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Winter Mammal Monitoring
– a pilot study

Authors

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1. Executive Summary

Introduction & Methods

Winter Mammal Monitoring (WMM) is a pilot survey run by the British Trust for Ornithology (BTO) and The Mammal Society for three winter field seasons (2001/02 to 2003/04). The project is funded by Defra, and aims to test the feasibility of using a volunteer-based UK-wide multi-species survey of winter mammals to monitor population trends in a suite of target species.

WMM has two components: a sightings survey to record the numbers of readily-detected and identified mammal species, and a field signs survey to record evidence of the presence of a target suite of mammals whose field signs can be identified by volunteers.

The primary sampling unit is the 1km OS grid square. Both components were carried out along line transects of between 2 and 3km in length. During the first year, sighting surveys were carried out between October and December, and field sign surveys between January and March. In the following years, both surveys were carried out between October and March (with few exceptions).

Volunteers were provided with recording forms, instructions and maps of their allocated square. They were also provided with information on how to identify the target mammal species (e.g. roe deer, fallow deer) by sight, and the field signs of the target species (e.g. badger latrines, molehills). Volunteers were asked to return forms to the BTO or The Mammal Society, by post, for inputting and analysis. During the three years of the project, four different newsletters were sent to current and potential volunteers, thanking them for their participation and providing some preliminary results.

At the start of the project, three species (brown rat, field vole and harvest mouse) were included in the list of field sign species and recording protocols were developed for these species. Between the first and subsequent seasons, the recording of field signs of two species groups (squirrel dreys and deer slots) were dropped, mainly because they were non-specific but also because of difficulties in detection and identification. Recording field signs of dormice (chewed hazelnuts) was also dropped, mainly due to the small amount of data collected in the first year

Results

Volunteers

Over the three field seasons, 907 volunteers carried out at least one survey (just under half of potential recruits that requested forms and were assigned a square). Of these, 553 carried out at least one sightings survey and at least one field signs survey. A small number of particularly dedicated individuals (18) carried out at least six different surveys over the three years of this project. Overall, 176 volunteers undertook either sign or sighting surveys on more than one site.

Based on the questionnaire, 60% of volunteers were male and 40% female. Only 7% of respondents had previously taken part in surveys for The Mammal Society, but more than 50% had previously taken part in surveys organised by the BTO or other organisations. Fourteen percent had taken The Mammal Society's *Look Out for Mammals* training course.

Sites

In total, 1121 sites were surveyed on at least one occasion using either method. Sightings were recorded in 1043 and field signs on 690 sites. Both methods were used on 612 sites. The majority of sites were in England (885), with lower numbers in Scotland (132), Wales (98), the Isle of Man (2) and Northern Ireland (4).

Although square allocation included a random element to minimise bias towards preferred sites, the geographical distribution of volunteers and the likelihood of their take-up of allocated squares inevitably resulted in unequal coverage across regions and landscape types. This means that landscapes such as lowland arable land were over-represented, whereas upland, montane and coastal landscapes were under-represented.

Site Turnover

The turnover rate for both sightings and field signs surveys was high. For sighting surveys, the proportion of sites revisited was 36% between the first and second winters and 49% between the second and third winters. Only 15% were surveyed for sightings in all three years. For the field signs survey, the proportion of sites revisited was 44% between the first and second winters and 47% between the second and third winters. Only 17% were surveyed for field signs in all three years.

The main factors positively influencing rate of revisit are: i) previous commitment, ii) the proportion of sightings or field signs detected, iii) number in the party, iv) the diversity of habitat along the route, v) the proportion of woodland or grassland habitat, vi) the proportion of transects along waterways, vii) participation in The Mammal Society's other surveys, and viii) age of volunteer. The only other significant effects were a higher tendency for sightings surveys to be abandoned after the first season, and a lower revisit rates from volunteers listing their occupation as academic.

Sites that had been visited previously were more likely (57%) to be revisited than those for which there was no previous visit (39%). Overall, there was no effect of the year that the survey was done, but after the first season, a larger proportion of sites where sightings were recorded in the first season were not revisited, compared to those surveyed for field signs. Sites where a high proportion of sections had sightings or signs were far more likely to be revisited than those with a low proportion.

Species coverage

Excluding records of species that were non-specific, domestic animals, feral cats and free-roaming dogs, 29 species were recorded during the Winter Mammal Monitoring sightings survey. Only 11 species (excluding cats and dogs) were seen at least 10 sites. Species such as red squirrel, badger, stoat, weasel and smaller mammals were sighted at very low rates. For the field signs component, the original target species were badger, fox, mole, rabbit, squirrels, and hedgehog. Hedgehogs are not generally active in the winter and hence were dropped from the list of target species. Three species (brown rat, field vole and harvest mouse) were added to the list of field sign species and recording protocols were developed. Results showed that brown rat and field vole could be monitored by these methods but that harvest mouse signs were detected at too low frequencies. In the first year, we also trialled the recording of squirrel dreys, deer slots and hazelnuts chewed by dormice. After the first season, these were all dropped, the first two because they were non-specific, and the dormice hazelnuts because of very low rates of detection.

Statistical Methodological Assessment

Power analyses – assessing the survey's capacity to detect population change

The crucial question is whether WMM will be able to provide information on changes in abundance of the target mammal species that can be used in conservation assessments (e.g. red listings, species of conservation concern) and with sufficient confidence in the measured changes. This assessment should take into account the magnitude of change that is thought to be an appropriate threshold (e.g. a 25% decline), the statistical power to detect a particular change, and the sample size. These will differ between species, between sightings and field signs, and the measures of abundance used (presence in the square, proportion of transect sections occupied, counts). Our assessment of our capacity to monitor each species is based on power analyses.

We carried out simulations using the empirical WMM data (the proportionate change between years) to determine the minimum detectable change (MDC) that could be detected for a given significance level and power from a range of sample sizes. This was carried out on both a matched dataset (where there were repeated visits to the same site) and an unmatched dataset (treating years as independent samples), yielding a series of graphs from which the MDC for a range of sample sizes could be extracted.

For sightings, the analyses based on repeat visits, using the proportion of transect sections in which the species was recorded, proved to be most powerful and hence those results are presented. The sightings data showed that for seven species (rabbit, brown hare, fox, grey squirrel, roe deer, fallow deer – and possibly muntjac), a decline of 50% and an increase of 100% could be detected with a WMM sample of 500 sites, with 95% confidence. Moreover, for two species (rabbit and grey squirrel), it would be possible to detect a decline or an increase of only 25% with 500 sites, with 95% confidence. If the sample of WMM squares was increased to 750-1000 sites, we would also be able to detect a 25% change in the abundance of fallow deer. However, it should be noted that 'abundance' in this context, and for field signs, strictly refers to changes in the proportion of transect sections with positive records of sightings (or signs) and not necessarily to the magnitude of change in numbers of animals.

The power analysis of field signs data showed that a change of ±25% could be detected for all signs except harvest mouse nests, with a sample size of 600 or less. Furthermore, for five species (brown rat, fox, field vole, mole and rabbit) sample sizes of 250 would be sufficient to achieve MDCs of this size.

With respect to monitoring mammal populations in different regions, it seems that sample sizes in some of the Scottish environmental zones are adequate (30-60 sites per zone) to detect large changes (declines of 50% or increases of 100%) for species such as field vole, mole and rabbit (using field signs) or grey squirrel and rabbit (using sightings). It should be possible to monitor a number of species in Scotland overall, as well as in the three England and Wales environmental zones.

The power analyses also highlighted three important methodological factors. Firstly, the sample sizes required to show a given change using signs were always much smaller than the sample required for sightings. Although this was only based directly on two species (foxes and rabbits), the pattern was evident throughout the power analysis. Secondly, a sampling strategy based on repeated visits to the same site, compared to randomly drawing samples of new sites each year, was much more powerful. In 94% of comparisons, the sample sizes for independent samples were larger than those required for repeated-measures, in many cases four or five times larger.

Comparison with the Breeding Bird Survey

Numbers and occurrence

The BTO/JNCC/RSPB Breeding Bird Survey (BBS) is a volunteer-based UK-wide survey organised by the BTO with RSPB and JNCC, running since 1994. In 1995 the BTO expanded its scope to collect information on mammals as well. BBS observers were asked to record counts of all mammals seen during their visits, and any evidence (such as field signs) of their presence. Approximately 85% of ca. 2000 participants provide this information annually**.** There is, therefore, considerable overlap in the species covered by both surveys, particularly for widespread species such as rabbit, brown hare, roe deer, muntjac, fallow deer, grey squirrel and red fox. However, WMM surveyors recorded almost no hedgehogs, which hibernate much of the winter period.

Of the species counted, absolute numbers of rabbits and brown hares were significantly higher during the summer BBS than during the winter WMM surveys, whereas numbers of grey squirrel and roe deer were higher during the winter compared to at least one of the BBS visits (early or late). None of the other species showed any significant differences. However, of species compared using evidence from field signs, rabbit, brown rat, fox and mole (the latter only in year 2) were detected more frequently during the winter than the summer. This is most likely due to the dedicated effort to search for field signs on WMM surveys. There is no standardisation of effort in BBS, but it has been possible since 2002 to distinguish between evidence based upon field signs, dead animals, visits other than the counting visit and local knowledge. With the exception of fox signs, which were recorded in fewer squares in the second winter, there were no differences in frequency of occurrence between the two years of the survey (BBS or WMM). There were also no marked differences in frequency of occurrence between matched and unmatched datasets.

Comparing annual changes between WMM and BBS

We found no significant differences in the inter-annual rates of change between WMM and the BBS (either early or late) for the seven species that could be compared by sightings (rabbit, brown hare, fox, fallow deer, muntjac, roe deer and grey squirrel). Only grey squirrel showed a consistent pattern – an increase – across surveys. However, because of small sample sizes and high variance, our capacity to detect differences was low for most species. Although the direction of the trends sometimes differed between winter and summer surveys, the only evidence of a significant difference was for brown hare, based on the matched dataset, and this was a very marginal level of significance. Based on field signs, foxes appeared to be less common during the second winter (but not the second summer) but there were no differences in the results based on field signs for any other species. Differences, whether significant or not, might be expected due to real changes in the numbers (e.g. adults during the winter versus adults and offspring during the summer) as well as differences in the direction of change of key environmental factors (e.g. food supply) between the two seasons.

Factors influencing measures of abundance for each species

Single species models using data from sites over all three field seasons provided information on parameters, both environmental and methodological, that influenced measures of abundance. These differed among species, but there were some broad patterns. It is important to note that for species with few data (e.g. muntjac), it is difficult to detect the influence of as many different factors. The results of the single species models can be compared to the analyses of factors using the general mammal response variable. However, although the latter is likely to be particularly useful in assessing the influence of the results on volunteer behaviour, it is less relevant to the assessment of variables such as habitat, because the relationships with many environmental factors are likely to differ across species.

Of four target species monitored solely using field signs, duration of survey had a positive effect on the proportion of transect sections with field signs for badger and rat but not for mole or field vole. Start time was important only for field vole, and number of observers was important only for mole. Latitude had an effect on badger, mole and rat (all were more abundant further south). Longitude had an effect on all four species, with badger and field voles more abundant in the west and rats and moles more abundant in the east. No weather variables had any effect. Habitat diversity had a positive effect on all four species, and all were influenced by habitat type. Three species were influenced by the presence of one of the linear features, but all differently. There was no effect of year or month.

Of five target species monitored in sufficient numbers to detect biologically important changes in abundance, duration influenced the number of sightings of squirrels and hares but had no effect on sightings of any of the deer species. Year and month influenced sightings of grey squirrel, and number of observers influenced positively sightings of muntjac. Latitude influenced four species, with roe deer, fallow deer and squirrels more common in the south, and brown hares more common in the north. Longitude also had an effect on four species. Habitat diversity positively influenced numbers of squirrel, hare and muntjac, and habitat type influenced numbers of all species. Four species were influenced by weather variables.

Two species (fox and rabbit) were monitored by both sightings and field signs, and additional models were run to test for the effect of survey type and its effect on year and other variables. Rabbit sightings were recorded in a significantly lower proportion of sections than signs (burrows). Both measures were positively related to duration and habitat diversity but not to year, month, start time or observer number. Farmland-related landscape types and the presence of hedges had a significant positive effect. Survey type interacted with start time, with more sightings but not field signs recorded on routes started later in the day.

Fox sightings were also recorded in a significantly lower proportion of sections than their signs. There was no effect of year overall but this differed between surveys. Sightings were significantly lower in the third year but there was no difference in the frequency of signs. A significant seasonal effect was evident, with the proportion of transect sections containing foxes or their signs increasing throughout the winter. No significant effect of either number of observers or start time was identified, but duration had a significant positive effect. Fox sightings and signs were greatest in lowland England and Wales and at lower latitudes. There was no effect of habitat diversity or linear features but sightings and signs were greater at sites with higher proportions of rough grassland or woodland.

Overall, of the methodological parameters, duration had a positive effect on detection of the two more cryptic field signs (badger latrines/setts and rat burrows) and sightings of the smaller species (squirrel and brown hare). Number of observers had little overall effect, and, surprisingly neither did the month in which the survey was carried out (except for grey squirrel). Weather variables had no effect on the detection of any field signs and little effect on sightings. Where they were significant, no more than one weather variable was retained in the model, and these showed that brown hare, grey squirrel and muntjac were more often seen on colder or less rainy days.

Of the spatial and habitat parameters, latitude and longitude were clearly important for most species – reflecting both east-west and north-south gradients in abundance. In general, these confirm the spatial patterns of abundance revealed by previous bespoke surveys of these species, such as for brown hare and badger, or the known distribution of the species, e.g. muntjac. Habitat diversity had a positive effect on all measures except for deer sightings, and most species showed some preference for particular habitats (e.g. woodland or arable land). At least one of the linear features was important for field signs of three species, as well as for sightings of grey squirrel and brown hare. Environmental zone was difficult to assess in the full models because it was confounded with latitude and longitude. When these variables were removed from the models, environmental zone was important for most species, reflecting the known distributions of the species.

2. Introduction

Britain's terrestrial mammal species differ considerably in population status, from those that are threatened or declining (e.g. water vole) to others that have increased markedly in number and range (e.g. roe deer), occasionally achieving pest status. This list also includes many species that have been introduced to Britain, since Norman times (e.g. rabbits) to recent introductions such as American mink.

Effective conservation action needs to be underpinned by a programme of mammal monitoring, in order to provide reliable information on their status, distribution and population trends. A range of organisations currently monitor British mammals, but there is no comprehensive national mammal monitoring scheme that encompasses the full range of important species. National monitoring programmes need to be designed appropriately, and to be as consistent as possible across regions, habitats and species, to allow interpretation of results and the setting of conservation priorities. Studies commissioned by Department of the Environment, Transport and the Regions (DETR) and Joint Nature Conservation Committee (JNCC) provided detailed recommendations on how to take mammal monitoring forward in a more coordinated way, and the Tracking Mammals Partnership is currently starting to implement some of the recommendations of these studies.

Amongst the recommendations in the report prepared by the British Trust for Ornithology (Toms *et al*., 1999) was the development of a multi-species winter sightings and field sign transect survey. Mammal sightings data, collected each summer as part of the BTO/RSPB/JNCC Breeding Bird Survey (BBS), had already provided evidence that a number of easily-detected species could be monitored effectively using multi-species sightings transects, at least in the summer. However, other species, especially the more cryptic ones, are best monitored by recording field signs. The proposed target species for the sign transects were mole, hedgehog, rabbit, grey and red squirrels, badger and fox. Rabbits can be effectively monitored using warren characteristics. The larger nocturnal species such as badgers and foxes can be monitored relatively easily using field signs (see Wilson *et al*., 1997). However, the squirrel species are problematic because it is not possible to differentiate the field signs of red and grey squirrels. This will complicate monitoring in the areas of overlap or areas of possible range expansion by grey squirrels. After assessing the potential methods for monitoring mammals by field signs, it was decided to exclude hedgehogs, which hibernate much of the winter, but additionally test the feasibility of monitoring brown rat, field vole, harvest mouse, dormouse and deer (all species combined) using field signs. Based on these experiences and with the potential limitations of the proposed methods in mind, the BTO and The Mammal Society won a tender to design and test a multi-species winter monitoring scheme for mammals in the UK that included recording using sightings and field signs.

Aims

The main aims were:

- To design and pilot a volunteer-based winter mammal monitoring survey for the UK
- To assess the scale of monitoring needed to detect significant long-term changes in abundance and distribution of as many mammal species as possible across the UK.
- To assess the feasibility of this scheme, including the accuracy and repeatability of the results, to provide clear recommendations for its implementation and to produce detailed costings.

Data collected during the first year of the pilot survey allowed spatial variation in mammalian abundance to be investigated. Data were validated where possible by comparison with other national surveys that used similar techniques to record mammals. On the basis of both feedback received from participants and the results of these initial analyses, the field recording methods used by volunteers were revised prior to a second and third season of data collection (winter 2002/03 and winter 2003/04, respectively). Running the monitoring programme for three years not only allowed mammal presence and abundance to be compared between years, but also permitted comparison of patterns of mammal distribution, enabling discrimination between robust relationships, i.e. those which prevailed in the data from all years, and those that were apparent only in one or two of the years and which may, therefore, have been more spurious

3. Survey Methods & Organisation

Survey Design

The pilot survey comprised two main components: a winter sighting transect survey for recording medium to large-sized mammals and a sign transect survey for recording evidence of a target group of species easily distinguishable by their field signs. The design and organisation of both components required close coordination in order to collect complementary information from the same sites and to ensure that the surveys could be run efficiently. Although each survey required the development of particular sampling protocols, the recording forms, systems for data capture, promotion, publicity and general operations applied to both surveys.

The spatial coverage of the survey was the whole of UK and the primary sampling units for both schemes were 1-km squares of the National Grid. This is the sampling unit used in most of the BTO's broad-scale surveys, including the Breeding Birds Survey (BBS), and was used for many national mammal surveys [brown hare – Temple, Clark & Harris (2000); badger – Clements, Neal & Yalden (1988), Cresswell, Harris, Jefferies (1990); Wilson, Harris & McLaren (1997)]. In the first year, squares were assigned randomly within geographic regions (approximately county-sized, that matched the BTO's standard regional units for volunteer surveys) and volunteers were allocated to one of the random squares in their area. The number of squares selected per region was initially based on the number of potential volunteers that had shown an interest in the survey. Hence, we employed a stratified random sampling design, where the strata were geographical regions of known size. This allowed correction for regional differences in sampling intensity.

In the two subsequent seasons, new volunteers, and existing volunteers that requested a new site, were allocated 1km squares selected at random from an area within 10 km from their home address. The selected square was first checked for suitability, in order to exclude sites comprising a high proportion of coast, urban areas or problems with access (e.g. motorway roundabouts, artillery ranges, etc). This procedure retained the random element at the local scale, but resulted in higher coverage in areas of higher volunteer density (e.g. in the southeast). The latter could be corrected by post-hoc stratification if considered necessary.

Field Methods

Field protocols for the sightings transects

Winter sightings transects were carried out by asking observers to walk line transects of approximately 2-3km length within their 1km square, matching the length used on the BBS and for the national fox survey. The ideal route crossed the 1km square twice on lines far apart enough to minimise double counting, but volunteers were given the flexibility to select a route along convenient linear features such as roads and paths that were practical and safe. In the first season, volunteers carried out their sightings survey once during the period October 2001 to December 2001. In the following seasons, sightings surveys were carried out at any time during the winter period from October to April. In order to allow the data to be compared to those collected on routes walked by BBS observers during their summer bird surveys, and to simplify fieldwork for volunteers, BBS participants were asked to walk their BBS routes. The transect route was recorded on the map provided. Surveyors were asked to record the numbers of each species of mammal seen in each transect section, and the numbers in each group. During the first season, they also recorded the perpendicular distance from the transect line.

Volunteers were asked to carry out their survey at first light to ensure that they were the first active person in the area and that any mammals present had not been scared off by the activity of other people such as dog walkers. Because this was not always possible, we also asked volunteers to record the timing of their survey in order to be able to test retrospectively for an effect of time of day and duration of survey.

Field protocols for the sign transects

Sign transects were undertaken along routes selected in exactly the same way as for the sightings survey, and where both types of survey were undertaken, along the same route. During the first field season, field sign surveys were carried out in the three months between January and March 2002. In the following two winters, the field sign survey could be carried out on any date between October and April. Routes were subdivided into transect sections of 100m in the first season, and into transect sections of 200m in the two following seasons. The recording of field signs was quantified as the presence/absence of a particular field sign per section. Volunteers were able to opt out of searching for some species during the sign survey if they did not feel confident about their identifications. Moreover, some field signs are only found in particular types of habitat (e.g. harvest mouse nests in tall grass) and observers were asked to search for those signs only in the relevant habitat. Hence, the measure of the abundance of each field sign was the proportion of transect sections searched in which positive evidence of field signs were found. Field signs of non-target species were also recorded for subsequent processing if needed.

The survey protocol requires that observers carry out a search for easily-recognisable field signs located in the wider countryside. There are potential problems with this approach, especially when some of the field signs require very different search methods (e.g. fox faeces and squirrel dreys). The target species for the signs transects, and the appropriate field signs, were as follows:

Mole: This species leaves characteristic mole hills, which are most obvious during January to March when vegetation is at its lowest and moles are repairing frost and flood damage to their tunnel systems (Gorman & Stone, 1990). Observers were asked to record the presence/absence of molehills per section of transect.

