment	2473.677	Coastal	D9	3378.064	1.3
c05	Saltmarsh	454.026	Coastal	D9	3378.064	1.3
c06	Supra-littoral rock	45.898	Coastal	D9	3378.064	1.3
c07	Supra-littoral sediment	235.151	Coastal	D9	3378.064	1.3
c08	Bog (deep peat)	5665.645	Mountain, heath, bog	D6	39360.74	14.7
c09	Dense dwarf shrub heath	7597.713	Mountain, heath, bog	D6	39360.74	14.7
c10	Open dwarf shrub heath	19870.9	Mountain, heath, bog	D6	39360.74	14.7
c11	Montane habitats	3973.544	Mountain, heath, bog	D6	39360.74	14.7
c12	Broad-leaved / mixed woodland	15634.9	Broad-leaved / mixed woodland	D1	15634.9	5.8
c13	Coniferous woodland	13633.62	Coniferous woodland	D2	13633.62	5.1
c14	Improved grassland	57905.15	Improved grassland	D4	57905.15	21.6
c15	Neutral grass	12738.03	Semi-natural grass	D5	43774.72	16.3
c16	Setaside grass	1784.447	Semi-natural grass	D5	43774.72	16.3
c17	Bracken	1917.203	Semi-natural grass	D5	43774.72	16.3
c18	Calcareous grass	11108.58	Semi-natural grass	D5	43774.72	16.3
c19	Acid grassland	15950.18	Semi-natural grass	D5	43774.72	16.3
c20	Fen, marsh, swamp	276.285	Semi-natural grass	D5	43774.72	16.3
c21	Arable cereals	21892.03	Arable and horticulture	D3	57811.27	21.5
c22	Arable horticulture	34826.28	Arable and horticulture	D3	57811.27	21.5
c23	Arable non-rotational	1092.967	Arable and horticulture	D3	57811.27	21.5
c24	Suburban / rural development	11863.75	Built up areas and gardens	D7	16708.48	6.2
c25	Continuous urban	4844.735	Built up areas and gardens	D7	16708.48	6.2
c26	Inland bare ground	2252.937	Mountain, heath, bog	D6	39360.74	14.7
c27	Unclassified	7548.441	Unclassified	D25	7548.441	2.8
		268295				

We first explored a similar criteria to that used for the analyses based on BBS habitat data, by adopting a 50% threshold for classifying a site as a particular habitat. Unsurprisingly a similar finding is found when a 50% or more CEH habitat criteria is used. Table 5.1.2 shows the mean number of BBS squares surveyed between 1994-2004 containing 50% or more of each aggregate habitat and number of these recording each of the nine mammal species for which annual trends are routinely produced at a UK level. Assuming that 40 or more 1-km squares are required to produce a robust population trends, this yielded trends for 11 species x habitat combinations. Comparing the sum of the mean number of sites included in habitat-specific trends with the mean number of squares included in the standard UK model for each species, one can see that a high proportion of sites would not be included in the production of trends (in bold in Table 5.1.2). It is therefore clear that adopting a 50% threshold for habitat occurrence resulted in trends being produced for relatively few species / habitat combinations, and these are mainly widespread habitats such as farmland.

Table 5.1.2. Mean number of BBS squares surveyed between 1994-2004 (excluding 2001) containing 50% or more of a single CEH aggregate habitat.

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	SUM	TOTAL in UK model
Brown Hare	1	3	261	83	28	5	2	1	1	0	**385**	**522**
Mountain Hare	0	0	1	10	5	20	0	0		0	**36**	**43**
Rabbit	12	8	322	185	56	21	32	1	3	3	**643**	**1063**
Grey Squirrel	16	6	93	67	13	1	74	0	0	0	**270**	**472**
Red Fox	2	4	51	41	13	3	15	0	1	1	**131**	**221**
Red Deer	0	2	2	2	6	28	0	0	0	0	**40**	**49**
Roe Deer	5	14	63	31	6	14	2	1	1	0	**137**	**235**
Fallow Deer	4	1	14	3	0	1	0	0	0	0	**23**	**38**
Reeves's Muntjac	2	2	22	1	1	0	1	0	0	0	**29**	**44**

We then explored the approach of producing trends for squares where the percent of a particular habitat exceeds the percent of that habitat that would occur in a 1-km square if the habitat were distributed randomly across the UK, i.e. the occurrence of a particular habitat is greater than expected by chance. This is quite an arbitrary cut-point, i.e. there is no reason to say that this is likely percent that is likely to be important for a particular species. This option would allow trends to be produced for about 30 species x habitat combinations (see Table 5.1.3) but a particular problem is that data from a large number of 1-knm squares will contribute to more than one habitat-specific trend. This is particularly true for rare habitats, where a number of habitats may exceed the threshold, even though the species may not have been recorded in that habitat.

Table 5.1.3 Mean number of BBS squares surveyed between 1994-2004 (excluding 2001) that contains a particular habitat that exceeds the percent of that habitat that would occur by chance, if that habitat were distributed randomly across the UK.

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	SUM	TOTAL in UK model
Brown Hare	201	52	378	217	118	20	104	22	12	5	**1129**	**522**
Mountain Hare	6	6	3	12	14	25	2	2	1	1	**72**	**43**
Rabbit	523	133	593	523	290	61	334	65	29	19	**2570**	**1063**
Grey Squirrel	316	72	209	201	114	9	218	38	4	3	**1184**	**472**
Red Fox	111	30	105	115	62	13	73	12	5	4	**530**	**221**
Red Deer	11	12	5	7	14	36	1	4	1	0	**91**	**49**
Roe Deer	131	72	123	113	47	30	45	11	3	2	**577**	**235**
Fallow Deer	30	12	21	13	6	2	7	2	0	0	**93**	**38**
Reeves's Muntjac	34	11	33	11	8	0	10	2	0	0	**109**	**44**

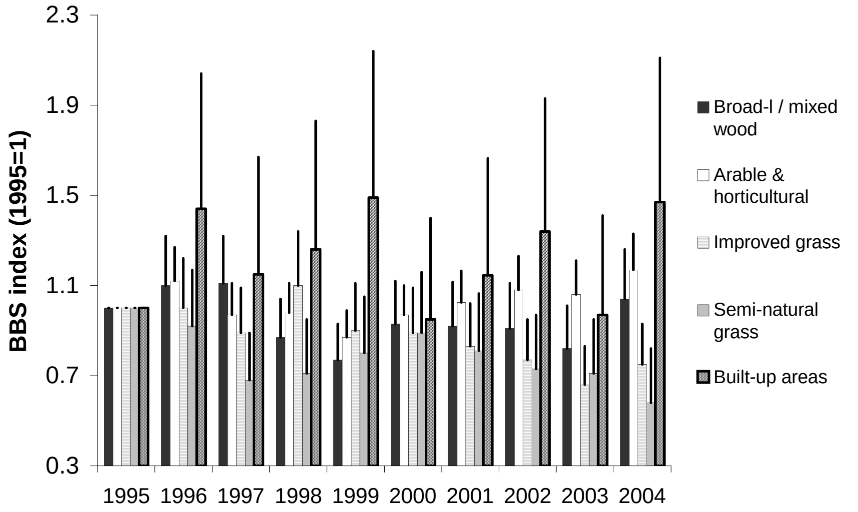
We eventually decided to produce trends for squares where the percentage of a specific habitat was at least double the percentage of that habitat in the broader UK landscape. This approach can be viewed as a compromise between the first and second options above. Whilst the number of squares contributing to multiple trends is reduced compared with the previous option, it makes much better use of the data than the first option with a 50% threshold for habitat classification. This option is particularly beneficial for rarer habitats, such as built-up areas and garden and broad-leaved and coniferous woodland, and would enable trends to be produced for about 26 species x habitat combinations (Table 5.1.4). We present habitat-specific temporal trends in relative abundance using this approach.

	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**SUM**	**TOTAL in UK model**
Brown Hare	112	28	291	104	51	11	44	17	8	4	**670**	**522**
Mountain Hare	1	4	1	11	9	22	1	1	1	1	**52**	**43**
Rabbit	319	78	386	236	101	34	198	48	22	17	**1439**	**1063**
Grey Squirrel	216	43	117	86	29	4	165	26	3	3	**692**	**472**
Red Fox	70	19	63	52	25	6	49	7	4	3	**298**	**221**
Red Deer	7	10	3	3	9	31	1	3	1	0	**68**	**49**
Roe Deer	90	54	75	42	16	20	23	8	3	2	**333**	**235**
Fallow Deer	24	9	15	3	1	1	3	1	0	0	**57**	**38**
Reeves's Muntjac	22	7	25	2	3	0	5	1	0	0	**65**	**44**

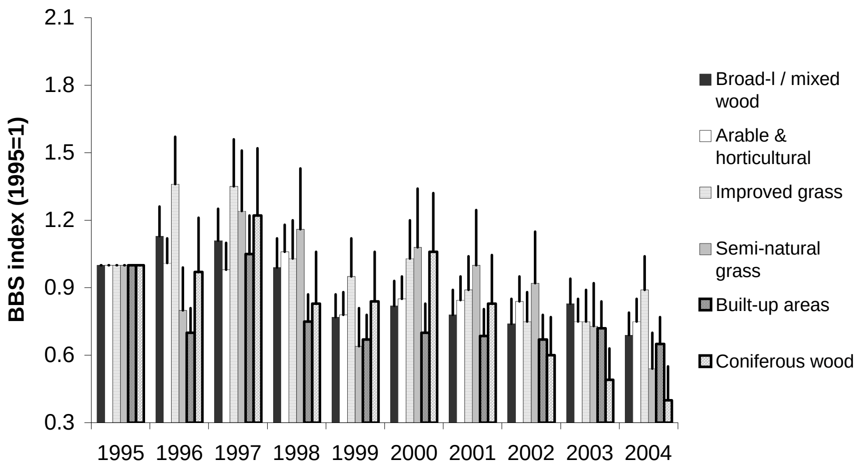
Data were adequate to produce habitat-specific trends for 26 species x habitat combinations, covering the five most abundant British mammal species (Rabbit, Brown Hare, Grey Squirrel, Red Fox and Roe Deer). The results shown in Figures 5.1.1a-e and Appendix 4 suggest that the abundance of Rabbit has declined significantly from 1995-2004 in habitat associated with broad-leaved and coniferous woodland, arable and horticultural, improved and semi-natural grassland and built-up areas. Red Fox has declined significantly in habitats associated with built-up areas, improved grassland, broad-leaved woodland and arable and horticultural, whilst Brown Hare shows declines in habitats associated with improved and semi-natural grassland and built-up areas, although the sample size for the latter is small. Species increasing significantly from 1995 and 2004 includes Roe Deer in arable and horticultural habitat and coniferous woodland and Grey Squirrel has increased significantly in habitat associated with built-up areas, broad-leaved woodland and on arable and horticultural land.

