BTO Research Report No. 321

Preliminary analyses of Breeding Bird Survey (BBS) mammal data

Authors

S.E. Newson & D.G. Noble

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under contract to the Joint Nature Conservation Committee (Contract No. F90-01-427)

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CONTENTS

Page no

LIST OF TABLES

Page no

LIST OF FIGURES

Page no

1. EXECUTIVE SUMMARY

1. In 1995 the scope of the BTO/RSPB/JNCC Breeding Bird Survey (BBS) was expanded to also record British mammals. This was the first multi-species, annual mammal survey to be carried out in the UK, with the focus on medium to large-sized easily identifiable species, although observers can record any mammal species seen or known to be present. Summaries of these data are regularly reported through the annual BBS reports, although there have been few analyses of these data or attempts to calculate population trends. In this report, we assess the effectiveness of the BBS for monitoring UK mammal populations and of detecting significant changes in abundance or distribution.

2. Preliminary analyses of BBS mammal data for 1995-2000 demonstrates that national populations of Brown Hare, Mountain/Irish Hare, Grey Squirrel, Red Fox, Red Deer, Fallow Deer, Roe Deer, Reeve’s Muntjac and Rabbit can be monitored by this survey. Of these, the Roe Deer increased significantly over this period, whilst all remaining species (with the exception of Reeve’s Muntjac), exhibited significant inter-year variation during this period. As expected, the BBS field methodology is not effective for monitoring bats, most mustelids, small mammals, and cetaceans and rare or highly localised species (e.g. Red Squirrel, Wildcat or Chinese Water Deer).

3. For a number of species, there are insufficient data to calculate reliable indices of abundance, but a large amount of indirect information on presence/absence from field signs or local knowledge of their presence in that year. For example, Badger, Mole, Hedgehog and Brown Rat. For these species, the change in presence on BBS was modelled to see whether there were sufficient data to produce reliable indices of abundance. Whilst the sample was adequate to do this, there were a number of problems with the resulting indices. Indices calculated for the first year or so may reflect awareness by the observer of the presence of the species and changes in the survey form may explain an apparent increase in these species in 1998. However, this is a method that may become more useful as data from further years are collected. This method may also be most appropriate for herding deer species, such as Red, Fallow and Sika Deer for which there was a large variance associated with indices based on counts and where modelling presence/absence may provide a more accurate means of monitoring change in their populations.

4. As with many analyses there is a conflict between maximising the sample size required to identify change with confidence and narrowing down the area to understand the exact pattern of change. In this study, we examine the use of count data to compare population trends for five species for which there was sufficient data (Brown Hare, Rabbit, Grey Squirrel, Red Fox and Roe Deer) within three broad regions. Of these, the Brown Hare showed a significantly larger decline in the southwest than in the north and southeast of Britain. Further analyses could examine pair-wise differences between regions for more species where the sample size in one region is limiting and additional analyses could change the boundaries of regions to better understand trends in different geographic areas.

5. Whilst data for a large proportion of species recorded by the BBS are insufficient to calculate indices of abundance or presence/absence, these data do provide important information on their distribution and relative abundance. Also, because observers record habitat information, we may be able to identify the habitat requirements of these species – essential for conservation initiatives and useful for planning of further targeted studies.

6. As mentioned above, the collection of habitat data on BBS squares is important for our understanding of species population trends. Trends may be unrelated to habitat, but could be directly related to a particular change in a specific habitat in which they occur. In this study, we calculate separate habitat-specific indices for four species (Brown Hare, Rabbit, Grey Squirrel and Red Fox) in two or more dominant habitats. These suggest that Brown Hare

declined on farmland between 1995 and 2000, whilst Rabbit also declined on farmland, but increased on grassland over this period, although abundance fluctuated widely between years. Abundance of Grey Squirrel also fluctuated over this period, whilst the Red Fox declined in urban areas but increased on farmland.

2. INTRODUCTION

In 2001, a group of organizations interested in the surveillance and monitoring of mammal populations in the UK met to discuss priorities and possible approaches. This group, currently informally known as the UK Mammal Network, identified a number of schemes (currently in operation or in the planning) stage that could be integral components of a UK-wide mammal monitoring strategy. One of the schemes is the multi-species mammal monitoring carried out by many participants in the BTO/RSPB/JNCC Breeding Bird Survey (BBS). Although summaries of the mammal component are regularly reported in the annual BBS reports (see Noble *et al*. 2001), there have, to date, been relatively few analyses of these data or attempts to identify population trends. This report provides an overview of the BBS mammal data collected to date, presents some preliminary population trends for mammal species monitored in sufficient numbers, and outlines approaches for future analyses and reporting of these data. This is NOT intended to be an exhaustive report on UK mammal trends as revealed by the BBS. Clearly, there is considerable scope for more comprehensive examination of these data, but that would require much greater effort than was possible in this contract.

In 1995, BTO, with the agreement of its partners, the Royal Society for the Protection of Birds and the Joint Nature Conservation Committee, expanded the scope of the national bird-monitoring scheme, the BBS also to collect information on British mammals. BBS observers, who are almost all volunteers, were asked to provide information on any mammals detected while carrying out bird surveys or during any other visits to the site. This was the first multi-species, annual mammal survey to be carried out in the UK and although the focus is on medium to large sized easily identifiable species, observers have the opportunity to record any mammals that they see. Summaries of the percentage occurrence of each mammal species are routinely reported in the BBS annual reports (e.g. Noble *et al,* 2001), but the first more detailed analyses were carried out by Toms *et al*. (1999) in a JNCC-funded study on the feasibility of developing a mammal monitoring network in the UK. Based on the first three years of BBS mammal data available (1995 to 1997), Toms *et al.* (1999) concluded that the BBS method would detect changes in occurrence on BBS squares of 20% or more for eight mammal species. They also demonstrated that a number of other species (e.g. Brown Hare) could be monitored effectively using count data.

In this report, we explore the first six years of mammal data collected by BBS observers (between 1995 and 2000) to assess the effectiveness of the BBS in monitoring UK mammal populations and detecting significant changes in abundance or distribution. We examine the potential of these data for producing annually updated population indices for widespread and abundant terrestrial mammal species in Britain in the same way as is done for breeding bird populations. We investigate whether differences in trends among regions of Britain and habitats can be compared and explore the use of presence/absence data on BBS squares for monitoring species such as Badger and Mole which are rarely observed but leave obvious signs of their presence. Distribution maps based on mammal presence on BBS squares are presented to illustrate species distribution, including information on observer coverage, which helps to differentiate species absence from the effects of low levels of coverage.

3. METHODS

3.1 Survey methods

The BBS is based on a stratified random sampling design, with 1 km squares from the National Grid assigned randomly within BTO regions (Noble *et al.* 2001). 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 monitoring in the BBS is done during the course of the bird surveys. 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). Counts of mammals are recorded during the two bird counting visits, the first 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 also asked to record the presence of mammal species on the basis of field signs, corpses, and information obtained from other visits to the square or local knowledge (e.g. gamekeepers and land-owners) as explained in the BBS instructions.

3.2 Data analysis

3.2.1 UK Population trends

The maximum number of each species of mammal sighted over the two visits (early and late) was determined for each 1 km square in each year. Using these data, log-linear Poisson regression was used to model site counts, with site and year effects (ter Braak *et al.* 1994), 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 d-scale option in SAS.

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 30 or more squares over the six years of the survey are presented, because of the low precision associated with small sample sizes. 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 highlight significance at the 5% level or more, separate formal analyses to examine differences between indices was not performed. Because a species may show large between-year fluctuations in abundance that are not important to the long-term trend of the species, a second model fitting linear trends across years was fitted to the data and significance of trend determined.

3.2.2 Regional trends

To examine whether the UK trends are representative for different areas within the UK, annual indices were calculated in the same way as above for each of three regions: north, southeast and southwest (shown in Fig. 1). These areas were calculated using the broader government regional development area (RDA) boundaries, where NORTH = northwest and northeast England, Yorkshire and Humber and Scotland, SOUTHEAST = east and west midlands, east and southeast England and London, and SOUTHWEST = southwest England and Wales. A second model fitting linear trends was again fitted to the data and statistically analysed to determine the significance of any difference between regions across years. A significant result shows that one of the three regions is significantly different from the others, so where a significant result was found, regions were constrained in a further analysis to establish which region was significantly different from the others. As above, only species occurring on a mean of 30 or more squares in two or more regions were included in the analyses. Northern Ireland and the Channel Islands were excluded from the regional analyses because of insufficient samples.

3.2.3 Habitat-specific indices

Because population change may be habitat-specific, these data were examined to assess whether separate habitat-specific annual indices could be produced using log-linear Poisson regression as above for any species in the dominant habitat/s in which they were observed.

BBS volunteers record the dominant habitat for each of the ten transect sections as one of nine classes: farmland, woodland, scrub, grassland, heath/bog, urban, water, rock and coastal. By counting the number of transect sections of each habitat class within squares, the main habitat for each square in each year was determined and defined as the habitat occurring in 50% or more of the square. Squares containing less than 50% of a particular habitat were classified as mixed. Because few species occurred on 30 or more squares across years in two or more habitat classes, 20 or more squares were chosen as a cut-off point and caution taken in the interpretation of results where smaller sample sizes were used. As above, the significance of the trend was examined by making a comparison between the first and last years of the survey, where non-overlapping 95% confidence intervals highlight significance at the 5% level or more. A further model fitting linear trends to the data was not used.

3.2.4 Analysis of presence/absence data

Species presence is defined here as information demonstrating that the species is present on the BBS survey square in that year. This may include counts as used in the above analyses or obvious field signs or reliable personal communication with landowners or gamekeepers. This category was introduced because several species that are rarely seen leave obvious signs of their presence and could potentially be monitored using these data as far as their presence is concerned on BBS squares. This includes such species as Badger and Mole (majority of records - field signs), Hedgehog (road-kills) and Brown Rat (personal communication). To examine the potential of data of this type, presence/absence of these species on BBS squares were modelled as a function of site and year using a logistic regression. The year effect here is an index of the change in presence on BBS squares relative to 1996, the first year that these four species appeared on the survey form. This year, (1996) is set to an arbitrary index value of 0.5 from which all other years are measured. The statistical significance of the trends was examined by making a comparison between the first and last years of the survey period. Because of the trial nature of this method, a further model fitting linear trends to the data was not used.

3.3 Statistical power of the analyses

Important to the above analyses is an understanding of the sample sizes of survey data points required to detect a specified change in those species populations. This was examined for presence/absence data using the formula in Sokal & Rohlf (1995, p. 768-769) to estimate the sample size required to detect, with a given power, a given difference (at a predetermined level of significance) between two proportions. This approach was used to simulate changes (declines) of 25% and 50% in those squares where presence was detected, varying the postulated power of detection and investigating a range of starting proportions from 0.05 to 1.00.

The results, given a required *P*-value of 0.05 are shown graphically in Figs. 2 and 3. The current BBS sample size of around 1,800 squares would detect 25% declines in reported presence with a power of between 60% and 90% given starting proportion of (approximately) 0.15 or higher (Fig. 2). Note that, for a given starting proportion, there is higher power associated with the detection of "true" increases than declines, because power increases as a function of the magnitude of both proportions being compared. These figures correspond roughly to, or are exceeded by the proportions of squares where Brown Hare, Rabbit, Grey Squirrel, Red Fox, Roe Deer and Mole have been reported as present in recent years.

A decline of 50% can be detected given the current mammal BBS sample and starting proportion of (approximately) 0.05 across the range of power tested (Fig. 3). This suggests that a 50% decline can be detected for eighteen species, which includes the above and Mountain Hare, Red Squirrel, Brown Rat, Red Deer, Fallow Deer, Muntjac, Hedgehog, Field Vole, Water Vole, Wood Mouse, Common Shrew, Badger, Stoat, Weasel, Mink, Otter and feral/domestic Cat.

4. RESULTS

Mammal data were collected from a mean of 1,773 1 km BBS squares between 1995 and 2000, with a general increase over the period (Table 1). In Table 2 we show the number of BBS squares recording counts of each species (and percentage of total BBS squares surveyed in parentheses) in each year and the number of BBS squares recording species presence (counts + field signs + personal communication) in each year are shown in Table 3.

4.1 Changes in the abundance of British mammals based on count data

Indices of relative abundance were calculated for nine mammal species (Red, Roe and Fallow Deer, Muntjac, Brown and Mountain/Irish Hare, Rabbit, Grey Squirrel and Red Fox) observed in a mean of 30 or more 1 km BBS squares in the UK on two or more years over the period 1995 to 2000 (Table 4.). Note that these figures will be smaller than the number of squares where particular species were counted every year because squares where species were only seen once over the survey period are excluded from the models. The error associated with indices calculated for species occurring on less than about thirty squares is normally too large to have confidence in the results, so the results for those are not presented. Of the nine species indexed in 2000, the Roe Deer was the only species to exhibit a significant population growth, which was confirmed by the significance if the linear trend fitted across years ($\chi^2_{715} = 6.77$, $P = < 0.01$; Fig. 4). Red and Fallow Deer showed significant declines (Figs. 5 & 6) when comparing the indices for 1995 and 2000 only. However, when linear trends were fitted to these data across years, there was no significant effect. This suggests that the difference in abundance between 1995 and 2000 might be explained by large annual fluctuations in numbers (on BBS squares) exhibited by these species, rather than longer-term declines.

Although the remaining six species (Brown Hare, Mountain/Irish Hare, Rabbit, Grey Squirrel, Red Fox and Muntjac) showed no evidence of an overall change in numbers between the years 1995 and 2000 (Figs. 7-12), all except Muntjac exhibited a significant year effect in at least one year during this period, as shown by a wide distance between standard error bars in one or more year. Brown Hare numbers were lowest in 1998 (Fig. 7). Mountain Hare numbers were significantly higher in 1996 and 1997 (Fig. 8). Rabbit numbers were significantly higher in 1997, and at their lowest in 1999 (Fig. 9). Grey Squirrels were recorded in higher numbers in 1996 than in any other year (Fig. 10) and Red Fox numbers were significantly lower in 1998 than at the start of the period in 1995 (Fig. 11). As these species shows a large distance between standard error bars compared to other year, the exact level of significance was not determined.

4.2 Regional variation in trends of changes in abundance

There were sufficient data to calculate regional indices of abundance using log-linear Poisson regression for five species of mammal, Brown Hare, Rabbit, Grey Squirrel, Red Fox and Roe Deer. Although several species showed a significant difference between the first and last years of the survey, the fitting of a second model with linear trends was used to reveal the underlying trends and to compare difference between regions. A significant difference between regions was found for the Brown Hare (Figure 13: $\chi^2_2 = 13.17$, $P = < 0.01$; slopes ± se: southwest –0.119 ± 0.001, north –0.038 ± 0.001, southeast –0.006 ± 0.001), with a larger decline in the southwest but declining less dramatically in the north and southeast ($\chi^2_2 = 9.97$, $P = 0.0016$). Rabbits appear to have undergone a large population increase in 1997 across all three regions. However, whilst abundance dropped in the southeast and in the north the following year, numbers remained high in the southwest (Fig. 14). Linear trends fitted to the Rabbit data illustrate these differences ($\chi^2_2 = 33.81$, $P = < 0.001$; slopes ± se: southwest 0.069 ± 0.004, north –0.039 ± 0.001, southeast –0.047 ± 0.002). A comparison between the southwest and the north/southeast highlighted the significant difference between these regions ($\chi^2_2 = 31.54$, $P = <0.0001$). There were no significant regional temporal differences in population trends of Roe Deer ($\chi^2_2 = 3.12$, $P = 0.21$), Grey Squirrel ($\chi^2_2 = 4.90$, $P = 0.09$) or Red Fox ($\chi^2_2 = 2.01$, $P = 0.37$).

4.3 Habitat variation in changes of abundance

In Table 5 we show the mean number of BBS squares surveyed across years recording counts of mammals in each habitat for each BTO region. Habitat here is defined as the dominant habitat in 50% or more of a BBS square, where squares containing less than 50% of a particular habitat are defined as mixed. Table 6 pools data across regions to show the mean number BBS squares in each habitat for each species. This shows that five species occurred on a mean of 20 or more squares over the survey in two or more habitats and for which habitat-specific indices were calculated. Comparisons between the standard error bars associated with indices for the first and last years of the survey (1994 and 2000) suggest a decline in Brown Hare abundance on farmland between 1995 and 2000 (Fig. 15). Rabbits have also declined on farmland over the period, but increased on grassland (Fig. 16). However, the Rabbit shows large fluctuations in the abundance between years, so these trends may not reflect long-term effects for this species. The Grey Squirrel has fluctuated widely across all habitats (Fig. 17), whilst Red Fox shows a decline in urban areas and an increase on farmland (Fig. 18).

4.4 Change in the presence of species on BBS squares

Table 2 allows a comparison of the number of sightings on BBS squares (the COUNT DATA column) and records of known presence from counts, field signs and personal communication (the PRESENCE DATA column) for each species. For four widespread species (Badger, Mole, Brown Rat and Hedgehog), data were insufficient to calculate reliable indices of abundance based on counts because sample sizes were too small. However, it was possible to model changes in their presence on BBS squares between 1996 and 2000 (Figs. 19-22). These trends should be treated with extreme caution for a number of reasons, most notably a change in wording on survey form in 1998, which may explain the apparent increase in the presence of all species on BBS squares in this year (see discussion for further details).

Stoats and Weasels are also widespread and relatively abundant being recorded on a mean of 126 and 101 BBS squares respectively between 1996 and 2000 on one or more occasions, but their detectability on these squares is low, meaning that few squares have repeated counts over the time scale of the BBS survey; a requirement for using the logistic regression model to calculate indices of abundance. However, changes in the abundance of species showing this pattern can be assessed using a chi-squared test. Firstly, a comparison of the number of BBS squares recording sightings in each year was made in relation to number of BBS surveyed. The results of these analyses suggest that stoat and weasel show no significant change in occurrence (Stoats: χ^2_4 = 1.81, P = 0.875; Weasels χ^2_4 = 2.20, P = 0.82) on BBS. However, when information on species presence from counts, field signs and personal communication is used, it suggests a significant increase in both species across the survey period (Stoats: χ^2_4 = 58.02, P = < 0.001; Weasels χ^2_4 = 53.46, P = < 0.001). The implications of these findings will be discussed in the discussion.

4.5 Distribution of British mammals

Information on the distribution of 21 British mammal species is presented by overlaying mammal presence on a map of observer coverage within each BTO region. In total there are 127 BTO regions in the UK, the boundaries of which are shown in Figure 23. By mapping distribution against observer coverage, real species absence from areas of Britain can be identified from areas of low observer coverage. Data for 1995 and 2000 are presented for 15 widespread and abundant species and pooled across years for a further six rarely recorded species (Appendix 1, Figs. 24–59).

5. DISCUSSION & CONCLUSIONS

5.1 The effectiveness of the BBS for monitoring British mammals

5.1.1 For which species are there sufficient data on abundance to calculate population trends?

These preliminary results demonstrate that mammal records collected by BBS observers can be used to monitor population changes in a number of medium to large-sized mammal species in the UK, including Brown Hare, Mountain/Irish Hare, Grey Squirrel, Red Fox, Red Deer, Fallow Deer, Roe Deer, Muntjac and Rabbit. Eight of these species (with the exception of Muntjac) exhibited significant inter-year variation in abundance during the period 1995 to 2000, but only three species showed a significant difference in abundance between the first and last years of the survey. Roe Deer increased significantly, whereas Red Deer and Fallow Deer exhibited significant declines between 1995 and 2000. Further examination of the data found that Red and Fallow Deer decline were due to fluctuating numbers in these years rather than underlying trends in these species. Although data for cats are not reliable due to changes in recording protocols, free-roaming cats might also be monitored using counts in the future.

As expected, the BBS field methodology is not effective for monitoring bats, most mustelids, small mammals, and cetaceans and rare or highly localised species (e.g. Red Squirrel, Wildcat or Chinese Water Deer). Bats are rarely observed during daylight hours and difficult to identify without the use of bat detectors and detectability of mustelids if present on a BBS square are low due to their size and habits. Small mammals are regularly recorded on BBS squares, although most are difficult to identify with confidence to species level unless they are caught and examined in the hand and too few individuals are recorded (if the identification were correct) to identify species change in abundance or distribution. In the case of Red Squirrel, Chinese Water Deer and Wildcat, the methodology of the BBS is probably fine for monitoring these species, but they are simply too rare or localised to be observed in sufficient numbers to be monitored effectively. As coastline represents a small proportion of BBS squares, it is unlikely to be able to monitor cetaceans through the BBS.