Rabbit: Our approach to monitoring rabbits was to use warrens, in particular, the presence of active warren entrances per section of transect. Although this technique is unlikely to provide a linear relationship with rabbit numbers, especially at high densities, the technique is quick and relatively easy to apply in the field.

Grey and **Red squirrel:** Winter drey counts can be used to monitor squirrel abundance (Gurnell & Pepper, 1994) but the main problem is that there are no field signs that can be used to differentiate the two species. Observers recorded the number of dreys per section, but in practice would be unlikely to record any dreys unless walking through, or alongside, wooded areas, urban green areas, or along hedgerows with trees.

Badger: Field signs are most conspicuous in late winter, when vegetation is at its lowest and when badger activity, associated with the birth of the cubs and territorial behaviour, is at its highest (Neal, 1986). Surveyors were asked to record the presence/absence of badger latrines and faeces in each transect section. Any setts found on the transect were recorded using the protocols developed by Harris for the two national badger surveys (Cresswell *et al*., 1990; Wilson *et al*., 1997). Sadlier *et al.* (2003) have been developing a badger monitoring technique based on faecal counts along linear features. Use of dung pits by badgers is related to population density and field trials have shown that >99% of badger faeces are deposited on linear features. Problems might occur because faecal persistence is affected by soil type or weather conditions, but these factors have been quantified by Sadlier *et al.* (2003), and could be used to adjust data interpretation.

Fox: Surveyors recorded the presence/absence of fox scats per section of transect. Late winter is ideal for recording fox field signs because the scats decompose less quickly than in summer and are not hidden by vegetation (Kolb, 1996). Experience gained from running national fox surveys (also based on winter faecal counts, see Webbon *et al*., 2004) can be used to interpret the relationship between the number of scats and fox abundance.

Trials to assess field sign methods for additional species

In order to broaden species coverage, four additional species of conservation concern were trialled in the field sign transects along linear features (harvest mouse, field vole, brown rat and dormouse). In Britain, roughly twenty species of avian and mammalian predators are largely dependent on two species of prey, the field vole and the rabbit (Harris *et al*., 2000). Hence, small changes in the numbers of these key prey species could have significant ecological impacts.

Field vole: Surveyors were asked to record the presence of field vole nests or runs, based on timed searches for five minutes in suitable habitat, if it occurred in each section of transect. Suitable habitat was defined as patches of rough grass along the linear feature.

Harvest mouse: Surveyors were asked to record the presence/absence of breeding nests during timed searches of five minutes in suitable habitat (patches of rough grass) if it occurred in each transect section.

Brown rat: To monitor brown rats, surveyors were asked to record the presence/absence of active rat holes in each transect section. An inactive hole was defined as one that is completely or partially blocked with vegetation or debris, or where the bottom of the hole is visible from the surface. Their characteristic burrows are most common along linear features, especially in degraded habitats where they are particularly easy to find.

Dormouse: To monitor dormice, surveyors were asked to carry out timed searches of five minutes in each transect section where there were mature hazel trees. Hazelnuts that appeared to have been chewed by dormice were collected and forwarded to The Mammal Society for verification.

Deer species: To monitor deer species, volunteers were asked to record the presence of deer footprints along their route. Because of difficulties in distinguishing between deer species by slots, this is a generic measure of the presence of deer and is not species-specific.

Field protocols for the collection of habitat data

As part of the winter mammal monitoring project, all volunteers were asked to collect simple habitat data. Whilst habitat data are not necessary for a monitoring programme *per se*, they are a valuable adjunct and enable further exploration of the factors influencing population changes. Moreover, habitat data collected by volunteers provide an immediate measure of habitat change. Habitat variables and classifications based on remotely-sensed Centre for Ecology and Hydrology, CEH (formerly Institute of Terrestrial Ecology, ITE) land use data formed an important part of models comparing our data to other surveys investigating differences in sampling. Habitat data are also important in the interpretation of the results and can be used to test the efficiency of sampling in different habitat types. The habitat recording form enabled the observer to record up to three linear features (e.g. road, hedgerow) and the main habitat type in each section of their transect (100m in the first season and each 200m section in the following two seasons).

The Questionnaire

Following the field signs component of WMM in Year 1, a questionnaire, the Winter Mammal Monitoring Questionnaire, was produced by The Mammal Society with contributions from the BTO. After circulating the draft to members of the Interim Working Group for Mammal Monitoring in the UK (now the Tracking Mammals Partnership) for comments, it was sent to all people who had expressed an interest in the project. The questionnaire had four aims:

- To find out why people had or had not taken part in the project
- To find out what the volunteers' experience had been of taking part in the project and what if anything they would like changed if a second year to the project was carried out
- To assess the survey techniques e.g. the ease of undertaking transect counts, collecting habitat and signs information etc.
- To find out the volunteers' past experience in surveying and in mammal surveys to enable us to stratify the data returned for analysis and comparison.

The questionnaire was comprised of 27 questions, divided up among six sections on (i) participation in the survey, (ii) the experience and affiliation of the volunteer, (iii) the ease of taking part in the project (were the instructions and forms easy to understand? was there enough support?), (iv) their experience on this survey and in identification, (v) their enjoyment of the survey, and (vi) their motivation. These questions were designed to answer the four aims of the questionnaire and provided the volunteers an opportunity for feedback.

The questionnaire was sent to all people who had expressed interest in the project, not just those who carried out a survey, as we were interested in the reasons for declining to take part in the project. The questionnaire accompanied the second newsletter and all returns were received by The Mammal Society by 10th June, 2002. Hence, this dataset relates to potential participants during the first season, and only those that completed the questionnaire.

Changes to survey design and field recording protocols in 2002/03

Although most elements of the sightings and field sign surveys were consistent throughout the duration of the project, there were important changes in field recording methods between the first field season (2001/2002) and the subsequent two field seasons (2002/2003 and 2003/2004). This section describes the changes and their rationale. During direct communication with WMM project participants and through the responses to questionnaires sent out with the survey packs at the beginning of the winter, a number of issues were raised concerning the protocol of the WMM project, which we considered during the analysis of the data. While it is important that the quality of data collected should remain high, it is vital that the volunteers remain content and enthusiastic if they are to continue to survey their sites. We sought, therefore, to alter the methodology of the survey such that the problems experienced by volunteers were addressed without compromising the high standard of the data collected.

a) Transect section lengths were changed from 100m to 200m

During the 2001/2002 season, participants were asked to divide their transect route into 100m sections and search each section in turn for field signs, recording either a series of counts (e.g. badger setts) or the presence or absence of each type of sign (e.g. molehills, fox faeces). As each survey ranged from 2 to 3 km in length, the majority of participants had to perform this search on at least 20 occasions during the course of the field signs transect. The survey protocol stated that in areas of suitable habitat, participants should spend up to five minutes searching for signs of field vole and harvest mouse in each transect section. Therefore, the field signs phase of the survey in this year demanded of participants much time and effort**.**

The number of sections also influenced observer effort during the habitat phase of the survey because habitat information was recorded in each transect section. As many participants found habitat recording the most arduous and least interesting part of the survey, we anticipated that reducing their workload at this stage may have increased their enthusiasm for the project as a whole.

Although some of the finer detail concerning habitat type may be lost, the main mammal species covered by the WMM project were likely to be relatively mobile and the 1km square was used, therefore, as the sampling unit for most analyses. Increasing the length of the transect sections also speeded up the data entry process as there were fewer lines of habitat and field sign information to input for each site.

It was decided, therefore, to increase the length of transect sections from 100m to 200m. Using 200m transect sections also makes the data directly comparable to that collected during the BBS, which a number of WMM volunteers were also undertaking.

b) Habitat codes

A number of volunteers found the habitat recording protocol to be very complicated and mentioned difficulties in distinguishing some of the habitat features. The categories that caused the most problems were ‘Improved Grassland’ and ‘Unimproved Grassland’, which represent a gradient from very rough grassland, used for seasonal grazing in upland areas, to rich lowland pasture heavily improved with fertilisers. While unimproved grassland can often be found at lowland sites and improved grassland at upland sites, maps of the distribution of these two habitats as reported by WMM volunteers (Fig. 1) suggest that in some cases they may have been confused or misclassified. As this distinction is unlikely to be of great ecological significance for the majority of the mammal species surveyed by the WMM project, the two habitat types were combined as ‘Grassland’ for future survey years, as has been the case in many recent publications concerning mammal distribution in the UK.

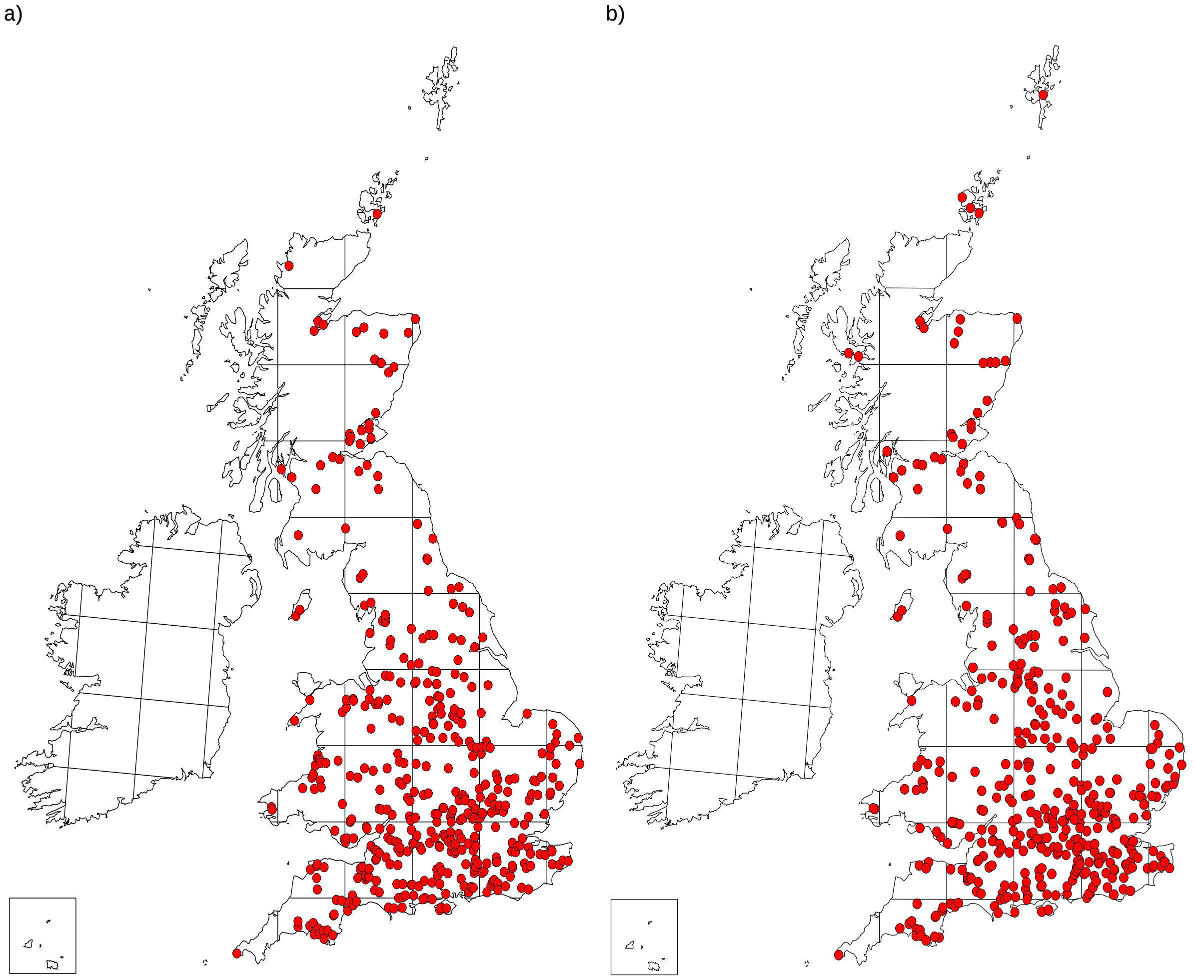


Fig. 1. Comparison of the national distribution of the two grassland habitat categories used in the survey; a) improved and b) unimproved – as recorded by the 2001/2002 WMM volunteers

c) Rationale for dropping the recording of non-specific field signs

Under the 2001/2002 pilot year methodology, WMM participants were asked to search for 11 types of sign left by a total of 10 different species/groups. However, the recording of three of the field signs proved to be problematic. Several volunteers found it difficult to differentiate deer slots from those of livestock, particularly sheep. Identification of squirrel dreys also proved to be difficult, with birds' nests and natural collections of leaves and twigs causing some confusion. As neither of these signs are species-specific, it was felt that both could be removed from the survey, simplifying the recording protocol and increasing observer morale without losing a great deal of information.

Volunteers during the pilot year were also asked to collect any hazelnuts with dormouse teeth marks on and send them to The Mammal Society who could confirm the identification. Very few specimens of gnawed hazelnuts were received from volunteers and only a few of those had been chewed by dormice. Removal of this species from the field signs phase protocol would cause minimal loss of data and would benefit participants. Recent studies (Eden & Eden, 1999) have also shown that dormice are much less dependent on areas of hazel woodland than previously thought. The established next-box survey provides in any case a more informative monitoring system (National Dormouse Monitoring Programme).

d) Changes in the timing of the sightings and field sign surveys

Some field signs may be hard to observe, particularly if they are obscured by thick vegetation. As the vegetation dies down over the winter period, such signs may become progressively more visible. During the pilot year, participants were, therefore, asked to perform the sightings phase of the survey during the first half of the winter period (October-December) and the field signs phase during the second half (January-April). However, many participants have a limited amount of time available in which to perform their survey visits, and during the winter period, survey opportunities are likely to be further restricted by periods of bad weather. In order to maximise the window of opportunity in which participants would be able to carry out their survey, from the 2002/2003 season onwards it was decided that the field signs and sightings phases could be carried out on any date and in any order within the specified winter period as long as they are not performed simultaneously. This protocol also makes the results of the sightings and field signs phases more directly comparable as data from each will have been collected over the same time period during the year.

e) Rationale for dropping distance sampling

Distance sampling methodology allows the density of individuals in a defined area to be estimated by calculating a detection function based on the probability of an individual being observed as its distance from the observer increases. It was hoped that this information could be used to produce national estimates of population size for a wide range of mammal species. During the 2001/2002 season, participants were, therefore, asked to estimate the distance of each mammal seen during the sightings phase from the transect route and to mark the position of the mammal on a map of the site. Several participants expressed concern that their estimation of distance was not of a high enough standard.

When analysing the data, it became apparent that the number of species for which density estimates could be calculated was limited. The minimum number of observations recommended for analysis of distance sampling data is 60-80 for each species. Only six species met this requirement – brown hare, fox, grey squirrel, rabbit, roe deer and fallow deer. Furthermore, if a species occurs in a herd or group, is it important to model detection at the group level rather than at the individual level, otherwise biases may occur due to the fact that large groups are more likely to be seen than small groups. The majority of fallow deer observations were of herds and the number of herds seen was insufficient to allow analysis of the distance data. In addition, if a species occurs in a number of habitats in which the detection of that species is likely to vary, e.g. woodland and open farmland, detection functions should be calculated for each habitat separately. Only rabbit, brown hare and grey squirrel were observed in sufficient numbers to allow habitat-specific detection functions to be calculated.

Even for these three species, however, there are still a number of potential problems with the data (see Appendix 1). Standard distance sampling analysis assumes that detection at zero distance from the line being walked is 100%. Because rabbits inhabit burrows, a certain proportion of the population is likely to be underground at any one time, so this assumption is invalid. In addition, rabbits often occur in dispersed groups, making it difficult for observers to decide whether to record distance at the group or at the individual level.

There are also biological reasons for treating estimates of density for grey squirrels or brown hare, collected during this survey, with caution. Grey squirrels are known to hide from observers when encountered at close range, which could result in an underestimate of numbers in the closest distance category. Brown hares tend to avoid linear features, preferring open areas where visibility is better and are, therefore, unlikely to be found in the closest distance category, preventing the calculation of an accurate detection function.

The data collected were, therefore, largely unsuitable for calculating the densities of individual mammal species and producing national estimates. For this reason it was decided that distance data should not be collected in future years of the WMM project

Data Management

System for data capture

During the first year, data recording forms for the sightings survey were returned to the BTO and those for the field signs survey were returned to The Mammal Society. In both subsequent years, all forms were returned to The Mammal Society office in London. Forms were collated, checked for completeness, and the dates of mailing and receipt of forms entered on the WMM database (see below). In all three years of the project, BTO entered all the Sightings and Habitat Data and The Mammal Society entered all the Field Signs data and kept track of all the changes of the volunteer data e.g. changes of address. The control of each component of the database by one of the organisations avoided duplication of data entry. After data entry was complete, the databases were synchronised to ensure that each organisation had a copy of the complete data set and could carry out the analyses.

Structure of the database

The Winter Mammal Monitoring database is a custom-designed fully relational database built in Microsoft Access 2000. It has full password protection to comply with Data Protection Act requirements. The main purposes of the database are:

- To provide an administrative tool for managing volunteers and site allocation.
- To provide an integrated repository for the field data and questionnaire returns

It uses the Microsoft Replication Model to allow stand-alone replicas to be used for data input, which are then synchronised into a single database. There are four replicas. The first, at The Mammal Society office, is for administration of the volunteer and site information, e.g. changes of address and new square allocations. It is also used for entering the sightings, field signs and habitat data along with two other replicas used exclusively for data entry. One of these is at the BTO and the other is held at Bristol University where The Mammal Society delegated some of its data inputting. The remaining replica, the design master, is reserved for development. The Mammal Society also has responsibility for synchronising the three working copies and redistributing the complete datasets to the participating organisations. The database was updated regularly during the data collation period and duplicate copies are stored at BTO and The Mammal Society, where systems for automatic computer backups ensure that raw data and analytical results are secure.

As this was a pilot project, the database was not linked to the main databases of The Mammal Society (SAD) or BTO. If WMM was to continue as a long term project this is something that would be changed to ensure full Customer Relation Management (CRM).

To provide the role described above, the database comprises six input modules, fourteen output queries and two formatted reports.

Input modules

The input modules reflect the basic structure of the database and the division of labour between the two main organisations (Table 1).

Table 1 Details of input modules in database

Volunteers	Holds basic name and address information along with details of membership, training and involvement with the survey. In addition, this module allows sites to be allocated to volunteers and a schedule of communications (such as the dates that volunteer packs are sent and returned) to be recorded.
Sites	This module provides a list of all allocated sites, with their OS grid reference. It also has a record of all visits and links to the three field-data modules
Habitat Visits Sightings Visits Field-signs Visits	These three modules store the data derived from field visits. Each module holds basic information relevant to the visit, such as dates, times, weather conditions, etc. Field data is recorded either by individual observation, in the case of Sightings, or by transect section.
Questionnaires	Provides a facsimile of the questionnaire in the form of multiple-choice check-boxes or numerically coded text-boxes.

Each module has an input form, which mimics as closely as possible the design of the field forms used for collecting the data. Data entry fields are validated to allow only relevant values, within specified ranges or categories. Categorical data are numerically coded to provide data integrity, space-savings and ease of analysis. Speed of entry is facilitated by using "drop-down" menus of categorical data values, such as species name.

The database was originally designed for the one-year Pilot project. With the extension to three years, modifications were made to allow data from multiple survey years to be stored. Modifications were also made to the Volunteer Module as more volunteer management was needed.

Output queries and reports

The output queries pull together data stored in the underlying tables. They integrate the volunteer and sites information with the four data modules in a number of ways. Data are presented in tabular form similar to a spreadsheet, known as "datasheet views". They can be further manipulated by sorting and filtering rows, moving and hiding columns and generally formatting and resizing, as with a spreadsheet. Selected columns, rows or blocks of cells, as well as the whole datasheet, can be automatically exported to Microsoft Excel. These selections can also be cut and pasted into any application that conforms to the Microsoft OLE protocol, such as MS Word or third-party statistical packages. An example of the type of output available is given in Table 2.

Table 2. Example output from the database.

GridRef	*Date*	*Start*	*Moles*	*Rabbit*	*BadgerSett*	*Fox*	*Vole*	*Rat*	*Deer*	*Squirrel*	*Mouse*	*Dormouse*
HU4353	04/02/2002	09:00	0	2	0	0	0	0	0	0	0	0
NC1730	04/05/2002	08:50	0	0	0	0	20	0	20	0	0	0
NC2423	04/06/2002	09:30	9	15	0	0	15	0	19	0	0	0
ND4898	29/03/2002	12:20	0	10	0	0	1	7	0	0	0	0
NF7332	17/03/2002	14:10	0	14	0	0	0	0	0	0	0	0
NF7625	14/03/2002	08:30	0	1	0	0	18	8	0	0	0	0
NG4730	19/03/2002	09:30	0	0	0	0	10	0	0	0	0	0

Two main types of output query are provided:

- Raw data views. These combine data from different tables to present whole datasets of, for example, field signs for every transect section. Where numeric coding has been used for categorical data, both the codes and text values are presented. The former would be used for statistical analysis, whilst the latter would be required for summary tables.

- Summary queries. These also combine data from different tables but then summarise counts or presence to give a tally by, for example, site.

Currently, there are two formatted reports which can be printed directly from the database.