Figure 5.1.1 Change in the relative abundance from counts of mammals in different habitats in the UK from 1995-2004. Error bars represent 95% confidence intervals

a) Brown Hare



b) Rabbit



c) Grey Squirrel

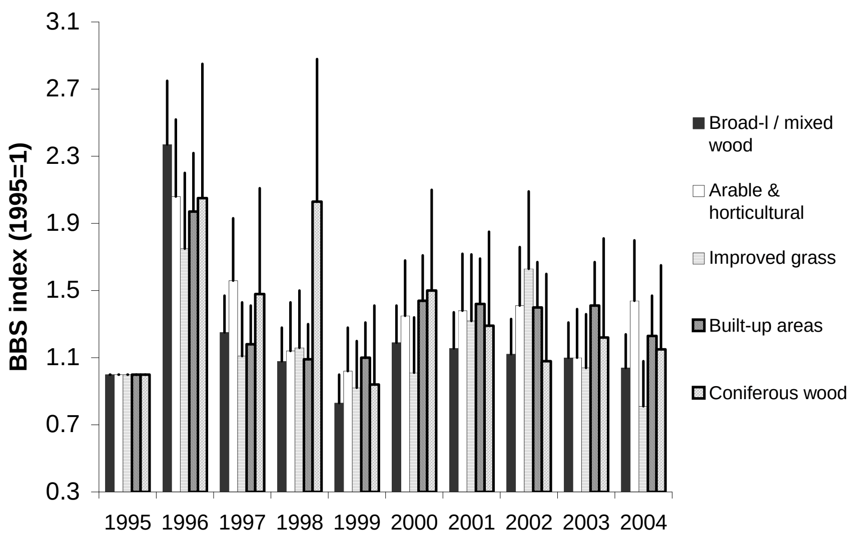
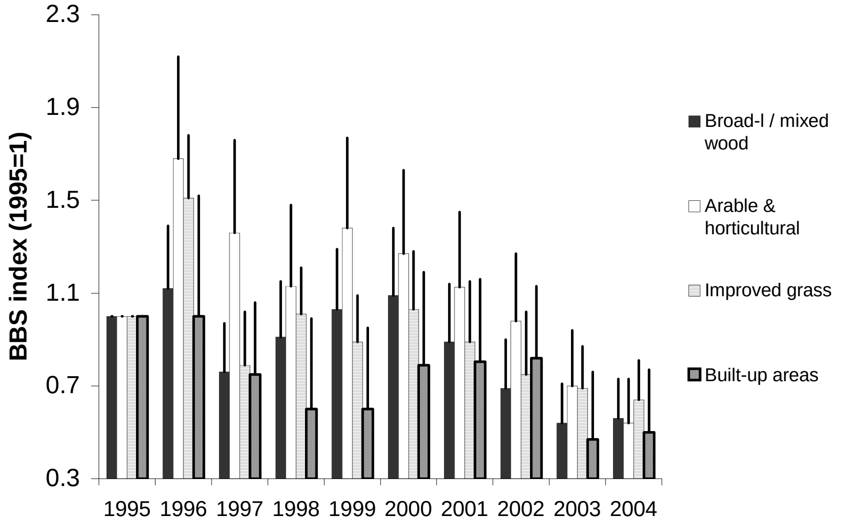
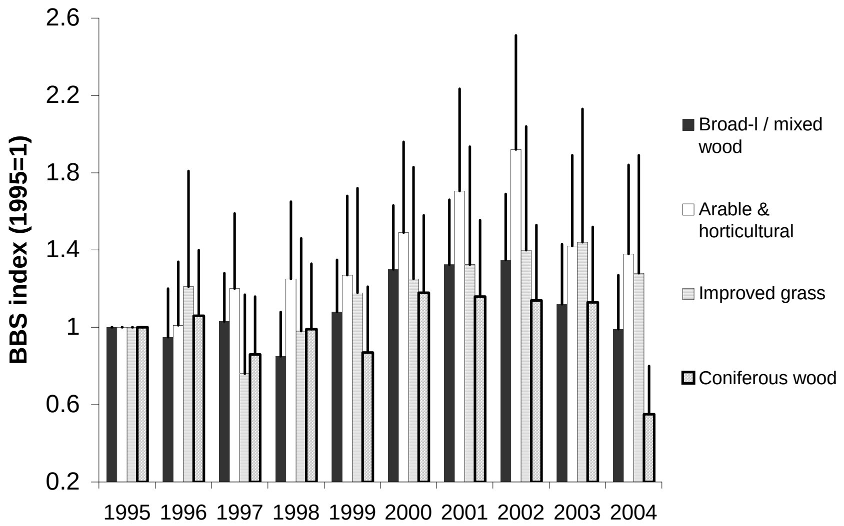


Figure 5.1.1 (continued)

d) Red Fox



e) Roe Deer



We believe that the chosen approach makes the best use of the data, whilst allowing biologically meaningful population trends to be produced. Of the nine species for which trends are produced at a UK level, it was possible to produce habitat-specific trends for five species for one or more habitat. Within species, significant changes in abundance were all in the same direction (an exception is Brown Hare in built-up areas which was based on a small sample size). However, increases in Roe Deer were greatest on arable and horticultural land and increases in Grey Squirrels were greatest in built-up areas. Declines were greatest for Red Fox in built-up areas and in broad-leaved woodland, for Brown Hare in semi-natural grassland and for Rabbit in coniferous woodland.

5.2 Examining the validity of trends for herding deer

Red and Fallow Deer show an apparent drop in relative abundance from 1995 to 1996 (Figures 4.1.6 and 4.1.7). In the past this has been interpreted with caution, because there are a few very large counts made in 1995 at a small number of sites, which could have biased these trends. For Red Deer there are some particularly large counts, including one of 700 and two of 200 individuals. For Fallow Deer the largest count is 73, with a further three sites reporting counts of 50 or more individuals.

We first explored the influence of these counts on the resulting population trends by re-running the analyses by: i) excluding the single highest count for each species, ii) all counts that are substantially greater than others (for Red Deer counts of 200 or more and for Fallow Deer counts of 50 or more). The results in Table 5.2.1 show that a single large count at a single site has had a large influence on the resulting trends for both species. The original trend for Red Deer shows a decline of 75% from 1995-2004. Excluding the single site with a count of 700 yields a population decline of only 45%. Excluding two additional sites with counts of 200 or more results in a decline of only 32% from 1995-2004. For Fallow Deer, excluding the single large count of 73 individuals changes the scale of decline from 87% to a 73% decline. Excluding a further three sites with counts of 50 or results in a decline of 63%.

A second goal was to look for a possible influence of counts at deer parks on the resulting trends. We found only one deer park on BBS sites included in the analyses for deer trends, where counts for both Red and Fallow Deer were large. The effect of excluding this site from the analyses is provided in Table 5.2.1.

To summarise, whilst trends produced for Red and Fallow Deer, the magnitude of the changes is altered considerably by excluding sites with high counts. Other options, which we have been unable to implement yet, include the modeling of alternative distributions to the deer data. Moreover, although the largest counts of these species are not being made at deer parks, it is recommended that deer parks be excluded from future analyses. Nevertheless, all versions of the trends suggest declines in Red and Fallow Deer since 1995, in agreement with recent trends from the national game bag survey.

Table 5.2.1. Population trends produced according to i) the standard approach, ii) excluding the site containing the single largest count, iii) excluding the greatest 3 or 4 largest counts, and iv) excluding counts made at a deer park.

		Year								
Species	*n*	1995	1996	1997	1998	1999	2000	2002	2003	2004
RED DEER										
Standard trend	49	1	0.61 (0.49-0.77)	0.67 (0.54-0.84)	0.70 (0.56-0.88)	0.37 (0.29-0.49)	0.52 (0.39-0.69)	0.41 (0.32-0.54)	0.26 (0.19-0.36)	0.25 (0.18-0.35)
Exclude largest count of 700	48	1	1.08 (0.86-1.35)	1.24 (0.99-1.55)	1.34 (1.07-1.68)	0.75 (0.58-0.98)	1.10 (0.83-1.46)	0.86 (0.66-1.13)	0.53 (0.39-0.72)	0.55 (0.41-0.75)
Exclude counts > 200 (n=3)	46	1	1.42 (1.12-1.80)	1.59 (1.25-2.01)	1.75 (1.38-2.23)	0.94 (0.72-1.23)	1.36 (1.03-1.80)	1.06 (0.81-1.38)	0.65 (0.48-0.88)	0.68 (0.50-0.92)
w/o deer park (SP2556)	48	1	0.61 (0.49-0.77)	0.67 (0.53-0.84)	0.69 (0.55-0.86)	0.38 (0.29-0.49)	0.51 (0.39-0.68)	0.43 (0.33-0.56)	0.27 (0.20-0.37)	0.26 (0.19-0.36)
FALLOW DEER										
Standard trend	38	1	0.47 (0.35-0.63)	0.48 (0.36-0.66)	0.41 (0.30-0.54)	0.26 (0.19-0.36)	0.64 (0.49-0.84)	0.49 (0.37-0.65)	0.20 (0.14-0.28)	0.13 (0.09-0.19)
Exclude largest count of 73	37	1	0.94 (0.68-1.30)	1.03 (0.73-1.44)	0.85 (0.62-1.18)	0.54 (0.38-0.77)	1.36 (1.00-1.84)	1.03 (0.75-1.41)	0.42 (0.39-0.61)	0.27 (0.18-0.40)
Exclude counts >50 (4 sites)	34	1	0.81 (0.60-1.10)	0.76 (0.55-1.06)	0.48 (0.34-0.68)	0.60 (0.43-0.83)	0.87 (0.65-1.18)	1.63 (1.24-2.13)	0.54 (0.38-0.76)	0.35 (0.24-0.52)
w/o deer park (SP2556)	37	1	0.46 (0.36-0.60)	0.48 (0.37-0.63)	0.22 (0.16-0.31)	0.33 (0.25-0.44)	0.38 (0.29-0.50)	0.80 (0.63-1.02)	0.22 (0.16-0.32)	0.19 (0.14-0.27)

5.3 Producing joint BBS / WBBS trends for Otter, American Mink and Water Vole

Water Vole, American Mink and Otter are not reliably monitored on an annual basis by any existing survey. The BTO/Environment Agency Waterways Breeding Bird Survey (WBBS) provides perhaps the best annual monitoring data for these species at a national level (see Newson & Noble, 2005). However, because sightings of these species on surveyed WBBS stretches are infrequent (about 5% of stretches), the power to detect change in the populations of these species based on sightings is very low. For example, at current rates of WBBS coverage, numbers of these species would need to change by 80-100% before a significant change would be detected.

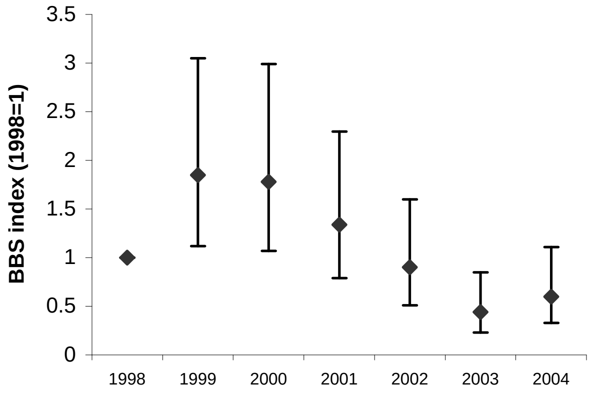
Because observers were more likely to find indirect evidence of presence (15% of stretches) on their WBBS transects than to see these species during their visit, the power to detect a change using these criteria is greater than using count data. At the current level of survey effort, a 48% decline in presence on WBBS stretches would need to occur for a significant effect to be detected. A method to boost the number of sites by combining WBBS and BBS mammal data was proposed in Newson & Noble (2005). This is appropriate for riparian species, because the fact that the WBSB sampling design is based upon a strictly waterways stratification is similar in effect to the fact that BBS squares containing waterways are the only ones where these species are likely to be recorded. Nevertheless, because these species are recorded on few BBS squares, the benefit of combining these data sources was small, improving the detectable decline from 48% to 43% (see Newson & Noble, 2005).