5.1.2 Which additional species could be monitored through their change in presence on BBS squares?

For species such as Badger or Mole, where the recording of setts and latrines, molehills and road kills, provides indirect information on presence/absence of these species, changes in presence over time can still be monitored. Although indices of the presence of Badger, Mole, Brown Rat and Hedgehog were calculated for the period 1996 to 2000, and the sample sizes seem adequate to do this, it is not certain how repeat visits by observers to a particular 1 km square have increased the rate of detection and the observer's awareness of the appropriate field signs. For this reason, the first year or more of data should perhaps be eliminated from the analyses in the future. Another problem is related to apparent increase in the presence of all species in 1998. A change in wording on the survey form was made in 1998 from 'present but not on transect' to 'known to be present in square' and this may explain this apparent increase in this year across all species.

Analysis of presence/absence rather than count data may be the most appropriate way for monitoring herding deer species, in particular Red, Fallow and Sika Deer. Although it was possible to calculate indices of relative abundance for Red and Fallow Deer using counts of individuals, there was relatively large variance associated with these data, probably related to the presence of herds rather than individuals during a particular visit. Using presence/absence data might reduce the variability and provide a more accurate way of monitoring change in deer populations.

In total, it may be possible to monitor at least six additional species using presence/absence data that could not be monitored using counts alone. For Badger, Mole, Brown Rat and Hedgehog, the majority of records are based on indirect evidence (field signs or local knowledge), and their frequencies of occurrence are sufficient to detect changes of 25% or more. However, care must be taken to ensure that records are based on evidence of presence during the year of the survey.

For the Badger, it may be worthwhile providing information to observers recording Badger setts, on how to look for signs of activity in order to exclude the possibility of recording abandoned setts, perhaps not used for many years, when assessing species' presence.

5.1.3 How and for what species is it possible to identify changes in distribution?

As with many analyses there is a conflict between maximising the sample size required to identify change with confidence and narrowing down the area of interest to determine the exact pattern of change. In this study, examination of the data found it adequate to examine and compare population trends using count data for five species within three regions of the UK, north, southeast and southwest. Further analyses could examine pair-wise differences between regions for more species where the sample size in one region is limiting and additional analyses could change the boundaries of regions to better understand trends in different geographic areas.

5.1.4 What useful information might be gathered for scarce or highly localised species?

For species for which indices of abundance using counts or presence/absence data could not be calculated, the BBS can nevertheless provide important information on their distribution and relative abundance. For example, a comparison of the number of 1 km squares where a species was recorded in each year could be made using a simple chi-square test, although there are many species for which counts or other evidence are too rare to carry out any meaningful statistics. However, for some species, especially medium to larger sized mammals (e.g. Polecat), BBS data might provide an indication of population change through changes in distribution. Since BBS habitat information is also recorded, we may be able to identify the habitat requirements of these species - essential information for conservation initiatives.

5.1.5 What may be gained by the collection of habitat data as part of the survey?

As mentioned above, the collection of habitat data on BBS squares is important for our understanding of species population trends. Although trends may be unrelated to habitat, they could be directly related to a particular change in say management in a specific habitat in which they occur. Therefore it is essential to have this information available to be able to make the most informed conservation decisions possible for each species. In this study, it was possible to calculate separate habitat-specific indices for four species (Brown Hare, Rabbit, Grey Squirrel and Red Fox) in two or more dominant habitats in which they occur.

5.2 The status of British mammals

These analyses have demonstrated the importance of the BBS for monitoring a number of British mammal species. Although these data are for a relatively short time period (1995 to 2000), it is already apparent that there have been a number of important changes within these populations during this time. Abundance data for the Brown Hare suggests a possible decline but the analysis showed no significant trend. However, examining trends separately for the southeast, southwest and north, identifies a significant decline in the southwest. In the past, the largest historical decline in Brown Hares is believed to have occurred in the southwest, resulting in the much higher densities in the southeast by the time of the national Brown Hare survey of 1991-1993 (Hutchings & Harris 1996). This difference in trends appeared to be related to a difference in habitat between these areas, with Hares mainly occurring on arable farmland in the southeast and pastoral habitat in the southwest (Hutchings & Harris 1996), although the underlying mechanism driving the decline is not understood. The national Brown Hare survey was repeated in 1997-1999 for which preliminary results suggest a slight decline in Brown Hares in arable and pastoral habitat from the time of the first survey (Steve Harris pers. comm. in Toms *et al*. 1999).

In the case of the rarer Mountain/Irish Hare, it was interesting to find that indices of abundance could be calculated, presumably because of the high detection rate of squares on which they occur. However, the variances associated with these estimates are likely to reduce the power for detecting population change and a species-specific survey updated at regular intervals may provide a better method for monitoring this species.

For the Rabbit, there has been no previous national survey of this type with which to compare, although literature in the 1980's suggests a slow increase nationally (Trout *et al*. 1986). There was no evidence from this survey to suggest any change in rabbit abundance between 1995 and 2000, although numbers increased nationally in 1997, followed by a decline in the southeast and north the following year. Whilst the reason for this difference in population change between regions is not understood, Rabbit numbers increased on grassland and declined on farmland, which are the predominant habitats for these species in the southwest and east of Britain respectively. This is the opposite trend to that observed for the Brown Hare.

The Grey Squirrel was another species showing no change in abundance over the six years of the survey, although we have no explanation for the steep increase observed in 1996 across all regions, followed by a drop to previous levels the following year. This could perhaps reflect high productivity in that year. It was interesting to observe that of three habitats (woodland, urban and farmland), the only significant change for Grey squirrels was an increase in urban habitats; perhaps a reflection of increased garden bird feeding in recent years?

For the Red Fox, no evidence was provided to suggest a change in abundance or difference between regions. However, it was interesting to find a significant decline in urban areas, where high fox densities are often recorded. In the mid-1990's, there was an outbreak of sarcoptic mange in foxes, which is likely to be most prevalent in urban areas where fox densities are highest; facilitating disease transmission (Lindstrom *et al*. 1994).

Both the Red and Fallow Deer showed a significant decline between 1995 and 2000, although the errors around these estimates are large and for reasons discussed above it may be better to monitor these species by the analysis of presence/absence data. Abundance data for Muntjac suggests a possible increase over the survey period, but the analysis showed no significant trend within its range in the southeast. It is interesting to see that within the stronghold of the Muntjac, Roe Deer has not increased, whilst it has increased significantly in the north and southwest of Britain. Although Roe Deer populations may have stabilised out naturally in the southeast, this species shows a high degree of niche overlap with Muntjac and in a study in Suffolk it was found that in areas of high Muntjac density, Roe Deer numbers were depressed (Forde 1989, cited in Chapman & Harris 1993).

5.3 Recommendations for improvement in mammal monitoring through the BBS

These analyses highlight the importance of maintaining continuity in the BBS survey form across years. Changes to the form can affect the apparent abundance or presence on BBS squares, making it difficult to interpret underlying population change. Changes to the BBS mammal form during this period include the addition of Hedgehog, Badger, Mole, Brown Rat, Stoat and Weasel to the survey form in 1996 and feral/domestic cat and Sika Deer in 2000. This resulted in a large increase in the number of squares recording Hedgehog, Badger, Mole and Brown Rat in 1996 and the huge apparent increase in feral/domestic cats on BBS squares in 2000. For this reason we recommend that data for 1995 are excluded from any analysis for Hedgehog, Badger, Mole and Brown Rat and data for feral/domestic cat prior to 2000 are also excluded. Stoat, Weasel and Sika Deer showed no large change in their occurrence on BBS squares, so appear little affected by the addition of these species names to the survey form.

Another problem relates to the method by which species presence on BBS squares is assessed. Volunteers are asked to record species presence from reliable signs or reliable information received via personal communication. The first problem with this is specific to Badgers. Badger presence on

BBS squares is mainly recorded through the recording of Badger setts. As discussed above, an increasing number of visits to a square are likely to increase the detection of setts, but of more concern is the possibility that old and abandoned setts are recorded and included in the analyses. To deal with this problem it is suggested that volunteers record the presence of setts as before, but also record whether there are signs of recent activity. A clear sett entrance and spoil heap, presence of footprints, snuffle holes and latrines all indicate an active sett. By doing this, the level of error in previous years can be assessed and perhaps corrected. A second problem related to the recording of species presence is particularly relevant for the mustelids (Stoat, Weasel, Polecat, Pine Marten & Mink). These species are rarely seen with most records from previous observations or personal communication. Although the survey form states that records be based on information for that year only, this may not be as clear as it could be and changes here should therefore be considered. It is suggested that data is collected as before, but that an additional tick box is provided to show if the record is based on information of presence for that year. We need to consider whether additional columns should be added to the form to record the type of evidence of presence (signs, dead animals etc.) used, while carefully considering the impact that any change to the survey form would have on how observers record mammals.

The analyses carried out on the BBS mammal data demonstrate that population trends for a number of medium to large-sized mammals can be determined. However, they also revealed some limitations in the BBS mammal data-set, particularly related to species that are usually recorded on the basis of field signs rather than counts during the bird surveys. One of the main problems is assessing the effects of different levels of effort (care and attention to mammals, expertise, number of visits to the square, etc) by volunteers on their recording of mammals. The focus of the BBS will remain the standardised recording of bird populations and as the UK's primary source of data on terrestrial bird populations, it is essential that the recording of mammals does not affect the quality of bird recording, the results of the bird monitoring or the motivation of the volunteers. It is therefore impossible to implement changes to mammal monitoring that involve changes in the timing of surveys, the field protocols, or the total effort required by volunteers. Nevertheless, it may be possible to modify the recording of mammals on the BBS in such a way as to improve the quality of the information gathered and to help in the interpretation. Obviously, any changes to the mammal recording forms must be undertaken very cautiously, because as has been demonstrated in this report, changes in recording often lead to unreliable changes in apparent abundance. In the 2002 field season, we modified the BBS mammal recording forms by the addition of a column to denote the basis for recording the presence of a particular species. The rationale for this is to determine, at least from 2002 onward, whether presence in a particular season is based on visual sightings, field signs or other indications, or gleaned from local knowledge. Another option that we have not, as yet, implemented is assessing in some way, the level of expertise in mammal identification by sightings or signs, of BBS volunteers. This information could be used in subsequent analyses of BBS mammal data to either restrict the dataset to be analysed, or compare results across different levels of expertise.

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Table 1. Number of 1 km BBS squares surveyed for mammals by year. Percentage of total 1 km squares in the UK is shown in parentheses.

	Year					
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
Squares surveyed	1300	1619	1871	1949	2013	1884

Table 2. The number of BBS squares recording counts of mammals on BBS squares (percentage of total BBS squares surveyed is shown in parentheses).

	COUNT DATA Year					
	1995	1996	1997	1998	1999	2000
Brown Hare	409 (31.5)	494 (30.5)	576 (30.8)	558 (28.6)	582 (28.9)	538 (28.6)
Mountain/Irish Hare	25 (1.9)	44 (2.7)	55 (2.9)	60 (3.1)	50 (2.5)	38 (2.0)
Rabbit	782 (60.2)	948 (58.6)	1123 (60.0)	1139 (58.4)	1152 (57.2)	1093 (58.0)
Red Squirrel	7 (0.5)	17 (1.1)	21 (1.1)	16 (0.8)	15 (0.7)	14 (0.7)
Grey Squirrel	288 (22.2)	480 (29.6)	489 (26.1)	501 (25.7)	490 (24.3)	509 (27.0)
Red Fox	171 (13.2)	241 (14.9)	240 (12.8)	221 (11.3)	265 (13.2)	225 (11.9)
Red Deer	46 (3.5)	67 (4.1)	56 (3.0)	61 (3.1)	50 (2.5)	39 (2.1)
Roe Deer	179 (13.8)	200 (12.4)	221 (11.8)	237 (12.2)	266 (13.2)	256 (13.6)
Fallow Deer	29 (2.2)	34 (2.1)	38 (2.0)	44 (2.3)	36 (1.8)	48 (2.5)
Muntjac Deer	38 (2.9)	35 (2.2)	39 (2.1)	45 (2.3)	53 (2.6)	49 (2.6)
Hedgehog	8 (0.6)	27 (1.7)	42 (2.2)	29 (1.5)	34 (1.7)	24 (1.3)
Common Shrew	18 (1.4)	51 (3.2)	44 (2.4)	71 (3.6)	64 (3.2)	4 (0.2)
Mole	16 (1.2)	73 (4.5)	54 (2.9)	30 (1.5)	44 (2.2)	5 (0.3)
Brown Rat	10 (0.8)	21 (1.3)	17 (0.9)	15 (0.8)	24 (1.2)	24 (1.3)
Badger	5 (0.4)	21 (1.3)	13 (0.7)	14 (0.7)	13 (0.6)	5 (0.3)
Stoat	24 (1.8)	27 (1.7)	31 (1.7)	29 (1.5)	35 (0.7)	25 (1.3)
Weasel	9 (0.7)	14 (0.9)	19 (1.0)	22 (1.1)	19 (0.9)	15 (0.8)
Pygmy Shrew	0	0	0	1 (0.1)	0	2 (0.1)
Water Shrew	0	0	1 (0.1)	2 (0.1)	0	0
Pipistrelle Bat	0	0	1 (0.1)	0	2 (0.1)	0
Natterer’s Bat	0	1 (0.1)	0	0	0	0
Bank Vole	3 (0.2)	7 (0.4)	5 (0.3)	4 (0.2)	3 (0.1)	2 (0.1)
Field Vole	2 (0.2)	3 (0.2)	5	8 (0.4)	6 (0.3)	2 (0.1)
Orkney Vole	0	0	0	0	1	1 (0.1)
Water Vole	4 (0.3)	7 (0.4)	8 (0.4)	6 (0.3)	18 (0.9)	9 (0.5)
Yellow-necked Mouse	0	0	0	0	0	0
Wood Mouse	2 (0.2)	9 (0.6)	2 (0.1)	3 (0.2)	3 (0.1)	4 (0.2)
Harvest Mouse	0	1 (0.1)	0	0	0	0
House Mouse	0	0	0	0	0	1 (0.1)
Pine Marten	0	2 (0.1)	0	1 (0.1)	1	2 (0.1)
Polecat	0	1 (0.1)	3 (0.2)	1 (0.1)	2 (0.1)	0
Mink	3 (0.2)	1 (0.1)	3 (0.2)	2 (0.1)	1 (0.0)	3 (0.2)
Otter	1 (0.1)	3 (0.2)	3 (0.2)	3 (0.2)	1 (0.0)	3 (0.2)
Feral/Domestic Cat	1 (0.1)	1 (0.1)	2 (0.1)	3 (0.2)	4 (0.2)	174 (9.2)
Common Seal	1 (0.1)	0	1 (0.1)	1 (0.1)	2 (0.1)	0
Grey Seal	0	2 (0.1)	2 (0.1)	4 (0.2)	2 (0.1)	1 (0.1)
Sika Deer	4 (0.3)	4 (0.2)	3 (0.2)	5 (0.3)	4 (0.2)	7 (0.4)
Chinese Water Deer	1 (0.1)	1 (0.1)	0	0	3 (0.1)	2 (0.1)
Park Cattle	1 (0.1)	0	0	0	0	0
Feral Goat	4 (0.3)	2 (0.1)	1 (0.1)	3 (0.2)	3 (0.1)	2 (0.1)

Table 3. The number of BBS squares recording the presence of mammals from counts, signs or personal communication on BBS squares (percentage of total BBS squares surveyed is shown in parentheses).

PRESENCE DATA

	Year					
	1995	1996	1997	1998	1999	2000
Brown Hare	471 (36.2)	564 (34.8)	627 (33.5)	625 (32.1)	663 (32.9)	612 (32.5)
Mountain/Irish Hare	37 (2.8)	60 (3.7)	68 (3.6)	76 (3.9)	62 (.31)	47 (2.5)
Rabbit	918 (70.6)	1084 (67.0)	1264 (67.6)	1330 (68.2)	1389 (69.0)	1269 (67.4)
Red Squirrel	15 (1.2)	30 (1.9)	32 (1.7)	33 (1.7)	28 (1.4)	26 (1.4)
Grey Squirrel	381 (29.3)	550 (34.0)	595 (31.8)	655 (33.6)	698 (34.7)	699 (37.1)
Red Fox	401 (30.8)	512 (31.6)	456 (24.4)	570 (29.2)	656 (32.6)	657 (34.9)
Red Deer	74 (5.4)	91 (5.6)	94 (5.0)	107 (5.5)	87 (4.3)	67 (3.6)
Roe Deer	239 (18.4)	281 (17.4)	291 (15.6)	347 (17.8)	381 (18.9)	363 (19.3)
Fallow Deer	46 (3.5)	57 (3.5)	55 (2.9)	85 (4.4)	77 (3.8)	83 (4.4)
Muntjac Deer	57 (4.4)	67 (4.1)	71 (3.8)	98 (5.0)	99 (4.9)	119 (6.3)
Hedgehog	24 (1.8)	135 (8.3)	155 (8.3)	226 (11.6)	238 (11.8)	260 (13.8)
Common Shrew	25 (1.9)	96 (5.9)	84 (4.5)	153 (7.9)	165 (8.2)	14 (0.7)
Mole	90 (6.9)	278 (17.2)	279 (14.9)	383 (19.7)	492 (24.4)	555 (29.5)
Brown Rat	20 (1.5)	73 (4.5)	63 (3.4)	125 (6.4)	151 (7.5)	181 (9.6)
Badger	79 (6.1)	147 (9.1)	150 (8.0)	230 (11.8)	264 (13.1)	269 (14.3)
Stoat	35 (2.7)	84 (5.2)	79 (4.2)	118 (6.1)	158 (7.8)	152 (8.1)
Weasel	19 (1.5)	67 (4.1)	65 (3.5)	99 (5.1)	122 (6.1)	118 (6.3)
Pygmy Shrew	1 (0.1)	2 (0.1)	2 (0.1)	4 (0.2)	3 (0.1)	3 (0.2)
Water Shrew	0	0	1 (0.1)	2 (0.1)	0	1 (0.1)
Scilly Shrew	0	1 (0.1)	0	2 (0.1)	0	0
Leisler's Bat	0	0	0	0	1 (0.0)	0
Noctule Bat	1 (0.1)	1 (0.1)	1 (0.1)	2 (0.1)	1 (0.0)	1 (0.0)
Pipistrelle Bat	3 (0.2)	5 (0.3)	6 (0.3)	4 (0.2)	10 (0.5)	4 (0.2)
Natterer's Bat	0	2 (0.1)	0	0	0	0
Bank Vole	3 (0.2)	15 (0.9)	10 (0.5)	8 (0.4)	5 (0.2)	4 (0.2)
Field Vole	13 (1.0)	21 (1.3)	14 (0.7)	16 (0.8)	16 (0.8)	11 (0.6)
Orkney Vole	2 (0.2)	1 (0.1)	0	3 (0.2)	3 (0.1)	2 (0.1)
Water Vole	5 (0.4)	8 (0.5)	12 (0.6)	14 (0.7)	23 (1.1)	17 (0.9)
Yellow-necked Mouse	0	0	1 (0.1)	0	0	1 (0.1)
Wood Mouse	8 (0.6)	15 (0.9)	6 (0.3)	6 (0.3)	12 (0.6)	11 (0.6)
Common Dormouse	1 (0.1)	1 (0.1)	2 (0.1)	1 (0.1)	1 (0.0)	0
Harvest Mouse	0	1 (0.1)	1 (0.1)	0	1 (0.0)	0
House Mouse	0	2 (0.1)	1 (0.1)	2 (0.1)	2 (0.1)	4 (0.2)
Harbour Porpoise	1 (0.1)	0	0	0	0	0
Pine Marten	2 (0.2)	9 (0.6)	3 (0.2)	2 (0.1)	2 (0.1)	5 (0.3)
Polecat	0	1 (0.1)	3 (0.2)	3 (0.2)	6 (0.3)	3 (0.2)
Mink	6 (0.5)	8 (0.5)	7 (0.4)	10 (0.5)	9 (0.4)	25 (1.3)
Otter	5 (0.4)	12 (0.7)	11 (0.6)	14 (0.7)	8 (0.4)	16 (0.8)
Feral/Domestic Cat	3 (0.2)	2 (0.1)	2 (0.1)	3 (0.2)	4 (0.2)	323 (17.1)

Common Seal	2 (0.2)	0	1 (0.0)	1 (0.1)	2 (0.1)	1 (0.1)
Grey Seal	1 (0.1)	2 (0.1)	2 (0.1)	4 (0.2)	2 (0.1)	1 (0.1)
Sika Deer	5 (0.4)	5 (0.3)	3 (0.2)	8 (0.4)	4 (0.2)	11 (0.6)
Chinese Water Deer	1 (0.1)	2 (0.1)	1 (0.1)	0	3 (0.1)	2 (0.1)
Park Cattle	1 (0.1)	0	0	0	0	0
Feral Goat	5 (0.4)	3 (0.2)	1 (0.1)	3 (0.2)	3 (0.1)	1 (0.1)

Table 4. Indices of relative abundance for species observed on a mean of 30 or more 1 km squares on two or more years in the UK over the period 1995 to 2000. Indices are calculated using log-linear Poisson regression which models site counts, with site and year effects. Results are means ± se. Species marked with an asterisk show a significant change in abundance between the two years 1995 and 2000 at the 5% level. n is the mean number of BBS squares recording counts in two or more years of the survey.