- Volunteer Address Labels. These facilitate mailings of data packs to all volunteers.
- Site Species Lists. These provide some feedback to volunteers and landowners, by simply providing a list of the species (both signs and sightings) recorded during the surveys. Lists can be produced for selected sites or all sites used in the survey.

Important benefits of database integration

This database has two levels of integration. Firstly, the three main sources of field-data have been stored together. This makes it easy to integrate habitat information with the signs and sightings data so that both can be analysed in relation to different habitat characteristics. Furthermore, sightings and signs have both been recorded in many sites. The integration makes it much easier to compare the results obtained from the two methods. Secondly, by integrating the volunteer and site information with the field data, it is easier to track the progress of the complete process, from volunteering, through site allocation, sending and return of data packs to the final input of data. In addition, the returns from the questionnaires can be easily linked to field-data to allow analysis of methodological issues such as observer experience.

Virus protection

The BTO’s computing network has been installed with McAfee VirusScan 4.5.0.534. Data files are upgraded regularly with version 4.0.4231 currently in operation. All electronic media are scanned prior to use at BTO and immediately prior to dispatch from the Trust. At The Mammal Society real time virus protection is provided on the server and workstations and on the e-mail gateway by the latest Sophos antivirus products. Both software and virus identity files are automatically updated with hourly checks against the Sophos servers.

Data Analysis

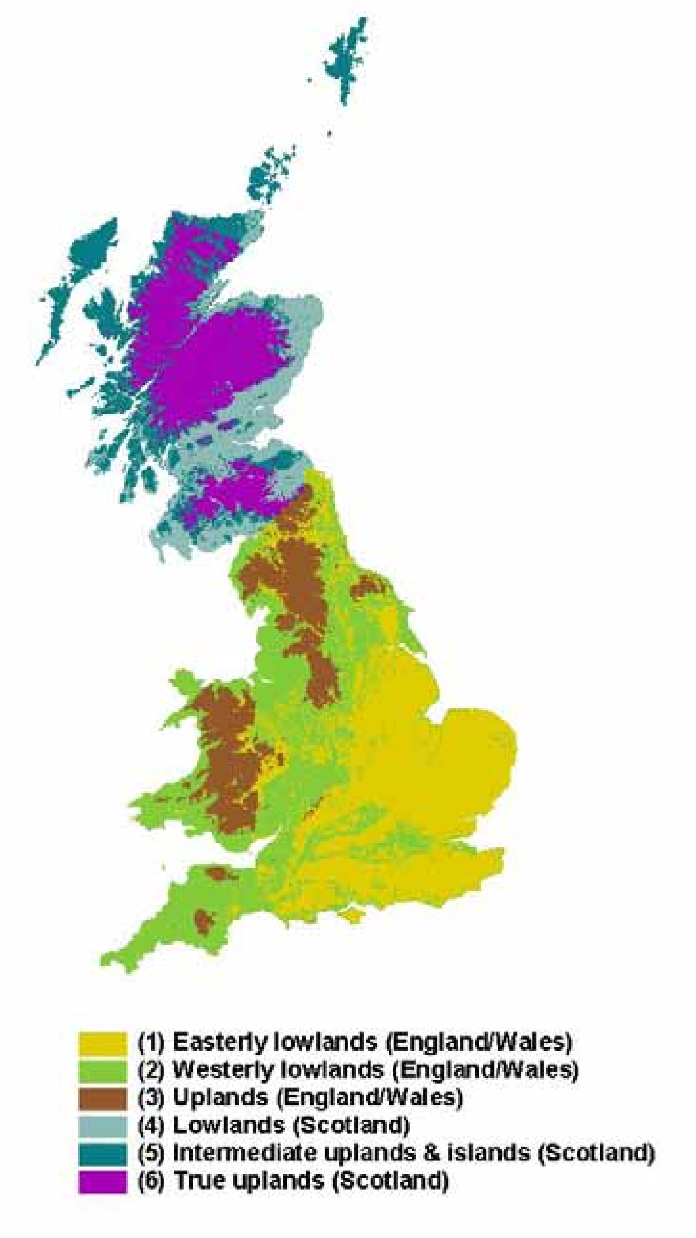
Following data capture and verification, results from all components were combined in order to carry out analyses on the integrated data. Analyses were carried out separately at BTO and The Mammal Society using SAS or equivalent analytical programs to extract and analyse the data.

Measures of abundance for each 1-km square were incorporated with spatial or landscape data in models that were then used to determine their influence on the abundance and/or presence/absence of the target mammal species. Using matched sites, data from the winter sighting transects and from the sign transects was first analysed separately, and then compared in order to assess the relative quality of data obtained from each. Winter Mammal Monitoring data was also compared to mammal data collected under the BTO’s Breeding Bird Survey (BBS).

Each 1km square surveyed by the WMM was assigned to one of six Environmental Zones (three in England and Wales, and three in Scotland) identified in the Countryside Survey 2000, which are themselves based on combinations of the 32 CEH (Centre for Ecology &

Hydrology) land class types (Bunce *et al*. 1996). Further information on the zones can be found on the Defra website: http://www.defra.wildlife-countryside/cs2000/01/04.htm

Fig. 2. Map showing the distribution of the six Environmental Zones of Great Britain used in the analyses in this report.



4. Volunteers and Project Organisation

Establishing and maintaining the volunteer network

Both the BTO and The Mammal Society have a network of committed volunteers they were able to draw upon for Winter Mammal Monitoring. The BTO has roughly 2000 volunteers who undertake summer sightings transects for mammals on the BBS, while over 4000 volunteers have participated in recent surveys run by The Mammal Society. We also wished to attract new people to this project.

As well as recruiting people to take part in the project, other issues to do with maintenance of the volunteer network, e.g. data protection and health and safety needed to be addressed.

Publicity Strategy

The main aims of the publicity strategy were to recruit volunteers to participate in the project and to identify the joint nature of the initiative.

Visual Identity

It was not felt necessary to have a specific logo for the project as this would detract from the joint nature of the work. All communications, including letters, featured the logos and contact details of both organisations. However, a project name was needed to ensure the project was referred to in a consistent manner and to communicate the nature of the work in a user friendly way. The project was named Winter Mammal Monitoring.

Volunteer Recruitment

Volunteer fieldworkers were recruited from a wide range of sources:

- Volunteers already carrying out bird surveys as part of the Breeding Bird Survey (BBS), run by the BTO/RSPB/JNCC. All current BBS volunteers (except in regions where Foot and Mouth Disease was still a problem) were first sent a letter accompanying their annual report describing the pilot mammal survey and asking those interested to contact BTO to add their name to our list of volunteers.
- Members of the BTO.
- Members of The Mammal Society.
- People trained on The Mammal Society's Training Courses (formerly the *Look Out for Mammals* project).
- Volunteers who had participated in The Mammal Society's previous mammal surveys.
- Information being sent round to offices of other NGOs, e.g. Wildlife Trusts, National Trust.
- Publicity in various media to attract new people to the project.

Table 3 outlines the timetable of publicity actions that were carried out to attract volunteers to take part. The press releases were written collaboratively by the BTO and The Mammal Society and were then sent out to each organisation's media list to take advantage of specialised contacts.

Table 4 outlines the media coverage that was subsequently received by the project.

Table 3a. Timetable of recruitment and publicity events in Year 1 – 2001/2002		
Year	*Item*	*Audience*
Summer 2001	Information flyer, with tear off strip circulated with the Summer 2001 issue (no.126) of The Mammal Society's newsletter *Mammal News*.	Members of The Mammal Society (plus extra readers). Circulation 3,000
	Joint press release sent out by the BTO and The Mammal Society to all press and media contacts. The Mammal Society also arranged a full page article in the September 2001 issue of *BBC Wildlife* magazine.	Press and Media contacts – several hundred.
	Information featured about the project and how to take part on the BTO (www.bto.org) and The Mammal Society websites (www.mammal.org.uk).	The online community, people wanting more information about the project and members of both organisations.
	Information about the project sent to all people making general enquiries to The Mammal Society office.	People who have some interest in mammals. Several hundred.
	Information about the project included in all of The Mammal Society's training courses.	People already interested in learning about identifying mammals. Several hundred.
	Information about the project sent to all BBS volunteers and the BTO regional representatives	Volunteers already contributing to the BBS
	Information about the project displayed on both the BTO and The Mammal Society's stands at the British BirdWatching Fair and people encouraged to volunteer to take part.	Attendees of the fair – people with a general and specialised interest in the countryside, environment and conservation. Several thousand attendees.
	Article in *BTO News* (No.235 July-August 2001) about the project including information about The Mammal Society and our joint relationship.	Members of the BTO. Circulation 12,500.
	Article in *County Mammal News* (No.11 August 2001) – The Mammal Society's newsletter for everyone involved in regional mammal work and recording. Article stressing how the record centres and county recorders will be able to access the data collected as part of the project.	Local Mammal Groups, County Mammal Recorders, Local Record Centres. Circulation 200.
Autumn 2001	Article in *Mammal News* (No.127 Autumn 2001) about the project including information about the BTO and our joint relationship.	Members of The Mammal Society (plus extra readers). Circulation 3,000
	Information flyer, with tear off strip sent out to c.800 NGOs e.g. Wildlife Trusts. Some organisations e.g. the Woodland Trust circulated them widely amongst colleagues and their other offices.	Staff and volunteers of the organisations.
	The British Ecological Society (2,000 members), Kent Mammal Group (150 members), Devon Mammal Group (100 members), RSPB Norfolk (100 members) sent the information flyer to all their members.	Staff and volunteers of the organisations.
November 2001	Press release sent out by The Mammal Society about the training workshop being run especially for the project in Hampshire.	Volunteers for the project, organisations, people and media in Hampshire and the surrounding counties.
	Update about the project in *County Mammal News* (Issue 12 November 2001).	Local Mammal Groups, County Mammal Recorders, Local Record Centres. Circulation 200.
	Update about the project in *Mammal News* (No.128 Winter 2001).	Members of The Mammal Society (plus extra readers). Circulation 3,000
	Information about the project presented at The Mammal Society's Autumn Symposium on Mammal Monitoring. Information provided to all attendees encouraging them to volunteer.	Attendees of the symposium – people with a specialised interest in mammal monitoring. Symposium attendance: 250.
January 2002	Update about the project in *Mammal News* (No.129 Spring 2002)	Members of The Mammal Society (plus extra readers). Circulation 3,000
Spring 2002	Article about the results of the first year in BTO News No. 239 March/April 2002	Members of the BTO. Circulation 12,500.

Table 3b. Timetable of recruitment and publicity events in Year 2 - 2002/2003 and Year 3 - 2003/2004

September 2002	Press release sent out about the extension of the pilot for a second year and calling for more volunteers.	Press and Media contacts – several hundred.
	Update in *Mammal News* 131 Autumn 2002	Members of The Mammal Society (plus extra readers). Circulation 3,000
	Project Update in September/October issue of BTO News no. 242	Members of the BTO. Circulation 12,500.
	Updated information about the project and how to take part on the BTO (www.bto.org) and The Mammal Society websites (www.mammal.org.uk).	The online community, people wanting more information about the project and members of both organisations.
	Info Flyer and Sign up Sheets calling for volunteers used at shows and fairs that The Mammal Society attends.	Attendees of the fairs – people with a general and specialised interest in the countryside, environment and conservation.
	Information about the project sent to all people making general enquiries to The Mammal Society office.	People who have some interest in mammals. Several hundred.
	Information about the project included in all of The Mammal Society's training courses.	People already interested in learning about identifying mammals. Several hundred.
	Press release sent out advertising the 4 training workshops being run for the Winter Mammal Monitoring project.	Press and Media contacts – several hundred. Organisations, people and media in the relevant counties.
November 2002	Information flyer about the project and calling for more volunteers included in the delegates packs at The Mammal Society's Autumn Symposium.	Attendees of the symposium. Symposium attendance: 250.
Spring 2003	Reminder to send data back in *Mammal News* 133 Spring 2003	Members of The Mammal Society (plus extra readers). Circulation 3,000
	Article in the May/June 2003 no. 246 issue of *BTO News*	Members of the BTO. Circulation 12,500.
	Update in *Mammal News* 134 Summer 2003	Members of The Mammal Society (plus extra readers). Circulation 3,000
Autumn 2003	Update in *Mammal News* 135 Autumn 2003	Members of The Mammal Society (plus extra readers). Circulation 3,000
	Article in the Nov/Dec 2004 issue no.249 of *BTO News* about the results of the 2nd year	Members of the BTO. Circulation 12,500.
	Contact made with targeted media outlets to see if they could squeeze the information in before the end of the fieldwork season.	Targeted media outlets: *BBC Wildlife* Magazine and *British Wildlife* Magazine.
	Updated information about the project and how to take part on the BTO (www.bto.org) and The Mammal Society websites (www.mammal.org.uk).	The online community, people wanting more information about the project and members of both organisations.
November 2003	Information flyer about the project and calling for more volunteers included in the delegates packs at The Mammal Society's Autumn Symposium.	Attendees of the symposium. Symposium attendance: 250.

Table 4. Details of media coverage received by the project	
Year	*Item*
September 2001	Whole page article in *BBC Wildlife* magazine
	Article in *Choice* magazine
	Article in *Country Living* magazine
	Article in National Trust's *Nature Conservation Newsletter*
October 2001	Article in *British Wildlife*
November 2001	Article in *BBC Gardener's World* magazine
	Mention in *Woodland Owner* magazine
	Mention in *Farmers Guardian*
December 2001	Article in *Gardening Which* magazine
	Pages on Telextext C4
	Numerous coverage in local and regional papers and radio stations including Aberdeen *Press and Journal*, *The Thetford and Watton Times*, Edinburgh *Evening News*, *Eastern Daily Press*, *The Bucks Herald*, *Oxfordshire Times*, *LBC Radio*
October 2002	Coverage in *Charity Week*
November 2002	Coverage in *The Countryman*
December 2002	Mention in *BirdWatching* magazine
	Mention in *BBC Wildlife* magazine
January 2004	Mention in *BBC Wildlife* magazine
February 2004	Coverage in the mammal report in *British Wildlife* magazine

Data protection issues

Due to the joint nature of the project both organisations would need access to the volunteers' names and addresses, e.g. to send out information packs. However, volunteers that came through either organisation might not realise that their personal data would be shared with the other organisation. A data protection statement was used to make this explicit; volunteers were also able to opt out of receiving further information from either or both organisations.

> *Your details will be held by both The Mammal Society and the British Trust for Ornithology for the purposes of this project. Please tick the boxes if you do not wish to receive other information from either or both of these organisations.*
>
> - *The Mammal Society will not pass your name and address to any other organisation. We may from time to time send you details about other activities of The Mammal Society, including joint initiatives with other organisations and trading activities. If you would prefer not to receive such information, please tick the box.*
> - *Your personal information may be held on a computerised database by the BTO for membership and fundraising purposes and for furthering the BTO's objectives. If you would prefer that this information should only be held for the purposes of the Wintering Mammal Monitoring Pilot, please tick the box.*

Health and safety issues

To ensure that volunteers did not put themselves at unnecessary risk during the course of these surveys, we included a set of common sense guidelines with the data recording forms and instructions, advising volunteers to carefully consider any factors that may affect their health or safety. These include being prepared for inclement weather, hazardous walking conditions, and potentially hazardous activities on the land in their 1km square. The information sheets for both parts of the project included information about health and safety measures – as below:

> *Fieldworkers should not put themselves in a position that could place them, or others, in danger. The British Trust for Ornithology and The Mammal Society do not take any responsibility or liability for any actions and subsequent consequences from the activities of fieldworkers.*

As with all outdoor fieldwork, make sure that you are adequately clothed and equipped, with appropriate footwear and waterproof clothing and always ensure that someone knows where you are going and when you expect to return.

If Winter Mammal Monitoring was to become a long term project after this pilot study, the health and safety guidelines provided to the volunteers would be altered in line with those now provided by the BTO and The Mammal Society following the discussions at the Tracking Mammals Partnership / NBN Workshop on Health and Safety and Volunteers 19 March 2004.

Volunteer Communication

Information Packs

Information packs for Winter Mammal Monitoring were sent out to the volunteers as outlined below. Each of the Sightings and Field Signs Survey packs contained a letter to the volunteer, a Letter of Introduction to Landowners, the recording forms, two or three copies of the map of their square, a larger-scale map showing the location of the square, and detailed instruction sheets including information on how to gain access to land along the transect route, how to set up the transect route, how to survey for mammals or field signs, how to record these data on the recording forms, and information on difficult to identify species or signs. The latter were prepared for the volunteers especially for this project by The Mammal Society.

<u>Year 1 (2001/2002)</u>

In Year 1 details about the Sightings and Field Signs Survey were sent out separately.

- Sightings Survey

The BTO allocated a square to each volunteer and sent out the first information pack in October and November 2001, requesting return of forms by January 15th, 2002. The square, or squares, allocated to each volunteer were recorded on the Winter Mammal Monitoring database.

- Field Signs Survey

The Mammal Society sent out the information packs in February 2002, requesting return of forms by April 15, 2002. These packs included the first newsletter about the project (see Newsletters).

- Winter Mammal Monitoring Questionnaire

The Mammal Society sent this to all potential volunteers in May 2002 requesting return by June 10, 2002. The mailing also included the second newsletter about the project (see Newsletters).

<u>Year 2 (2002/2003)</u>

In Year 2, the Sightings and Field Signs forms were sent out together, as this year volunteers could carry out either part at any time. The volunteers were asked to send their forms back by February 17, 2003. This deadline was later extended to March 17, 2003 for those new volunteers who had experienced delays with square allocation. The packs were sent out by The Mammal Society in October/November 2002 and were sent to all people who had expressed an interest in the project from 2001/02 (whether they had taken part or not). The Mammal Society also carried out the square allocation for the new volunteers and sent them their packs as well.

Year 3 (2003/2004)

Again, the Sightings and Field Signs forms were sent out together. The BTO sent out them out to all existing volunteers, while The Mammal Society carried out the square allocation and sent out packs to the new volunteers. Information packs were sent out to volunteers during November 2003, with a deadline for return by February 28, 2004. This deadline was later extended to March 31, 2004 for those new volunteers who had experienced delays with square allocation.

Newsletters

Where possible, newsletters were sent out with the information packs to minimise costs and, hopefully, to increase the participation rate in the survey. As well as information about the project, the newsletters also included information about other mammal activities that the BTO and The Mammal Society were running, to show how Winter Mammal Monitoring fitted into other work for mammals and to increase the volunteers' commitment to the BTO and The Mammal Society.

Newsletter 1 – February 2002 (4 pages, black and white)

This was sent out with the information packs for the Field Signs Survey in Year 1. A large part of the newsletter was thanking the volunteers for participating in the first Sightings Survey and encouraging them to carry out the Field Signs Survey. As it was too soon to have any results from the Sightings Survey, it comprised simple feedback about the mammals that had been seen and information about the maps we were using of the volunteers' squares. There was also information about the Winter Mammal Monitoring Workshop being run in Hampshire and about The Mammal Society's publication *A guide to British mammal tracks and signs* as a useful aid for the Field Signs survey.

Newsletter 2 – May 2002 (2 pages, black and white)

This was sent out with the Questionnaire to all volunteers. Again, the newsletter concentrated on thanking people for taking part so far and encouraging them to fill in the questionnaire. It also explained that the data analysis would be continuing over the summer months and that a full report on the first year of data would be sent to them by the end of the year.

Newsletter 3 – January 2003 (12 pages, colour)

This was sent out to all volunteers following submission of the interim report to Defra. The newsletter contained details of the data recorded in the first year and how this was analysed by region and habitat etc. The newsletter also acted as encouragement to people who were volunteering for the second year of the project and provided information on the workshops developed to accompany the project. This larger, more detailed, full colour newsletter was accompanied by photographs and graphs and was well received by the volunteers.

Newsletter 4 – October 2003 (4 pages, black and white)

The fourth newsletter was sent to volunteers with the information packs for the third year of the project. It was used to tell the volunteers that the project was continuing for a third pilot year and to update them on the results and analyses of the first two years of the project, especially the value of the WMM project to mammal monitoring.

In Years 1 and 2 the mailings were sent to all people who had originally expressed an interest in participating in the project. This was done in recognition that circumstances (e.g. ill health, family matters) sometimes prevent a volunteer from participating in a section of the project but does not necessarily mean that they are no longer interested or do not intend to take part in future. Obviously, volunteers who said that they were no longer able to take part in the project or who didn't want to receive further information about the project were excluded from the mailings.

In Year 3, mailings were only sent to volunteers who had participated in at least one part of Winter Mammal Monitoring (Sightings, Field Signs and Questionnaire) in Years 1 and 2. We did not include people who had expressed an initial interest but had not taken part in anything – this included many people from the BBS who had decided not to participate.

Ongoing Communications

A major consideration in running Winter Mammal Monitoring was to ensure that the volunteers had the information they needed, and enough feedback about the project to maintain their interest and enthusiasm. Feedback was through the organisations' respective websites, their telephone helplines, newsletters to members, and the Winter Mammal Monitoring newsletters, outlined above.

Throughout the project, some volunteers got in touch to say that it was not possible to carry out the surveys in the square they had been allocated due to difficulties getting landowner permission or because the square was now not suitable (e.g. a new power station had been constructed on it). These volunteers were, therefore, allocated a new square and the inaccessible squares marked as so on the database (so as not to re-allocate the square to new volunteers). The volunteers who withdrew from the project were also marked on the database (to remove them from the mailing lists) and their relationship with their square was deemed completed, meaning that the square was available for re-allocation to other volunteers.