Analytically the problem of combining BBS and WBBS is similar to combining BBS and Common Birds Census (CBC) data, discussed in detail in Freeman *et al*. (in press). As with the production of joint CBC / BBS indices, it is necessary to deal with the complication that BBS data are weighted to account for the stratified random sampling design whereas WBBS have never been weighted. In order for data from a BBS site to have the same impact on the trend as a WBBS site in the joint trends, we have weighted BBS in the usual way, and assigned all WBBS sites a single weighting equal to the mean weighting across sites and years.

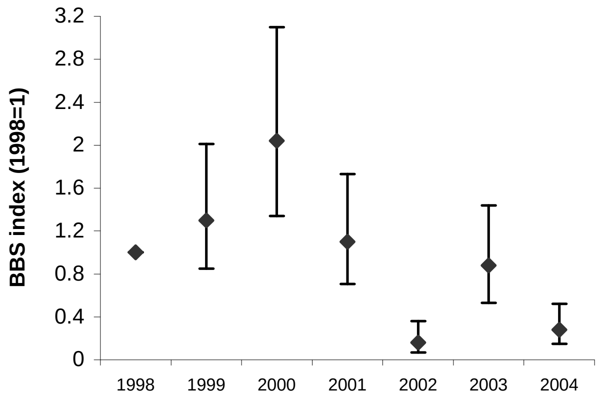
Joint WBBS / BBS trends from sightings and presence / absence data for 1998 to 2004 are shown in Figures 5.3.1 and 5.3.2 and in Appendix 5. The trends based on sightings data are based on a very small sample size and should be interpreted with extreme caution. Combining the data on presence from BBS and WBBS sites resulted in a larger sample size, and could provide a means of monitoring these species between national surveys, carried out for Water Voles and Otters. Of those presented here, perhaps the only trend that is both statistically significant and visually convincing is the increase in the occurrence of Otters.

Figure 5.3.1. Change in relative abundance of riparian species from WBBS and BBS counts in the UK from 1998-2004. Error bars represent 95% confidence intervals (see Appendix 5 for raw data). The sample size is shown in brackets.

a) Water Vole (n=14)



b) American Mink (n=4)



c) Otter (n=6)

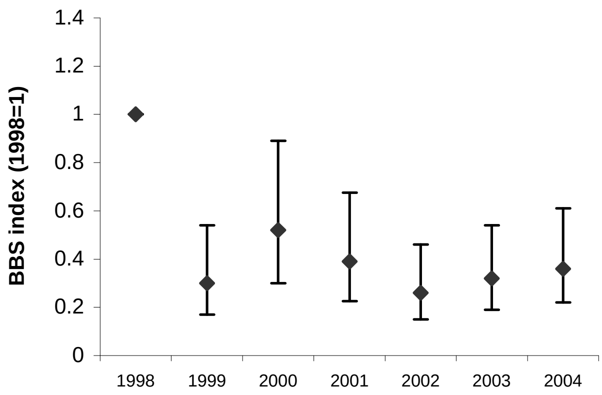
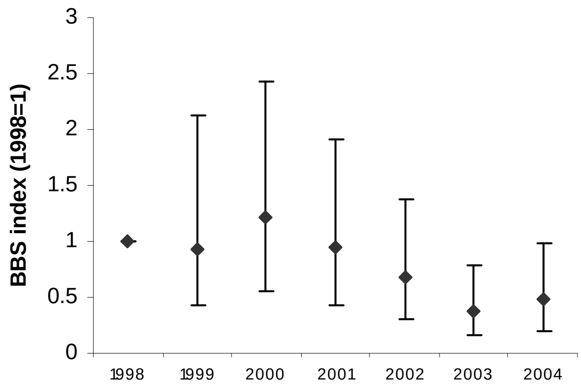
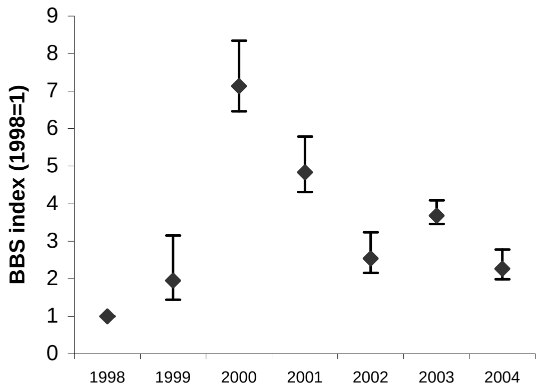


Figure 5.3.2. Change in the presence of riparian species from WBBS and BBS counts in the UK from 1998-2004. Error bars represent 95% confidence intervals (see Appendix 5 for raw data). The sample size is shown in brackets.

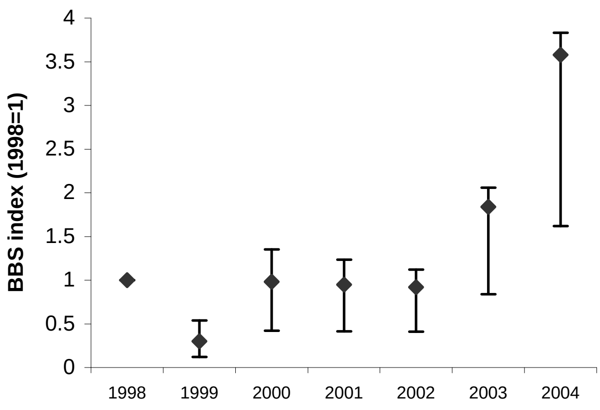
a) Water Vole (n=29)



b) American Mink (n=45)



c) Otter (n=43)



5.4 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). 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 5.4.1. 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. 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.

Using sightings data for Rabbit and Fallow Deer for 1995 and 2004, we interpolate statistically valid maps of relative abundance using geostatistical methods, specifically using the Geostatistical Analyst extension of ArcGIS (Johnston *et al*. 2001). 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 5.4.2, it is clear that the addition of habitat as the predictor can improve the resulting predictions of relative abundance across the UK. For Rabbit, improved grassland in 1995 and improved and semi-natural natural grassland in 2004, provided the best predictive variables (Figure 5.4.1), whilst for Fallow Deer, the inclusion of habitat did not improve the models further (Figure 5.4.2). A change map is shown for both species is shown in Figure 5.4.3. Data for Fallow Deer is sparse, and is not believed that the interpolated map here provides a good representation of Fallow Deer relative abundance. Note that the last map (Figure 5.4.3 (b) (ii) is blank because there were no estimated areas of decline in this species.

For species not counted, or for which relatively little evidence of occurrence is recorded, distribution maps of species presence combined over intervals of five or ten-years might be considered. Moreover, using similar methodology for binary data (indicator kriging), it may 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 Rabbit and Fallow 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.

Table 5.4.1 Definition of seven aggregate habitat classes and associated subclasses.

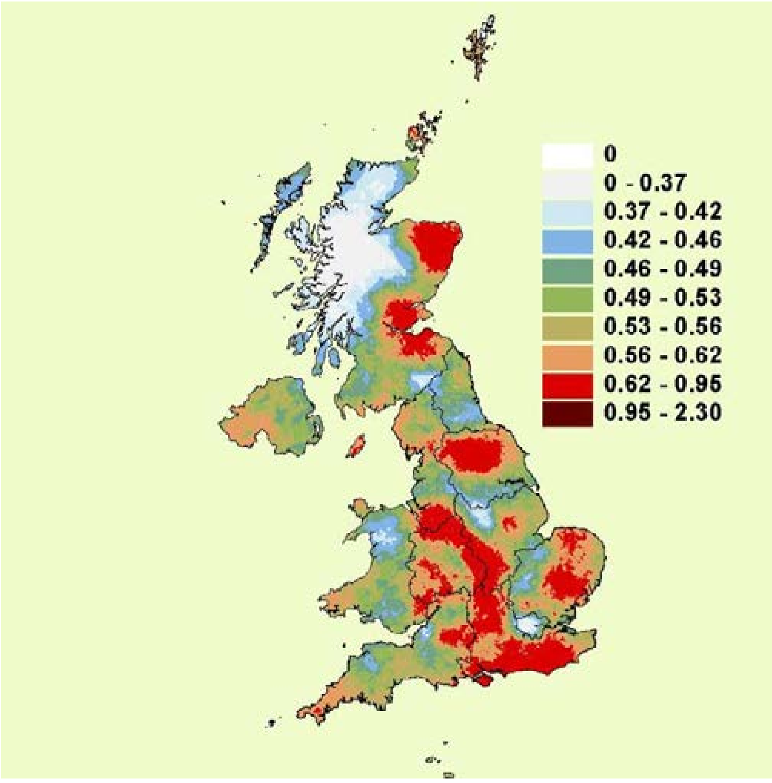
Aggregate class definition	Subclass definition
Mountain, heath, bog	Bog (deep peat), open and dense dwarf shrub heath, montane habitats, inland bare ground
Broad-leaved / mixed woodland	Broad-leaved / mixed woodland
Coniferous woodland	Coniferous woodland
Improved grassland	Improved grassland
Semi-natural 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

Table 5.4.2 Comparison of model fit and error associated with the prediction of Rabbit and Fallow Deer abundance across the UK from BBS sightings data for 1995 and 2004 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 chosen model is marked with an asterisk.

Model: 1995	Root-mean-square prediction errors	Standardized mean prediction errors	Model: 2004	Root-mean-square prediction errors	Standardized mean prediction errors
RABBIT			RABBIT		
No habitat: Simple kriging	0.9933	0.01554	No habitat: Simple kriging	0.9752	0.01542
Moorland, heath & bog	0.9639	0.01299	Moorland, heath & bog	0.9774	0.02086
Broadleaved woodland	0.9744	0.06597	Broadleaved woodland	0.9762	0.05679
Coniferous woodland	0.9667	0.00282	Coniferous woodland	0.9726	0.01411
Improved grassland*	0.9627	0.00599	Improved grassland	0.9746	0.00740
Semi-natural grassland	0.9676	-0.00435	Semi-natural grassland	0.9750	0.00353
Arable	0.9821	0.05106	Arable	0.9912	0.05240
Human	0.9999	0.04859	Human	0.9945	-0.01556
Improved grass + Coniferous wood	0.9749	0.00933	Improved + Semi-natural grassland*	0.9701	-0.00132
FALLOW DEER			FALLOW DEER		
No habitat: Simple kriging*	1.000	2.496e-16	No habitat: Simple kriging*	0.9997	0.00030
Moorland, heath & bog	1.001	0.00011	Moorland, heath & bog	0.9998	0.00754
Broadleaved woodland	0.9974	0.01696	Broadleaved woodland	0.9928	0.00396
Coniferous woodland	0.9981	0.00342	Coniferous woodland	1.002	0.00388
Improved grassland	1.000	0.00328	Improved grassland	0.9998	0.00094
Semi-natural grassland	1.000	-0.00089	Semi-natural grassland	1.001	-0.00538
Arable	1.000	0.00984	Arable	1.001	0.01763
Human	0.9999	0.00384	Human	1.008	0.03860