		Year					
Species	*n*	1995	1996	1997	1998	1999	2000
Brown Hare	526	1	1.02 (0.93-1.12)	0.94 (0.85-1.03)	0.94 (0.86-1.04)	0.88 (0.80-0.97)	0.93 (0.84-1.02)
Mountain/Irish Hare	45	1	1.54 (0.13-2.09)	1.90 (1.41-2.57)	1.29 (0.93-1.79)	1.00 (0.70-1.42)	1.10 (0.78-1.56)
Rabbit	1040	1	0.99 (0.92-1.06)	1.24 (1.16-1.32)	0.99 (0.93-1.06)	0.85 (0.79-0.91)	0.93 (0.87-1.00)
Grey Squirrel	460	1	2.19 (1.96-2.43)	1.23 (1.08-1.38)	1.06 (0.94-1.21)	0.88 (0.78-1.00)	1.12 (0.99-1.26)
Red Fox	227	1	1.08 (0.92-1.28)	0.90 (0.75-1.08)	0.75 (0.62-0.91)	0.94 (0.78-1.13)	0.92 (0.76-1.11)
Red Deer	53	1	0.64 (0.48-0.86)	0.80 (0.60-1.08)	1.00 (0.75-1.35)	0.56 (0.39-0.79)	0.46 (0.32-0.67) *
Roe Deer	227	1	1.03 (0.89-1.20)	0.98 (0.84-1.15)	1.12 (0.96-1.30)	1.16 (1.00-1.36)	1.23 (1.05-1.44) *
Fallow Deer	38	1	0.43 (0.30-0.62)	0.53 (0.36-0.79)	0.35 (0.24-0.50)	0.16 (0.10-0.24)	0.52 (0.37-0.73) *
Muntjac	43	1	1.15 (0.80-1.65)	1.12 (0.76-1.64)	1.10 (0.74-1.63)	1.10 (0.75-1.60)	1.24 (0.86-1.78)

Table 5. The mean number of BBS squares containing >50% of the 1 km square in one habitat type in each BTO region. Mixed habitat is classified is where no one habitat comprises 50% or more of a particular habitat type.

BTO region	coastal	farmland	grassland	heath/ bog	mixed habitat	rock	scrub	urban	inland water	woodland
Aberdeen (north)	0	50	0	7	2	0	2	6	0	1
Anglesey	1	9	2	0	0	0	0	2	0	0
Angus	0	10	0	4	0	0	0	1	0	0
Co Antrim	0	15	4	1	0	0	0	0	0	0
Argyll (north & Mull)	0	0	1	3	1	0	0	0	0	3
Argyll (south & Gigha)	0	1	0	3	6	0	3	0	0	3
Co Armagh	0	7	0	0	6	0	0	3	0	0
Avon	0	149	0	0	8	0	0	19	2	10
Ayrshire	0	11	2	0	5	0	0	0	0	1
Bedfordshire	0	84	0	0	7	0	0	5	0	12
Benbecula & The Uists	0	0	0	3	0	0	0	0	0	0
Berkshire	0	89	0	0	4	0	0	3	9	8
Birmingham	0	16	0	0	1	0	0	10	3	3
Borders	0	17	7	0	3	0	2	0	0	6
Brecon	0	15	0	0	4	0	0	0	0	3
Buckinghamshire	0	65	0	0	4	0	0	6	0	12
Caernarfon	0	9	0	0	0	0	0	0	0	0
Caithness	0	0	0	8	0	0	1	0	0	1
Cambridgeshire	0	54	0	0	4	0	0	3	0	0
Cardigan	0	10	0	2	2	0	0	0	0	3
Carmarthen	0	10	1	0	0	0	0	0	0	3
Central Scotland	0	24	2	2	11	0	3	7	0	1
Channel Islands	0	3	2	0	0	0	0	0	0	2
Cheshire (mid)	0	9	0	0	4	0	0	0	3	0
Cheshire (north & east)	0	40	0	0	0	0	2	5	2	0
Cheshire (south)	0	36	0	0	2	0	0	1	0	0
Cleveland	0	3	0	5	6	0	0	0	0	3
Clwyd (east)	0	7	0	1	1	0	0	6	0	4
Clwyd (west)	0	13	2	0	0	0	0	0	0	5
Cornwall	0	13	0	0	0	0	0	0	0	4
Cumbria (north)	0	32	5	3	0	0	0	0	0	5
Cumbria (south)	0	25	4	0	2	0	0	0	0	6
Derbyshire (north)	0	10	1	4	3	0	0	0	0	2
Derbyshire (south)	0	9	0	0	4	0	0	3	0	5
Devon	0	93	4	2	4	0	7	13	0	17
Dorset	6	109	0	0	10	0	0	13	0	14
Co Down	0	22	0	0	0	0	0	0	0	0
Dumfries	0	12	4	0	4	0	3	0	0	8
Durham	0	15	0	3	0	0	0	0	0	0
Essex (north-east)	0	12	0	0	1	0	0	2	0	0
Essex (north-west)	0	53	0	0	4	0	0	0	0	0
Essex (south)	1	15	0	0	4	0	0	6	1	0
Fife & Kinross	0	34	3	0	5	0	3	3	0	7

Glamorgan (mid)	0	5	3	0	0	2	0	5	0	0
Glamorgan (south)	0	9	0	0	0	0	4	5	0	0
Glamorgan (west)	0	4	0	0	2	0	0	0	0	3
Gloucestershire	0	65	1	0	3	0	0	2	0	10
Gwent	0	51	3	1	6	0	0	4	0	10
Hampshire	0	127	6	3	9	0	2	14	0	37
Herefordshire	0	23	0	0	0	0	0	0	0	4
Hertfordshire	0	179	0	2	3	0	0	24	0	12
Huntingdon & Peterborough	0	28	0	0	0	0	0	0	0	0
Isle of Man	0	8	0	0	3	0	0	0	0	0
Inverness (east)	0	5	3	35	2	0	0	0	0	4
Inverness (west)	0	0	0	4	1	0	0	0	0	3
Isle of Wight	0	0	0	0	9	0	0	0	0	3
Kent	3	110	7	0	11	0	0	19	2	28
Kincardine	0	11	0	27	9	0	1	0	0	13
Kirkcudbright	0	6	3	0	3	0	0	0	0	0
Lanark, Renfrew & Dunbarton	0	10	2	4	8	0	0	0	3	4
Lancashire (east)	0	41	2	0	3	0	0	2	0	3
Lancashire (northwest)	0	16	2	0	4	0	0	1	0	5
Lancashire (south)	0	21	0	0	0	0	0	8	0	0
Co Londonderry	0	5	1	7	0	0	2	4	0	0
Leicestershire & Rutland	0	17	0	0	1	0	0	6	0	0
Lewis and Harris	0	0	0	2	1	0	0	0	0	0
Lincolnshire (east)	0	30	0	0	0	0	0	0	0	0
Lincolnshire (north)	0	2	0	0	0	0	1	0	3	0
Lincolnshire (south)	0	19	0	0	1	0	7	0	0	5
Lincolnshire (west)	0	45	0	0	0	0	0	2	0	0
London & Middlesex	0	4	0	0	5	0	0	55	0	3
Lothian	0	12	2	3	2	0	0	2	0	6
Manchester	0	42	5	4	14	0	4	18	0	1
Merioneth	0	4	0	0	0	0	0	0	0	0
Merseyside	2	18	0	0	3	0	0	5	0	0
Montgomery	0	21	0	1	2	0	3	0	1	0
Moray & Nairn	0	10	0	6	2	0	0	1	0	6
Northumberland	0	43	7	2	6	0	0	3	0	18
Northamptonshire	0	22	0	0	8	0	0	4	4	7
Norfolk (northeast)	0	23	0	0	7	0	0	10	0	0
Norfolk (northwest)	0	44	0	0	4	0	0	3	0	0
Norfolk (southeast)	0	26	0	0	0	0	0	5	0	0
Norfolk (southwest)	0	44	5	0	6	0	0	0	5	5
Nottinghamshire	0	70	0	0	3	0	0	7	3	5
Orkney	0	8	3	5	0	0	0	0	0	0
Oxfordshire (north)	0	12	0	0	0	0	0	4	6	7
Oxfordshire (south)	0	85	0	0	17	0	0	8	3	5
Pembrokeshire	0	15	0	0	4	0	0	0	0	0
Perthshire	0	9	5	6	6	0	0	0	0	2
Radnorshire-	0	9	1	2	1	0	0	0	0	0
Rugby	0	5	0	0	3	0	0	0	0	0
Small isles	0	0	0	1	0	0	0	0	0	0
Ross-shire	0	13	5	14	2	2	2	0	0	13

Isles of Scilly	0	2	0	0	0	0	0	0	0	0
Shetland	0	0	0	2	0	0	0	0	0	0
Shropshire	0	84	0	1	1	0	0	5	5	3
Skye	0	0	2	10	0	0	0	0	0	0
Somerset	0	26	5	0	0	0	0	0	0	6
Staffordshire (central)	0	13	0	0	0	0	0	0	0	0
Staffordshire (north)	0	44	0	3	5	0	0	7	0	3
Staffordshire (south)	0	22	0	3	3	0	0	7	0	0
Suffolk	0	115	10	0	10	0	0	2	2	28
Surrey	0	59	0	0	13	0	0	30	0	32
Sussex	0	65	0	0	9	0	2	11	0	37
Sutherland	0	2	0	16	3	0	0	0	0	1
Co Tyrone	0	17	0	7	3	0	0	0	0	3
Warwickshire	0	18	0	0	4	0	0	2	0	0
Wigtown	0	7	0	0	2	0	2	0	0	2
Wiltshire (south)	0	36	4	0	0	0	0	5	0	1
Wirral	0	9	0	0	0	0	0	6	0	0
Worcestershire	0	100	0	0	11	0	0	6	2	14
Yorkshire (Bradford)	0	21	4	2	2	0	0	6	0	0
Yorkshire (east)	0	29	0	3	6	0	0	0	0	3
Yorkshire (Leeds & Wakefield)	0	15	0	0	0	0	0	7	0	5
Yorkshire (northeast)	0	20	0	6	0	0	0	0	0	0
Yorkshire (Harrogate)	0	41	0	0	11	0	0	0	0	0
Yorkshire (north)	0	18	7	2	5	0	0	0	2	0
Yorkshire (northwest)	0	7	2	0	0	0	0	0	0	0
Yorkshire (southeast)	0	19	0	0	4	0	0	4	0	0
Yorkshire (southwest)	0	10	1	5	4	0	0	5	4	4
Yorkshire (York)	0	42	3	0	2	0	0	3	0	4

Table 6. Mammal species occurring on a mean of one or more BBS squares across years.

Species	Main habitat								
	farmland	woodland	grassland	heath/bog	mixed	urban	scrub	water	coastal
Brown Hare	422	20	14	7	32	10	4	6	1
Mountain/Irish Hare	15	1	2	22	3	0	0	0	0
Rabbit	725	75	27	27	71	74	8	9	3
Red Squirrel	7	5	0	1	2	0	0	0	0
Grey Squirrel	250	64	4	3	28	97	2	4	0
Red Fox	146	23	6	7	15	21	2	2	1
Red Deer	7	6	3	32	4	0	1	0	0
Roe Deer	129	45	6	16	14	6	4	2	0
Fallow Deer	19	14	0	1	2	1	1	0	0
Muntjac	29	10	1	0	1	2	1	0	0
Hedgehog	17	1	0	0	3	5	0	0	0
Mole	27	3	1	1	3	2	0	1	0
Brown Rat	14	1	0	0	1	2	0	0	0
Badger	9	1	0	0	1	0	0	0	0
Stoat	19	2	2	1	4	1	0	0	0
Weasel	12	1	1	0	1	1	0	0	0

Figure 1. Regions of Britain used in the regional analysis. For regional analysis, regions were derived using government regional development agency (RDA) area boundaries, where NORTH = northwest and northeast England, Yorkshire and Humber and Scotland, SOUTHEAST = east and west midlands, London and east and southeast England and SOUTHWEST = southwest England and Wales.

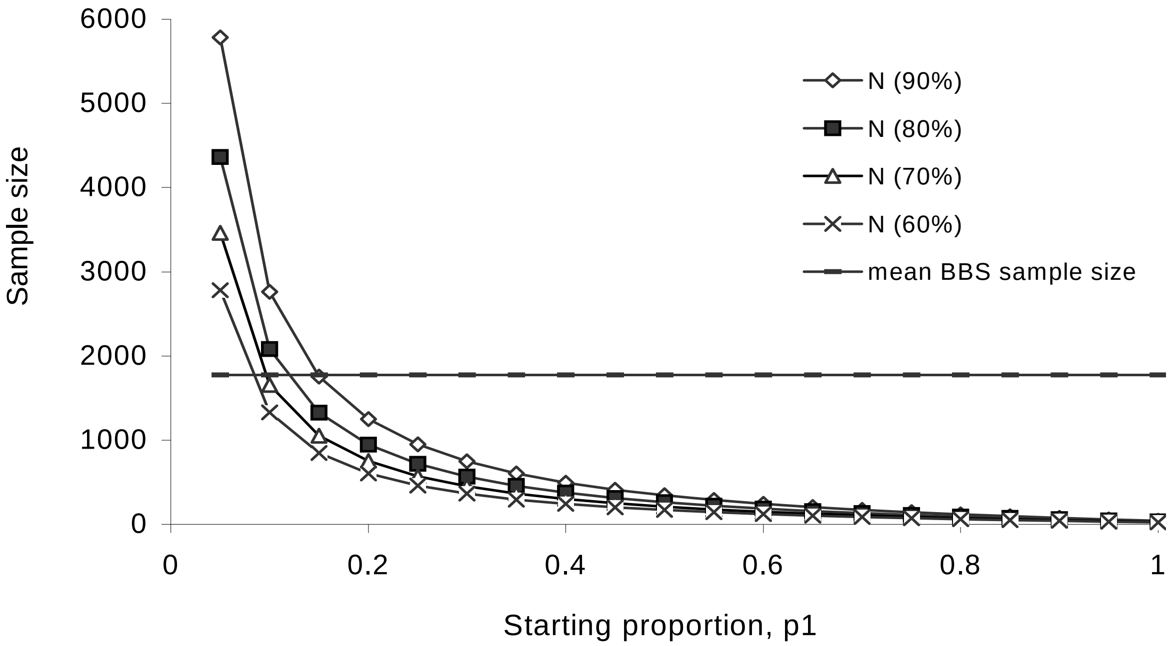

Figure 2. Sample sizes required for the detection of a 25% decline from a starting proportion p1 at a 0.05 level of significance (N = statistical power).

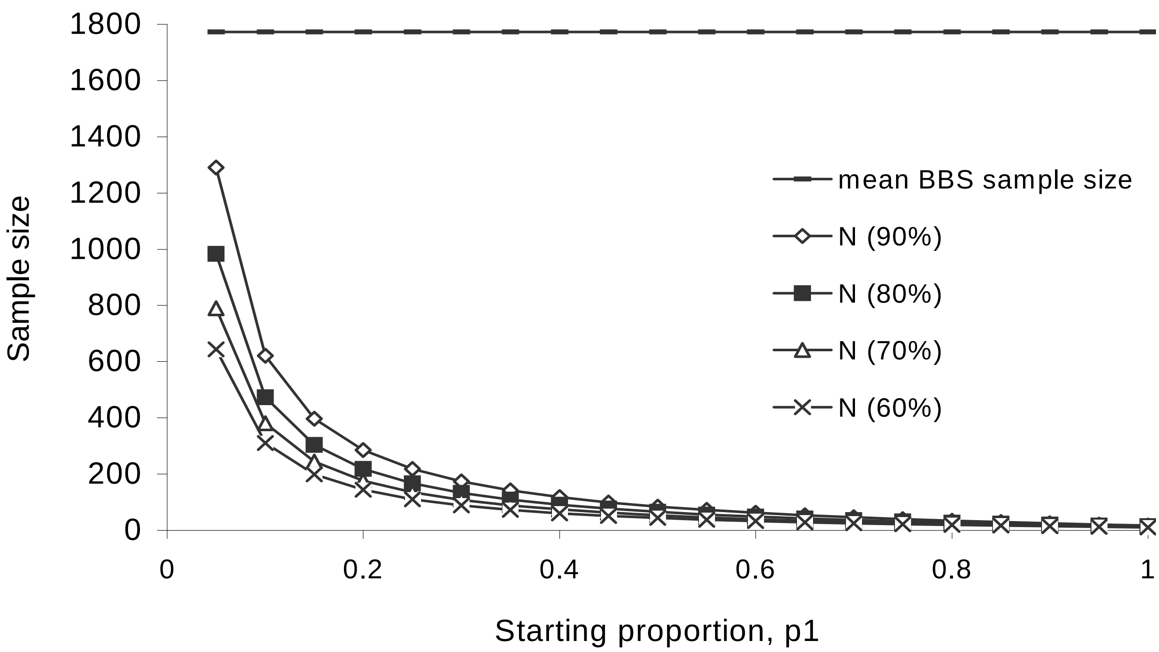

Figure 3. Sample sizes required for the detection of a 50% decline from a starting proportion p1 at a 0.05 level of significance (N = statistical power).

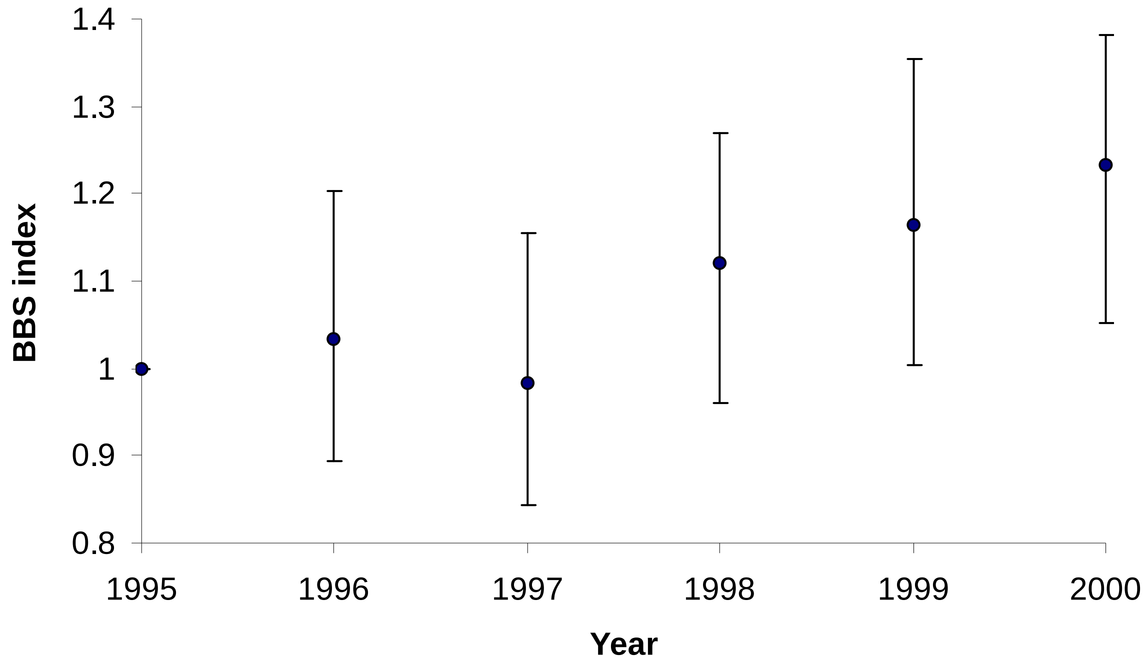

Figure 4. BBS indices of Roe Deer between 1995-2000. Results are means ± 95% CI.