Future Communications

A fifth newsletter will be sent to the volunteers after the submission of this final report. This will provide feedback to the volunteers on the results from the 3 year pilot project and our conclusions about the methods used etc. It will also be the ideal place to inform the volunteers of our future intentions for the project and its methods. When this newsletter is produced we will also act to publicise the results of the project.

If Winter Mammal Monitoring carries on to be a long-term project then the number of newsletters will be rationalised. It is envisaged that one newsletter will be sent to the volunteers each year. This would be in the middle of the summer, once data analysis was complete, and would update them on the results of the field work season they had just taken part in and inform them of the arrangements for the forthcoming fieldwork season. Following positive volunteer feedback to Newsletter 3 it is envisaged that the annual newsletter will be full colour and similar in style to Newsletter 3.

Although it is felt that only one newsletter a year is needed, volunteers do like to have contact with the organisers of the project, particularly after they have sent their data back. It is, therefore, envisaged that they will be sent a postcard acknowledging receipt of their data, thanking them for their participation and letting them know when they can expect to hear back about the results.

Contract Delays

Most volunteer recruitment was carried out at the start of the project, in Year 1. When the contract for the project was extended for Year 2, and then for Year 3, some recruitment and publicity actions were carried out, but these were constrained by the late date of contract extension. Volunteer recruitment and publicity activities would normally be carried out 4-5 months before the start of the fieldwork season. A consequent drop in the amount of press coverage received by the project (see Table 4) and in volunteer participation (see Chapter 6) can be seen in Years 2 and 3.

The delay in extending the project contract in Years 2 and 3 also had consequences for the existing volunteers, as at the end of the fieldwork seasons it was not possible to tell them whether the project was to be on-going and whether we would like them to participate again. It was not even possible to tell them this during the summer when we were analysing the data. In fact, existing volunteers were only informed of the project's continuation as the fieldwork season was starting, giving them little time to plan their participation. This gave a poor impression of the project: many of the volunteers felt that the delay in telling them about the continuation of the project meant the project was not being run very efficiently and that we cared little about their participation.

If the Winter Mammal Monitoring project is to continue as a long term project, it is vital that funding is allocated 6-9 months prior to the start of the field work, and is given consistently from one year to the next, to ensure that we can maximise our communications with volunteers.

Training

Training of volunteers was considered essential to improve their skills and encourage participation in surveys. The Mammal Society runs an extremely successful programme of training courses and has so far trained over 3000 people in the field skills needed to participate more actively in mammal conservation work. In collaboration with the Field Studies Council, it has developed a widely respected accreditation scheme and at the end of the Mammal Identification Course, there is a practical exam that tests the identification skills of course attendees, as well as their ability to complete recording forms and read map references. Over 85% of course attendees attain the required level of expertise and are accredited. Winter Mammal Monitoring volunteers who wanted training were encouraged to attend one of about 20 Mammal Identification courses held each year at a variety of different locations from north-east Scotland to south Cornwall or to attend one of the Winter Mammal Monitoring one-day workshops.

Although the contract for the Winter Mammal Monitoring Project did not include any funding to run training for participants, we felt this was a crucial aspect of the project. The project was testing a new method and required a great deal of input from volunteers, potentially on a long-term basis. It is important that they are completing the survey accurately; feel that their input is worthwhile and that they understand how the project fits into the bigger picture. Hence, training is not only a way of ensuring that volunteers are trained to a particular standard, but also gives them a chance to air concerns and feel that they are part of the project.

Pilot Winter Mammal Monitoring one-day workshop at Chilbolton, Hampshire – November 18, 2001

It was decided that by running training courses specifically tailored to the Winter Mammal Monitoring project, the pool of volunteers willing to take part in the project could be greatly enhanced. For these reasons a one-day Winter Mammal Monitoring training course was piloted in November 2001. The response from volunteers was very positive and over 60 people attended. The aim of the workshop, taught jointly by The Mammal Society and the BTO, was to provide training on the main mammal identification skills needed to participate in the project, as well as answer questions about how to fill in forms, select transect routes and gain access. It also provided an opportunity for volunteers to meet others taking part in the project. The workshop included illustrated lectures, question and answer sessions and a chance to look at mammal specimens. The one-day workshop consisted of 4 main sections:

- The current situation regarding mammal monitoring, why such a monitoring project is needed and why data need to be collected in this way.
- The main identification features of all the key mammal species in the Sightings Survey, how to fill out the forms and questions.
- The identification of the mammal field signs that volunteers would be asked to record in the project, how to fill out the forms and questions.
- Explaining why volunteers are asked to walk transects, how to select a route and how to fill out the habitat forms.

Comments received from participants were very encouraging. They felt the workshop to be most useful for giving them the confidence to participate in the project and seeing the importance of the work they were doing.

Training initiatives in 2002

Following the success of the pilot workshop in Hampshire, a proposal to develop a set of materials enabling trainers to teach standard courses for people participating in the project was put forward by The Mammal Society. This project was then funded by a grant from the Endangered British Mammals Fund. The necessary work was carried out over the summer of 2002 to develop a set of resources based on a similar programme to the pilot workshop. Four workshops were organised around the country for the winter of 2002/03. Workshops were arranged at the following venues:

- Risley Moss visitor centre, Warrington - October 26, 2002

  18 participants
- Cardiff University graduate centre, Cardiff, Wales - November 2, 2002

  20 participants
- University of Stirling campus, Stirling, Scotland - November 16, 2002

  27 participants
- Juniper Hall, Field Studies Centre, Dorking, Surrey - January 18, 2003

  23 participants

These workshops were all well attended and well received by the participants.

Unfortunately there was no funding to carry out any training in Year 3. It is hoped that if Winter Mammal Monitoring does become an ongoing project, there will be funds to carry out training – to improve the accuracy of the data collected and because training will encourage volunteers' participation in the project.

5. Results

Volunteers

After initial expressions of interest, 1,886 volunteers (including partners or groups) signed up to take part and were assigned sites. The vast majority of these volunteers were from England (Fig. 3), with smaller numbers from Wales and Scotland. A very small number of volunteers were recruited from the Isle of Man and Northern Ireland, which is encouraging considering that in this pilot we did not specifically target them.

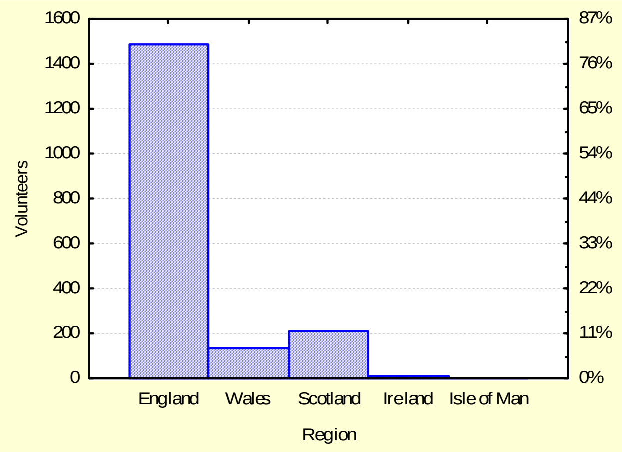


Fig. 3. Number of volunteers taking part in each country of the UK (Isle of Man =2)

We were not able to use Regional Development Agencies in England (RDAs) because of insufficient number of sites in each of these nine regions. So, for the purposes of preliminary analyses, we defined four broad areas within Great Britain:

- Region 1: Scotland
- Region 2: Northern England (northwest and northeast England, Humberside and Yorkshire)
- Region 3: Eastern England (east midlands, London and southeast England).
- Region 4: Wales and Western England (southwest, west midlands)

The numbers of volunteers within each region was very different (Fig. 4). This showed the percentage of volunteers decreasing from southerly to northerly regions in the order of Eastern England > Western England and Wales > Northern England > Scotland

Less than half of the volunteers assigned squares actually undertook a survey, for a variety of reasons. Of the 1,886 volunteers expressing interest, 979 did not return any data (Table 6) giving a total of 907 active volunteers. Of these, 860 undertook at least one sightings survey and 555 took part in at least one signs survey. However, some volunteers undertook surveys on more than one site. For example, 70 volunteers undertook sightings and signs on two sites, and 14 did the same on three. Overall 176 volunteers undertook either sign or sighting surveys on more than one site.

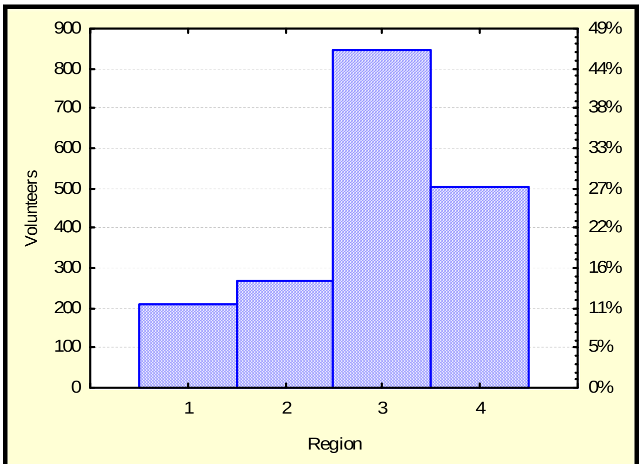


Fig. 4. Distribution of volunteer by Region. (See text for explanation of region numbers.)

Sites

A total of 1,121 sites were visited on at least one occasion using either method. Sightings were recorded in 1,043, with signs being recorded in 690 sites. From this, both methods were used in 612 sites (1,043 + 690 – 1,121).

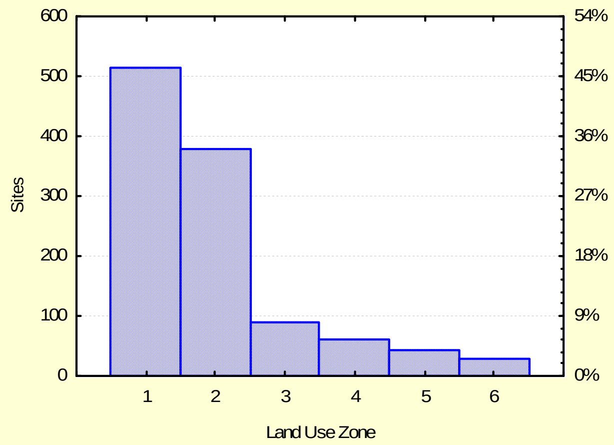


Fig. 5. Distribution of sites by Environmental Zone.

Sites were distributed between the regions in a similar pattern to volunteers. However, sites were also assigned to six Environmental Zones derived from the ITE land classes (Fig. 5). The two-way breakdown of these allocations is shown in Table 5. Note that these two factors are inevitably totally confounded because environmental zones are defined at least partly by country. Zones 1, 2 and 3 were found in all three regions of England and Wales, but not in Scotland. In contrast, zones 4, 5 and 6 were only found in Scotland. This has important consequences for the analyses because it makes it difficult (and not sensible) to include both of these factors in the same statistical model.

Of the 1,121 sites overall, 880 were visited in 2001/2, 537 in 2002/3 and 323 in 2003/4. A full analysis of the influences on turnover of site is given in "Site Turnover" below.

Table 5. The allocation of sites to Region and Environmental Zone. (The six unassigned sites were from Northern Ireland or the Isle of Man.)

		Region					
		Unassigned	*1*	*2*	*3*	*4*	*Total*
Zone	*Unassigned*	6					**6**
	1			16	438	61	**515**
	2			82	116	181	**379**
	3			37	7	44	**88**
	4		61				**61**
	5		42				**42**
	6		30				**30**
	Total	**6**	**133**	**135**	**561**	**286**	**1121**

Questionnaires

A total of 425 people returned the questionnaire, approximately half of the number of people who had carried out the sightings survey in Year 1 but also including many people who did not carry out any surveys. However, some volunteers did not answer all the questions. There were fewer returns from non-participants, but of those that did not take part in either the sightings or field-signs parts of the project, the major reason given was lack of time (10% for the Sightings and 24% for the Field Signs). This is encouraging if it implies that volunteers may be willing to take part in future years if the time to do the survey

Table 6. The numbers of volunteers undertaking different combinations of sites with sightings and signs.

		Signs					
		0	*1*	*2*	*3*	*4*	*Total*
Sightings	*0*	979	40	7	0	0	**1026**
	1	304	387	9	2	1	**703**
	2	46	16	70	1	2	**135**
	3	2	2	1	14	0	**19**
	4	0	0	0	1	1	**2**
	5	0	1	0	0	0	**1**
	Total	**1331**	**446**	**87**	**18**	**4**	**1886**

was increased e.g. by getting recording forms out earlier and extending the survey period. Where surveyors were asked to give a score rating to a question ranging from 1 to 5, 1 = difficult/poor/not interesting and 5 = easy/good/very interesting. The results from each of the individual questions are presented in Appendix 2.

The majority of volunteers (51%) were aged between 45-64 with the age range 25-44 following close behind (30%). Sixty percent of participants were male and 40% female. Most of the volunteers were new to mammal surveys with only 7% having taken part in surveys for The Mammal Society before. Fourteen percent had taken The Mammal Society's *Look Out for Mammals* training course and over half of the volunteers were experienced surveyors, having taken part in surveys for the BTO and other organisations before. Twenty-six percent of volunteers were members of The Mammal Society and 40% were members of the BTO, leaving over 30% who had been drawn into the project through the publicity targeted at the general public. The majority of volunteers (63%) had an interest in natural history and the countryside, with 20% being professional countryside workers (consultant, warden, ecologist etc) and 7% academics. These are useful figures with which to stratify the results and compare groups of volunteers in ongoing analyses (e.g. pp 41-42).

The majority of participants found the instructions and information packs clear and easy to understand. Over 80% of people rated the packs for Sightings as either 4 or 5 (good or very good) and 75% of people found that the recording forms were easy to complete. For Field Signs, 70% rated the recording forms as 4 or 5 and 66 % rated the instruction packs as either 4 or 5. Over half the volunteers (64%) made use of support, mainly The Mammal Society's laminated colour identification keys and the telephone helpline. This demonstrates the importance of having the project run by an organisation that has the resources to provide the high levels of support that volunteers require. Although the Field Signs component was usually considered more difficult (according to 11%) than the Sightings component, 4% found the sightings more difficult.

Most people (58%) were happy with the square they were allocated but a significant percentage (42%) were not. The main reason given was that their square was too far away (20%) and that it had few or no mammals (18%). This is an important issue because people who are unhappy with their square are unlikely to continue to take part in future years. The square allocation method must take account, where possible, of the desire for a local square amongst the volunteers. Project newsletters and general information about the project must continue to emphasise the importance of survey design and that even squares with few mammals provide useful data. Despite the aftermath of the Foot and Mouth Disease outbreak (2001), over three quarters of people (76%) returning the questionnaire had no problems with access to their square. Access was a problem to 8% mainly due to difficulties with urban/industrial areas.

The majority of volunteers found it easy to identify the species in the project by sightings, with 95% of people rating lagomorphs as easy. The most difficult group was the small carnivores, but 50% of people still rated them as 4 or 5. Some signs were obviously very easy – 99% of people rating molehills as 4 or 5 and 90% of people being confident about rabbit burrows. Only 18% of people rated harvest mouse nests and 25% field vole signs as 4 or 5. This confirms the importance of giving people the opportunity to 'opt-out' of species for the Signs survey and suggests where training should be focused. Over two thirds of people found the survey interesting and enjoyable to complete. Interestingly, this figure was slightly higher (66% versus 63%) for Signs than for Sightings – perhaps the greater difficulty was compensated for by the greater incidence of field signs compared to sightings. Among the reasons that people gave for taking part in the project, almost half (48%) were related to the fact that they were monitoring mammals in their local area. People also liked the fact that the project was being run by organisations that they knew (64%), and 39% liked participating because the subject was mammals.

Sightings

A total of 43 species or species groups were recorded during the three survey years. These are listed in taxonomic order in Table 7, and displayed graphically in Fig. 6. The 33 identified species belonged to six orders and twelve families. The most widely represented families were Muridae, Mustelidae and Cervidae, each with six species identified. Each of these also had two unidentified groupings, although it could be argued that the polecat/ferret record and the red/sika record represents hybrids rather than confused identification.

The number of sites where each species was recorded ranged from 491 in the case of rabbits to just one site for seven species. Grey squirrels were also commonly recorded with 361 sites. However, it is worth noting that even these two commonest species were not recorded in 53% and 65% of sites, respectively. The next three wild species (brown hare, roe deer and fox) formed a group of relatively frequently recorded species, ranging from 190 down to 147 sites. Then two feral/ domestic species were followed by the remaining group of species, all recorded in fewer than 50 sites. This extreme distribution is illustrated by the fact that 36 of the 43 species (84%) were recorded in less than 4.7% of the sites. Indeed, half the species were recorded in 7 or fewer sites, representing only 0.7% of all sites visited.

Table 7. Taxonomic list of all species recorded during the sightings survey, with the number (and percentage) of sites in which the species or species group was recorded.

Latin Name	*Common Name*	*Sites*		*Latin Name*	*Common Name*	*Sites*	
INSECTIVORA				CARNIVORA	Carnivores	2	0.2%
Erinaceidae				**Canidae**	Dogs	2	0.2%
Erinaceus europaeus	Hedgehog	3	0.3%	*Vulpes vulpes*	Fox	147	13.1 %
Talpaidae				*Canis domesticus*	Free-roaming dog	73	6.5%
Talpa europaea	Mole	24	2.1%	**Mustelidae**			
Soricidae				*Martes martes*	Pine marten	1	0.1%
Sorex araneus	Common shrew	6	0.5%	*Mustela erminea*	Stoat	10	0.9%
				Mustela nivalis	Weasel	16	1.4%
LAGOMORPHA				*Mustela vison*	Mink	5	0.4%
Leporidae				*Mustela erminea/nivalis*	Stoat/weasel	7	0.6%
Oryctolagus cuniculus	Rabbit	491	43.8 %	*Mustela putorius/furro*	Polecat/ferret	1	0.1%
Lepus	Hares	8	0.7%	*Meles meles*	Badger	7	0.6%
Lepus europaeus	Brown hare	190	16.9 %	*Lutra lutra*	Otter	2	0.2%
Lepus timidus	Mountain /Irish hare	6	0.5%	**Felidae**	Cats	2	0.2%
				Felis silvestris	Wildcat	1	0.1%
RODENTIA				*Felis catus*	Feral cat	136	12.1 %
Scuiridae				*Felis silvestris / catus*	wildcat / domestic cat	22	2.0%
Sciurus vulgaris	Red squirrel	5	0.4%				
Sciurus carolinensis	Grey squirrel	361	32.2 %	PERISSODACTYLA			
Muridae				**Equidae**			
	Mouse sp.	11	1.0%	*Equus caballus*	Horse	1	0.1%
	Vole sp.	8	0.7%				
Clethrionomys glareolus	Bank vole	3	0.3%	ARTIODACTYLA			
Microtus agrestis	Field vole	12	1.1%	**Cervidae**	Deer	14	1.2%
Arvicola terrestris	Water vole	7	0.6%	*Cervus elaphus*	Red deer	18	1.6%
Apodemus sylvaticus	Wood mouse	3	0.3%	*Cervus nippon*	Sika deer	6	0.5%
Mus domesticus	House mouse	2	0.2%	*Cervus elepahs / nippon*	Red / sika deer	1	0.1%
Rattus norvegicus	Brown rat	23	2.1%	*Dama dama*	Fallow deer	48	4.3%
Gliridae				*Capreolus capreolus*	Roe deer	168	15.0 %
Muscardinus avellanarius	Common dormouse	1	0.1%	*Muntiacus reevesi*	Muntjac	43	3.8%
				Hydropotes inermis	Chinese water deer	1	0.1%

The site counts for the fourteen most common species have been further broken down by year (Fig. 7). All these species were seen on at least ten sites in at least one of the three years. Certain of the more common species showed considerable variation in proportion of sites across the three years of the survey. In particular, rabbits, brown hares and foxes showed a range of at least 25%. Similar proportionate differences were also found in some of the scarcer species such as red deer and weasel.