Figure 5.4.1 Interpolated relative abundance of Rabbit from BBS mammal data. Units are numbers detected per 1-km^2.

a) 1995



b) 2004

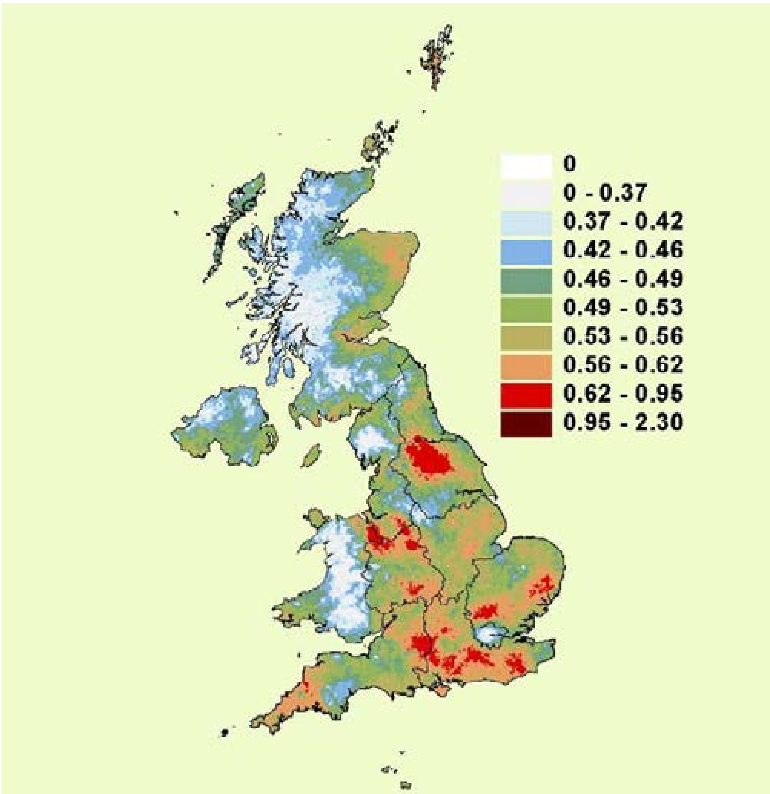
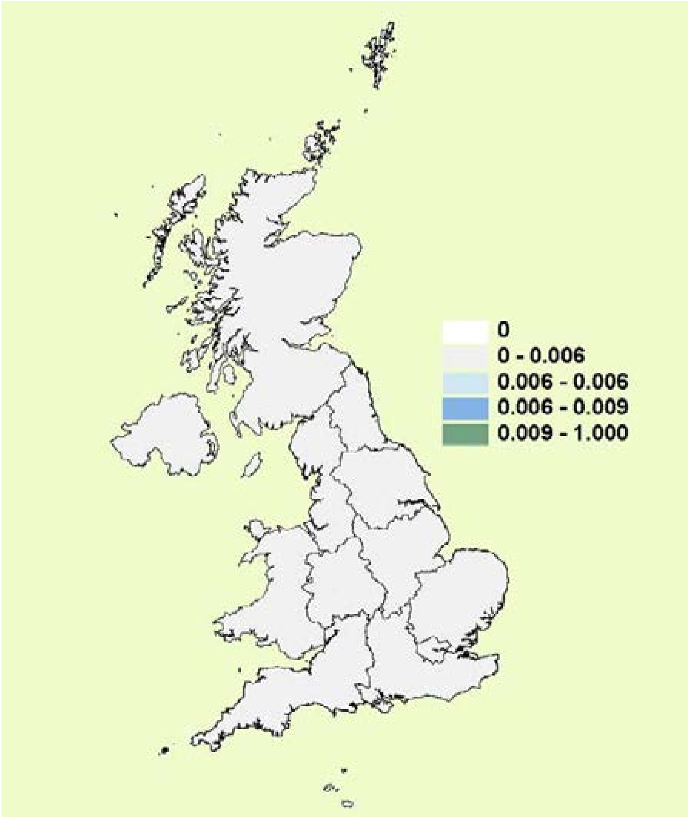


Figure 5.4.2 Interpolated relative abundance of Fallow Deer from BBS mammal data. Units are numbers detected per 1-km^2.

a) 1995



b) 2004

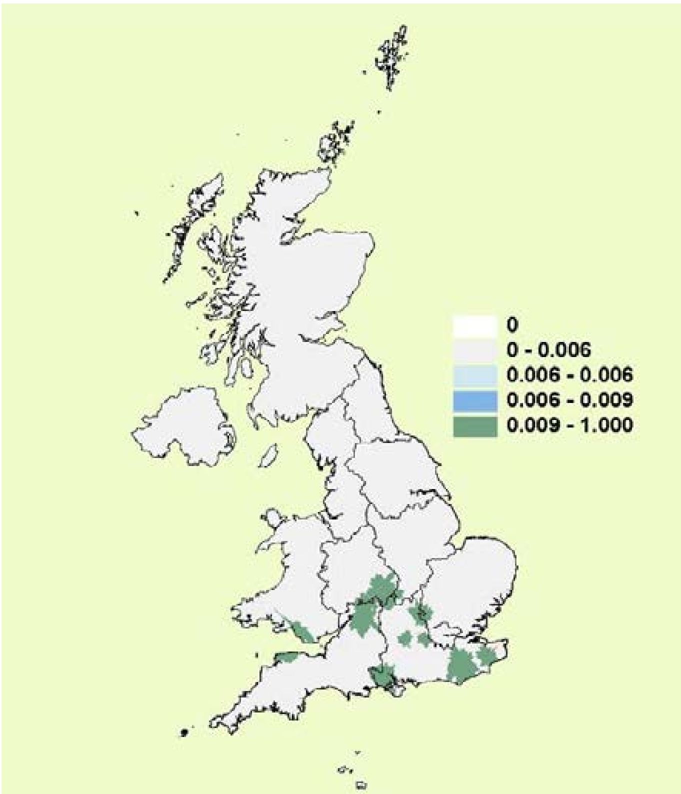
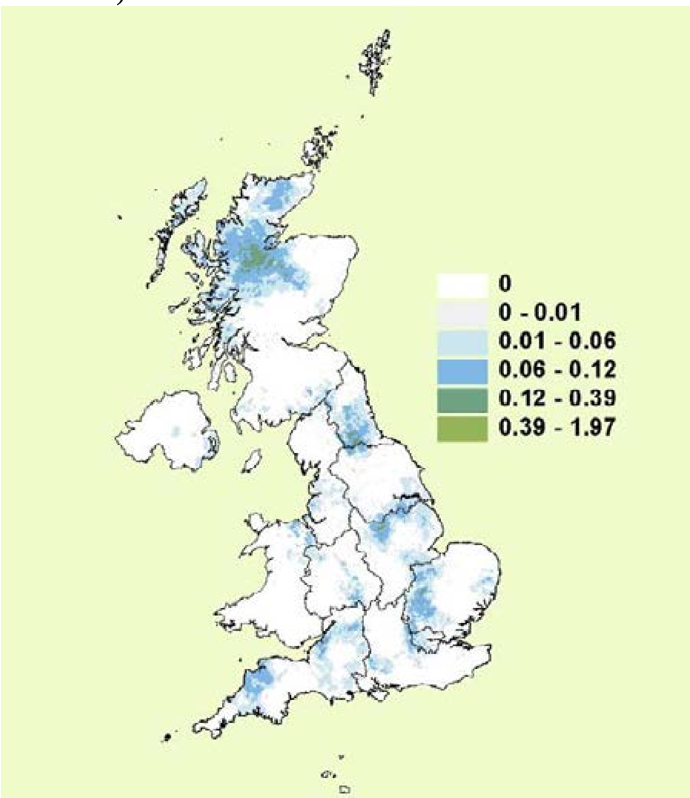


Figure 5.4.3 Change in relative abundance of Rabbit and Fallow Deer between 1995 and 2004. Units are numbers detected per 1-km^2.

a i) Rabbit increase (1995-2004)



a ii) Rabbit decline (1995-2004)

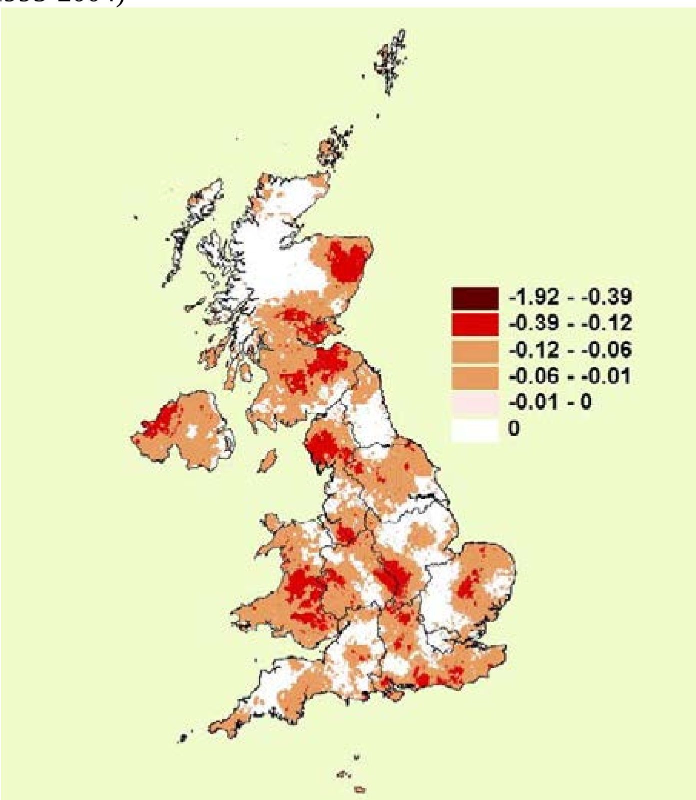
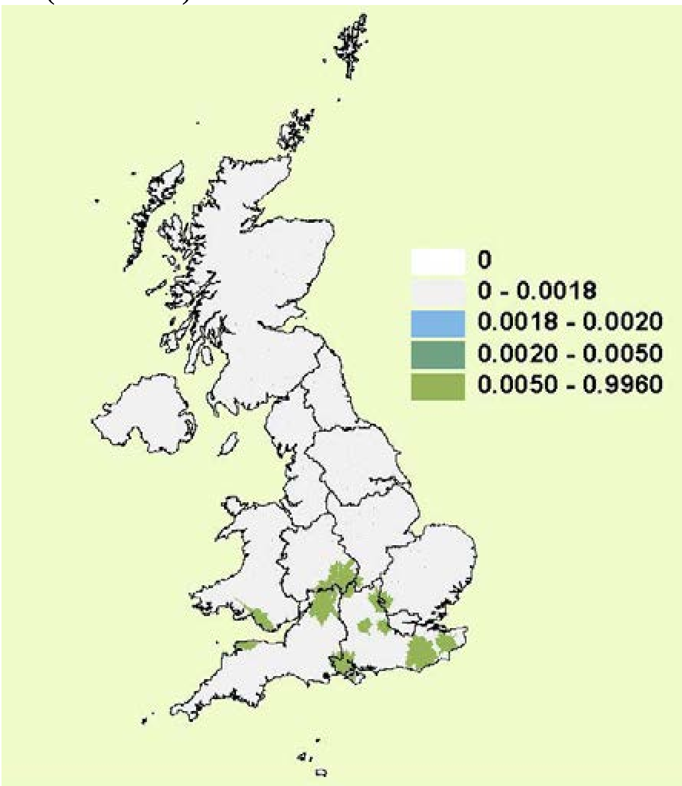
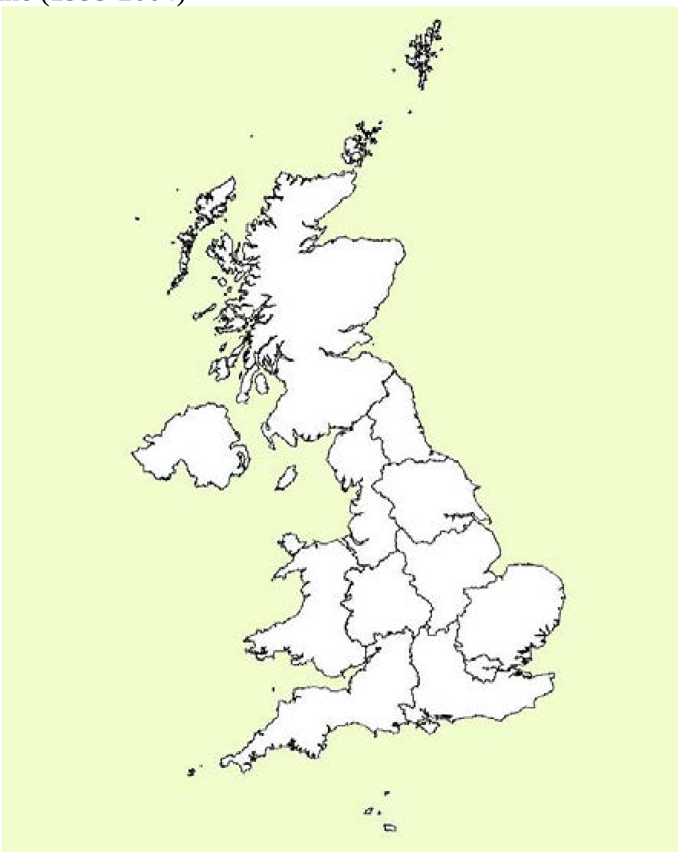