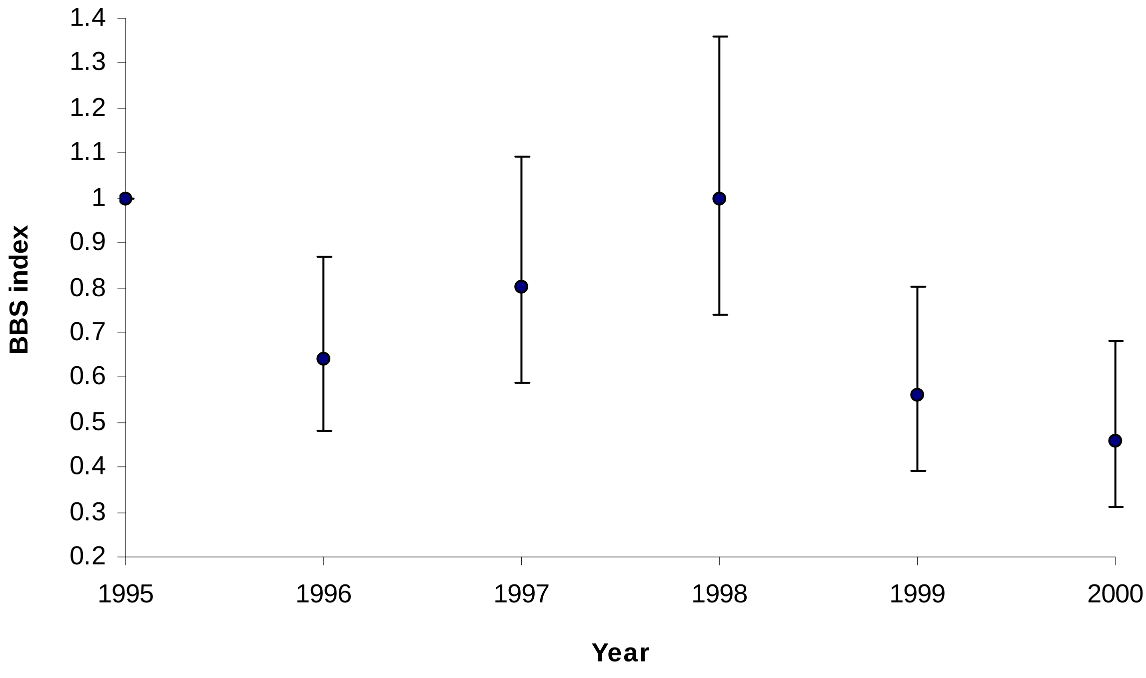

Figure 5. BBS indices of Red Deer between 1995-2000. Results are means ± 95% CI.

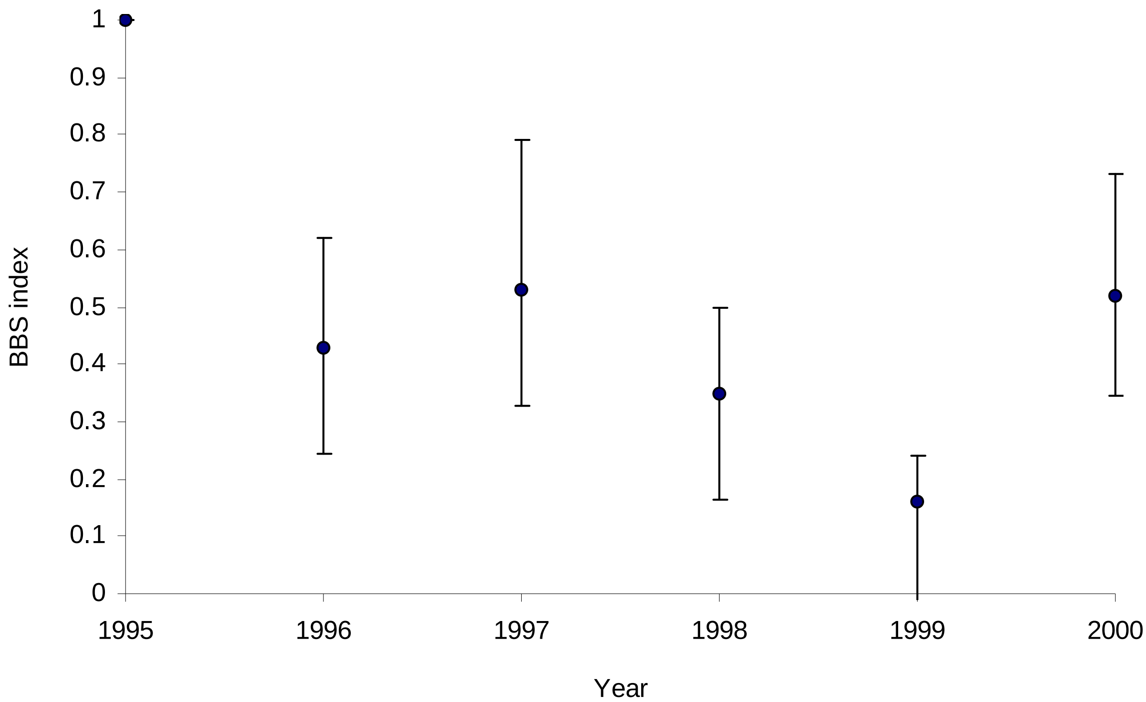

Figure 6. BBS indices of Fallow Deer between 1995-2000. Results are means ± 95% CI.

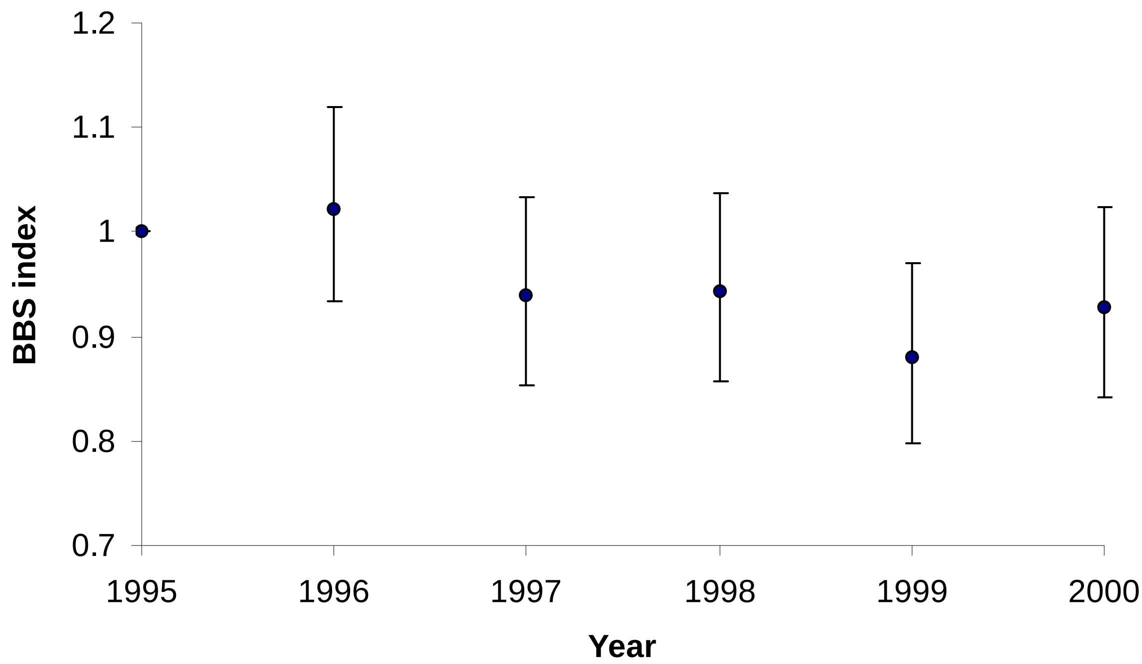

Figure 7. BBS indices of Brown Hare between 1995-2000. Results are means ± 95% CI.

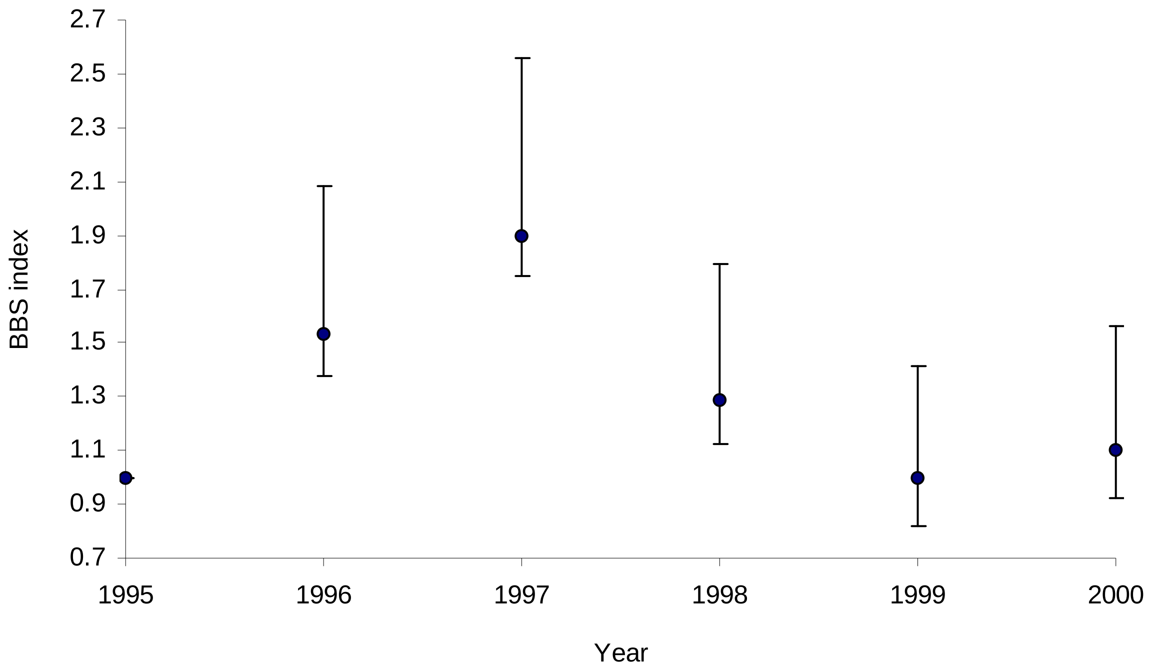

Figure 8. BBS indices of Mountain/Irish Hare between 1995-2000. Results are means ± 95% CI.

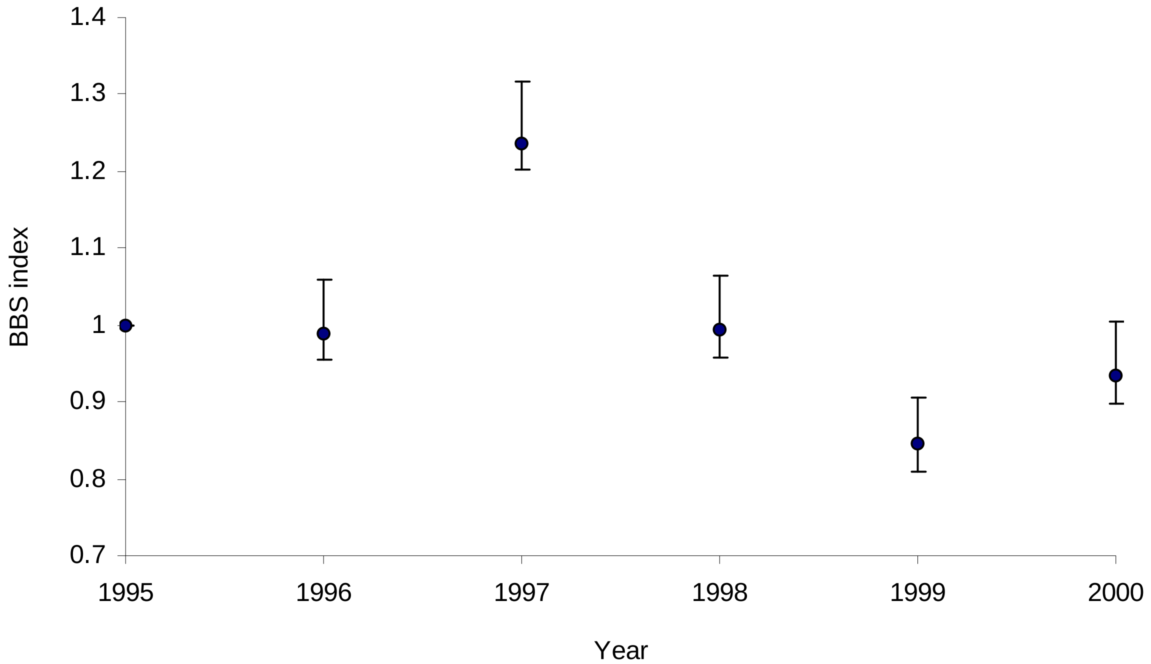

Figure 9. BBS indices of Rabbit between 1995-2000. Results are means ± 95% CI.

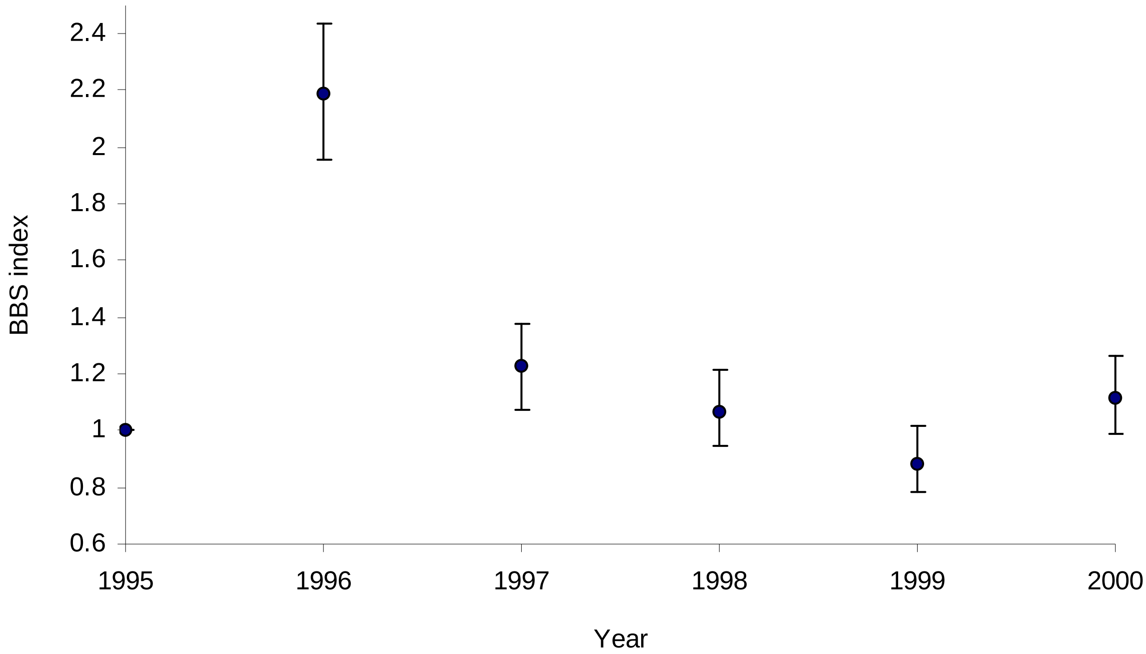

Figure 10. BBS indices of Grey Squirrel between 1995-2000. Results are means ± 95% CI.

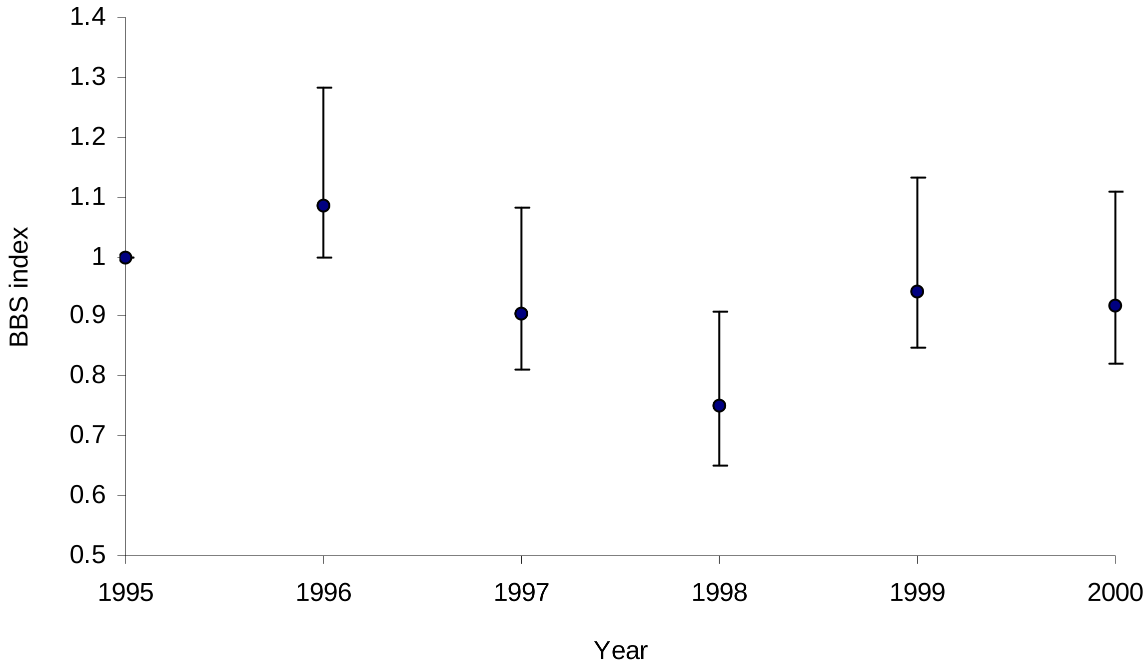

Figure 11. BBS indices of Red Fox between 1995-2000. Results are means ± 95% CI.

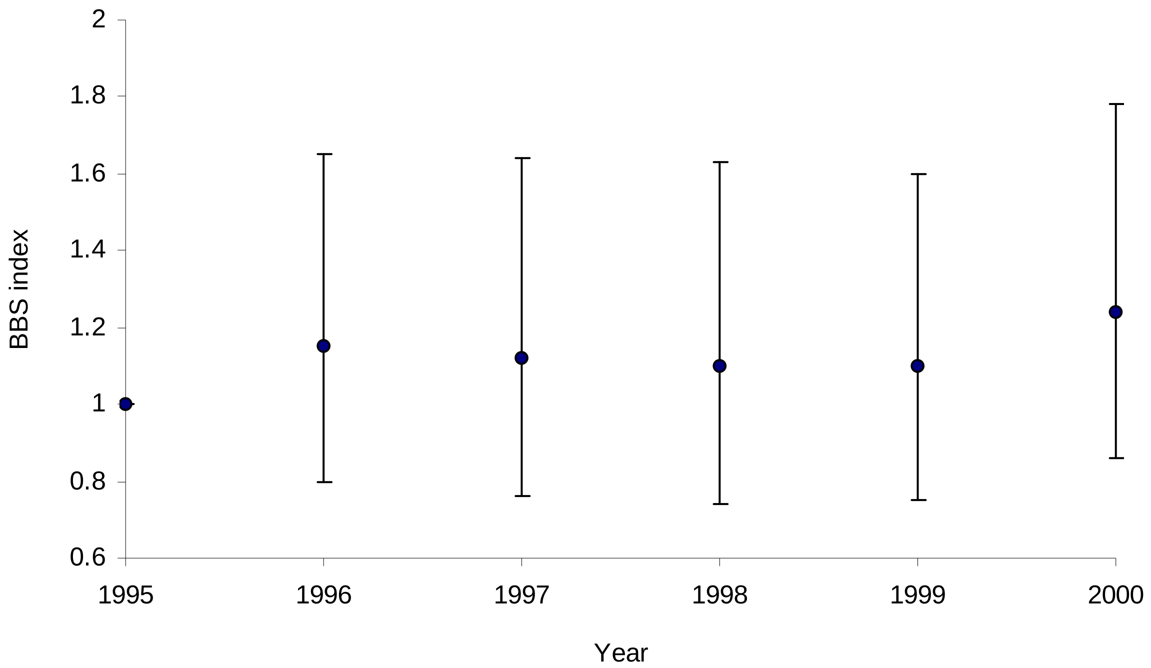

Figure 12. BBS indices of Muntjac between 1995-2000. Results are means ± 95% CI.

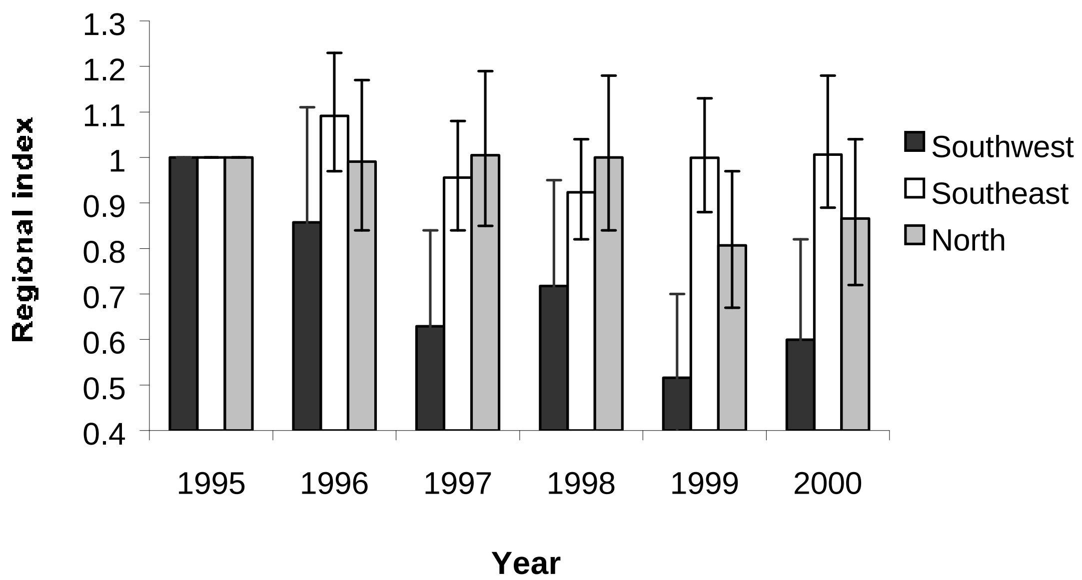

Figure 13. BBS regional indices of Brown Hare between 1995-2000. Results are means ± 95% CI.