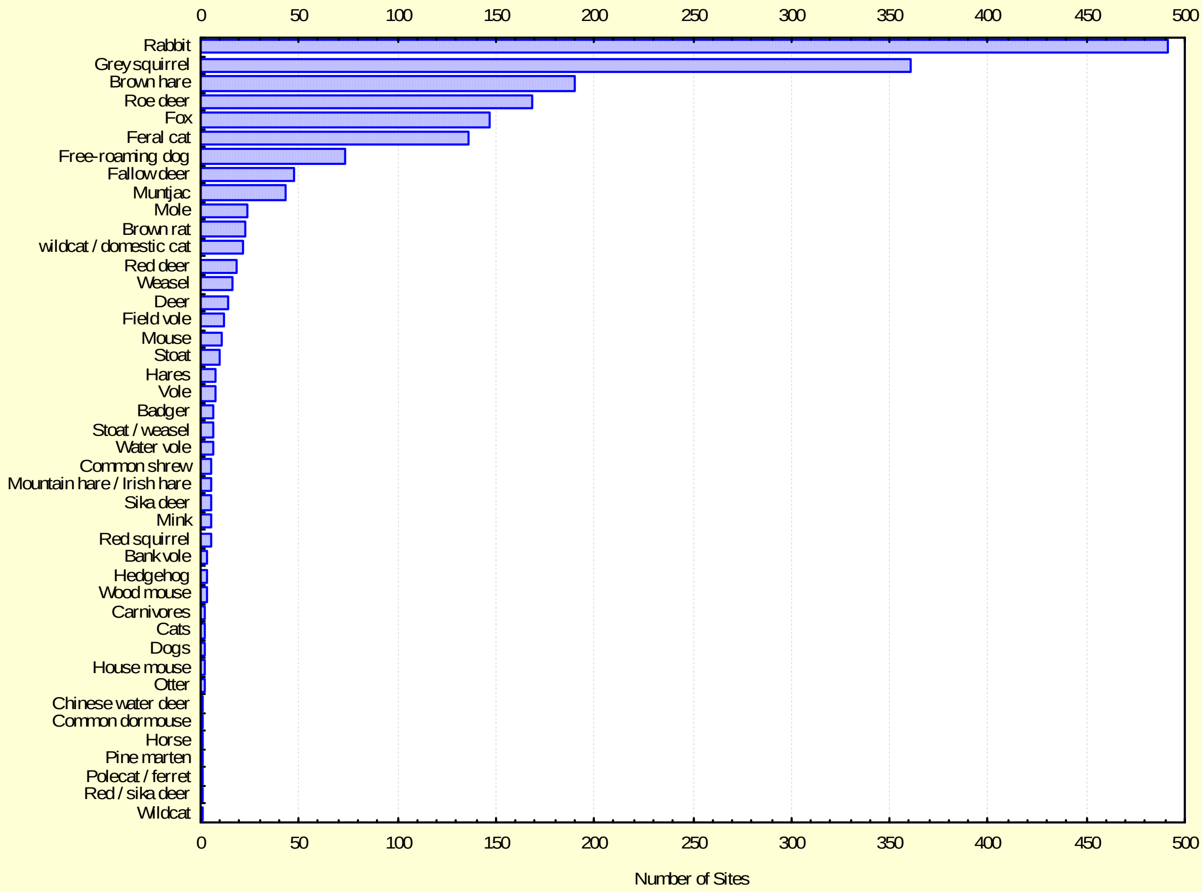


Fig. 6. Number of sites within which sightings of each species or species group were recorded.

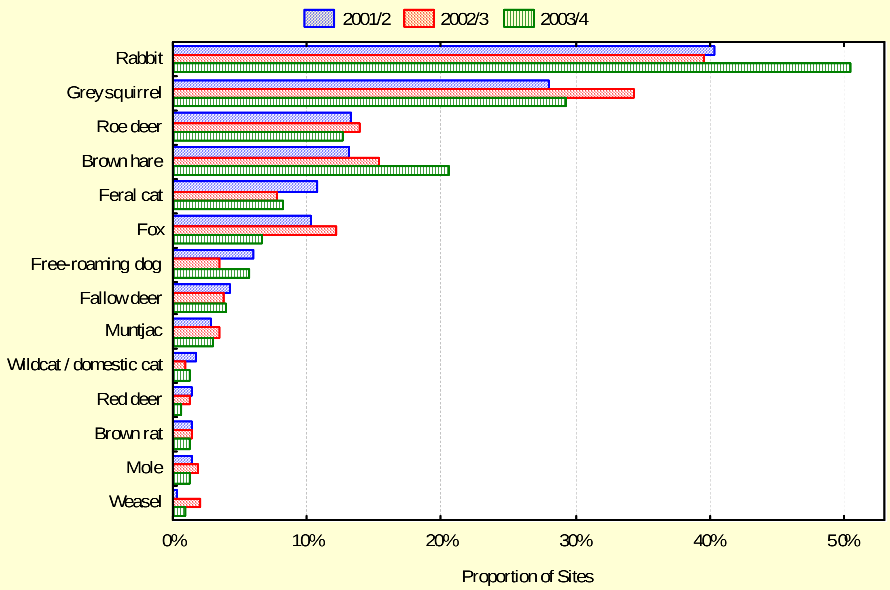


Fig. 7. Proportion of sites within which the fourteen most common species sightings were recorded in each year.

Field Signs

The number of sites in which the original 11 signs were recorded is shown in Fig. 8. These have been divided into two groups because, as described in “Changes to survey design and field recording protocols in 2002/03” in the Survey Methods section, three of the signs (squirrel dreys, deer slots and dormouse-chewed nuts) were dropped after the first year. Of the remaining eight signs, all except field vole runs and harvest mouse nests were searched for in over 90% of the sites. The most frequently encountered sign was mole hills (75% of sites), followed by field vole, rabbits and foxes.

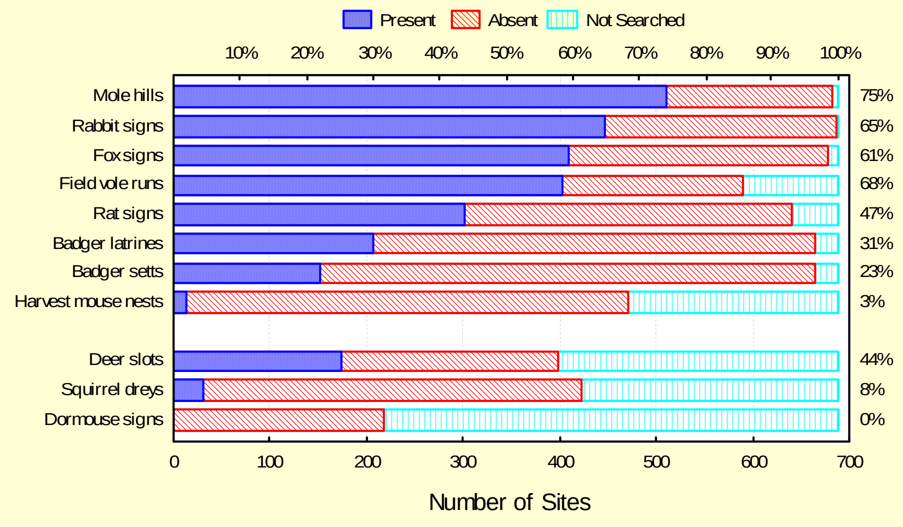


Fig. 8. Number of sites within which each sign was recorded. The lower three signs were only recorded in 2001/2. The figures on the right-hand axis represent the proportion of searched sites containing signs.

An annual breakdown of the proportion of sites in which the major signs were recorded is given in Fig. 9. In general there was little variation between years for the commonest signs. However, badger signs appeared to be less common in the second year, and harvest mouse nests were not found at all in the first year.

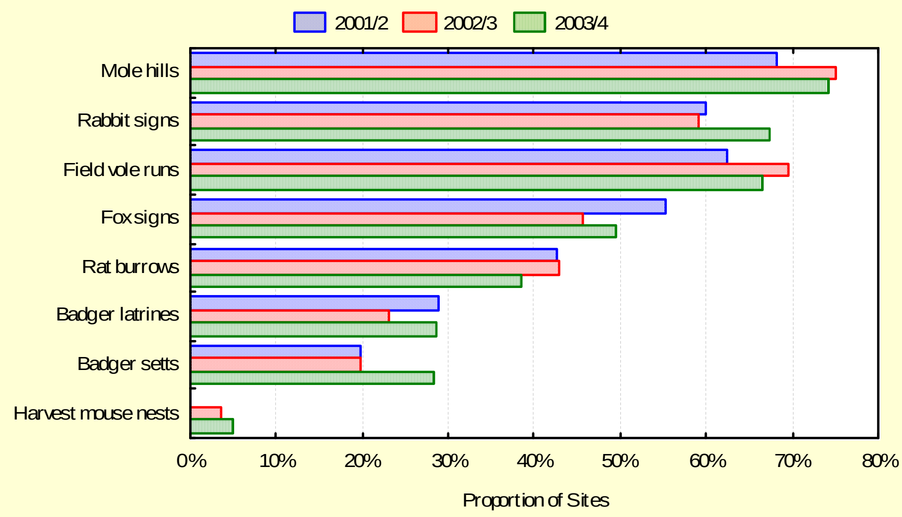


Fig. 9. Proportion of sites within which each major sign was recorded in each year.

Habitat Data

Habitat data were returned from 1081 sites from at least one year. The six adjacent habitat variables were quite evenly represented across all sites and years (Fig. 10). However, the proportions of habitats recorded differed considerably over the three years. Most significantly, in 2001/2, approximately 21% of sections were bounded by urban land, with only 2% bounded by water. However, in 2002/3 and 2003/4, the proportion of urban sections fell to 0.5%, whilst water bounded sections increased to 17%. There were other large increases in the average proportion of grassland sections, and decreases in arable and pastoral.

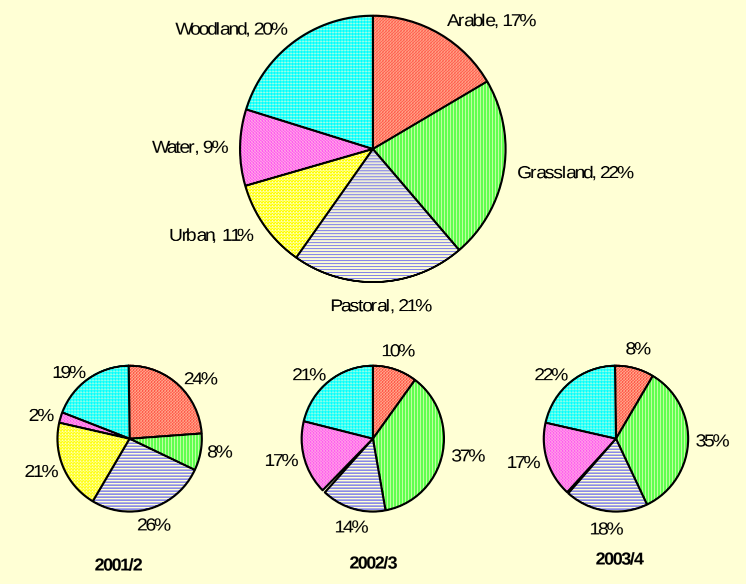


Fig. 10. The mean proportions of sections per site bounded by six different habitat types. The large upper chart shows proportions averaged over all three years, with an annual breakdown in the lower row of charts.

The six linear feature variables were also fairly equitably represented across all years, although waterways were present along more than 26% of the sections (Fig. 11). However, as with adjacent habitats, there was a major change in proportions between the first and subsequent years. In 2001/2, waterways comprised only 8% of the sections, which increased to approximately 45% in the next two years. Conversely, "other" types of linear features and paths declined dramatically from 29% and 24%, respectively to 7%.

Both these patterns of change are related to the large turnover of sites after the first year. This is explored further in the "Site Turnover" section below.

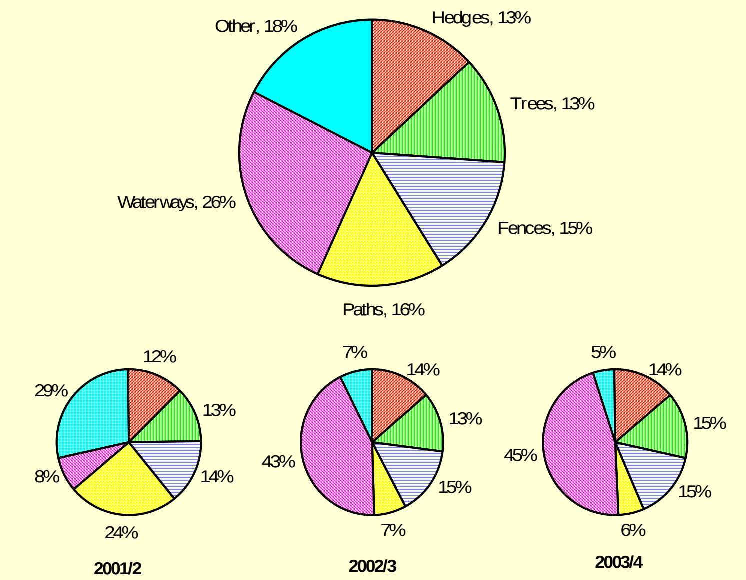


Fig. 11. The mean proportions of sections per site bounded by six different linear features. The large upper chart shows proportions averaged over all three years, with an annual breakdown in the lower row of charts.

6. Methodological Analyses

Site Turnover

For the purposes of this analysis, a slightly reduced sub-set of the data was used, comprising the 1,121 sites from which habitat data were recorded. Of these, 1,043 were visited on at least one year to record sightings and 690 to record signs. Both methods were undertaken at least once on 612 sites, representing 55% of the dataset.

The number of visits made in each year is shown in Fig. 12. The 1,121 sites were visited a total of 2691 times. For both sightings and signs, the turnover rate was very high. For example, of the 803 sites where sightings were made in the first year, only 286 (36%) were revisited in the second year. The turnover was lower from the second year, with 239 of the 490 (49%) being revisited in the third. However, in the second year a new tranche of 204 sites were started, representing 25% of the new sites in the first year. In the third year, only 36 new sites were added. The pattern was similar for signs, with turnovers of 44% and 47% in the first and second years respectively. However, the proportion of new sites in the second year was higher at 44%. The consequence of this turnover of sites is that the tranches of sites running through all three years were comparatively small. Only 15% of sites with sightings and 17% with signs were visited on all three years.

This relatively high turnover rate has important consequences for the analyses which can be carried out on the data (see “Comparison of Statistical Models” below). In order to investigate which factors are related to high turnover, we undertook a series of logistic regressions incorporating various methodological, habitat and volunteer factors (see Table 6) as predictor variables. The response variable in these models was whether a site was revisited in the following year (true or false). This is represented by the hatching pattern in Fig. 12; horizontal hatching represents revisited (true) whilst vertical hatching represents not revisited. These responses were calculated separately for the turnover from year 1 to year 2 and from year 2 to year 3, and for each method, resulting in 2150 cases. Two other variables used in the analysis were also derived from the data model in Fig. 12. Firstly, the first year of the turnover (1 or 2) and whether the site had been visited in the previous year. Clearly, this was not possible for year 1, but for year two allowed the relationship between previous visit and subsequent visit to be analysed.

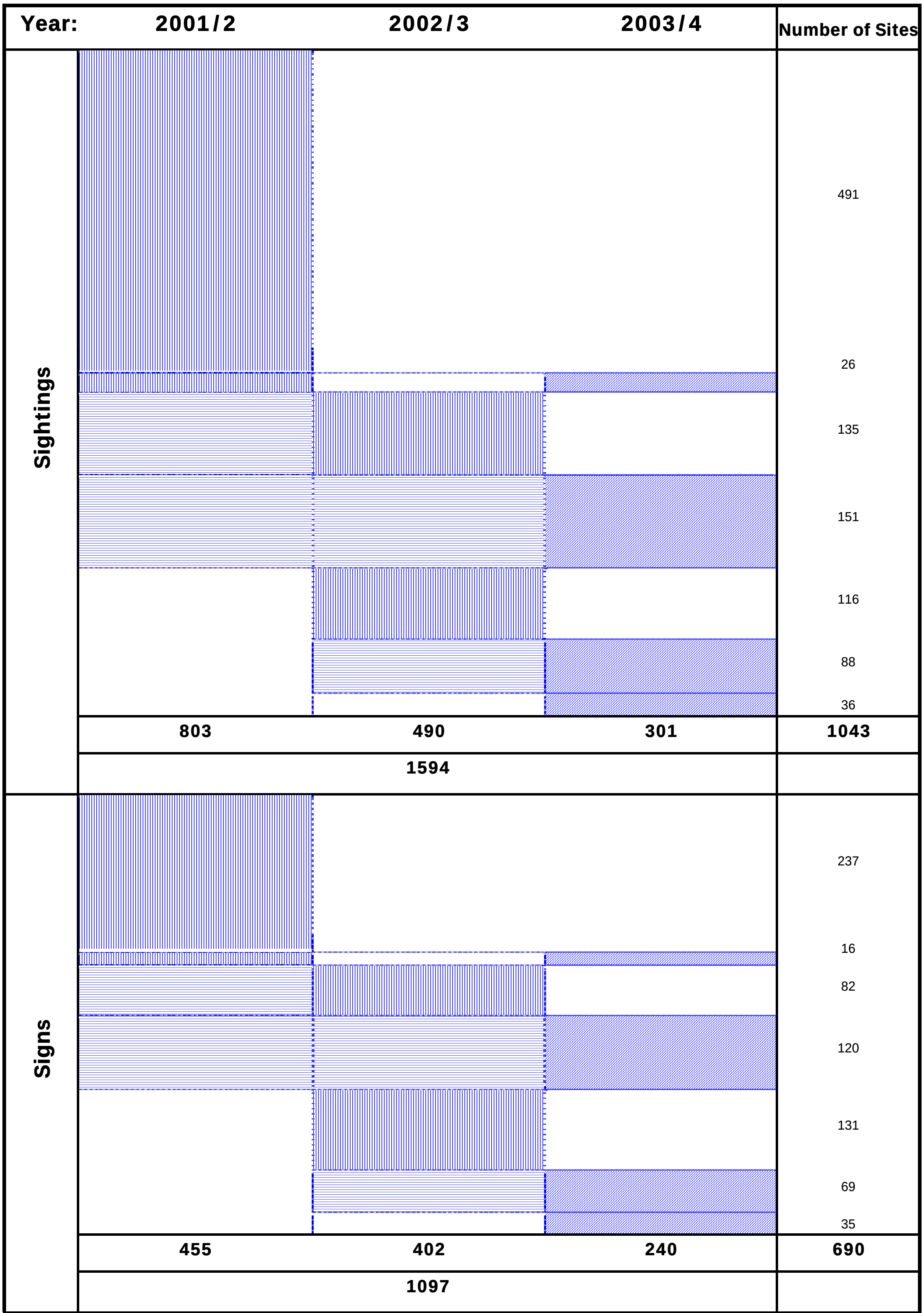


Fig. 12 The number of sites visited in each year of the survey, shown separately for sightings and signs. The height of the rows represent the number of sites (shown in the right-hand column). Each row represents a tranche of sites with a unique pattern of visits between years. Vertical hatching represents a year/tranche not revisited, whilst a horizontal hatching represents revisited year/tranches.

Methodological Factors

The first logistic regression model was built with five predictor variables. These were Method (sightings or signs), StartYear and PreviousYear (as described above), EffortIndex (a continuous variable representing the overall proportion of sections searched for sightings or signs) and ResultIndex (the proportion of sections within a site which had signs or sightings of any species). The initial model included the 2-way interactions between Method and the other four variables. However, as two of these (with EffortIndex and ResultIndex) were not significant ($p \approx 0.65$ and $p \approx 0.91$ respectively), the model was rerun without them (Table 8).

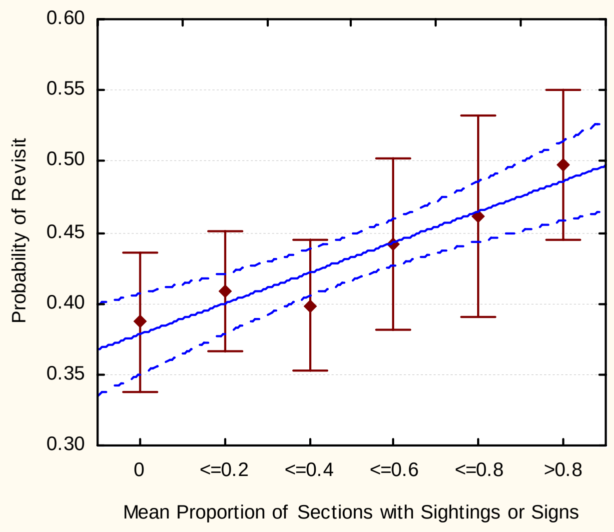


Fig. 13. The relationship between the mean proportion of sections within a site in which sightings or signs were recorded and the probability of a site being revisited.

The most significant factor apparent from this model was the Previous Year. Sites which had previously been visited were far more likely to be revisited (57%) than those which had not (39%). As the Start Year was not significant, this was not just a difference between turnovers from the second year as opposed to the first year.

The Result Index was also a significant factor in predicting turnover. Sites where a high proportion of sections had sightings or signs were far more likely to be revisited than those with a low proportion (Fig. 13). For example, sites where over 80% of sections had records had a 50% probability of being revisited. In contrast, when no sightings or signs were recorded then the probability of the site being revisited was only 39%.

The final effect in this model which was a significant predictor was the interaction between Method and the Start Year (Fig. 15). This can be interpreted as the difference between the probability of revisit between sightings and signs in the two years. In the tranche which started in 2001/2, there was a significant greater probability of sites where signs were recorded being revisited (57%) than those where sightings were made (40%). However, this distinction was entirely absent in the second tranche starting in 2002/3.

A second model was built which included four other methodological variables; Zone (six categories), Number of Observers, Start Time and Duration (continuous variables). The inclusion of these variables had little effect on the previous results, but did reveal a significant relationship between the number of observers taking part in the visit and turnover rate. When this continuous variable was categorised into three groups (Fig. 15), the revisit rate declined from 45% for single observers to 23% when groups of more than two observers were involved. There was no relationship with the other three variables.

Table 8. The methodological factors influencing turnover

	DF	*Wald* χ^2	*p*
Intercept	1	2.977	0.0844
Method	1	0.923	0.3366
StartYear	1	0.308	0.5787
PreviousYear	1	26.056	0
EffortIndex	1	0.111	0.7389
ResultIndex	1	6.701	0.0096
Method x StartYear	1	9.331	0.0023
Method x PreviousYear	1	5.205	0.0225

Habitat Factors

Two groups of habitat factors were analysed separately. Firstly, four indices of habitat type were derived;

- Dominant habitat
- Dominant linear feature

These two variables were simply the category which had the highest proportion of sections within the site. A seventh category of "No Dominant Category" was used in the case of ties.