Figure 5.4.3 (continued)

b i) Fallow Deer increase (1995-2004)



b ii) Fallow Deer decline (1995-2004)



Acknowledgments

This work is funded by the Joint Nature Conservation Committee (JNCC) under the supervision of Dr Jessa Battersby. We are grateful to Mike Raven for managing the BBS mammal database, and to Steve Freeman for statistical advice. The BBS is supported by a partnership between the BTO, the Royal Society for the Protection of Birds (RSPB) and JNCC - the on behalf of the Countryside Council for Wales, English Nature, Scottish Natural Heritage and the Department of Environment for Northern Ireland.

References

Battersby, J. (Ed) & Tracking Mammals Partnership. (2005) *UK Mammals: Species Status and Population Trends*. First Report by the Tracking Mammals Partnership. JNCC/Tracking Mammals Partnership, Peterborough.

Battersby, J.E. & Greenwood, J.J.D. (2004) Monitoring terrestrial mammals in the UK: past, present and future, using lessons from the bird world. *Mammal Review*, **34**, 3-29.

Chiles, J. & Delfiner, P. (1999) *Geostatistics. Modeling Spatial Uncertainty*. John Wiley & Sons, New York.

Crick, H.Q.P. (1992) A bird-habitat coding system for use in Britain and Ireland incorporating aspects of land-management and human activity. *Bird Study*, **39**, 1-12.

Haines-Young, R.H., Barr, C.J., Black, H.I.J., Briggs, D.J., Bunce, R.G.H., Clarke, R.T., Cooper, A., Dawson, F.H., Firbank, L.G., Fuller, R.M., Furse, M.T., Gillespie, M.K., Hill, R., Hornung, M., Howard, D.C., McCann, T., Morecroft, M.D., Petit, S., Sier, A.R.J., Smart, S.M., Smith, G.M., Stott, A.P., Stuart, R.C. & Watkins, J.W. (2000) *Accounting for nature: assessing habitats in the UK countryside*, DETR, London ISBN 1 85112 460 8.

Harris, S., Morris, P., Wray, S. & Yalden, D. (1995) *A review of British mammals: population estimates and conservation status of British mammals other than cetacean.,* Joint Nature Conservation Committee, Peterborough.

Hastie, T.J. & Tshibirani, R.J. (1990) *Generalized Additive Models*. Chapman & Hall. London

Isaaks, E.H. & Srivastava, R.M. (1989) *An Introduction to Applied Geostatistics.* Oxford University Press, New York.

Johnston, K., Ver Hoef, J.M., Krivoruchko, K. & Lucas, N. (2001) *Using ArcGIS Geostatistical Analyst.* ESRI.

Joys, A.C., Noble, D.G. & Baillie, S.R. (2003) *Evaluation of species coverage and precision using the BBS indexing method*. BTO Research Report No. 317. BTO, Thetford.

Macdonald, D W. & Tattersall, F. (2003) *The State of Britain's Mammals 2003*. Mammals Trust UK and WildCRU, London.

McCullagh, P. & Nelder, J.A. (1989) *Generalized Linear Models*, 2nd edn. Chapman and Hall, London.

Newson, S.E. & Noble, D.G. (2003) *Preliminary analyses of Breeding Bird Survey (BBS) mammal data*. BTO Research Report No. 321. BTO, Thetford.

Newson, S.E. & Noble, D.G. (2005) *The production of population trends for UK mammals using BBS mammal data, 1995-2002*. BTO Research Report No. 360. BTO, Thetford.

Newson, S.E., Noble, D.G. & Marchant, J.H. (2005). *Waterways Breeding Bird Survey: preliminary analyses of mammal data 1998-2003*. BTO Research Report No. 405. BTO, Thetford.

Noble, D.G., Newson, S.E., Baillie, S.R., Raven, M.J. & Gregory, R.D. (In press) Recent changes in UK bird populations measured by the Breeding Bird Survey. *Bird Study*.

SAS Institute. (2001) *SAS/STAT user's guide, version 8.02*. North Carolina: Cary.

ter Braak, C.J.K., van Strien, A.J., Meijer, R. & Verstrael, T.J. (1994) Analysis of monitoring data with many missing values: Which method? *Bird Numbers 1992. Proceedings of the 12th International Conference of IBCC and EOAC Noordwijkerhout, The Netherlands.* Statistics Netherlands, Voorburg/Heerlen & SOVON, Beek-Ubbergen.

Whitlock, R.E., Aebischer, N.J. & Reynolds, J.C. (2003) *The National Gamebag Census as a Tool for Monitoring Mammal Abundance in the UK.* A report to JNCC, Peterborough.

Appendix 1a The number of BBS squares recording counts of mammals on BBS squares (percentage of total BBS squares surveyed is 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. Note that following the first year of the survey, a number of species were added to the surveyors form which influences the numbers reported, 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.

	Year								
Species	1995	1996	1997	1998	1999	2000	2002	2003	2004
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)	4 (0.2)
Mole	18 (1.4)	76 (4.7)	56 (3)	30 (1.5)	45 (2.2)	6 (0.3)	0	0	2 (0.1)
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)	1 (0)
Pygmy Shrew	0	0	0	1 (0.1)	0	2 (0.1)	1 (0.1)	0	0
Water Shrew	0	0	1 (0.1)	2 (0.1)	0	0	0	0	0
Natterer's Bat	0	1 (0.1)	0	0	0	0	0	0	0
Pipistrelle Bat	0	0	1 (0.1)	0	2 (0.1)	0	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)	1106 (53.1)
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)	507 (24.3)
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)	30 (1.4)
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)	14 (0.7)
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)	482 (23.1)
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)	1 (0)
Field Vole	2 (0.2)	6 (0.4)	5 (0.3)	9 (0.5)	7 (0.3)	2 (0.1)	3 (0.2)	0	1 (0)
Orkney Vole	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	1 (0.1)	1 (0.1)	1 (0.1)	1 (0)
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)	5 (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)	1 (0)
Harvest Mouse	0	1 (0.1)	0	0	0	0	0	0	0
House Mouse	0	0	0	0	0	1 (0.1)	0	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)	11 (0.5)
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)	167 (8)
Pine Marten	2 (0.2)	2 (0.1)	0	1 (0.1)	1 (0.1)	3 (0.2)	0	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)	14 (0.7)
Weasel	9 (0.7)	14 (0.9)	22 (1.2)	22 (1.1)	20 (1)	15 (0.8)	10 (0.6)	10 (0.5)	14 (0.7)
Polecat	0	1 (0.1)	3 (0.2)	1 (0.1)	2 (0.1)	0	0	0	0
Ferret	0	0	0	0	0	0	1 (0.1)	0	0

Species	Year								
	1995	1996	1997	1998	1999	2000	2002	2003	2004
American Mink	3 (0.2)	1 (0.1)	3 (0.2)	2 (0.1)	1 (0.1)	6 (0.3)	0	2 (0.1)	1 (0)
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)	6 (0.3)
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)	1 (0)
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)	229 (11.0)
Park Cattle	1 (0.1)	0	0	0	0	0	0	0	0
Minke Whale	0	0	0	0	0	0	1 (0.1)	0	0
Harbour Porpoise	1 (0.1)	0	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)	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)	0
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)	29 (1.4)
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)	3 (0.1)
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)	31 (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)	208 (10)
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)	44 (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)	3 (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)	3 (0.1)

Appendix 1a (continued)

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 is 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. Note that following the first year of the survey, a number of species were added to the surveyors form which influences the numbers reported, 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.