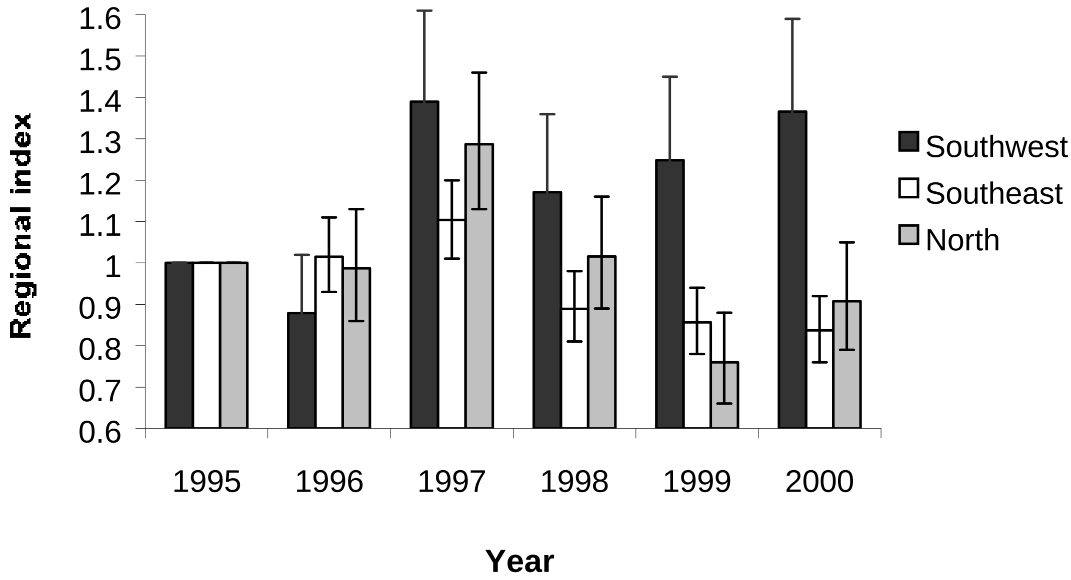

Figure 14. BBS regional indices of Rabbit between 1995-2000. Results are means ± 95% CI.

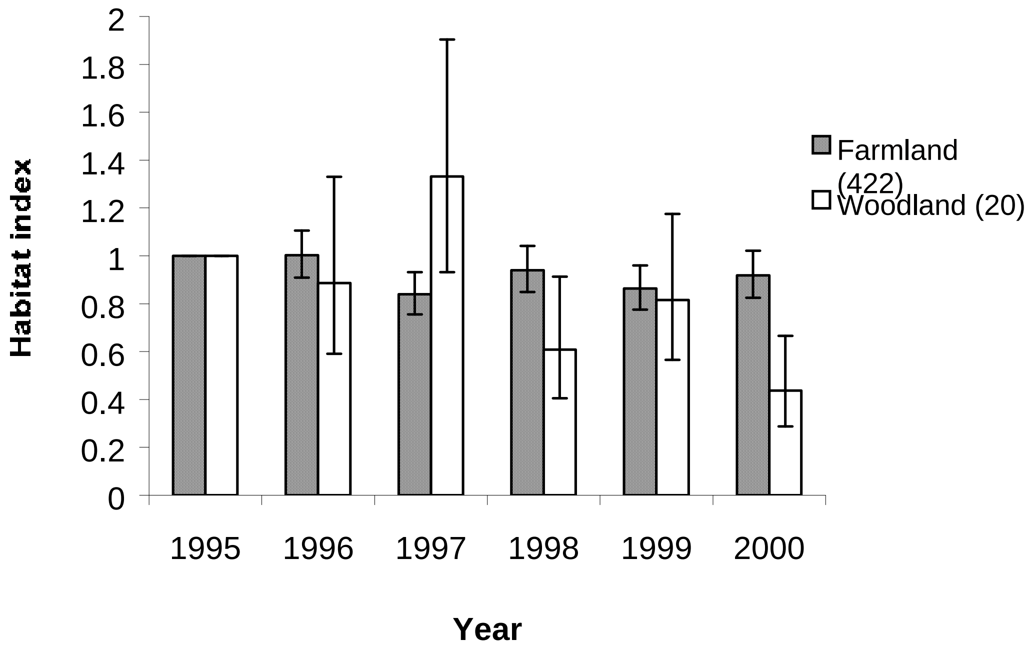

Figure 15. Change in the abundance of Brown Hare on farmland and woodland habitats between 1995-2000. Results are means ± se. Samples sizes for each habitat are shown in brackets.

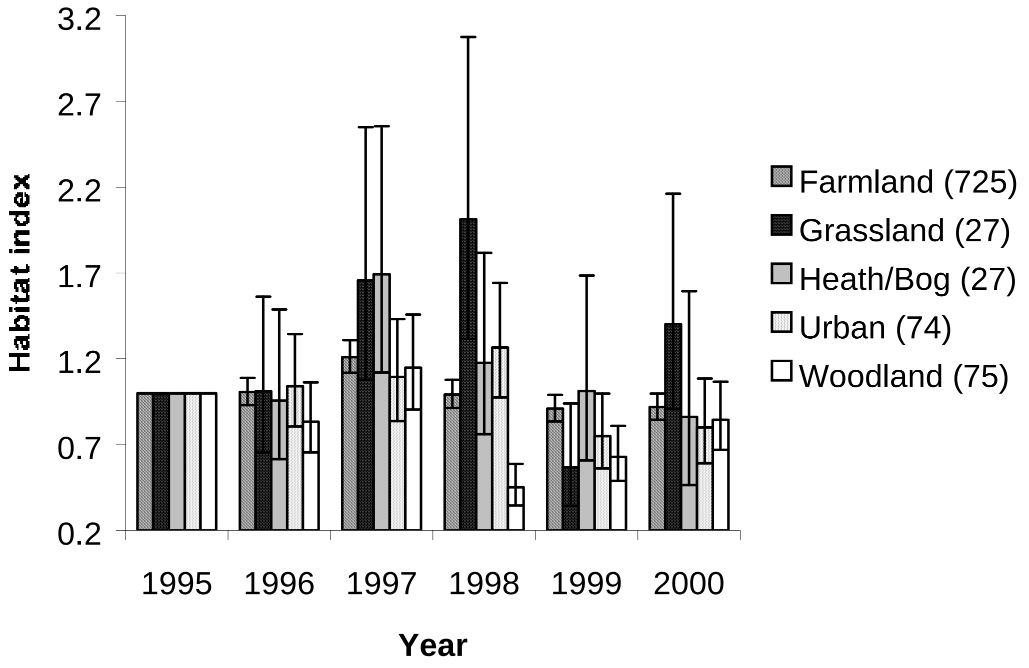

Figure 16. Change in the abundance of Rabbits on farmland, grassland, heath/bog, urban and woodland habitats between 1995-2000. Results are means ± se. Samples sizes for each habitat are shown in brackets.

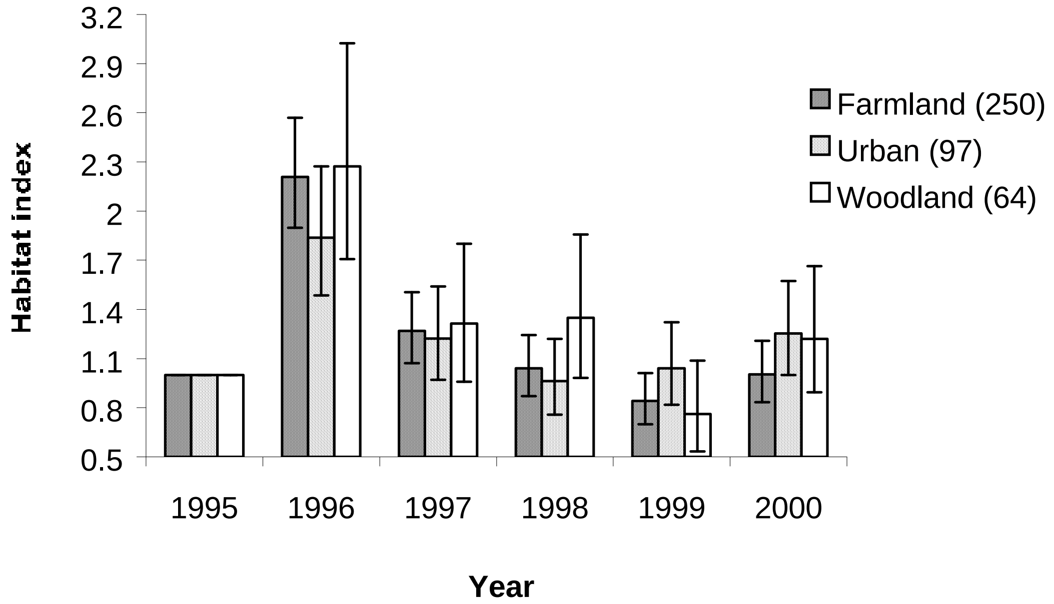

Figure 17. Change in the abundance of Grey Squirrel on farmland, urban and woodland habitats between 1995-2000. Results are means ± se. Samples sizes for each habitat are shown in brackets.

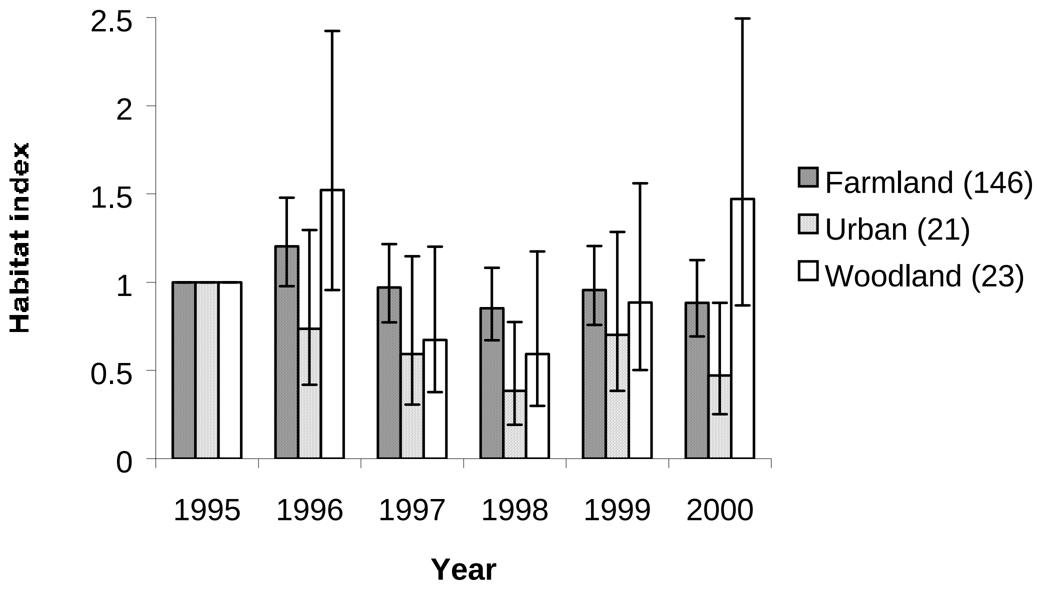

Figure 18. Change in the abundance of Red Fox on farmland, urban and woodland habitats between 1995-2000. Results are means ± se. Samples sizes for each habitat are shown in brackets.

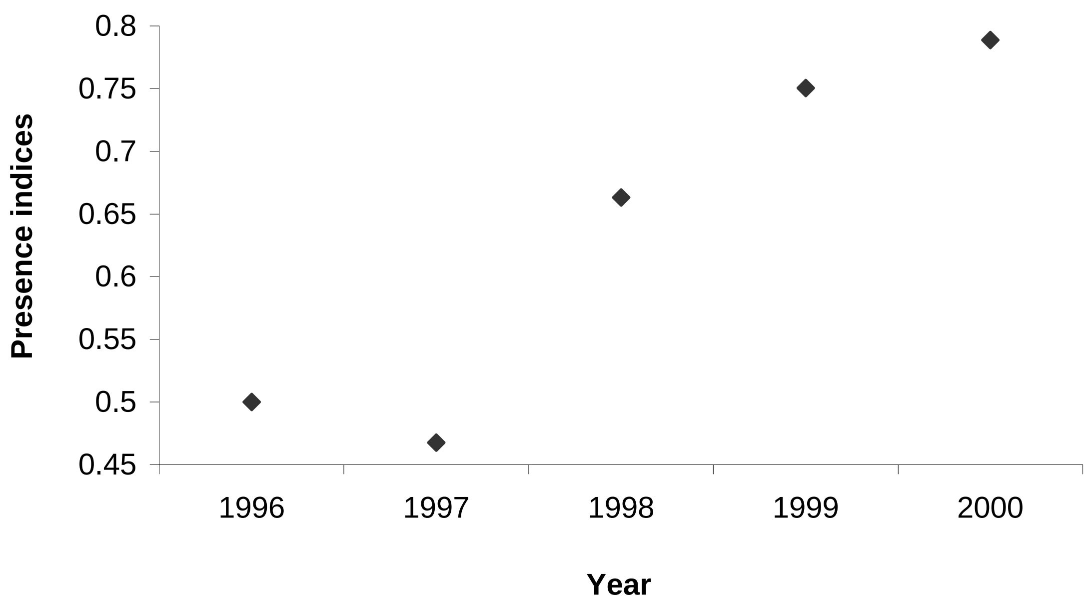

Figure 19. Change in the presence of Mole on BBS squares between 1996-2000. It is important to note that the apparent increased presence on BBS squares in 1998 is likely to be due to a change in the survey form in this year.

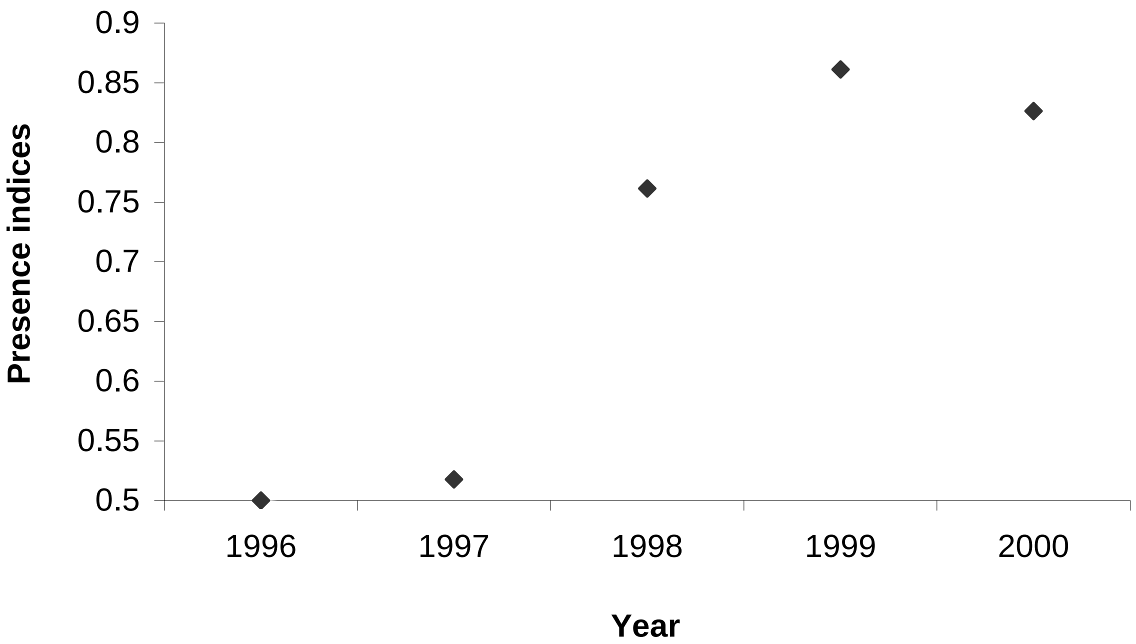

Figure 20. Change in the presence of Badger on BBS squares between 1996-2000. It is important to note that the apparent increased presence on BBS squares in 1998 is likely to be due to a change in the survey form in this year.

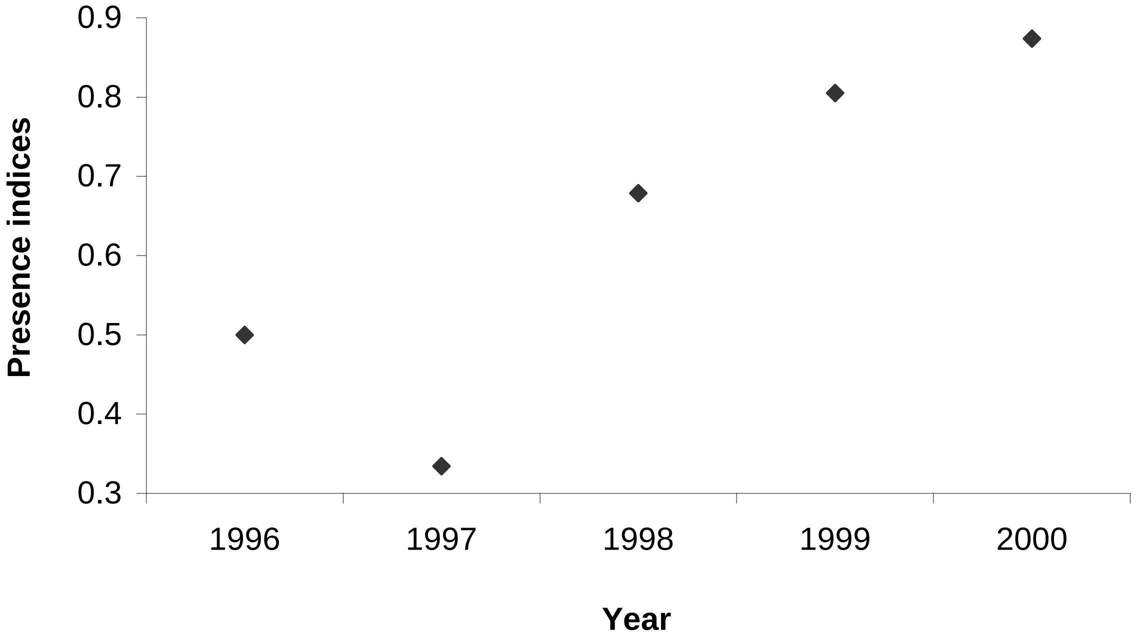

Figure 21. Change in the presence of Brown Rat on BBS squares between 1996-2000. It is important to note that the apparent increased presence on BBS squares in 1998 is likely to be due to a change in the survey form in this year.

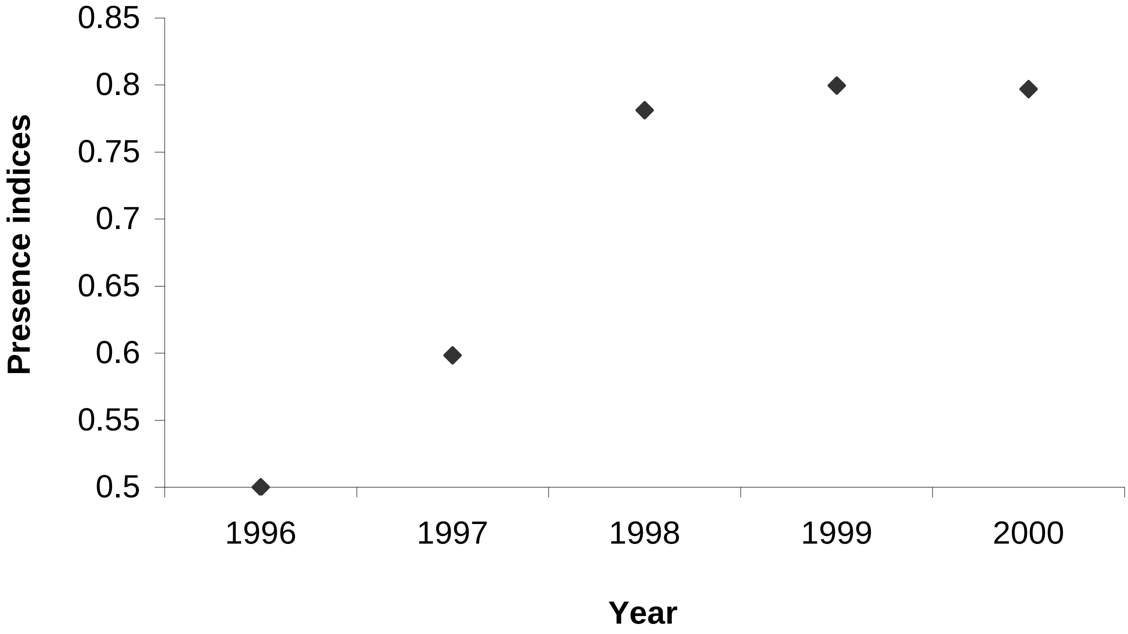

Figure 22. Change in the presence of Hedgehog on BBS squares between 1996-2000. It is important to note that the apparent increased presence on BBS squares in 1998 is likely to be due to a change in the survey form in this year.