- Shannon-Wiener Index for habitats
- Shannon-Wiener Index for linear features

These two were continuous variables derived using the Shannon-Wiener Index (*H*') for habitat diversity;

$$H' = -\sum_{i=1}^{k} p_i \log p_i$$

This results in a continuous variable ranging from zero when only one category is present to log *k* when each of the *k* categories is present in equal proportions. These four factors were included in a logistic regression model with Method, Start Year, Previous Year (being the main structural factors), Result Index and the interaction between Method and Start Year (which were previously significant). The model also included the interaction between Method and these four habitat variables.

Unfortunately, the inclusion of all these terms resulted in an "ill-conditioned matrix", which meant that the iterations could not be completed. However, separate partial models without the Effort Index, and without the interactions, indicated that none were significant effects. The only significant factor in the resultant model was the Habitat Shannon-Wiener Index, which showed a strong positive association with turnover. When this continuous variable was categorised for clarity (Fig. 16), low diversity sites had a lower probability of revisit (< 40%) compared to the most diverse sites (57%).

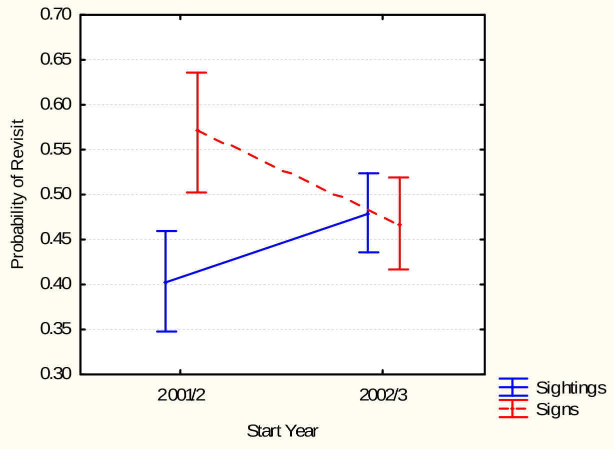


Fig. 14. The interaction between the method and start Year on the probability of a site being revisited.

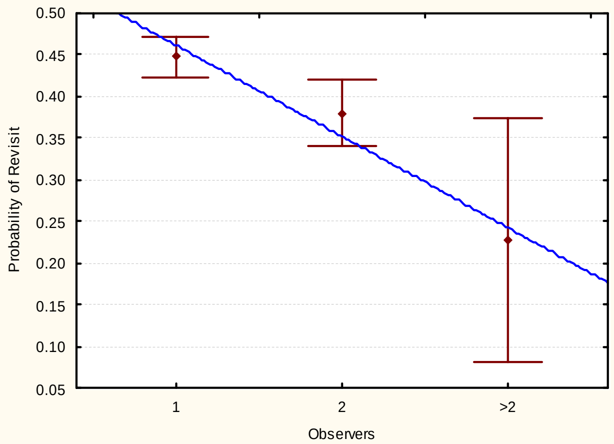


Fig. 15. The relationship between the number of observers and the probability of a site being revisited.

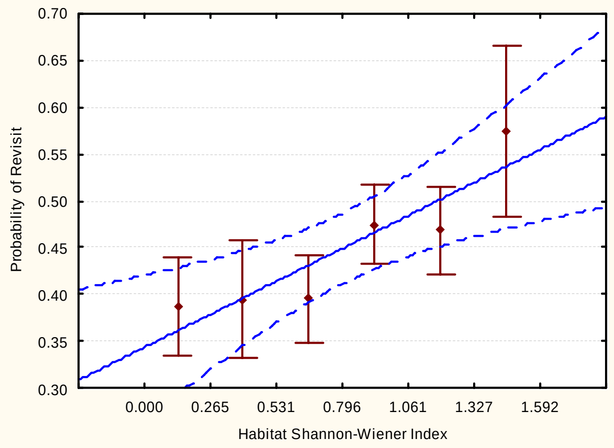


Fig. 16. The relationship between the Shannon-Weiner Index of Habitat Diversity and the probability of a site being revisited.

The second group of habitat variables were derived from the six raw habitat variables and the six raw linear feature variables. The main problem with using these raw variables as predictors in a logistic regression model is that they are very highly correlated with each other. (In fact, being exclusive proportions, the six variables in each group are perfectly correlated.) To overcome this problem Principal Components Analysis (PCA) was used to derive uncorrelated components of variation independently for habitat and linear features. The components explaining the majority of variation were then used as predictor variables in the logistic models.

The first four components in the habitat PCA explained 83% of the overall variation in the raw habitat variables. These were fitted to a model with Method, Start Year, Previous Year and the Method x Start Year interaction. Previous Year remained the most significant factor, but components 1 & 3 also achieved significance at the 95% level (Table 9). The two components account for over 45% of the overall variation in habitats between sites.

Table 9. The components of Habitat which influence turnover.

	Co-efficient	*Wald χ^2*	*p*
Intercept	-0.071	1.611	0.2043
Method	-0.088	3.646	0.0562
StartYear	0.010	2.041	0.1531
PreviousYear	-0.312	20.158	0.0000
Method x StartYear	-0.010	4.639	0.0313
Component 1	-0.112	4.339	0.0373
Component 2	0.048	0.999	0.3175
Component 3	0.133	8.366	0.0038
Component 4	-0.055	1.465	0.2262

To interpret these components, it is necessary to project the raw variables into the space defined by the two significant components (Fig. 17). These two components create a space in which the raw variables are extremely well spaced. So, component 1 has a strong positive correlation with sites dominated by pastoral and arable, and a low correlation with grassland-dominated sites. In contrast, component 3 also has a high value for pastoral but also for woodland-dominated sites, and a negative value for Urban sites. However, reference to Table 9 shows that the co-efficient for component 1 is negative, whilst the co-efficient for component 3 is positive. This means that low values of 1 and high values of 3 are strong predictors of high turnover. In other words, sites with high proportions of woodland and grassland (the upper-left quadrat in Fig. 17) have a greater probability of being revisited compared to those with high proportions of urban and arable (the lower-right quadrant). Indeed, sites with both woodland and grass have a probability of revisit of nearly 50%, but when sites have arable and urban present, the probability of revisit is only 38%.

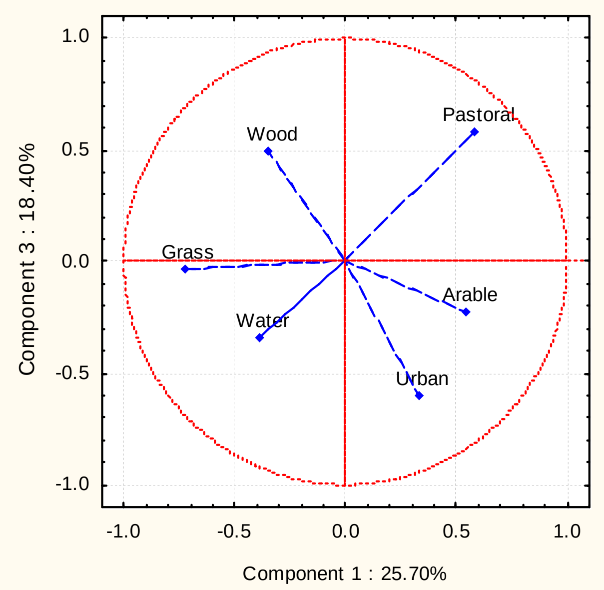


Fig. 17. The six Habitat variables projected onto the plane defined by the first and third components.

A similar analysis has been carried out with the linear features variables. In this case, only the first principal component is

Table 10. The components of Linear Features which influence turnover.

	Co-efficient	*Wald χ^2*	*p*
Intercept	-0.086	2.352	0.1252
Method	-0.095	4.254	0.0392
StartYear	0.194	6.541	0.0105
PreviousYear	-0.308	19.510	0.0000
Method x StartYear	-0.099	4.597	0.0320
Component 1	0.240	14.061	0.0002
Component 2	-0.002	0.001	0.9728
Component 3	-0.074	2.603	0.1067
Component 4	0.018	0.153	0.6960

a significant predictor of turnover (Table 10). This component alone explains over 26% of the variance in the raw linear feature variables. To interpret this component, the raw variables have been projected onto the space defined by components 1 and 2 (Fig. 18), simply to partition them out and make them easier to view, despite there being no significance in component 2. Component 1 is highly positively correlated with Water and negatively correlated with Paths and Other features. To illustrate this, in sites where water comprises over 30%of the transect length, the probability of revisit is over 52%, whilst in sites where paths and other features are both over 10%, then the probability of revisit is only 39%.

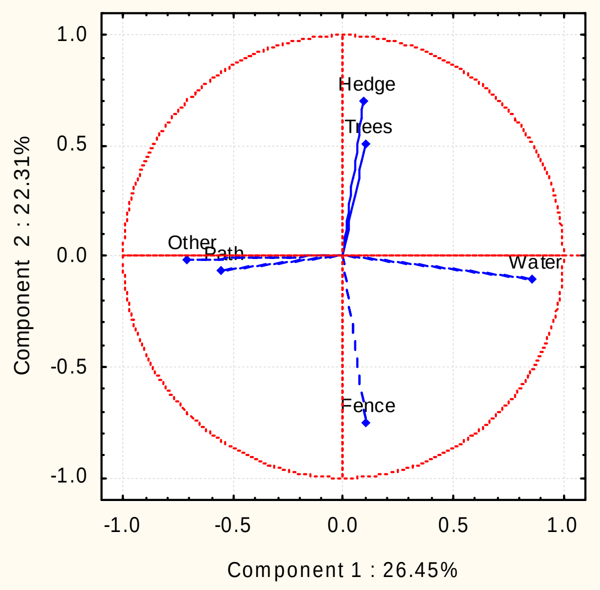


Fig. 18. The six Linear Features variables projected onto the plane defined by the first and second components.

These significant habitat and linear features should be considered cautiously. It may be that features such as woodland, grassland and water make sites intrinsically attractive to visit. Conversely, sites with high urban features or dominated by arable land may be intrinsically less interesting for mammal observations. Both these influences could contribute directly to turnover rates. However, the general analysis of sightings and signs (see "Factors influencing the recording of Sightings & Signs" below) indicates that certain habitat and linear feature variables appear to influence the results. As we have already shown that a high Result Index appears to result in a greater likelihood of revisit, it may be habitat factors are only influencing turnover indirectly. In other words, sites with certain types of habitat have higher rates of sightings and signs, which generates more interest for the observer, which in turn, encourages them to revisit the site.

Volunteer Factors

A range of variables describing the volunteers who visited the sites have been derived from a variety of sources, including the questionnaires. Several different models had to be constructed to accommodate the different sources, so it only possible to present a summary of these factors.

Firstly, several of the questions relating to how easy or enjoyable the volunteer found the survey were significant predictors of turnover. This tells us little though, because it is hardly surprising that if a volunteer returns the questionnaire expressing satisfaction with the survey or their square, we find that there is a high probability that the site will be revisited in subsequent years. Another question which was positively related to turnover was whether there was adequate support in terms of help-lines and advice, which is encouraging. Volunteers who recorded the maximum score were far more likely for their sites to be revisited (over 60%) than those who scored the minimum (31%).

Rather surprisingly, attendance at The Mammal Society's training courses, membership of The Mammal Society or the BTO had no relationship whatsoever to turnover. Conversely, if volunteers participate frequently in The Mammal Society's other surveys (but not BTO or general surveys), their sites had a higher probability of being revisited (Table 11).

The most significant personal factors which influenced turnover were age and occupation. Age was originally treated as an eight-point ordinal variable and was very highly significant. When categorised into four groups for ease of interpretation (Fig. 19), it is clear that the squares of younger volunteers were far less likely to be revisited than those of older volunteers, despite the slight fall-off at 65 and above.

Occupation was classified on a six-point categorical scale. In the final model, it was a marginally significant factor, but with a very clear pattern (Fig. 20). Academics were clearly far less likely to have squares which were revisited than the other groups, with an average revisit rate of only 11%. Volunteers with a specific interest in mammals or a general natural history interest were the most likely to have squares which were revisited at between 55% and 60%. Professional countryside workers were intermediate between those with a mammal or natural history interest and academics.

Table 11. The volunteer factors which influence turnover.

	DF	*Wald* χ^2	*P*
Intercept	1	40.484	0.0000
Method	1	0.145	0.7036
StartYear	1	0.014	0.9054
PreviousYear	1	0.148	0.7001
Occupation	5	13.525	0.0189
Age	1	22.367	0.0000
Other Mam. Soc. Surveys	1	19.397	0.0000
"Adequate Support?"	1	9.660	0.0019
"Happy With Square?"	1	8.618	0.0033

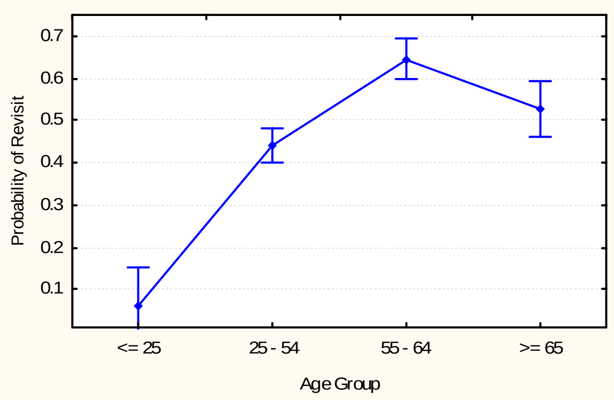


Fig. 19. The relationship between Age Group and the probability of a site being revisited.

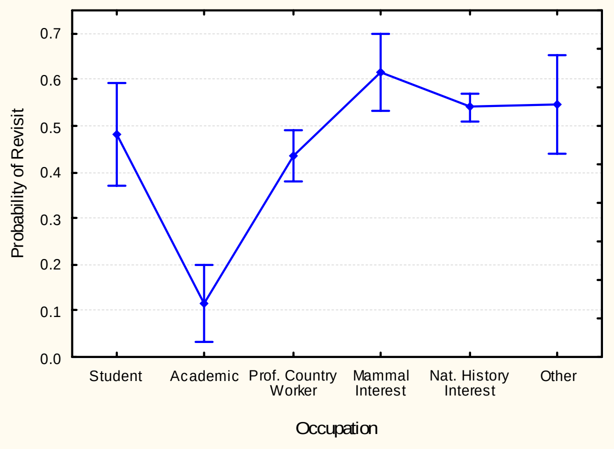


Fig. 20. The relationship between Occupation and the probability of a site being revisited.

Comparison of Statistical Models

The analysis of turnover described in the previous section, and especially the size of the year cohorts illustrated in Fig. 12, raises several problems for the subsequent analyses. Turnover between subsequent years ranged from 44% to 64%. This means that the cohort of sites visited throughout the whole of the monitoring programme has declined rapidly. For example, in the first year there were 803 sites visited where sightings were made. In the second year, although a total of 490 sites were visited, only 186 had been visited in both years. And by the third year, this cohort had diminished to only 151 sites. If both methods were included (in other words sites which were visited six times; three for sightings and three for signs) the cohort contained only 93 sites.

This is a very small proportion of 1,121 sites used in the survey, and the 558 (93 × 6) visits is also a small proportion of the 2,700 visits made in total. This indicates that three different approaches can be taken to the analysis. The purpose of this section is to explore the advantages and disadvantages of each.

- The simplest model is for all 2,700 visits to be included as the cases in an analysis with no indication of the site to which they belong. The main advantage of this approach is that all data are used in the analyses. However, it ignores the fact that the data only came from 1,121 sites, so the individual cases will not be independent of each other.
- The second option is for each of the 1,121 sites to contribute a single case to the analysis. This can be achieved by randomly selecting only one of the measurements where repeated measures have been made, plus the single measurement from sites only visited once. This has the advantage that all the cases will be independent of each other, but at the cost of only using about 40% of the data.
- It is known from basic statistical theory that paired or "repeated-measures" analyses are intrinsically more powerful than analyses based on independent samples. This is because in the former case, the variation between sites can be accounted for by including a "blocking" factor in the statistical model, whereas in the latter this variation is just part of the error term, making it larger and, consequently, the overall model less powerful. So, the data from the cohort of sites visited in all three years can be fitted to this type of model. Although it is intrinsically more powerful, it only uses a small proportion (about 20%) of the overall dataset, which is likely to decline further in the future.

A fairly simple Analysis-of-Covariance (ANCOVA) model was constructed to test these three approaches. The response variable was the proportion of sections in which sightings or signs (as appropriate) of any species were recorded. As this variable has a binomial distribution, it was transformed using a square-root arcsin transformation. Two main factors were included; Method and Survey Year, plus their interaction. An "Effort Index" was also derived based on the average number of sections searched for signs, or used for sightings. This was transformed and used as a covariate in the model.

The results are given in Table 12. The first important comparison is that the Repeated-Measures model has an additional three terms, which represent the Site blocking factor and its two-way interactions with the other two main factors. These have been "extracted" from the error term, which is now reduced to the three-way interaction between Method, Survey Year and Site. This has two main consequences. Firstly, the model is more powerful, as 80% of the overall variance is explained by the model (Adjusted R^2), compared to less than 35% in the other two models. The Error mean-square (MS) and the Error degrees-of-freedom (DF) are both reduced, which influences the F-ratios of the factors of interest.

The only term which was significant in all three models was Method. However, because of the inclusion of the Site × Method interaction in the repeated-measures model, the level of significance was much greater. In contrast, the R^2 values and Error MS in the Full Dataset and Random Sub-set models were very similar to each other, indicating that they are essentially the same type of model. However, the *p*-value for Method in the former model was nearly 60 times smaller (more significant), partly caused by the increased sample size. Also, although the Survey Year was not significant in either model, the *p*-value was over eight times smaller in the Full Dataset model.

Table 12. Comparison of three models for the analysis of the proportions of sections with signs or sightings.

		Numerator		*Denominator*			
		DF	*MS*	*DF*	*MS*	*F*	*p*
Full Dataset							
Effort Index	Continuous	1	0.494	2693	0.043	11.40	0.00074
Method	Fixed	1	51.121	2.72	0.020	2610.66	0.00004
SurveyYear	Random	2	0.185	1.92	0.018	10.42	0.09317
Method x SurveyYear	Random	2	0.018	2693	0.043	0.41	0.66096
Error		2693	0.043				
Adjusted R^2	34.4%						
Random Sub-set							
Effort Index	Continuous	1	0.318	1114	0.040	7.98	0.00482
Method	Fixed	1	15.223	2.33	0.069	221.61	0.00231
SurveyYear	Random	2	0.021	1.99	0.073	0.28	0.77834
Method x SurveyYear	Random	2	0.073	1114	0.040	1.83	0.16110
Error		1114	0.040				
Adjusted R^2	34.7%						
Repeated-Measures							
Effort Index	Continuous	1	0.036	183	0.014	2.56	0.11125
Method	Fixed	1	9.313	72.01	0.056	165.20	$<10^{-20}$
SurveyYear	Random	2	0.003	0.69	0.002	1.75	0.47095
Method x SurveyYear	Random	2	0.002	183	0.014	0.15	0.85701
Site		92	0.148				
Site x Method		92	0.082				
Site x SurveyYear		184	0.014				
Error (Site x Method x SurveyYear)		183	0.014				
Adjusted R^2	80.4%						

The conclusion from this comparison is that the Random Sub-set approach is probably the best compromise. The Repeated-Measures model is intrinsically more powerful, but due to the high rate of turnover, results in a very small proportion of the data being available to it. Furthermore, when more complex models are built, including factors such as Land-Use Zone (which introduces a nested design) or habitat factors (which change with Survey Year), the models become extremely difficult to construct and run successfully. In contrast, the Full Dataset model introduces a spurious degree of power by ignoring the non-independence of the cases. This could result in factors being identified as significant when they are in fact not (Type I error, *cf.* “Power Analysis” below). In addition, because the number of visits (cases) in each site can vary between one and six, sites will contribute different “amounts” of information to the final model.

The Random Sub-set model does not violate any assumptions about non-independence of cases, but suffers from using only a proportion of the available data. As the Method (sightings/signs) has been shown to be very highly significant in all models, the proportion of data used could be increased by accepting this distinction and analysing the methods separately. Alternatively, repeated randomisations could utilised to use all (or most) of the data and increase the robustness of the models.

Factors influencing the recording of Sightings & Signs

The Random Sub-set approach has been used to investigate the factors influencing the recording of sightings and signs. The response variable (proportion of sections with sightings or signs of any species) and covariate (Effort Index) were arcsine square-root transformed as in the previous section. Three main groups of explanatory factors were included in the model; Spatio-temporal factors defined by the survey design, Observer determined factors and Habitat factors (Table 13).

Table 13. The three groups of factors influencing the recording of Sightings & Signs.