	Year								
Species	1995	1996	1997	1998	1999	2000	2002	2003	2004
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)	181 (8.7)
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)	547 (26.3)
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)	8 (0.4)
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)	4 (0.2)
Water Shrew	0	0	1 (0.1)	2 (0.2)	0	1 (0.1)	2 (0.2)	0	1 (0)
Lesser white-toothed Shrew	0	1 (0.1)	0	2 (0.2)	0	0	1 (0.1)	1 (0.1)	1 (0)
Greater Horseshoe Bat	0	0	0	0	0	0	1 (0.1)	0	0
Natterer's Bat	0	2 (0.2)	0	0	0	0	0	0	0
Daubenton’s Bat	0	0	0	0	0	0	0	0	1 (0)
Noctule Bat	2 (0.2)	1 (0.1)	1 (0.1)	2 (0.2)	1 (0.1)	1 (0.1)	0	0	0
Leisler's Bat	0	0	0	0	1 (0.1)	0	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)	14 (0.7)
Long-eared Bat	0	1 (0.1)	0	1 (0.1)	1 (0.1)	0	0	1 (0.1)	1 (0)
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)	1478 (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)	726 (34.9)
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)	55 (2.6)
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)	29 (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)	783 (37.6)
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)	5 (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)	15 (0.7)
Orkney Vole	2 (0.2)	1 (0.1)	0	3 (0.2)	3 (0.2)	2 (0.2)	2 (0.2)	2 (0.1)	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)	11 (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)	14 (0.7)
Yellow-necked Mouse	0	0	1 (0.1)	0	0	1 (0.1)	0	1 (0.1)	0
Harvest Mouse	0	1 (0.1)	1 (0.1)	0	1 (0.1)	0	1 (0.1)	2 (0.1)	0

Species	Year 1995	1996	1997	1998	1999	2000	2002	2003	2004
House Mouse	0	2 (0.2)	1 (0.1)	2 (0.2)	2 (0.1)	4 (0.3)	3 (0.2)	2 (0.1)	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)	191 (9.2)
Common Dormouse	1 (0.1)	1 (0.1)	2 (0.2)	1 (0.1)	1 (0.1)	0	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)	686 (32.9)
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)	2 (0.1)
Stoat	37 (2.8)	86 (5.4)	85 (4.6)	123 (6.3)	162 (8)	159 (8.4)	111 (6.2)	112 (5.8)	127 (6.1)
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)	97 (4.7)
Polecat	0	1 (0.1)	3 (0.2)	3 (0.2)	6 (0.3)	4 (0.3)	0	0	2 (0.1)
Ferret	0	0	0	0	0	1 (0.1)	2 (0.2)	0	1 (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)	24 (1.2)
Badger	82 (6.2)	152 (9.5)	156 (8.3)	235 (12)	273 (13.5)	287 (15.1)	305 (16.9)	337 (17.6)	379 (18.2)
Otter	6 (0.5)	13 (0.9)	12 (0.7)	14 (0.8)	8 (0.4)	18 (1)	16 (0.9)	28 (1.5)	32 (1.5)
Wild Cat	1 (0.1)	0	0	0	0	0	0	1 (0.1)	0
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)	413 (19.8)
Chillingham Cattle	1 (0.1)	0	0	0	0	0	0	0	0
Wild Boar	0	0	0	0	0	0	1 (0.1)	0	2 (0.1)
Minke Whale	0	0	0	0	0	0	1 (0.1)	0	0
Harbour Porpoise	1 (0.1)	0	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)	4 (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)	4 (0.2)
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)	79 (3.8)
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)	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)	94 (4.5)
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)	461 (22.1)
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)	147 (7.1)
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)	5 (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)	3 (0.1)
Red-necked Wallaby	0	0	0	0	0	0	1 (0.1)	0	0

Appendix 1b (continued)

Appendix 2a UK temporal trends in relative abundance for nine mammal species for the period 1995-2004. 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. A visual representation of temporal trends in abundance for the UK are shown in Figures 4.1.1 – 4.1.9.

		Year									
Species	*n*	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Brown Hare	522	1	1.06 (0.97-1.16)	0.97 (0.89-1.07)	0.99 (0.90-1.09)	0.91 (0.83-1.00)	0.96 (0.88-1.06)	0.98 (0.90-1.08)	1.00 (0.91-1.10)	0.92 (0.84-1.02)	0.99 (0.90-1.09)
Mountain Hare	43	1	1.40 (1.07-1.82)	2.01 (1.56-2.58)	1.42 (1.08-1.85)	1.17 (0.87-1.58)	1.05 (0.80-1.40)	0.93 (0.71-1.25)	0.81 (0.61-1.09)	0.64 (0.47-0.86)	0.87 (0.65-1.16)
Rabbit*	1063	1	1.07 (1.01-1.14)	1.25 (1.18-1.33)	1.00 (0.94-1.07)	0.81 (0.76-0.87)	0.93 (0.87-1.00)	0.85 (0.79-0.91)	0.76 (0.71-0.82)	0.72 (0.67-0.78)	0.70 (0.65-0.75)
Grey Squirrel	472	1	2.13 (1.93-2.36)	1.31 (1.17-1.46)	1.16 (1.03-1.30)	0.98 (0.87-1.10)	1.25 (1.11-1.39)	1.29 (1.15-1.44)	1.33 (1.19-1.48)	1.24 (1.11-1.39)	1.12 (1.00-1.26)
Red Fox*	221	1	1.31 (1.16-1.48)	0.91 (0.80-1.05)	0.94 (0.82-1.08)	0.96 (0.84-1.10)	1.03 (0.90-1.18)	0.91 (0.79-1.04)	0.78 (0.68-0.90)	0.55 (0.47-0.64)	0.57 (0.49-0.66)
Red Deer*	49	1	0.61 (0.49-0.77)	0.67 (0.54-0.84)	0.70 (0.56-0.88)	0.37 (0.29-0.49)	0.52 (0.39-0.69)	0.47 (0.36-0.62)	0.41 (0.32-0.54)	0.26 (0.19-0.36)	0.25 (0.18-0.35)
Roe Deer	235	1	1.12 (0.97-1.29)	1.04 (0.90-1.20)	1.17 (1.02-1.35)	1.15 (1.00-1.33)	1.30 (1.13-1.50)	1.43 (1.25-1.65)	1.56 (1.36-1.79)	1.33 (1.15-1.54)	1.00 (0.86-1.17)
Fallow Deer*	38	1	0.47 (0.35-0.63)	0.48 (0.36-0.66)	0.41 (0.30-0.54)	0.26 (0.19-0.36)	0.64 (0.49-0.84)	0.57 (0.43-0.75)	0.49 (0.37-0.65)	0.20 (0.14-0.28)	0.13 (0.09-0.19)
Reeves's Muntjac	44	1	1.19 (0.90-1.56)	1.13 (0.84-1.52)	1.16 (0.86-1.57)	1.20 (0.90-1.59)	1.33 (1.01-1.76)	1.43 (1.08-1.89)	1.52 (1.15-2.01)	1.24 (0.92-1.68)	1.06 (0.79-1.43)

Appendix 2b Regional temporal trends in relative abundance for eight mammal species for the period 1995-2004. 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	2004
Brown Hare											
NW England	52	1	1.16 (0.91-1.48)	0.94 (0.72-1.23)	1.03 (0.79-1.35)	0.77 (0.57-1.03)	1.03 (0.77-1.37)	0.95 (0.71-1.27)	0.86 (0.64-1.16)	0.67 (0.49-0.92)	0.80 (0.58-1.08)
Yorks & Humber	44	1	1.48 (1.05-2.09)	1.21 (0.85-1.72)	1.04 (0.73-1.50)	0.94 (0.65-1.37)	0.92 (0.63-1.34)	1.16 (0.81-1.66)	1.39 (0.98-1.98)	1.21 (0.84-1.72)	1.14 (0.80-1.62)
East Midlands*	60	1	1.15 (0.86-1.53)	0.85 (0.62-1.16)	0.85 (0.63-1.17)	1.16 (0.87-1.55)	1.17 (0.87-1.56)	1.30 (0.97-1.73)	1.42 (1.07-1.89)	1.22 (0.92-1.62)	1.55 (1.19-2.03)
East of England*	119	1	1.18 (0.99-1.41)	1.07 (0.89-1.29)	1.08 (0.89-1.30)	1.13 (0.94-1.35)	1.11 (0.92-1.33)	1.14 (0.95-1.38)	1.17 (0.97-1.42)	1.20 (0.99-1.46)	1.28 (1.05-1.55)
SE England	72	1	0.96 (0.76-1.20)	0.92 (0.73-1.15)	0.87 (0.69-1.09)	0.83 (0.66-1.05)	0.77 (0.61-0.98)	0.77 (0.61-0.97)	0.76 (0.60-0.96)	0.75 (0.59-0.96)	0.91 (0.72-1.15)
SW England*	50	1	1.58 (1.17-2.13)	1.16 (0.85-1.59)	1.39 (1.03-1.89)	0.88 (0.63-1.22)	0.99 (0.71-1.38)	1.09 (0.78-1.51)	1.18 (0.85-1.63)	1.57 (1.14-2.17)	1.52 (1.11-2.09)
England*	449	1	1.18 (1.07-1.29)	1.03 (0.93-1.13)	0.99 (0.90-1.10)	0.95 (0.86-1.05)	1.01 (0.91-1.11)	1.07 (0.96-1.18)	1.12 (1.01-1.24)	1.05 (0.95-1.16)	1.15 (1.04-1.27)
Scotland*	52	1	0.73 (0.55-0.98)	0.89 (0.66-1.18)	0.96 (0.73-1.27)	0.75 (0.56-1.02)	0.72 (0.54-0.97)	0.68 (0.50-0.92)	0.63 (0.46-0.86)	0.54 (0.39-0.75)	0.59 (0.43-0.80)
Rabbit											
NW England*	89	1	1.19 (0.96-1.46)	1.07 (0.86-1.33)	0.81 (0.64-1.03)	0.49 (0.37-0.66)	0.79 (0.62-1.02)	0.71 (0.56-0.92)	0.63 (0.49-0.82)	0.57 (0.44-0.76)	0.57 (0.43-0.76)
Yorks & Humber	75	1	1.30 (1.02-1.66)	1.39 (1.10-1.76)	1.03 (0.80-1.32)	1.03 (0.80-1.32)	1.22 (0.96-1.55)	1.18 (0.92-1.50)	1.13 (0.88-1.44)	1.17 (0.92-1.50)	1.11 (0.86-1.42)
East Midlands*	71	1	0.59 (0.48-0.73)	0.72 (0.57-0.91)	0.58 (0.45-0.75)	0.38 (0.28-0.50)	0.58 (0.45-0.75)	0.52 (0.40-0.69)	0.46 (0.34-0.63)	0.54 (0.41-0.69)	0.49 (0.38-0.63)
East of England	154	1	1.74 (1.48-2.05)	1.66 (1.41-1.97)	1.23 (1.02-1.47)	1.10 (0.91-1.32)	1.12 (0.94-1.35)	1.18 (0.99-1.42)	1.24 (1.04-1.49)	1.41 (1.18-1.68)	1.17 (0.98-1.41)
West Midlands*	89	1	0.56 (0.45-0.71)	0.68 (0.54-0.85)	0.67 (0.54-0.84)	0.67 (0.54-0.84)	0.60 (0.48-0.76)	0.58 (0.44-0.71)	0.56 (0.44-0.71)	0.75 (0.60-0.94)	0.78 (0.63-0.97)
SE England*	207	1	1.09 (0.96-1.24)	1.16 (1.02-1.33)	0.95 (0.82-1.09)	0.91 (0.79-1.05)	0.81 (0.70-0.94)	0.79 (0.68-0.92)	0.76 (0.66-0.89)	0.83 (0.72-0.96)	0.70 (0.60-0.82)
SW England*	133	1	0.84 (0.69-1.03)	1.43 (1.17-1.75)	1.05 (0.85-1.31)	1.30 (1.07-1.59)	1.46 (1.19-1.78)	1.29 (1.04-1.59)	1.11 (0.88-1.40)	1.12 (0.90-1.39)	1.37 (1.12-1.69)
England*	854	1	1.06 (0.99-1.14)	1.15 (1.07-1.23)	0.92 (0.85-0.99)	0.86 (0.80-0.93)	0.91 (0.85-0.99)	0.88 (0.82-0.95)	0.84 (0.78-0.91)	0.90 (0.84-0.97)	0.86 (0.79-0.93)
Scotland*	98	1	1.06 (0.88-1.28)	1.49 (1.23-1.79)	1.11 (0.92-1.35)	0.75 (0.60-0.92)	0.95 (0.78-1.17)	0.77 (0.62-0.95)	0.58 (0.46-0.73)	0.40 (0.31-0.52)	0.43 (0.33-0.55)
Wales	73	1	1.07 (0.84-1.35)	0.80 (0.61-1.05)	0.76 (0.57-1.00)	0.74 (0.56-0.98)	0.66 (0.49-0.90)	0.81 (0.61-1.08)	0.96 (0.73-1.26)	1.03 (0.79-1.33)	0.81 (0.62-1.07)
Grey Squirrel											
East of England	71	1	2.36 (1.85-3.02)	1.38 (1.06-1.80)	1.21 (0.91-1.60)	1.00 (0.75-1.34)	1.14 (0.86-1.51)	1.09 (0.82-1.45)	1.04 (0.77-1.39)	1.00 (0.74-1.35)	1.24 (0.93-1.65)
West Midlands*	56	1	1.67 (1.31-2.13)	1.01 (0.77-1.33)	0.77 (0.58-1.03)	0.78 (0.58-1.05)	0.98 (0.74-1.29)	1.01 (0.78-1.36)	1.03 (0.78-1.36)	0.82 (0.62-1.10)	0.56 (0.41-0.78)
SE England	126	1	1.92 (1.61-2.30)	1.12 (0.92-1.37)	1.11 (0.91-1.36)	0.81 (0.65-1.00)	1.22 (1.00-1.49)	1.10 (0.90-1.34)	0.97 (0.79-1.19)	1.03 (0.84-1.27)	1.09 (0.89-1.34)
SW England	62	1	1.98 (1.52-2.59)	1.52 (1.15-2.01)	0.94 (0.69-1.29)	1.07 (0.79-1.45)	1.39 (1.03-1.88)	1.57 (1.17-2.11)	1.75 (1.31-2.33)	1.00 (0.73-1.39)	0.95 (0.69-1.33)
England	421	1	2.02 (1.82-2.24)	1.27 (1.14-1.42)	1.08 (0.96-1.21)	0.90 (0.80-1.02)	1.20 (1.07-1.34)	1.20 (1.07-1.35)	1.20 (1.07-1.35)	1.16 (1.03-1.30)	1.08 (0.96-1.22)
Wales	38	1	2.85 (1.98-4.12)	1.51 (1.00-2.29)	1.75 (1.17-2.63)	1.33 (0.87-2.03)	1.40 (0.90-2.16)	1.56 (1.03-2.37)	1.72 (1.15-2.58)	1.40 (0.92-2.13)	0.90 (0.57-1.41)
Red Fox											
SE England	49	1	1.20 (0.91-1.59)	1.17 (0.88-1.56)	1.23 (0.92-1.64)	1.19 (0.89-1.58)	1.56 (1.19-2.06)	1.18 (0.89-1.58)	0.80 (0.58-1.10)	0.61 (0.43-0.86)	0.85 (0.62-1.17)
SW England*	38	1	1.28 (0.94-1.75)	0.55 (0.38-0.80)	0.88 (0.63-1.23)	0.93 (0.67-1.29)	0.78 (0.54-1.11)	0.79 (0.55-1.13)	0.80 (0.56-1.15)	0.60 (0.41-0.89)	0.56 (0.38-0.81)
England*	178	1	1.35 (1.18-1.55)	0.99 (0.86-1.15)	0.96 (0.82-1.12)	0.91 (0.78-1.06)	0.91 (0.78-1.06)	0.90 (0.77-1.04)	0.88 (0.75-1.02)	0.60 (0.50-0.70)	0.57 (0.48-0.68)
Red Deer											
Scotland*	38	1	0.61 (0.44-0.84)	0.67 (0.49-0.91)	0.67 (0.48-0.92)	0.38 (0.26-0.55)	0.51 (0.34-0.77)	0.46 (0.31-0.69)	0.41 (0.28-0.61)	0.26 (0.17-0.41)	0.26 (0.16-0.40)
Roe Deer											
SE England*	61	1	1.35 (0.98-1.86)	0.91 (0.64-1.29)	1.08 (0.77-1.51)	1.27 (0.92-1.77)	1.27 (0.91-1.76)	1.59 (1.16-2.17)	1.90 (1.41-2.57)	1.67 (1.22-2.27)	1.86 (1.37-2.52)
SW England	60	1	1.11 (0.82-1.50)	1.07 (0.80-1.44)	0.90 (0.67-1.22)	0.80 (0.59-1.09)	1.54 (1.15-2.07)	1.76 (1.32-2.34)	1.97 (1.49-2.61)	1.71 (1.28-2.28)	1.17 (0.86-1.60)