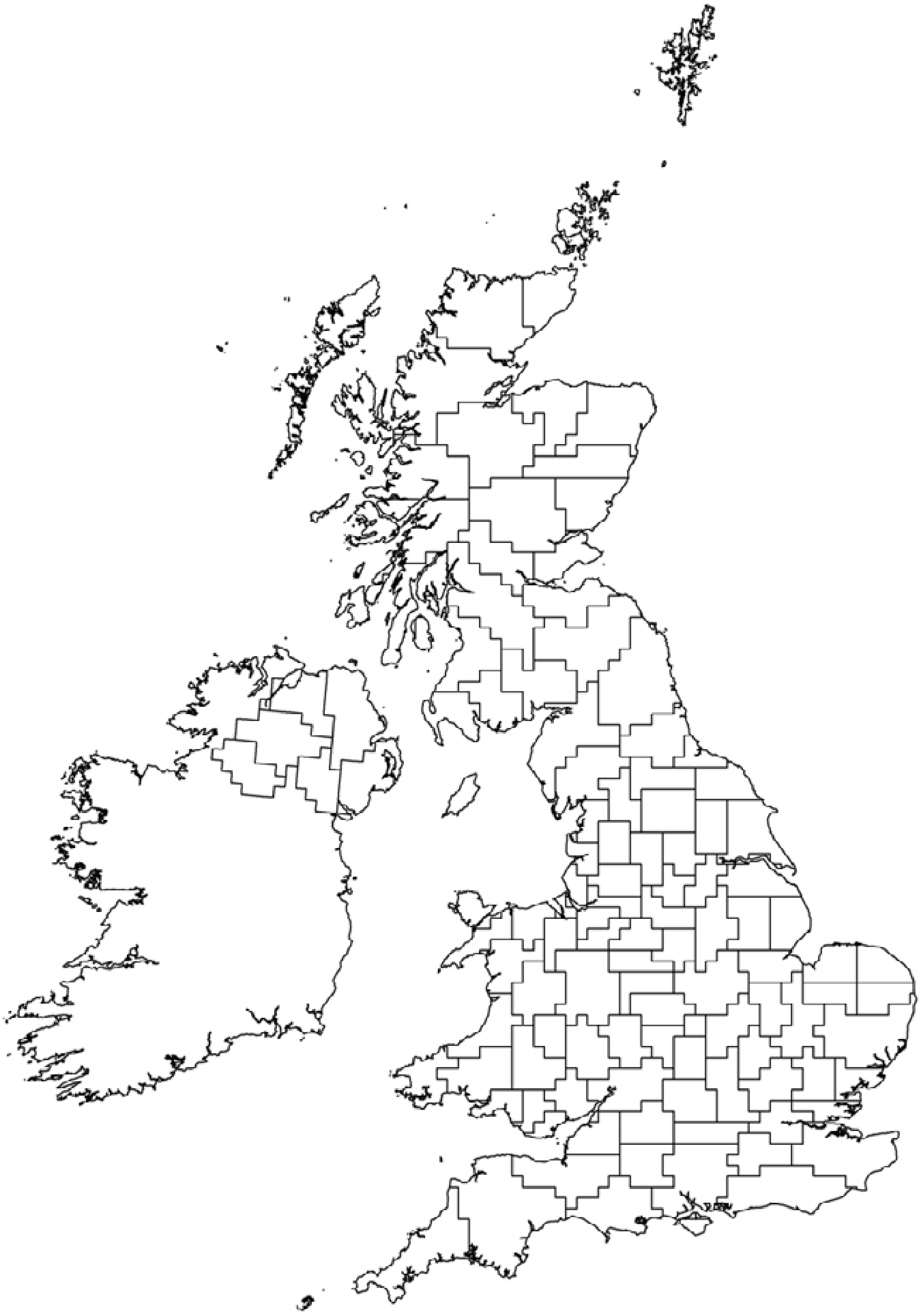

Figure 23. Map showing the boundaries of the BTO regions.

APPENDIX 1. MAMMAL DISTRIBUTION FIGURES.

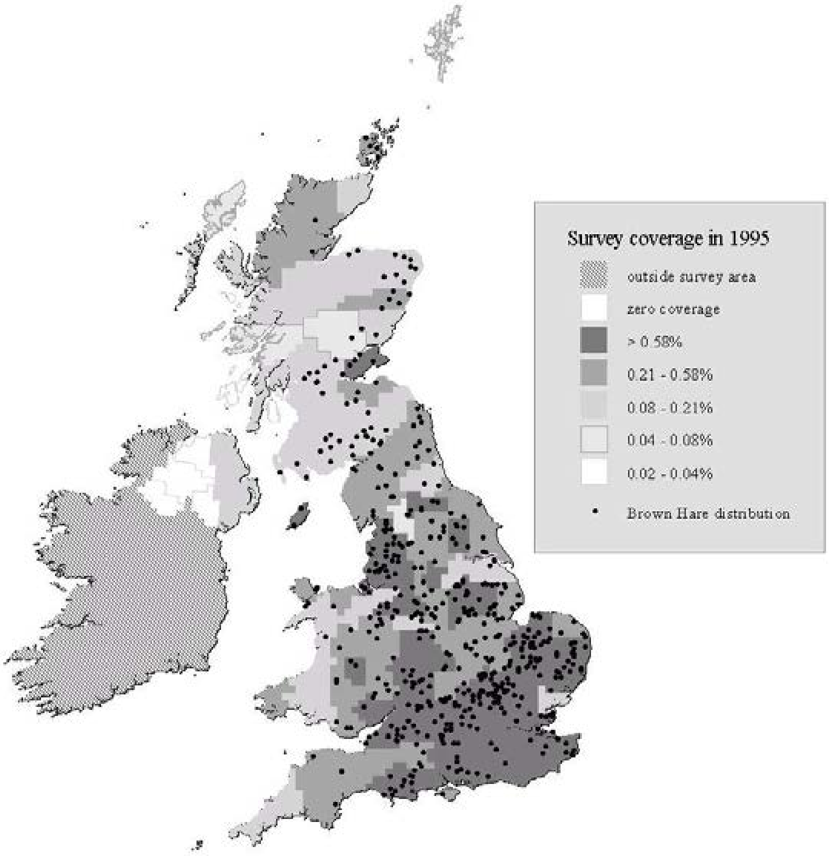

Figure 24. Presence of Brown Hare on BBS squares in 1995.

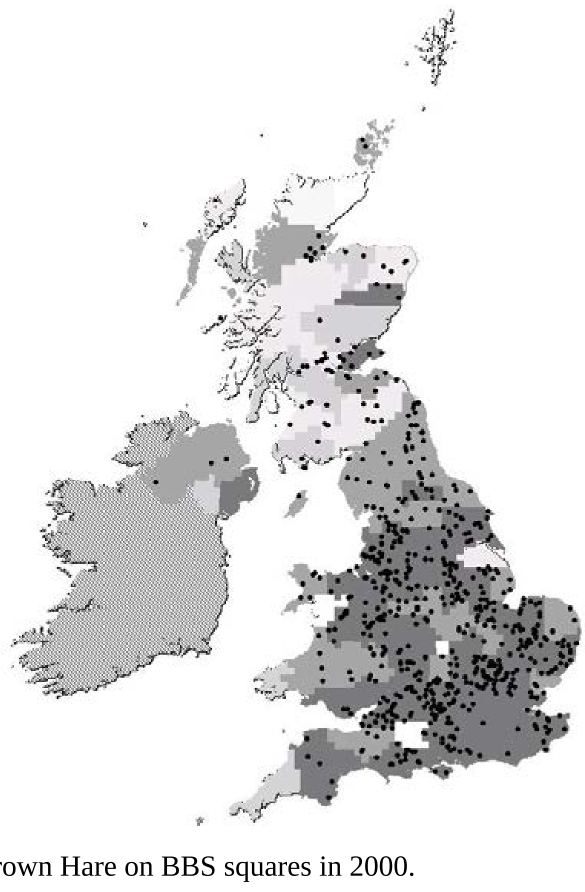

Figure 25. Presence of Brown Hare on BBS squares in 2000.

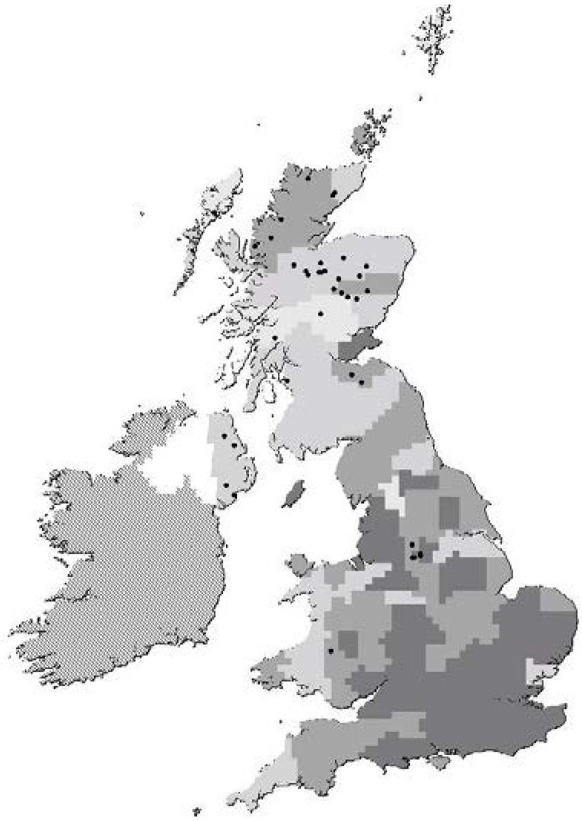

Figure 26. Presence of Mountain/Irish Hare on BBS squares in 1995.

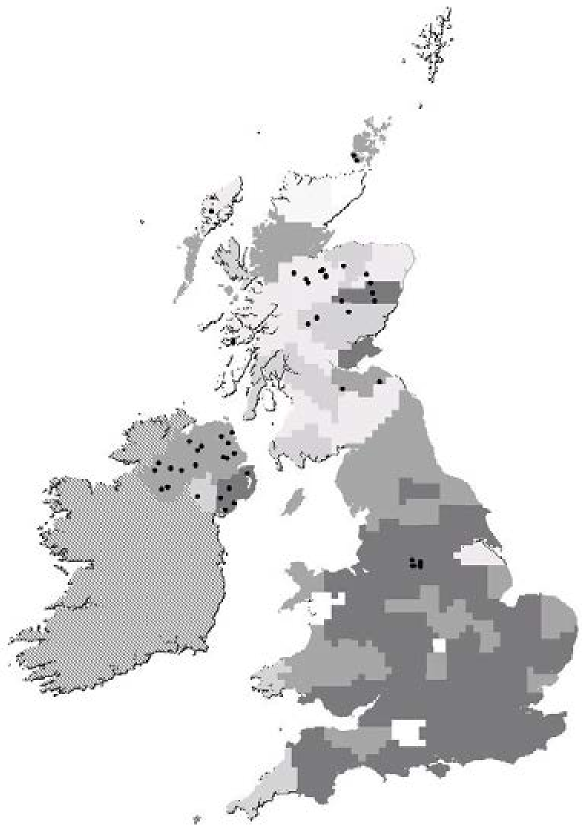

Figure 27. Presence of Mountain/Irish Hare on BBS squares in 2000.

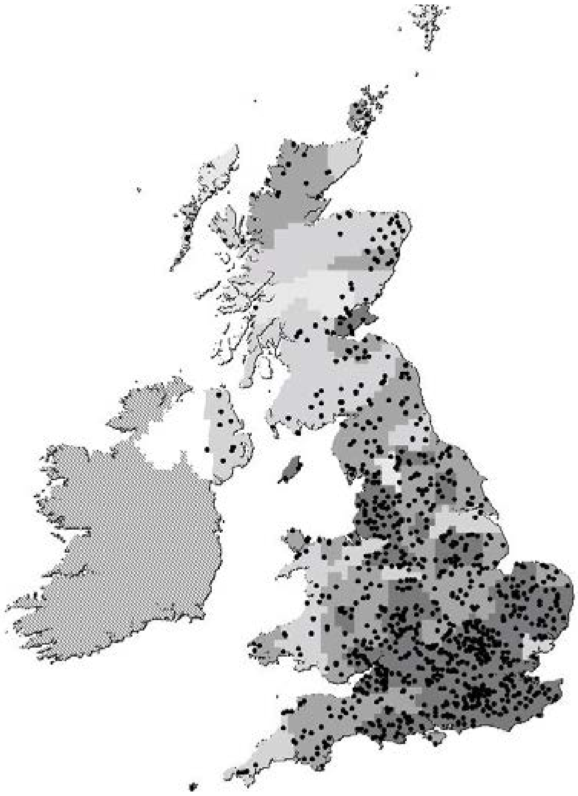

Figure 28. Presence of Rabbit on BBS squares in 1995.

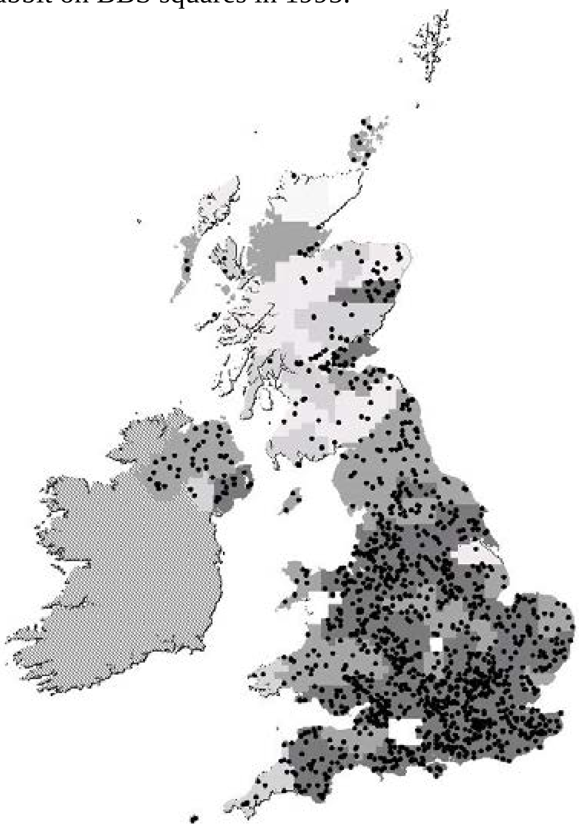

Figure 29. Presence of Rabbit on BBS squares in 2000.

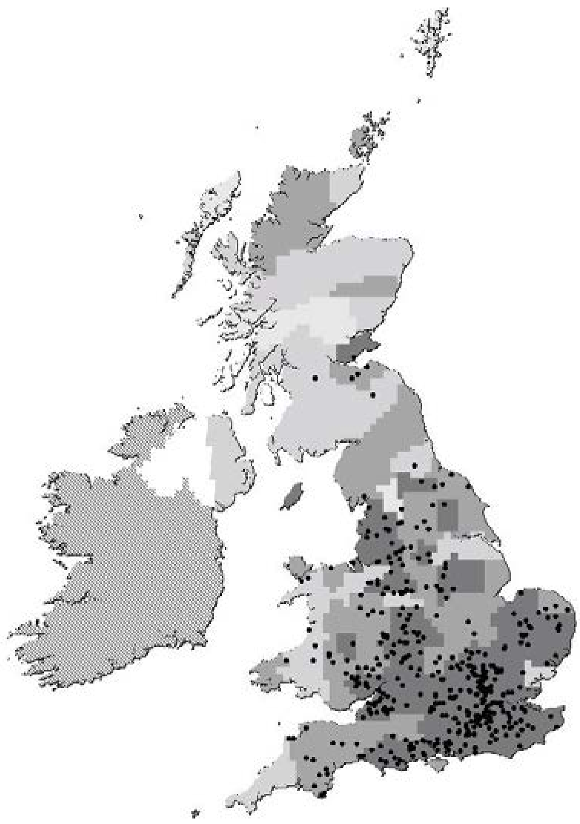

Figure 30. Presence of Grey Squirrel on BBS squares in 1995.

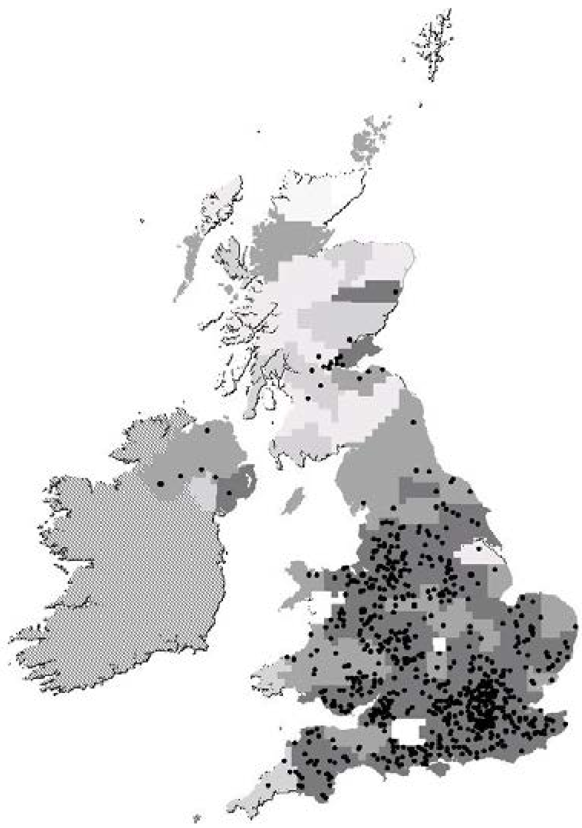

Figure 31. Presence of Grey Squirrel on BBS squares in 2000.

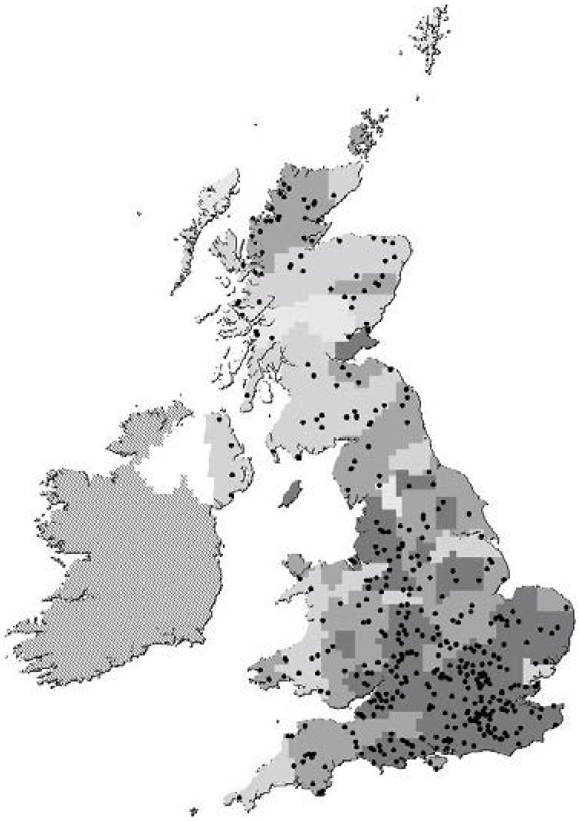

Figure 32. Presence of Red Fox on BBS squares in 1995.