	Variable	*Type*	*Effect*	*Values*
Spatio-temporal	Method	Categorical	Fixed	Sightings or Signs
	Survey Year	Categorical	Random	2001/2, 2002/3 or 2003/4
	Environmental Zone	Categorical	Fixed	England/Wales 1: Easterly lowlands, 2: Westerly Lowlands, 3: Uplands Scotland 4: Lowlands, 5: Intermediate uplands & islands, 6: True uplands
	Easting	Continuous		Km east of NGR SV00
	Northing	Continuous		Km north of NGR SV00
Observer	No. of Observers	Categorical	Fixed	1 or >1
	Month	Categorical	Fixed	November or earlier, December, January, February or later
	Start Time	Continuous		Hours
	Duration	Continuous		Minutes
Habitat	Dominant Habitat	Categorical	Fixed	Six values (plus none)
	Dominant Linear-feature	Categorical	Fixed	Six values (plus none)
	Habitat Shannon-Wiener	Continuous		
	Linear-feature Shannon-Wiener	Continuous		
	Habitat Principal Components (5)	Continuous		
	Linear-feature Principal Components (5)	Continuous		

The factors and covariates were built into a mixed-model ANCOVA using a GLM model building approach with Type III sums-of-squares. All main factors were included along with their first-order interactions with Method. (Note that the total number of cases is slightly reduced in this model as a few sites had missing values for some of the variables.)

Effect of Method

The previous comparison of the three different approaches to the analysis ("Comparison of Statistical Models") showed in all cases that Method was very highly significant. The first question for this more complete analysis is whether the addition of a number of other explanatory variables affects this result. With all the Method interactions fitted in the model, there was very little influence on the significance levels of Method ($p < 0.004$), Survey Year ($p = 0.24$) and the Method × Survey Year interaction ($P = 0.38$). However, a large amount of

Table 14. ANCOVA model of the main factors affecting the proportion of sections with sightings or signs. Factors marked * were marginally significant, those marked ** were highly significant.

		Effect			Error				
		SS	*DF*	*MS*	*DF*	*MS*	*F*	*p*	
Effort Index	Fixed	0.241	1	0.241	1078	0.036	6.78	0.0094	
Method	Fixed	2.831	1	2.831	203.8	0.037	76.85	0.0000	**
Survey Year	Random	0.297	2	0.148	1.9	0.059	2.51	0.2906	
Zone	Fixed	0.476	5	0.095	1078	0.036	2.68	0.0206	*
ObsIndex	Fixed	0.003	1	0.003	1078	0.036	0.07	0.7904	
Easting	Fixed	0.191	1	0.191	1078	0.036	5.37	0.0207	*
Northing	Fixed	0.038	1	0.038	1078	0.036	1.06	0.3027	
Month	Fixed	0.190	3	0.063	1078	0.036	1.78	0.1492	
Start Time	Fixed	0.154	1	0.154	1078	0.036	4.34	0.0376	*
Duration	Fixed	1.450	1	1.450	1078	0.036	40.81	0.0000	**
Method x Survey Year	Random	0.117	2	0.058	1078	0.036	1.64	0.1941	
Method x Zone	Fixed	0.671	5	0.134	1078	0.036	3.78	0.0021	**
Method x Easting	Fixed	0.820	1	0.820	1078	0.036	23.07	0.0000	**
Error		38.302	1078	0.036					

the variation in Method was apportioned to the many interactions with this factor, most of which were insignificant. To make the model more parsimonious, the five non-significant interactions (but not Method × Survey Year) were removed. This model revealed Method still to be the most significant factor (Table 14). By un-transforming the means of the predicted values from this model the mean proportion of sections which had sightings was 14.0% (12.6% – 15.4%), whereas the mean proportion with signs was 63.7% (59.2% – 68.2%). This massive difference implies very strongly that the overall amount of information available from signs is significantly greater than that provided by sightings

Spatio-temporal and Observer Factors

The next most significant explanatory factor was Duration (the time spent on site – Fig. 21). Note that there was no significant interaction with method, although there is clearly a log-linear effect in this relationship. Overall, 26% of the variation is sightings and 37% of the variation in signs was explained by Duration. In other words, by broadly categorising duration into hours, we can see that for sightings, when the duration was less than one hour the mean response was about 11% of sections, whereas when the duration was more than two hours, the mean response was

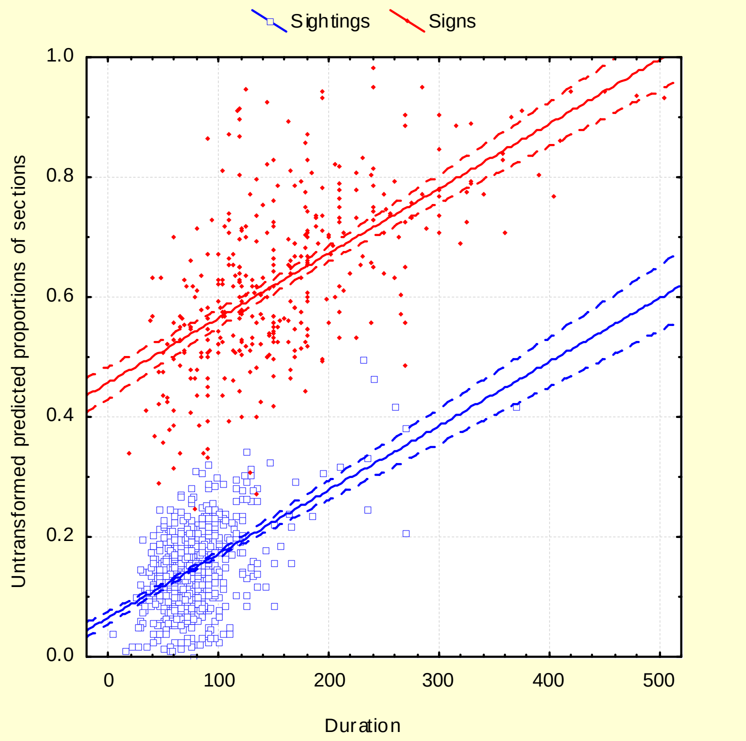


Fig. 21. The relationship between the predicted proportion of sections (untransformed) and the Duration. Observations are coded by Method, with independent linear regression lines and 95% confidence intervals.

approximately 24% of sections. Similarly, for sign visits, when the duration was less than two hours, the mean response was 56% of sections, but with durations of over four hours, the response was over 78% of sections. This also illustrates that more time was spent on signs visits than sightings which results in a complex three-way interaction between these factors. Furthermore, although there was a significant positive correlation between Duration and the Effort Index, the latter only explained about 3.5% of the variation in Duration, so for the purposes of this analysis, the Duration effect can be considered real.

Three other main factors were marginally significant in this model. Start-time was not a good predictor of the response variable, but Zone and Easting both had significant interactions with Method. The Method × Zone interaction can be explained in two parts (Fig. 22). Firstly, the three English zones (1 to 3) did not have significantly different signs responses, but they had very significantly different sightings. Zone 3 (Uplands) had significantly fewer sightings (5%) than the two lowland zones (18% & 14% respectively). Secondly, although there was no difference between the responses in the Scottish zones for either method, Zone 4 (Scottish Lowlands) had significantly more signs (90%) than the two English lowland zones (62% and 59% respectively).

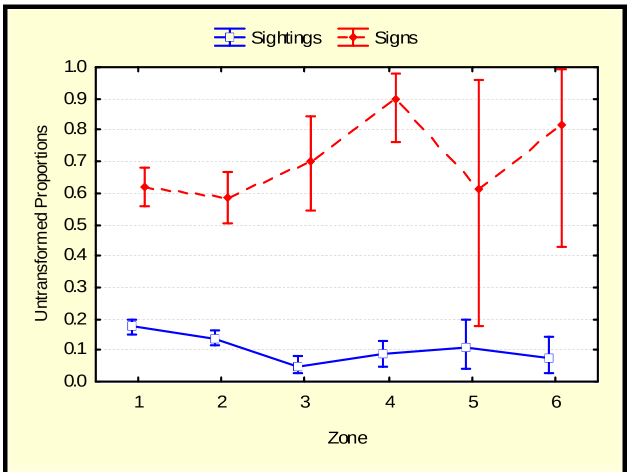


Fig. 22. The interaction between Method and Zone in predicting the proportion of sections. Untransformed means and 95% confidence intervals are plotted.

In addition to the effect of zones, eastings were also a significant predictor of sightings and signs, but with a highly significant interaction with Method (Fig. 23). The proportion of sections with sightings increased in an almost linear fashion from west to east, such that sites with an easting less than 300 (the western half of Scotland, western Wales and Devon and Cornwall only had an average of only 10% of sections with sightings. In East Anglia and Kent (eastings greater than 550), however, the average proportion of sections with sightings was more than 20%. The converse situation occurs with signs. In the far west, the proportion of sections with signs averaged about 75%, whilst in the east this fell to below 50%.

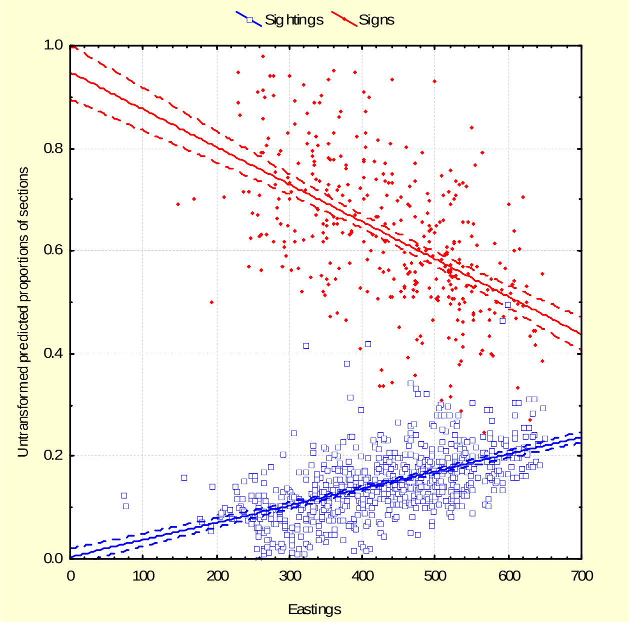


Fig. 23. The relationship between the predicted proportion of sections (untransformed) and the Easting value of the site. Observations are coded by Method, with independent linear regression lines and 95% confidence intervals.

Clearly, there must be a relationship between Zone and Eastings (and Northings) which has not been fully explored in this model. When these two interactions were added to the model, the main factors for Zone and Easting, become non-significant, but their interaction was only marginally significant ($p = 0.03$). Furthermore, the two relationships shown in Fig. 21 and Fig. 22 were completely unaffected. Interestingly, the interaction between Zone and Northing was entirely non-significant (see map in chapter 3).

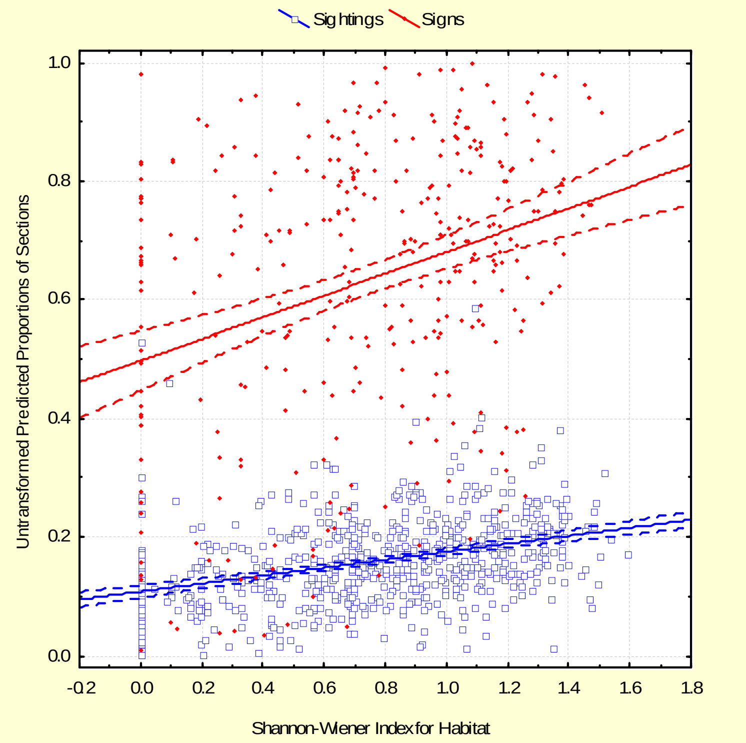


Fig. 24. The relationship between the predicted proportion of sections (untransformed) and the Shannon-Wiener Index for Habitat. Observations are coded by Method, with independent linear regression lines and 95% confidence intervals.

Habitat Factors

A total of 14 Habitat variables were derived as described in Table 13 and the "Site Turnover" section above. These were all fitted to the ANCOVA model used in the previous analysis, firstly to ensure that the factors which had been identified as significant remained so and, secondly, to identify any habitat factors which might further influence the recording of sightings and signs. All 14 variables were fitted to the model along with their interactions with Method.

Table 15. The five significant Habitat effects.

	SS	*DF*	*MS*	*F*	*p*
Habitat Shannon-Wiener	0.390	1	0.390	12.44	0.00044
Habitat PCA 3	0.343	1	0.343	10.93	0.00098
Linear-feature PCA 3	0.407	1	0.407	12.97	0.00033
Method x Habitat PCA 2	0.223	1	0.223	7.12	0.00777
Method x Habitat PCA 3	0.521	1	0.521	16.61	0.00005
…					
Error	30.665	978	0.031		

Three of the four effects (Method, Duration and Method × Easting) which had been previously identified as highly significant remained so. However, the Method × Zone interaction became non-significant, but Zone itself now became highly significant. ($p < 0.0006$). So, overall, there was little consequence on these main factors of the fitting of the habitat variables.

However, of the 28 main effects and interactions, four achieved marginal significance ($0.05 > p > 0.01$) and have not been considered further. However, five other effects were highly significant (Table 15), three main factors and two interactions. The Shannon-Wiener Index of habitats was significantly positively related both to the proportions of sections with sightings and with signs (Fig. 24). Although this factor explained a greater proportion of the variation in sightings (14%) than signs (10%), the interaction was not significant. Consequently, when habitat diversity was at a maximum, the average proportion of sections with sightings was over 20%, whereas when it was zero (i.e. there was only one habitat present in the site), the proportion was 10%. The equivalent proportions for sightings were around 75% and 50% respectively.

Two of the Habitat Principal Components were also significant factors. Principal Component 2 had a highly significant positive interaction with Method (Fig. 25). In other words, when values on this axis were high, the proportion of sections with signs was much greater, but the same relationship did not exist for sightings. Approximately 24% of the variation in the proportion of sections with signs was explained by this component. The interpretation of the habitat variables contributing to this component is given at the bottom of Fig. 25. Low values represent high proportions of Woodland and Urban habitats within the site, whilst high values represent Grassland and to a lesser extent Arable and Pastoral sites. So using this interpretation when sites contain a high proportion of Woodland and Urban habitat they have lower proportions of sections with signs (36%) but when they contain more Grassland, they have higher proportions of sections with signs (67%). The equivalent proportions for sightings are 12% and 15% respectively.

The third Principal Component had a very significant negative relationship with both methods, but the interaction was also highly significant (Fig. 26). Consequently, this component explained over 27% of the

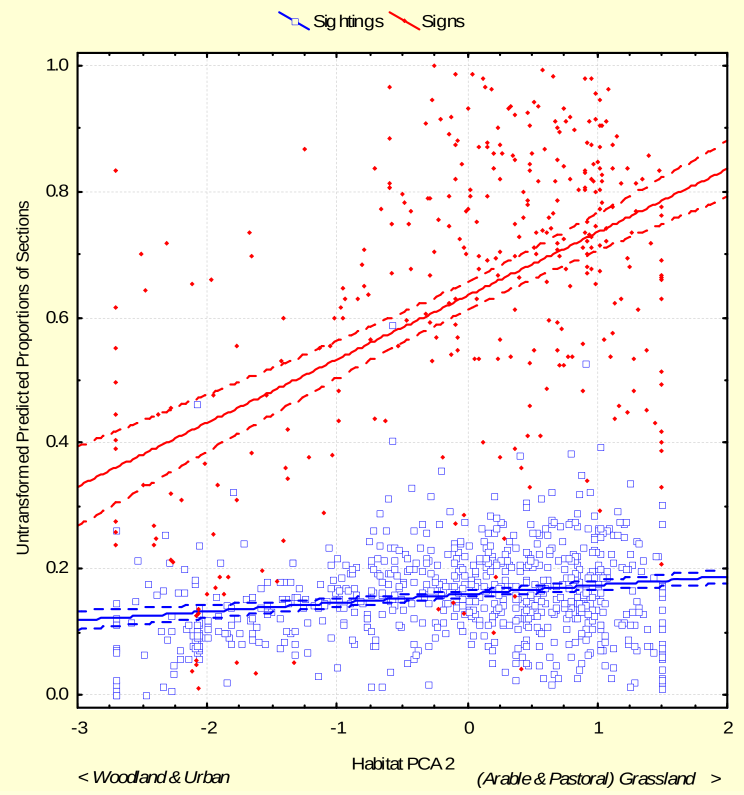


Fig. 25. The relationship between the predicted proportion of sections (untransformed) and the second Habitat Principal Component. Observations are coded by Method, with independent linear regression lines and 95% confidence intervals.

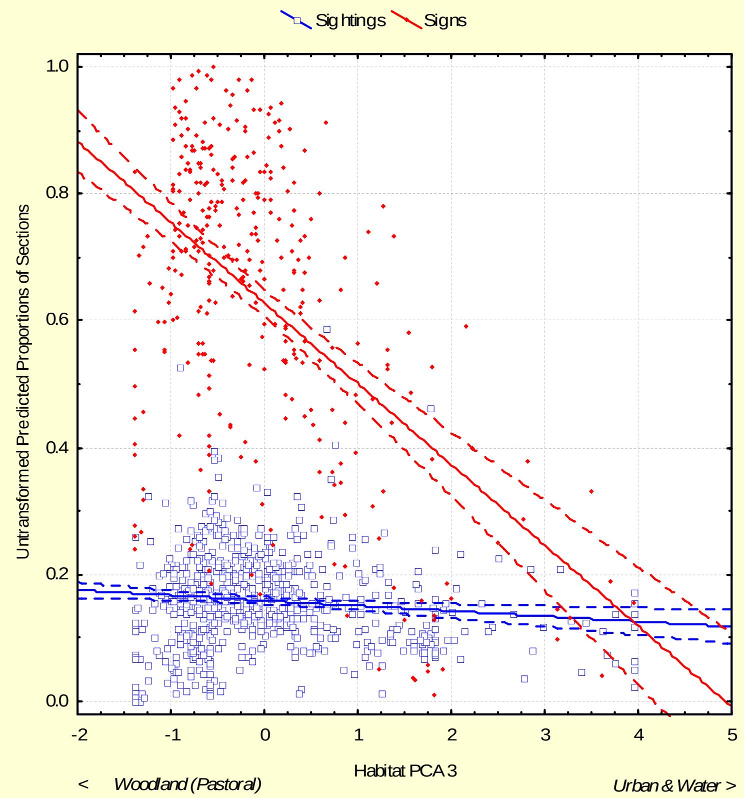


Fig. 26. The relationship between the predicted proportion of sections (untransformed) and the third Habitat Principal Component. Observations are coded by Method, with independent linear regression lines and 95% confidence intervals.

variation in the proportion of sections with signs, but only 1% of the variation is sightings. The interpretation of the component is that high values represent sites dominated by Urban and especially Water habitats, whereas, to a lesser extent, low values represent sites with a strong Woodland and Pastoral element. So, when sites are dominated by Urban and Water they have low proportions of sections with signs (31%), but with strong Woodland and Pastoral elements, they have higher proportions (70%). The equivalent values for sightings were 15% and 12% respectively.

Clearly, these two components are interacting, because Woodland appears to have opposite effects, which probably results in little overall influence on the proportions of signs. The two habitat factors which have consistent effects in both principal components are Urban (negative) and Pastoral (positive), but taking the much stronger influence of component 3 into account (Table 15), Water also has a strong negative influence.

The final factor which was a strong predictor of both methods, as the interaction was not significant, was Linear-features Principal Component 3, which had a negative relationship. However, it only explained 7% of the variation in proportion of sections with signs, and 3% of the proportion with sightings. Moreover, both relationships were quite strongly influenced by outliers, so their predictive ability was not strong.

However, this component represented low proportions of sections with Trees and to a lesser extent high proportions of both Paths and Waterways. So, the interpretation of this is that sites with high proportions of Trees had more signs (66%) and sightings (19%) while those with high proportions of Paths and Waterways had fewer signs (56%) and sightings (15%).

Model Consistency and Robustness

The analysis described above was based on the random subset of data to avoid the problems of non-independence of sample units. Consequently, only about 40% of the full dataset was used. Not only does this appear to be wasteful of data, but it also results in a loss of potentially important information. Furthermore, although some very significant predictive factors were identified, the significance was based entirely on the dataset used to construct the model. There was no testing of "unseen" data to investigate how consistent and robust these results were. In other words, had a different dataset been used, would the same explanatory variables have been identified, and if the model was tested on unseen data, would it still predict as well?

In order to address these issues a subsidiary analysis was carried out. The dataset was divided into six subsets, based on the Method and Survey Year categories. So, one subset was constructed from visits where Sightings were collected in 2001/2, another from Sightings in 2002/3, and so on. In this way, each subset comprised a unique and independent set of data cases. The full ANCOVA model described in the previous section (with modifications) was applied to each of these datasets in turn. The modifications were that the Method and Survey Year factors, the Method × Survey Year interaction and all the Method interactions were now unnecessary as these were constants within each dataset. The resultant model just had 20 main factors plus the Effort Index covariate.