Species	*n*	Year									
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
England	174	1	0.97 (0.82-1.15)	0.95 (0.80-1.12)	0.90 (0.76-1.07)	0.95 (0.80-1.12)	1.10 (0.93-1.31)	1.36 (1.16-1.60)	1.61 (1.38-1.89)	1.24 (1.05-1.47)	1.08 (0.91-1.28)
Scotland	61	1	1.27 (0.96-1.69)	1.13 (0.84-1.52)	1.47 (1.11-1.95)	1.37 (1.02-1.83)	1.50 (1.12-2.01)	1.49 (1.11-2.00)	1.47 (1.10-1.98)	1.42 (1.05-1.92)	0.84 (0.59-1.19)
Fallow Deer											
England*	36	1	0.40 (0.29-0.54)	0.42 (0.31-0.58)	0.36 (0.27-0.48)	0.24 (0.18-0.33)	0.58 (0.44-0.75)	0.50 (0.38-0.66)	0.42 (0.32-0.56)	0.17 (0.12-0.24)	0.10 (0.07-0.15)
Reeves's Muntjac											
England	44	1	1.19 (0.91-1.56)	1.13 (0.84-1.51)	1.16 (0.86-1.56)	1.19 (0.90-1.58)	1.33 (1.01-1.76)	1.35 (1.02-1.79)	1.37 (1.03-1.82)	1.26 (0.93-1.70)	1.06 (0.79-1.43)

Appendix 2b (continued)

Appendix 2c Temporal trends in relative abundance for six mammal species for the period 1995-2004 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	2004
Brown Hare											
Zone 1*	281	1	1.13 (1.00-1.27)	1.06 (0.93-1.20)	0.92 (0.80-1.05)	0.94 (0.83-1.07)	0.96 (0.85-1.10)	1.04 (0.92-1.19)	1.12 (0.98-1.27)	1.06 (0.93-1.20)	1.16 (1.02-1.32)
Zone 2	138	1	1.41 (1.19-1.67)	0.99 (0.83-1.20)	1.23 (1.03-1.47)	1.07 (0.88-1.29)	1.20 (1.00-1.44)	1.18 (0.98-1.42)	1.17 (0.97-1.40)	1.14 (0.95-1.37)	1.18 (0.98-1.41)
Zone 3*	50	1	0.82 (0.64-1.06)	0.63 (0.48-0.84)	0.80 (0.61-1.04)	0.66 (0.50-0.87)	0.94 (0.72-1.24)	0.87 (0.60-1.07)	0.80 (0.60-1.07)	0.57 (0.42-0.78)	0.67 (0.49-0.90)
Rabbit											
Zone 1*	467	1	1.02 (0.93-1.12)	1.15 (1.05-1.27)	0.91 (0.83-1.01)	0.86 (0.78-0.95)	0.91 (0.83-1.01)	0.88 (0.80-0.98)	0.85 (0.77-0.94)	0.93 (0.85-1.03)	0.82 (0.74-0.91)
Zone 2	360	1	1.15 (1.03-1.28)	1.15 (1.03-1.29)	0.93 (0.83-1.05)	0.87 (0.77-0.98)	0.91 (0.81-1.03)	0.88 (0.78-1.00)	0.85 (0.75-0.96)	0.95 (0.84-1.08)	0.97 (0.86-1.09)
Zone 3*	103	1	0.96 (0.78-1.20)	1.00 (0.81-1.24)	0.87 (0.70-1.07)	0.84 (0.67-1.04)	0.88 (0.71-1.10)	0.90 (0.73-1.13)	0.91 (0.73-1.13)	0.80 (0.64-1.00)	0.77 (0.62-0.96)
Zone 4*	57	1	1.06 (0.84-1.33)	1.34 (1.06-1.69)	0.62 (0.48-0.81)	0.65 (0.50-0.84)	0.68 (0.52-0.89)	0.62 (0.41-0.75)	0.55 (0.41-0.75)	0.29 (0.19-0.42)	0.33 (0.23-0.46)
Grey Squirrel											
Zone 1*	235	1	1.92 (1.67-2.19)	1.21 (1.05-1.41)	1.06 (0.91-1.24)	0.86 (0.73-1.01)	1.31 (1.13-1.52)	1.22 (1.05-1.42)	1.13 (0.97-1.32)	1.09 (0.93-1.27)	1.19 (1.02-1.38)
Zone 2	192	1	2.07 (1.78-2.41)	1.35 (1.15-1.60)	1.19 (1.01-1.42)	1.03 (0.86-1.22)	1.16 (0.98-1.38)	1.29 (1.09-1.53)	1.41 (1.19-1.67)	1.22 (1.02-1.45)	1.05 (0.87-1.26)
Red Fox											
Zone 1*	95	1	1.50 (1.24-1.81)	1.17 (0.95-1.43)	1.23 (1.00-1.51)	1.02 (0.83-1.25)	1.23 (1.00-1.51)	1.10 (0.89-1.35)	0.96 (0.78-1.19)	0.60 (0.47-0.76)	0.59 (0.47-0.75)
Zone 2*	80	1	1.14 (0.93-1.39)	0.69 (0.55-0.87)	0.80 (0.63-1.00)	0.90 (0.72-1.13)	0.73 (0.58-0.93)	0.74 (0.59-0.95)	0.74 (0.58-0.95)	0.66 (0.52-0.85)	0.66 (0.52-0.84)
Roe Deer											
Zone 1	98	1	0.96 (0.76-1.21)	1.05 (0.84-1.33)	0.99 (0.79-1.25)	1.02 (0.81-1.29)	1.02 (0.80-1.28)	1.36 (1.09-1.69)	1.69 (1.37-2.09)	1.07 (0.84-1.37)	1.11 (0.88-1.40)
Zone 2	65	1	0.97 (0.73-1.29)	0.83 (0.63-1.10)	0.70 (0.52-0.93)	0.85 (0.64-1.12)	1.32 (1.01-1.73)	1.49 (1.15-1.94)	1.66 (1.28-2.15)	1.48 (1.14-1.93)	1.08 (0.83-1.41)
Reeves's Muntjac											
Zone 1	39	1	0.80 (0.59-1.09)	0.89 (0.66-1.21)	0.96 (0.71-1.31)	0.96 (0.72-1.28)	1.11 (0.84-1.48)	1.10 (0.83-1.48)	1.09 (0.82-1.47)	0.92 (0.66-1.27)	0.87 (0.64-1.18)