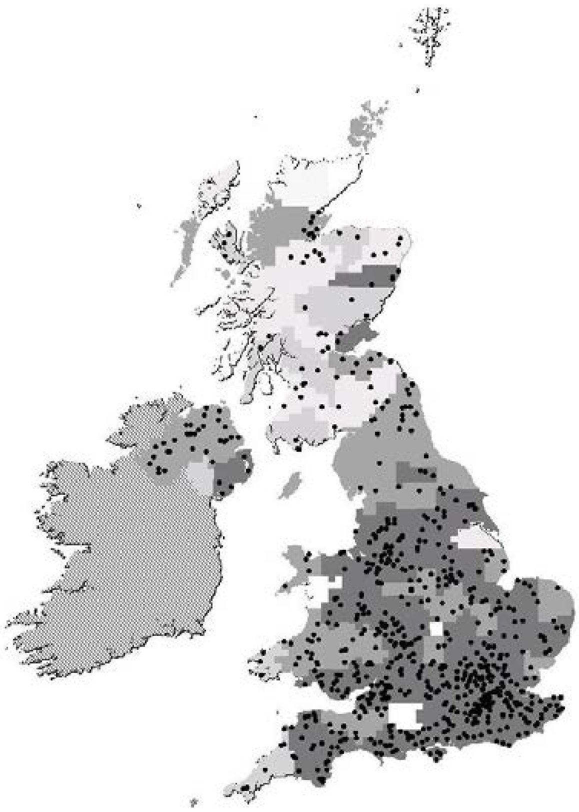

Figure 33. Presence of Red Fox on BBS squares in 2000.

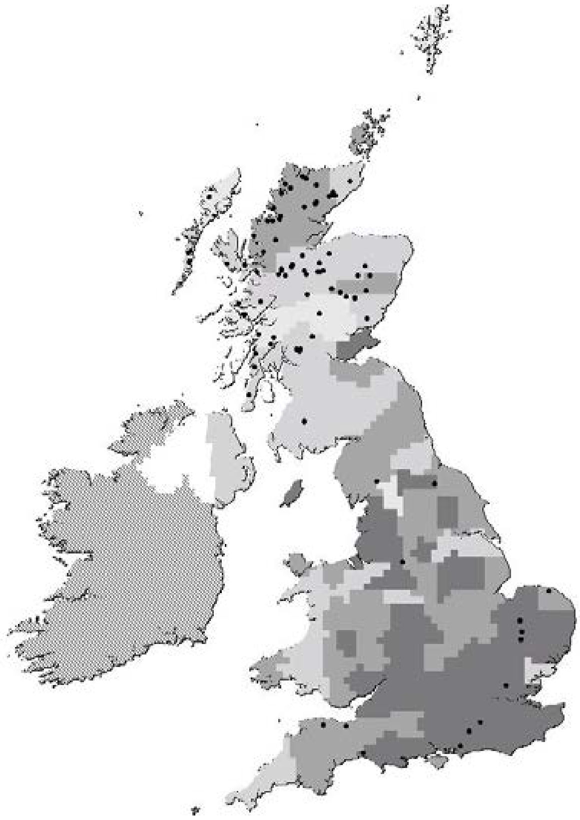

Figure 34. Presence of Red Deer on BBS squares in 1995.

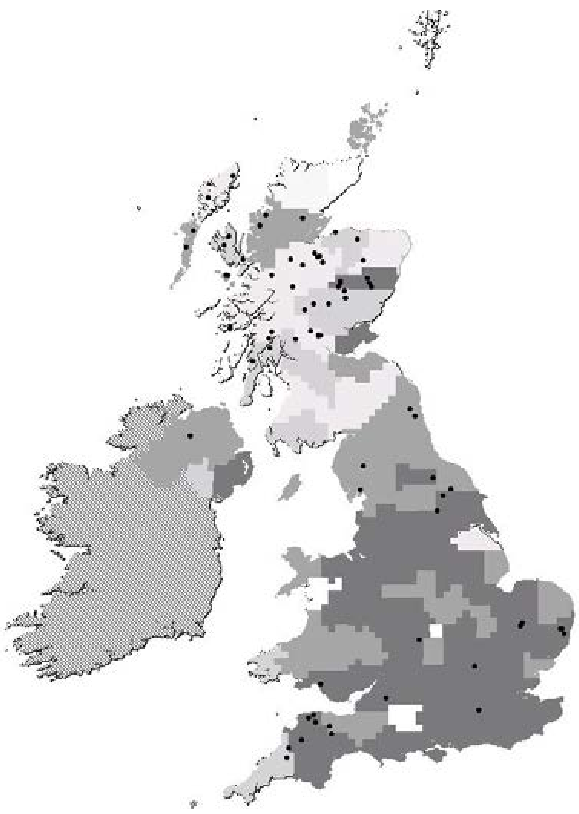

Figure 35. Presence of Red Deer on BBS squares in 2000.

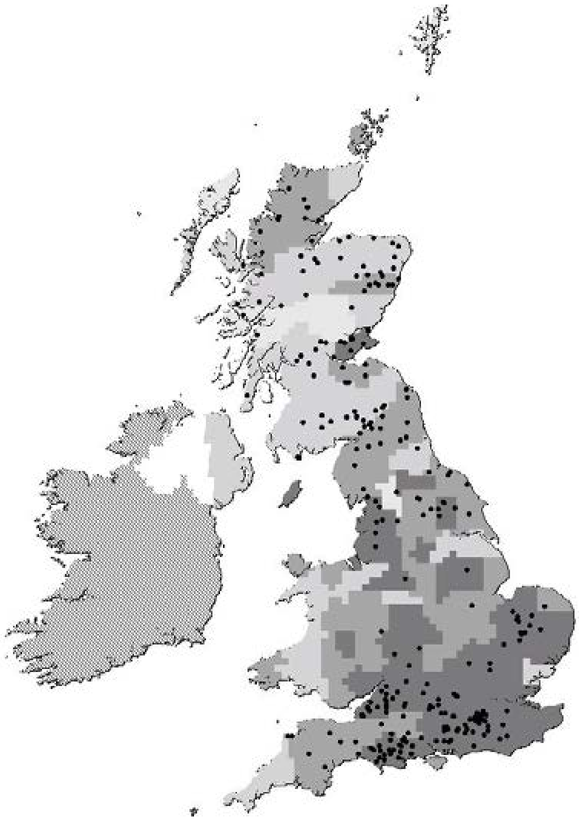

Figure 36. Presence of Roe Deer on BBS squares in 1995.

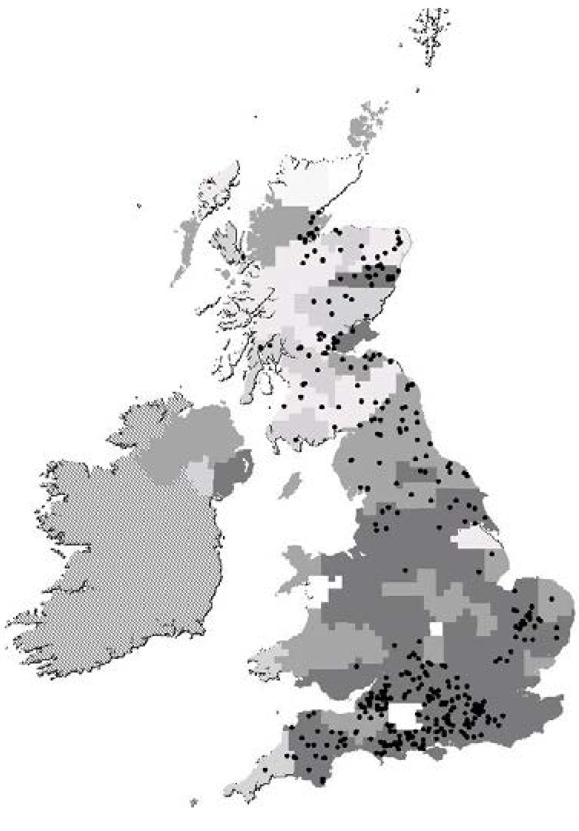

Figure 37. Presence of Roe Deer on BBS squares in 2000.

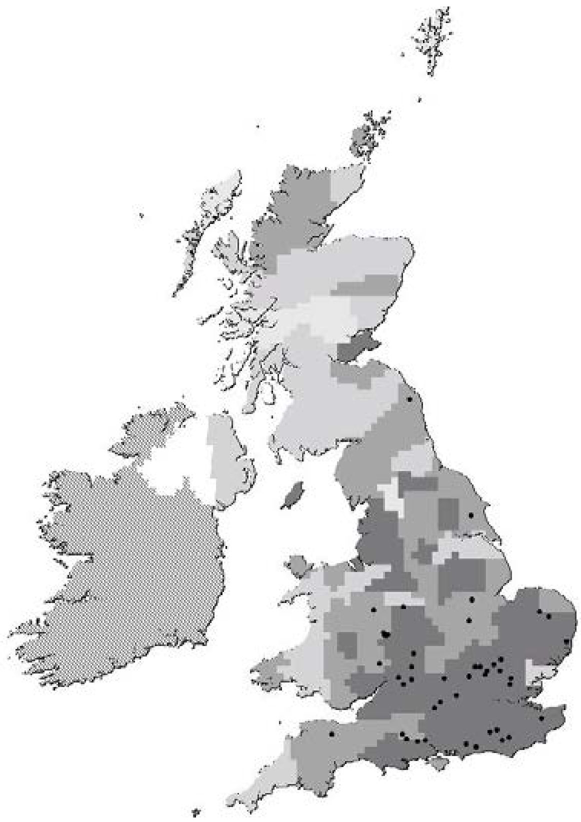

Figure 38. Presence of Fallow Deer on BBS squares in 1995.

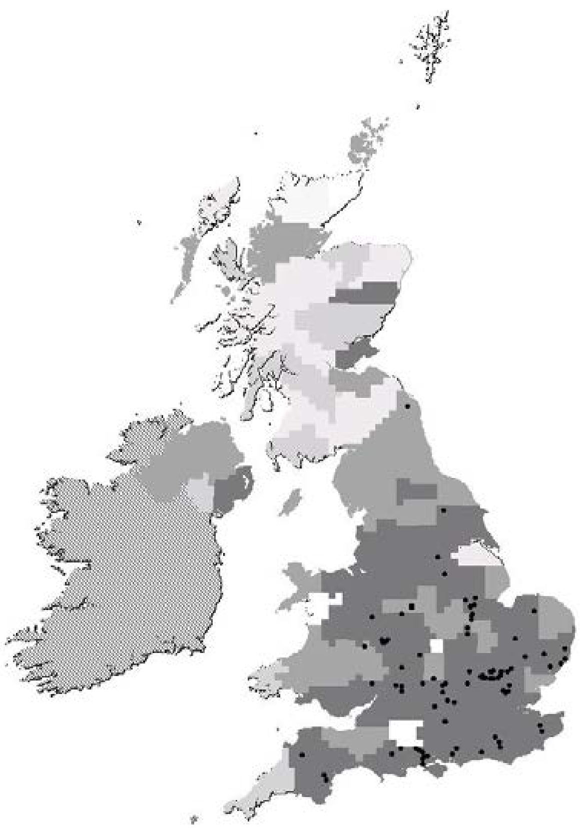

Figure 39. Presence of Fallow Deer on BBS squares in 2000.

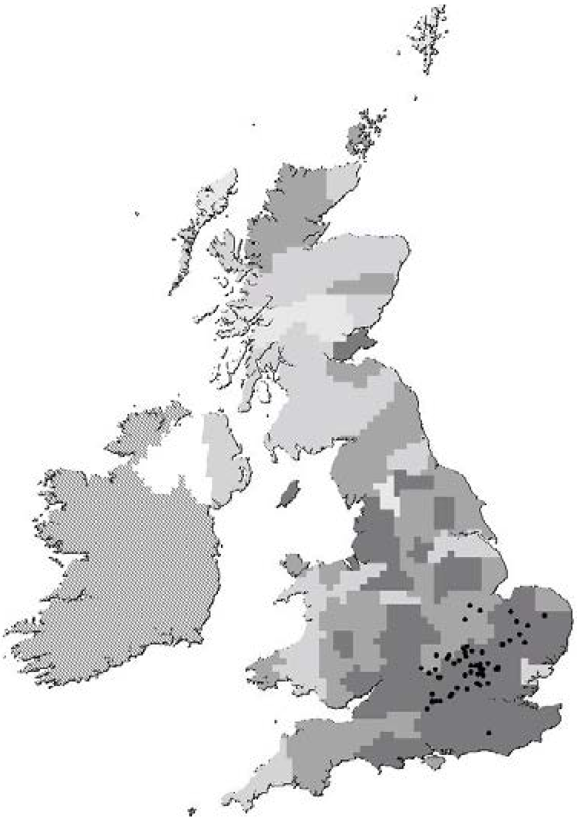

Figure 40. Presence of Muntjac on BBS squares in 1995.

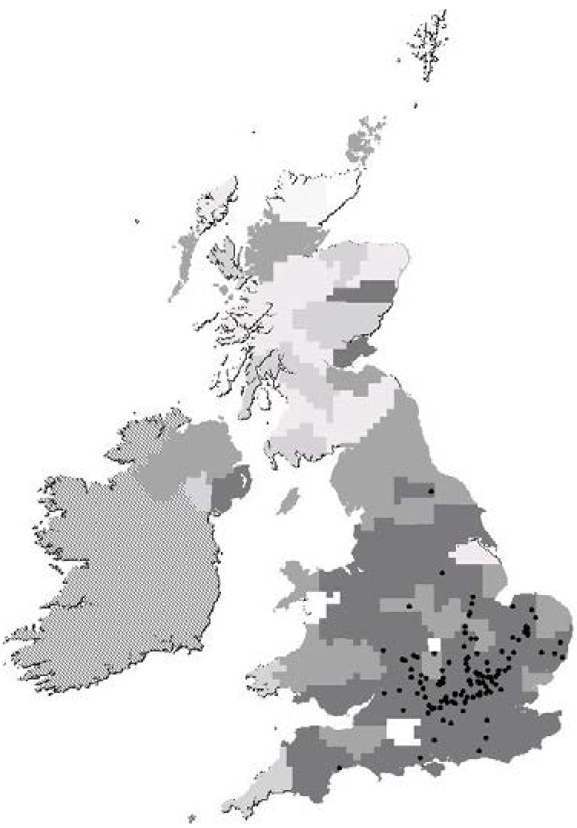

Figure 41. Presence of Muntjac on BBS squares in 2000.

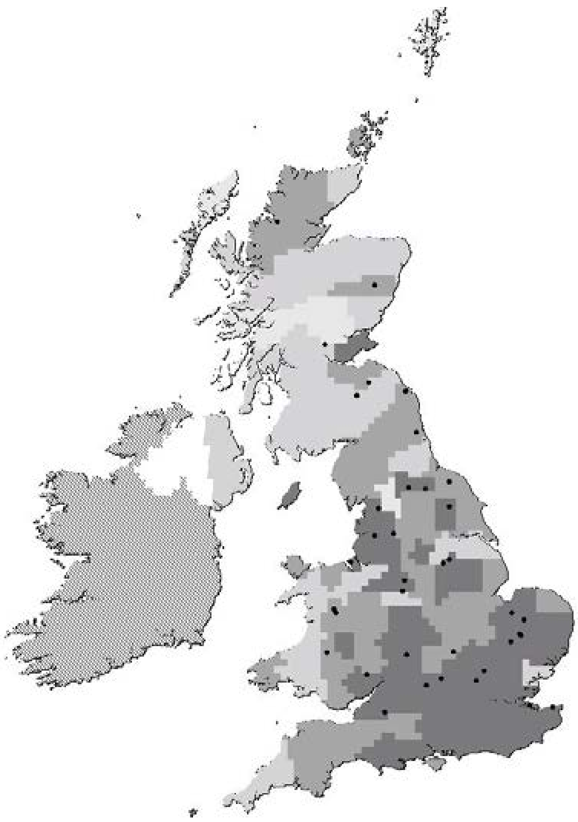

Figure 42. Presence of Stoat on BBS squares in 1995.

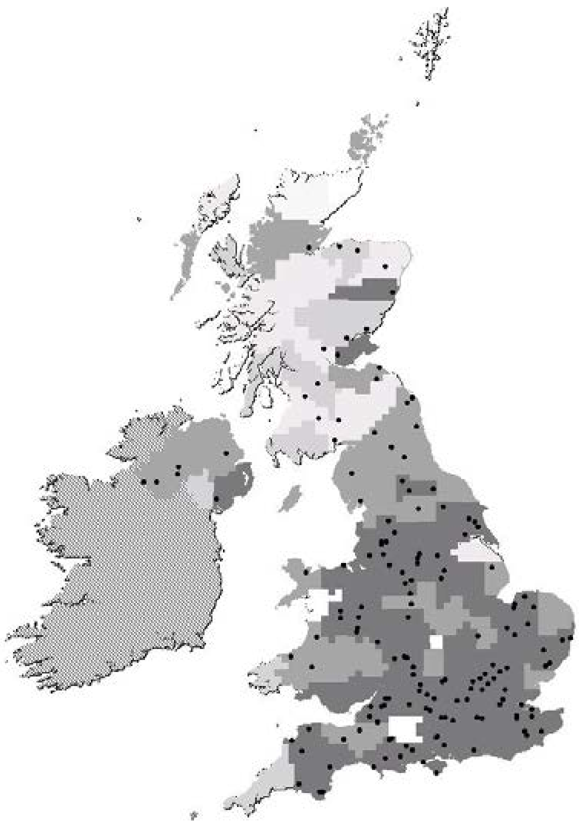

Figure 43. Presence of Stoat on BBS squares in 2000.

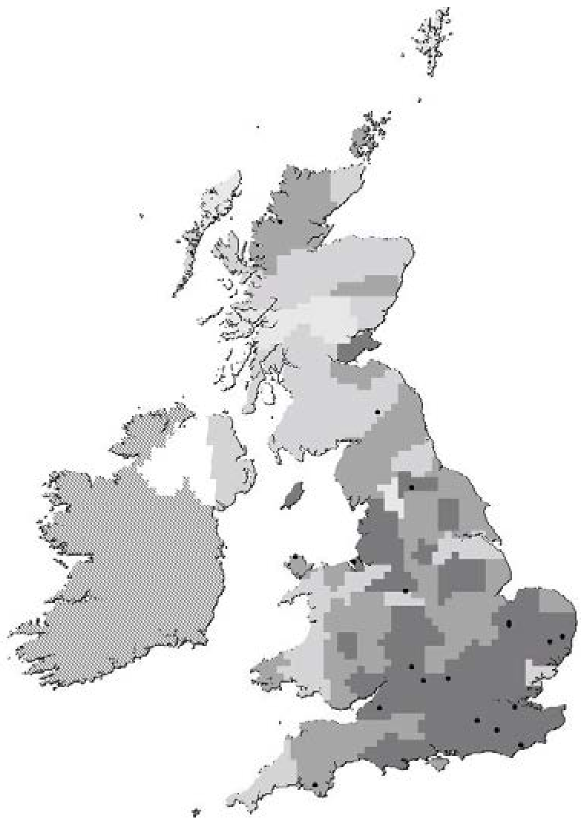

Figure 44. Presence of Weasel on BBS squares in 1995.

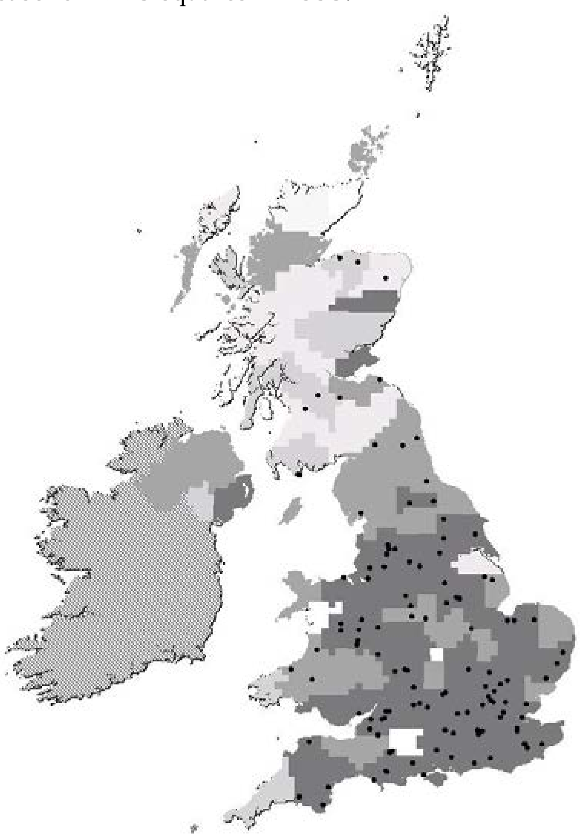

Figure 45. Presence of Weasel on BBS squares in 2000.

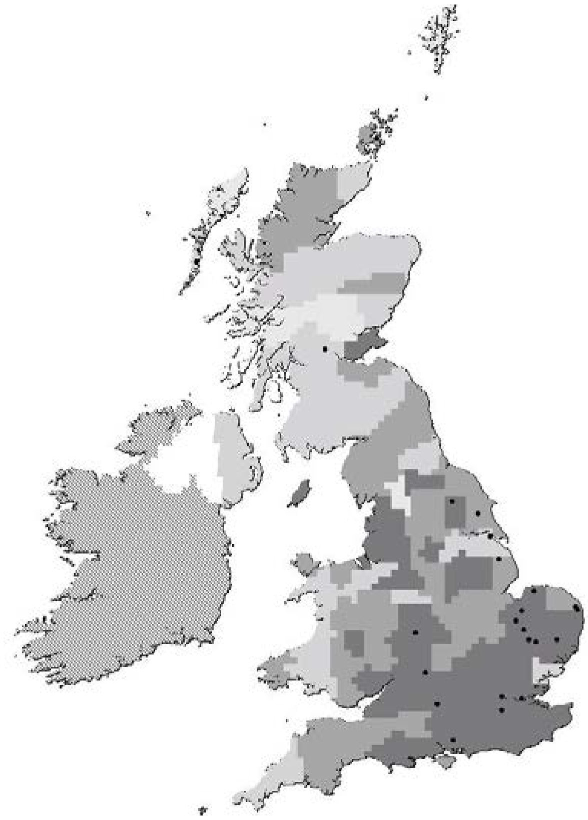

Figure 46. Presence of Brown Rat on BBS squares in 1995.

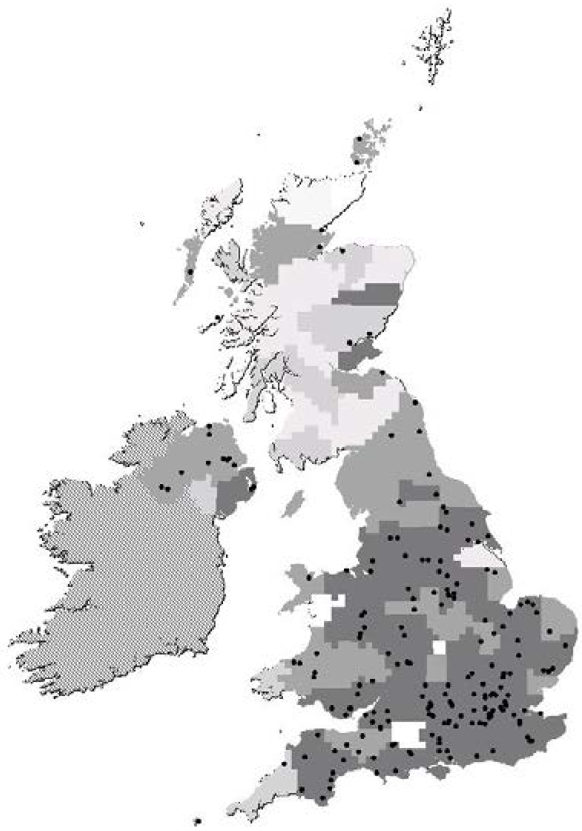

Figure 47. Presence of Brown Rat on BBS squares in 2000.

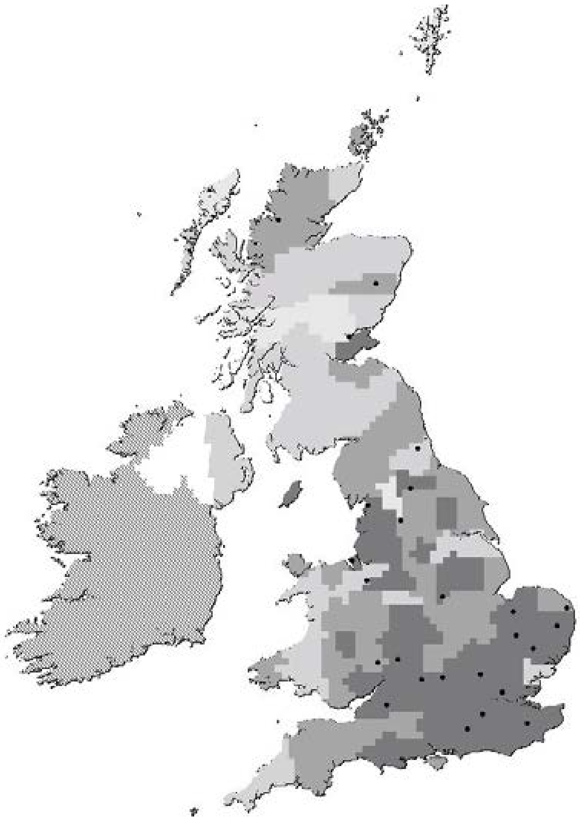

Figure 48. Presence of Hedgehog on BBS squares in 1995.

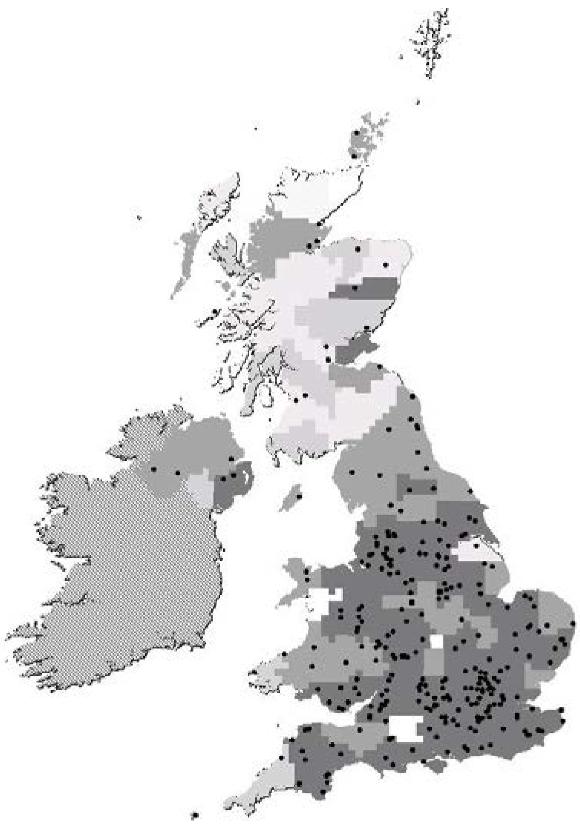

Figure 49. Presence of Hedgehog on BBS squares in 2000.

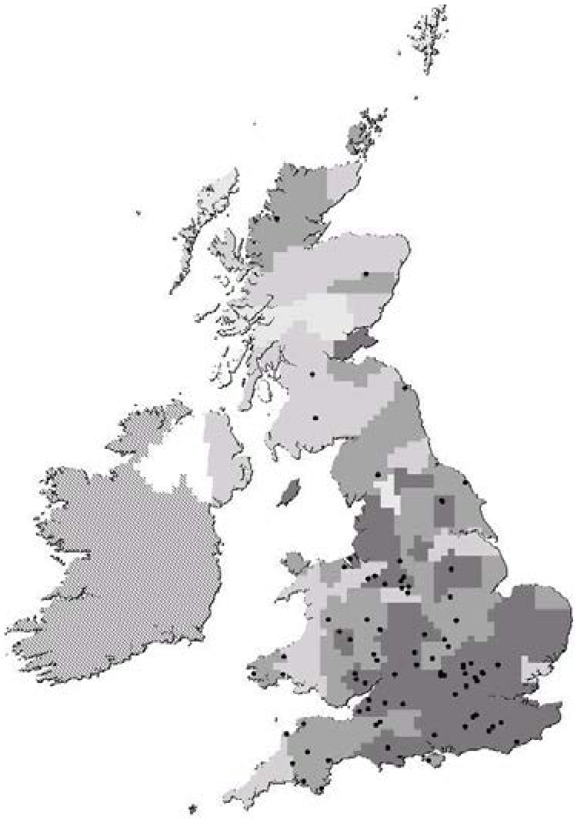

Figure 50. Presence of Badger on BBS squares in 1995.

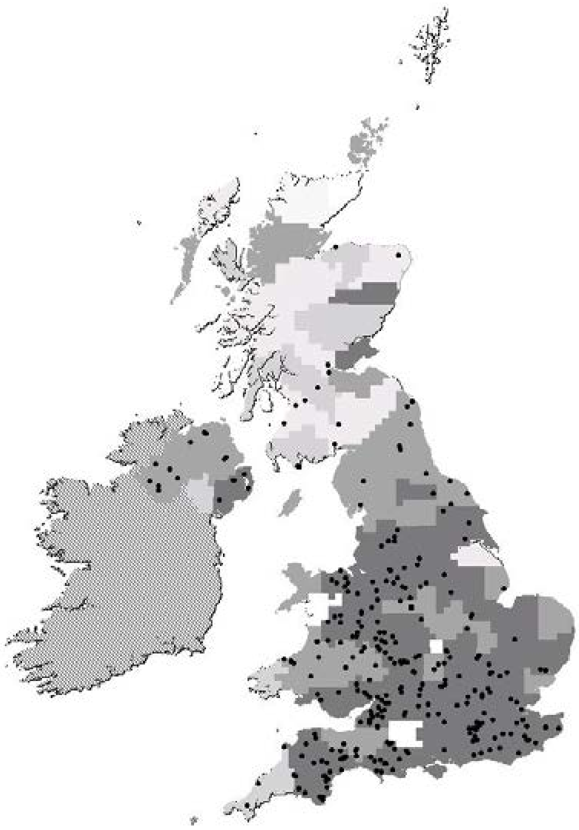

Figure 51. Presence of Badger on BBS squares in 2000.

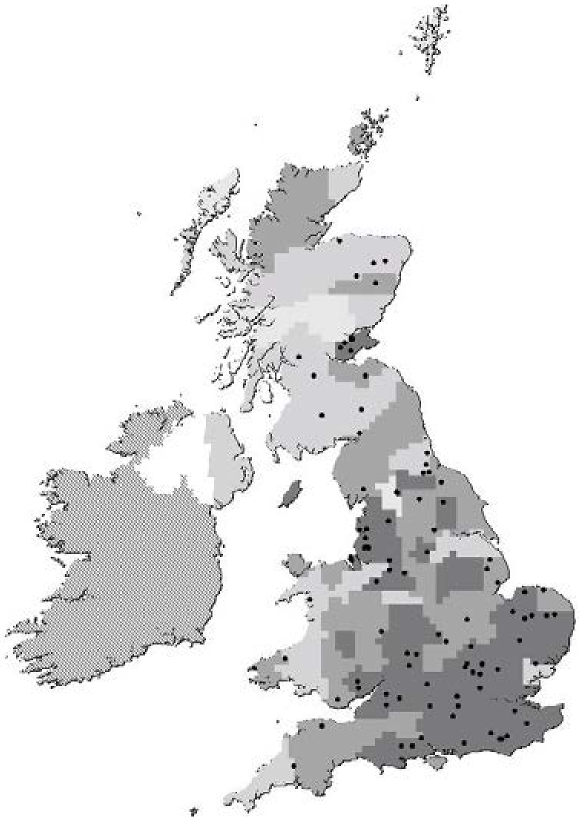

Figure 52. Presence of Mole on BBS squares in 1995.

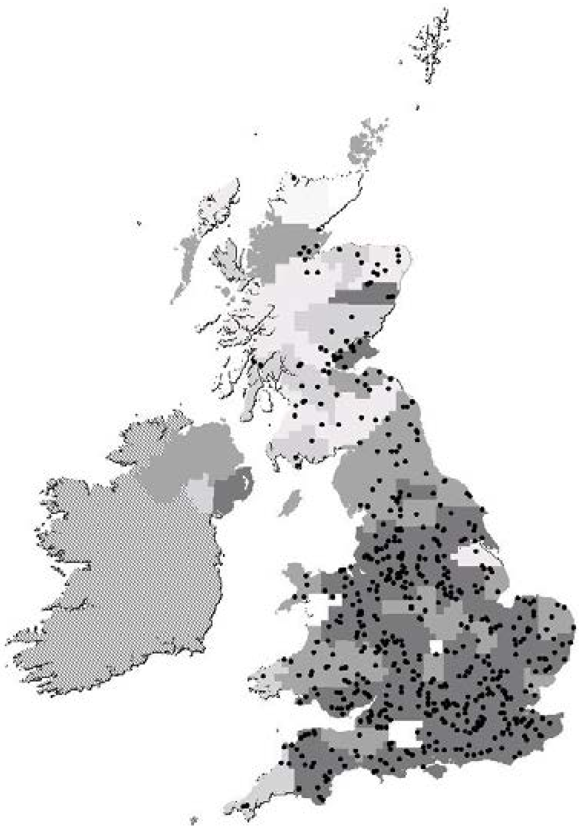

Figure 53. Presence of Mole on BBS squares in 2000.

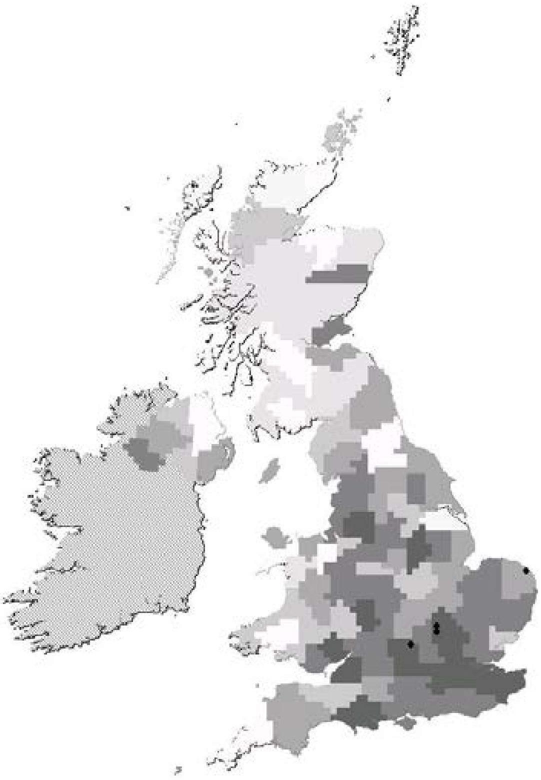

Figure 54. Presence of Chinese Water Deer on BBS squares between 1995 and 2000.

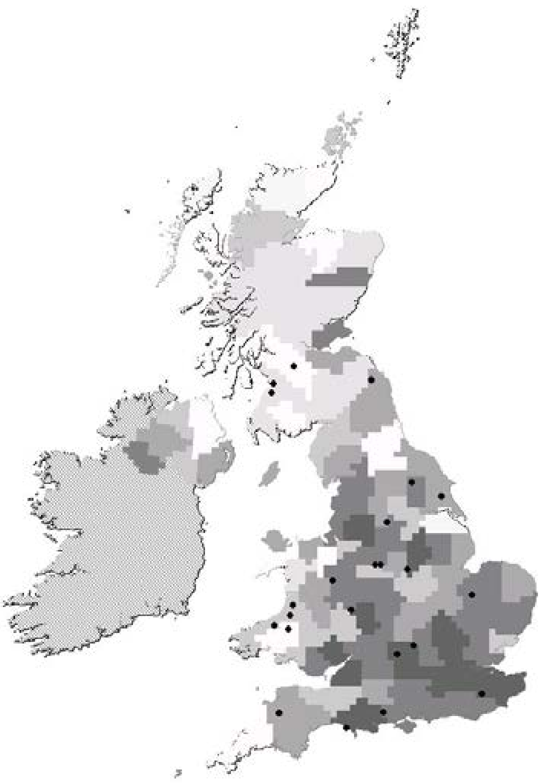

Figure 55. Presence of Mink on BBS squares between 1995 and 2000.

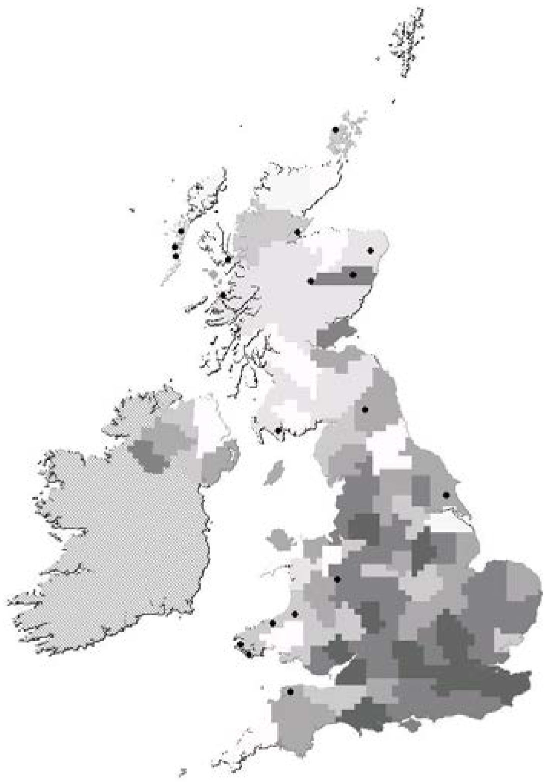

Figure 56. Presence of Otter on BBS squares between 1995 and 2000.

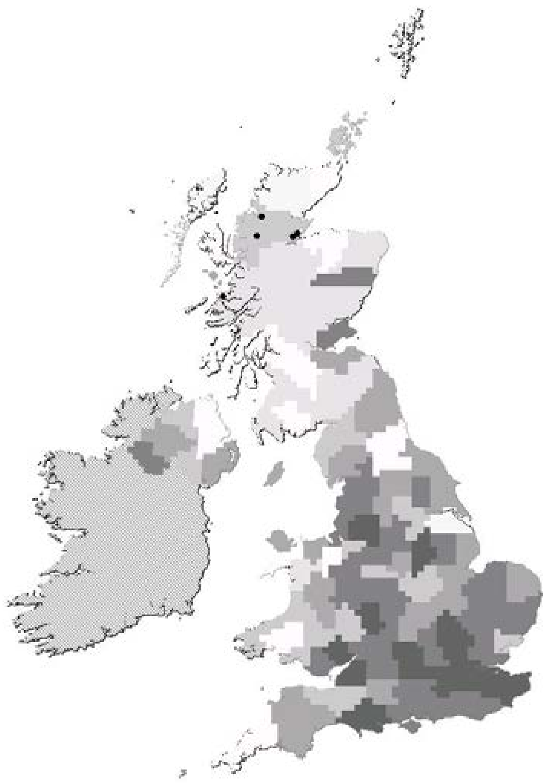

Figure 57. Presence of Pine Marten on BBS squares between 1995 and 2000.

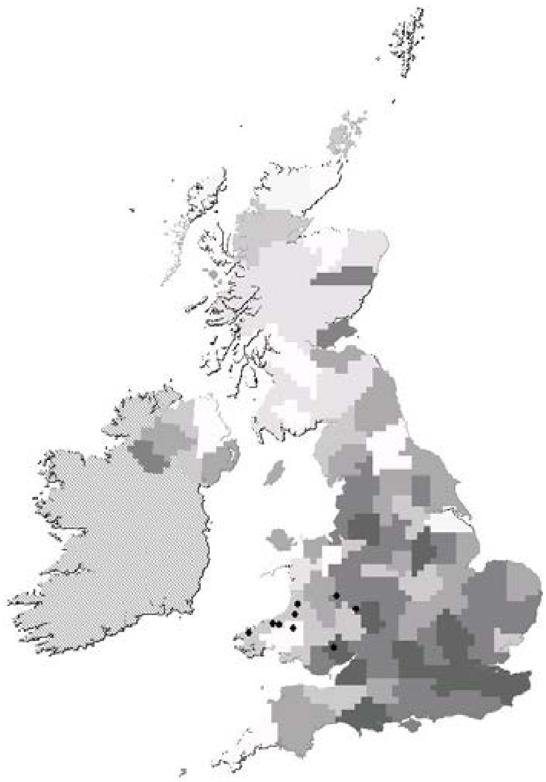

Figure 58. Presence of Polecat on BBS squares between 1995 and 2000.

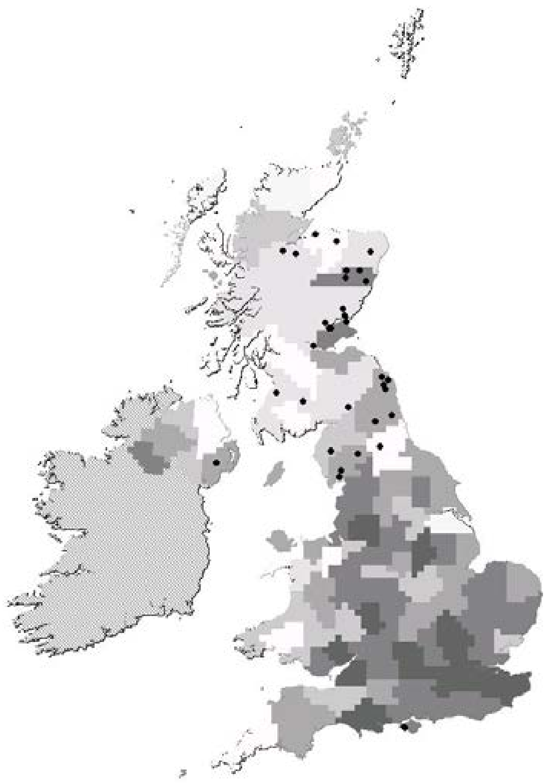

Figure 59. Presence of Red Squirrel on BBS squares between 1995 and 2000.