Appendix 3 Change in the presence of six mammal species for the period 1995-2004. 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	2004
Mole*	451	1	0.62 (0.6-0.63)	1.34 (1.31-1.37)	2.50 (2.45-2.56)	6.05 (5.92-6.19)	5.85 (5.72-5.98)	5.64 (5.51-5.77)	6.42 (6.27-6.56)	3.51 (3.43-3.59)
Hedgehog*	191	1	0.68 (0.66-0.70)	1.76 (1.71-1.81)	1.36 (1.33-1.41)	3.77 (3.66-3.88)	2.91 (2.83-3.00)	2.05 (1.99-2.11)	1.44 (1.40-1.49)	1.57 (1.52-1.61)
Badger*	240	1	0.74 (0.71-0.76)	1.72 (1.67-1.77)	1.93 (1.87-1.98)	3.28 (3.18-3.37)	3.52 (3.41-3.62)	3.75 (3.64-3.86)	4.30 (4.17-4.43)	6.45 (6.27-6.64)
Brown Rat*	136	1	0.33 (0.32-0.35)	1.23 (1.19-1.28)	1.76 (1.70-1.83)	4.62 (4.46-4.79)	4.28 (4.13-4.43)	3.94 (3.80-4.08)	4.00 (3.86-4.14)	3.36 (3.24-3.48)
Stoat*	109	1	0.48 (0.46-0.50)	1.31 (1.26-1.35)	2.33 (2.25-2.41)	3.14 (3.04-3.25)	2.24 (2.16-2.31)	1.33 (1.28-1.37)	1.44 (1.39-1.50)	2.87 (2.78-2.98)
Weasel*	86	1	0.52 (0.50-0.55)	1.19 (1.14-1.24)	1.60 (1.53-1.66)	2.92 (2.81-3.05)	2.28 (2.19-2.37)	1.64 (1.57-1.71)	1.22 (1.17-1.27)	1.76 (1.69-1.83)

Appendix 4 Habitat-specific temporal trends in relative abundance for mammal species for the period 1995-2004 in the UK. 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	2004
Broad-l woodland											
Brown Hare	112	1	1.10 (0.92-1.32)	1.11 (0.93-1.32)	0.87 (0.72-1.04)	0.77 (0.63-0.93)	0.93 (0.77-1.12)	0.92 (0.76-1.11)	0.91 (0.75-1.11)	0.82 (0.67-1.01)	1.04 (0.86-1.26)
Rabbit*	319	1	1.13 (1.00-1.26)	1.11 (0.99-1.25)	0.99 (0.88-1.12)	0.77 (0.67-0.87)	0.82 (0.72-0.93)	0.78 (0.69-0.89)	0.74 (0.65-0.85)	0.83 (0.73-0.94)	0.69 (0.61-0.79)
Grey Squirrel	216	1	2.37 (2.04-2.75)	1.25 (1.06-1.47)	1.08 (0.91-1.28)	0.83 (0.70-1.00)	1.19 (1.00-1.41)	1.16 (0.98-1.37)	1.12 (0.95-1.33)	1.10 (0.93-1.31)	1.04 (0.87-1.24)
Red Fox*	70	1	1.12 (0.90-1.39)	0.76 (0.60-0.97)	0.91 (0.71-1.15)	1.03 (0.81-1.29)	1.09 (0.86-1.38)	0.89 (0.70-1.14)	0.69 (0.53-0.90)	0.54 (0.41-0.71)	0.56 (0.42-0.73)
Roe Deer	90	1	0.95 (0.75-1.20)	1.03 (0.82-1.28)	0.85 (0.67-1.08)	1.08 (0.87-1.35)	1.30 (1.04-1.63)	1.33 (1.06-1.66)	1.35 (1.07-1.69)	1.12 (0.88-1.43)	0.99 (0.77-1.27)
Coniferous woodland											
Rabbit*	78	1	0.97 (0.78-1.21)	1.22 (0.98-1.52)	0.83 (0.65-1.06)	0.84 (0.66-1.06)	1.06 (0.85-1.32)	0.83 (0.66-1.05)	0.60 (0.46-0.77)	0.49 (0.37-0.63)	0.40 (0.30-0.55)
Grey Squirrel	43	1	2.05 (1.48-2.85)	1.48 (1.04-2.11)	2.03 (1.43-2.88)	0.94 (0.63-1.41)	1.50 (1.07-2.10)	1.29 (0.91-1.85)	1.08 (0.74-1.60)	1.22 (0.83-1.81)	1.15 (0.80-1.65)
Roe Deer*	54	1	1.06 (0.80-1.40)	0.86 (0.63-1.16)	0.99 (0.74-1.33)	0.87 (0.63-1.21)	1.18 (0.88-1.58)	1.16 (0.87-1.56)	1.14 (0.85-1.53)	1.13 (0.84-1.52)	0.55 (0.38-0.80)
Arable & horticultural											
Brown Hare*	291	1	1.12 (0.99-1.27)	0.97 (0.86-1.11)	0.98 (0.86-1.11)	0.87 (0.76-0.99)	0.97 (0.85-1.10)	1.03 (0.90-1.17)	1.08 (0.95-1.23)	1.06 (0.93-1.21)	1.17 (1.03-1.33)
Rabbit*	386	1	1.01 (0.91-1.12)	0.98 (0.88-1.10)	1.06 (0.94-1.18)	0.78 (0.70-0.88)	0.85 (0.76-0.95)	0.85 (0.75-0.95)	0.84 (0.74-0.95)	0.75 (0.67-0.85)	0.75 (0.67-0.85)
Grey Squirrel*	117	1	2.06 (1.68-2.52)	1.56 (1.26-1.93)	1.14 (0.90-1.43)	1.02 (0.81-1.28)	1.35 (1.07-1.68)	1.38 (1.10-1.72)	1.41 (1.13-1.76)	1.10 (0.88-1.39)	1.44 (1.16-1.80)
Red Fox*	63	1	1.68 (1.33-2.12)	1.36 (1.06-1.76)	1.13 (0.87-1.48)	1.38 (1.08-1.77)	1.27 (0.98-1.63)	1.13 (0.87-1.45)	0.98 (0.75-1.27)	0.70 (0.53-0.94)	0.54 (0.39-0.73)
Roe Deer*	75	1	1.01 (0.76-1.34)	1.20 (0.90-1.59)	1.25 (0.94-1.65)	1.27 (0.96-1.68)	1.49 (1.13-1.96)	1.71 (1.3-2.235)	1.92 (1.47-2.51)	1.42 (1.07-1.89)	1.38 (1.03-1.84)
Improved grass											
Brown Hare*	104	1	1.00 (0.82-1.22)	0.89 (0.72-1.09)	1.10 (0.90-1.34)	0.90 (0.73-1.11)	0.89 (0.72-1.09)	0.83 (0.67-1.02)	0.77 (0.62-0.95)	0.66 (0.53-0.83)	0.75 (0.60-0.93)
Rabbit	236	1	1.36 (1.18-1.57)	1.35 (1.17-1.56)	1.03 (0.89-1.20)	0.95 (0.81-1.12)	1.03 (0.89-1.20)	0.89 (0.76-1.04)	0.75 (0.63-0.88)	0.75 (0.64-0.89)	0.89 (0.75-1.04)
Grey Squirrel	86	1	1.75 (1.39-2.20)	1.11 (0.87-1.43)	1.16 (0.90-1.50)	0.92 (0.70-1.20)	1.01 (0.77-1.34)	1.32 (1.03-1.72)	1.63 (1.28-2.09)	1.04 (0.80-1.36)	0.81 (0.61-1.08)
Red Fox*	52	1	1.51 (1.13-2.03)	0.79 (0.57-1.10)	1.01 (0.73-1.40)	0.89 (0.65-1.24)	1.03 (0.75-1.43)	0.89 (0.64-1.25)	0.75 (0.53-1.06)	0.69 (0.49-0.98)	0.64 (0.45-0.91)
Roe Deer	42	1	1.21 (0.80-1.81)	0.76 (0.50-1.17)	0.98 (0.66-1.46)	1.18 (0.81-1.72)	1.25 (0.85-1.83)	1.33 (0.91-1.94)	1.40 (0.96-2.04)	1.44 (0.98-2.13)	1.28 (0.87-1.89)
Semi-nat. grassland											
Brown Hare*	51	1	0.92 (0.72-1.17)	0.68 (0.52-0.89)	0.71 (0.53-0.95)	0.80 (0.60-1.05)	0.89 (0.68-1.16)	0.81 (0.61-1.07)	0.73 (0.54-0.97)	0.71 (0.53-0.95)	0.58 (0.42-0.82)
Rabbit*	101	1	0.80 (0.65-0.99)	1.24 (1.01-1.51)	1.16 (0.95-1.43)	0.64 (0.50-0.81)	1.08 (0.87-1.34)	1.00 (0.80-1.25)	0.92 (0.73-1.15)	0.73 (0.57-0.92)	0.54 (0.42-0.70)
Built-up areas											
Brown Hare*	44	1	1.44 (1.01-2.04)	1.15 (0.80-1.67)	1.26 (0.87-1.83)	1.49 (1.04-2.14)	0.95 (0.64-1.40)	1.15 (0.79-1.67)	1.34 (0.93-1.93)	0.97 (0.67-1.41)	1.47 (1.03-2.11)
Rabbit*	198	1	0.70 (0.60-0.81)	1.05 (0.92-1.22)	0.75 (0.64-0.87)	0.67 (0.58-0.78)	0.70 (0.60-0.83)	0.69 (0.59-0.81)	0.67 (0.57-0.78)	0.72 (0.61-0.84)	0.65 (0.55-0.77)
Grey Squirrel*	165	1	1.97 (1.67-2.32)	1.18 (0.99-1.41)	1.09 (0.91-1.30)	1.10 (0.92-1.31)	1.44 (1.22-1.71)	1.42 (1.20-1.69)	1.40 (1.18-1.67)	1.41 (1.19-1.67)	1.23 (1.03-1.47)
Red Fox*	49	1	1.00 (0.79-1.27)	0.75 (0.57-0.98)	0.60 (0.45-0.80)	0.60 (0.45-0.80)	0.79 (0.60-1.04)	0.81 (0.61-1.07)	0.82 (0.62-1.09)	0.47 (0.34-0.65)	0.50 (0.36-0.67)

Appendix 5 Change in the abundance and presence of Water Vole, American Mink and Otter in the UK for the period 1995-2004. Trends are produced from WBBS and BBS data for the period of overlap between the two surveys. 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. Note the trends based on sightings data is particular are based on very small samples and should be interpreted with caution.

Species	*n*	1998	1999	2000	2001	2002	2003	2004
Sightings								
Water Vole	14	1	1.85 (1.12-3.05)	1.78 (1.07-2.99)	1.34 (0.79-2.30)	0.90 (0.51-1.60)	0.44 (0.23-0.85)	0.60 (0.33-1.11)
American Mink *	4	1	1.30 (0.85-2.01)	2.04 (1.34-3.10)	1.10 (0.71-1.73)	0.16 (0.07-0.36)	0.88 (0.53-1.44)	0.28 (0.15-0.52)
Otter *	6	1	0.30 (0.17-0.54)	0.52 (0.30-0.89)	0.39 (0.23-0.68)	0.26 (0.15-0.46)	0.32 (0.19-0.54)	0.36 (0.22-0.61)
Presence absence								
Water Vole	29	1	0.93 (0.42-2.06)	1.22 (0.55-2.7)	0.95 (0.43-1.48)	0.68 (0.30-1.55)	0.38 (0.16-0.91)	0.48 (0.20-1.14)
American Mink	45	1	1.95 (0.84-4.54)	7.13 (3.13-16.25)	4.84 (2.11-7.56)	2.54 (1.09-5.91)	3.68 (1.62-8.37)	2.27 (0.98-5.26)
Otter *	43	1	0.30 (0.12-0.77)	0.98 (0.42-2.26)	0.95 (0.42-1.49)	0.92 (0.41-2.09)	1.84 (0.84-4.03)	3.58 (1.62-7.92)