Firstly, to investigate consistency, the results (*p*-values) of running the six independent models were compiled (Table 16). The pattern of significances across the variables in the six models indicates that there is very little consistency between models. Of the 20 variables used, 16 were marginally significant in at least one of the models and nine of them were significant at $p <= 0.005$. Moreover, only one variable (Duration) was significant at this level in more than one model. This gives a very strong indication that the predictive variables selected within a model were highly dependent on which dataset was used. So, for example, although Easting was shown to have a positive relationship with Sightings and very strong negative relationship with signs (Fig. 23), only one of the six datasets (Sightings in 2001/2) found Easting to be significant. Furthermore, one of the datasets (signs in 2003/4) produced a model without any significant effects at all. Although this was the smallest, with only 228 cases, it contained nearly a quarter of the cases used in the random sub-sample for the main analysis.

The other test of interest was how robust these models were. In other words, if we built a predictive model on one dataset, how well would it predict on another unseen (presumably future) dataset? To test this, a cross-validation exercise was undertaken on each analysis. Firstly, the residuals from the analysis were stored. Then a random subset of similar size to the analysis dataset was generated from the unseen data gathered using the same method. The model generated from the analysis dataset was then fitted to the validation dataset and the residuals stored. For example, for the model generated from Sightings gathered in 2002/3 (475 cases – *c.f.* Table 16), a subset of 479 cases was randomly selected from the 1,062 cases where Sightings were recorded in 2001/2 and 2003/4. So, each of the six models generated two sets of residuals, its own analysis residuals, and a set of independent validation residuals.

The residuals from a parametric analysis such as these ANCOVAs represent the discrepancy between the predicted and observed values for each case. As such, the average of the absolute residuals represent the goodness-of-fit of the model to the observed values. A very small mean absolute residual, indicates that the model is a very good fit, whereas larger means represent a poor fit.

The absolute value of the residuals were then used as the response variable in a three-way fixed-effect ANCOVA (with the observed values used as a covariate to account for intrinsic differences). The three-way interaction is shown in Fig. 27. Although this interaction itself was not significant ($p = 0.51$), it clearly shows all the main effects and interactions. Most importantly, the only two-way interaction which was significant was Year × Analysis ($p < 10^{-6}$). In other words, for both Sightings and Signs, the mean absolute residuals from the 2001/2 and 2003/4 models were significantly greater using the validation dataset, but this was not the case in 2002/3. This implies that the latter models were quite robust because they predicted unseen data as well as their "own" analysis data. However, this did not occur in the first and third years. It is also interesting to

Table 16. P-values from six independent analyses using a standard ANCOVA mdoel on different Method / Year datasets. Values marked in *italics* are marginally significant ($p<0.05$), whilst those in **bold** are significant at $p<0.01$.

	Sightings			*Signs*		
	2001/2	*2002/3*	*2003/4*	*2001/2*	*2002/3*	*2003/4*
N	767	475	295	432	389	228
Zone	**0.005**	*0.044*	0.193	0.251	0.070	0.686
PooledMonth	**0.002**	0.151	0.910	0.084	0.550	0.109
DomHabitat	*0.024*	0.468	0.304	0.141	0.186	0.936
DomLinear	0.841	0.186	*0.023*	0.148	0.567	0.202
Easting	**0.005**	0.054	0.243	0.096	0.266	0.473
Northing	0.154	0.601	0.580	0.071	0.705	0.678
Start	0.867	0.226	0.129	0.721	**0.002**	0.251
Duration	*0.012*	**0.005**	0.135	0.088	**0.004**	0.277
HabitatSW	*0.040*	*0.022*	0.551	0.101	0.363	0.650
LinearSW	*0.024*	0.225	0.294	0.154	0.130	0.373
Habitat PCA1	0.264	0.333	0.403	0.574	0.717	0.827
Habitat PCA2	0.101	0.895	0.102	**0.003**	0.254	0.738
Habitat PCA3	0.765	0.924	0.392	0.203	**0.004**	0.179
Habitat PCA4	0.661	0.285	0.204	0.086	0.088	0.445
Habitat PCA5	0.810	0.897	0.126	**0.004**	0.379	0.677
Lin.-features PCA1	0.532	0.551	*0.015*	0.893	*0.047*	0.944
Lin.-features PCA2	0.267	**0.005**	*0.012*	0.698	0.174	0.837
Lin.-features PCA3	0.118	*0.047*	0.281	0.684	0.076	0.207
Lin.-features PCA4	0.304	0.689	0.135	0.938	0.378	0.584
Lin.-features PCA5	*0.043*	0.183	0.482	0.639	0.078	0.635

note that the models derived using Sightings data were significantly better than those from Signs

The final conclusion from this subsidiary analysis is that the overall models built on methodological, observer and habitat variables should be interpreted with caution. Different datasets generated different suites of predictor variables. This implies that there were probably other factors which were not recorded as part of the pilot, which were influencing the proportion of sections with sightings and signs. However, it should also be remembered that the response variables were composites of the responses of several species, which could be reacting in a complementary or additive way. The analysis of individual species might indicate where this variation originates. Finally, the fact that the majority of models did not predict well on unseen data implies that the relationships between predictor and response variables may not be repeatable in future years.

Clearly, as more years are added to the pool of data (given the methodological constraints discussed above) the predictive power should increase. So, a model built on three years' data should predict a fourth better than the single-year models used here. This is a strong indicator of the value of a multi-year baseline in any monitoring programme. Not only should the baseline give us a starting value against which to measure changes, but it is also important to have some indication of the inherent variation of this starting value. In this sense, it may not be necessary to monitor every year to be able to detect a change of a given amount. This subject is explored further in the next section.

Power Analysis

Conventionally, power analyses are carried out to discover the power that a statistical test would have in detecting a given change from a given sample size. This is usually achieved by using an estimate of the population variance obtained from a pilot study such as this. However, power is not a particularly useful factor to treat as a variable because it is usually set implicitly during testing, along with the significance level (α) which is set explicitly. The factor which is under the control of the monitoring program is sample size, so it is more useful to express power in terms of the **minimum detectable change** (MDC) which can be detected (for a give significance level and power) from a range of sample sizes. This is the approach taken in this section.

It is easiest to explain the concept of MDC in terms of a simple statistical example – a two-sample t-test. Imagine a sample of 100 sites visited in year one and a second sample of 100 sites visited in year 2. Within each site, the abundance of a species is recorded by some convenient measure. It would then be possible to calculate the mean abundance for the year1 sample and the mean abundance for the year2 sample. A two-sample t-test could then be employed to test the null

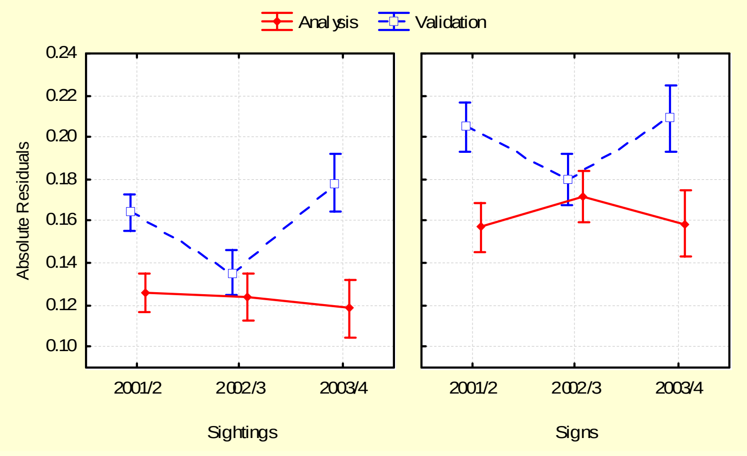


Fig. 27. The three-way interaction between Analysis/Validation, Method and Year for the absolute residuals of the six analyses shown in Table 16.

hypothesis that there was no difference between the mean abundances in the two years. Let us assume that mean abundance in year1 was 10 and in year 2 was 15, giving a difference (or change) of +5. And let us further assume that the result of the t-test was that we would reject the null hypothesis with a significance level of exactly 95% ($\alpha = 0.05$). In other words, had the mean of year 2 been 16, the significance level of this test would have been greater (*e.g.* $\alpha = 0.02$), whereas if it had only been 14, we would not have rejected the null hypothesis ($\alpha = 0.08$). So, in this example, we could claim that the minimum detectable change (with 95% confidence) would be +5. Less than this and a statistical test would not be able to detect a change with the desired confidence. Obviously, if we were interested in detecting any sort of change, there would also be a negative MDC representing a decline.

Minimum Detectable Changes have been derived in two main ways:

- Firstly, the empirical data from both the sightings and signs surveys have been utilised in a Monte Carlo technique to derive 95% and 99% MDC limits. These have been derived for a range of sample sizes from 50 to 1000 and are expressed in terms of the proportionate change.
- Secondly, to provide some information for the rarer species, theoretical MDC limits have been calculated from the binomial distribution. These have been calculated for sample sizes from 50 to 2000 and a range of starting proportions.

Minimum Detectable Change from Empirical Data

A full explanation of the mathematical procedures used for these power analyses are given in Appendix 5. In summary, this process analysed the change between two tranches of sites – from 2001/2 to 2002/3 and, separately, from 2002/3 to 2003/4. All changes were expressed in relative terms.

MDC calculations were made for 41 species from the sightings survey and the eight signs, with a number of different variations. Firstly, both datasets were analysed as if they had come from independent year samples. In other words, the sites contributing to the sample in year 1 were different from those in year 2. Both datasets were also analysed as if they came from dependent or “paired” samples of sites. In this analysis, only those sites which were visited in 2001/2 **and** 2002/3 were included, with a second tranche which were visited in 2002/3 **and** 2003/4. This allowed the comparison of the power obtained from revisiting sites with that from independent year samples.

The sightings data were also summarised in two different ways. Within each site/visit, these data were expressed both as the proportion of sections in which a species was seen and the total number of animals counted in the site. This means that for each species in the sightings survey, four analyses were carried out (independent / paired × proportions / sections). On the other hand, each sign was only analysed as the proportion of sections within the site where the sign was recorded. This gave a total of 180 analyses ($[41\times4] + [2\times8] = 180$).

Unfortunately, a large proportion of these analyses were unable to yield meaningful MDCs. The datasets for 135 analyses had mean values which were either zero or so small that the MDCs did not converge. However, the remaining 45 analyses yielded useful relationships between sample size and MDC. An example for fox signs based on the repeated-visit (paired) analysis is given in Fig. 28). This shows the upper and lower minimum detectable changes which can be expected with 95% and 99% confidence. So for example, with a sample size of 500 sites, we can expect to detect an increase of about 18% or a decrease of about 15% with 95% confidence. However, if we only had a sample of 200 sites, these limits would be an increase of 28% and a decrease of 23%.

Where MDCs have been successfully calculated, they are displayed using the style of Fig. 28 under the individual species in chapter 7.

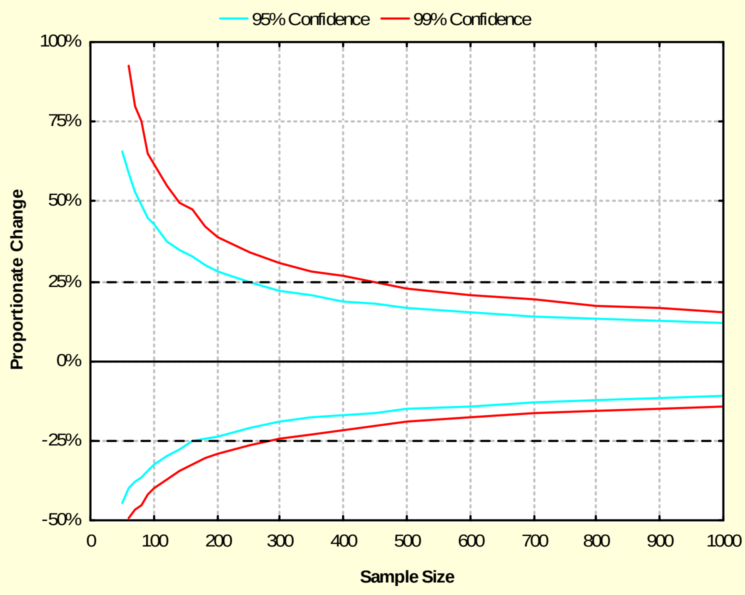


Fig. 28. The Minimum Detectable Changes for fox signs based on repeated visits to the same sites, for a range of sample sizes.

To allow a comparison of these MDCs between species, we can summarise the data displayed in Fig. 28 in a number of different ways. Firstly, the two horizontal dashed lines represent increases and decreases of 25% from the starting value. So we can read off the sample sizes needed to attain these degrees of change with, say 95% confidence. In this example, they would be approximately 250 and 160 respectively.

However, these are quite “good” limits and many of the other species or signs had much broader limits. This means that many more than 1000 sites would be required to detect these quite small changes. A less “demanding” statistic is the sample size required to detect a doubling or halving from the starting value. (In Fig. 28 this is represented by the upper and lower bounds of the y-axis.) This is especially useful as it is clear that these MDC limits are asymmetrical about 0. In the fox example, we would only need a sample of around 50 sites to be able to detect with 95% confidence a halving or doubling in the proportion of sections with signs.

These two statistics allow us to compare the vast range of MDCs derived from the 45 successful analyses. They will now be used to explore which species and signs can be monitored with 95% confidence (unless otherwise stated) using either method.

Sightings

Of the 43 species recorded during the sightings surveys only nine yielded useful MDCs – in all the other cases the MDCs were either uselessly large or failed to converge. In all of these nine species, a halving or doubling could be detected with samples of between 50 and 500 sites (Fig. 29a). Furthermore, three species (fallow deer, grey squirrel and rabbit) had such narrow MDCs that and change of ±25% could be detected with sample sizes of 1,000 or less (Fig. 29b).

It could be argued that had we been prepared to accept a lower degree of confidence (say 90%), more species would fall into the ± 25% change category. However, even applying these relaxed conditions only reduced the sample sizes for fallow deer to 500 to detect a decrease and 700 for an increase. All of the six other species in Fig. 29a required sample sizes of greater than 700 to detect a 25% decrease.

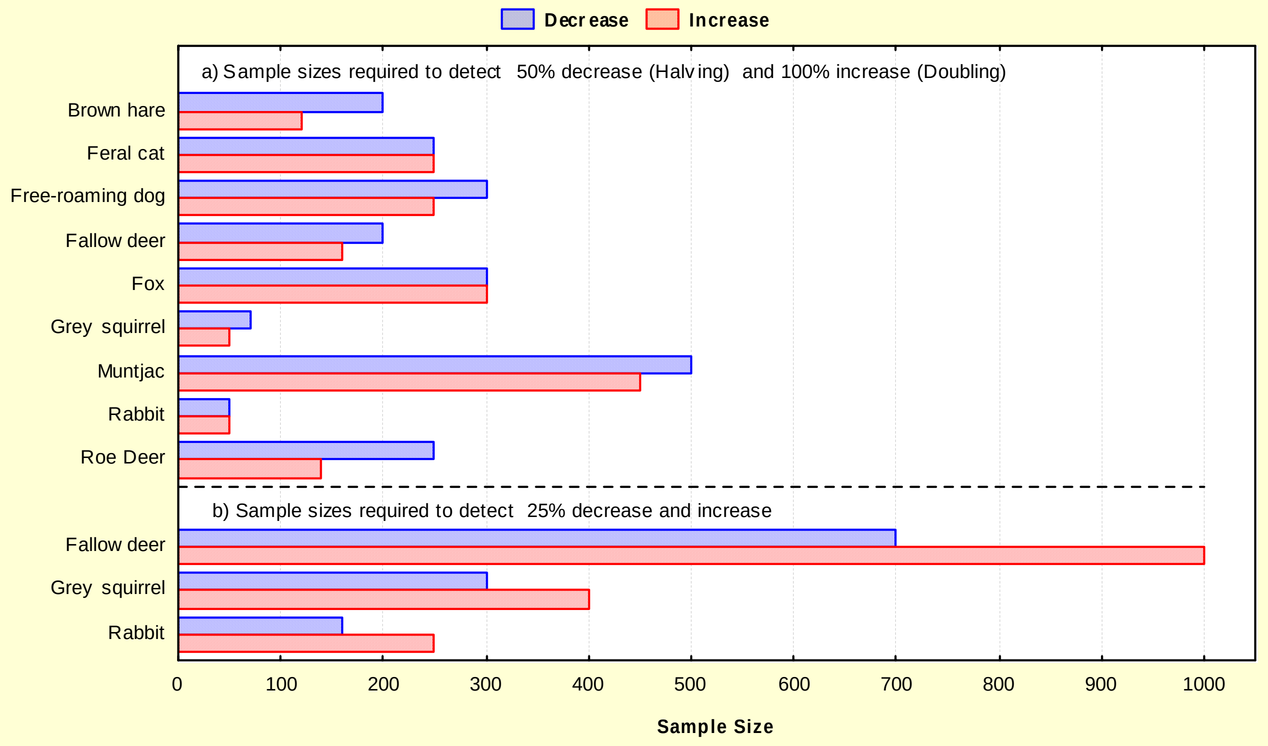


Fig. 29. The sample sizes required to detect (with 95% confidence) a) moderate changes in sightings of nine species and b) small changes in sightings of three species, based on repeated visits to the same sites.

Signs

Using a pairwise approach to the analysis, seven of the eight signs would be able to yield detectable changes with reasonable sample sizes (Fig. 30). The only sign which could not yield useful MDCs was harvest mouse nests. For five of the signs, ±25% changes could be detected with sample sizes of 250 or less. Furthermore, if the two badger signs were combined into a single variable, ±25% changes could probably be detected with samples smaller than 300.

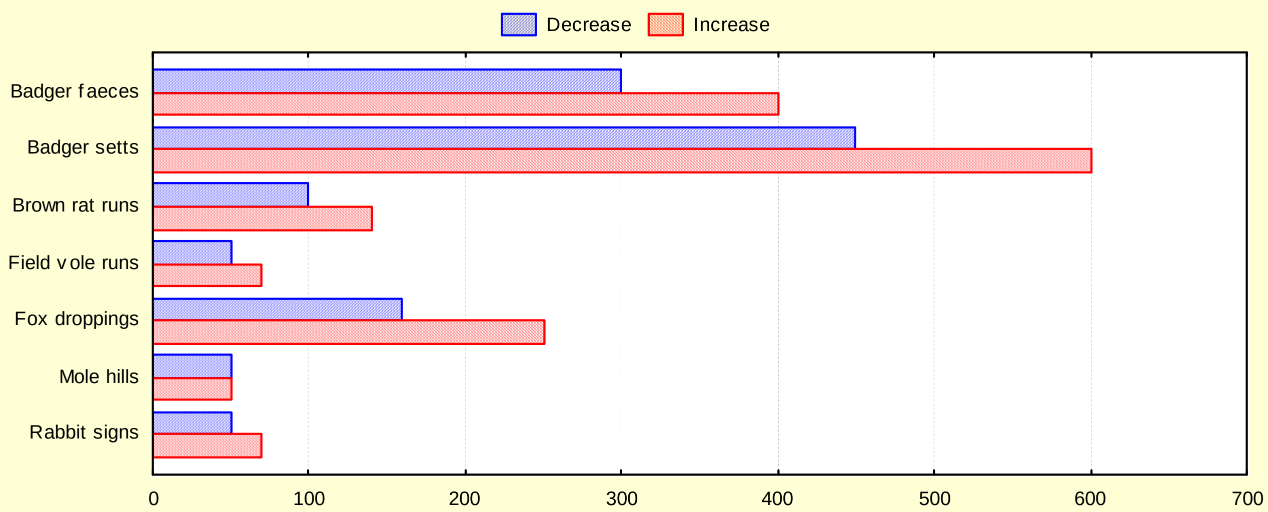


Fig. 30. The sample sizes required to detect (with 95% confidence) changes of ±25% in signs of seven species, based on repeated visits to the same sites.

Summary

These two analyses can be further summarised by calculating the ability to detect a change of ±25% with a given sample size – say 500 (Table 17). Only two species could be detected with this degree of change with a sample size of 500 sites. In contrast, all signs except harvest mouse nests could show a change of ±25% with this sample size (although badger setts would require a sample of 590 to show an increase).

Table 17. Ability to detect ±25% change with a sample size of 500 sites. The sign marked* requires a sample size of 590 to detect a 25% increase.

	-25%	*+25%*
SIGHTINGS		
Brown Hare	-	-
Feral Cat	-	-
Free-roaming Dog	-	-
Fox	-	-
Grey squirrel	√	√
Fallow Deer	-	-
Muntjac	-	-
Rabbit	√	√
Roe Deer	-	-
SIGNS		
Badger faeces	√	√
Badger setts	√	*
Brown rat runs	√	√
Field vole runs	√	√
Fox droppings	√	√
Harvest mouse nests	-	-
Mole-hills	√	√
Rabbit signs	√	√

Methodological Comparisons from the power analysis

To compare the powers available from different methodological approaches, we have extracted the 95% MDCs calculated from sample sizes of 500 for each of the 45 adequate analyses. These have been used to make three methodological comparisons.

Firstly, we can compare the MDCs available from the two different survey methods – sightings versus signs. Foxes and rabbits were the only two species where adequate data were obtained from both methods and these have been analysed using both a paired and independent approach. The resultant eight comparisons all showed larger MDCs from sightings than from signs (Fig. 31). In every case, this sample size was adequate to show a 25% or less change from signs. However, only two changes (rabbits with pair-wise analysis) could show changes as

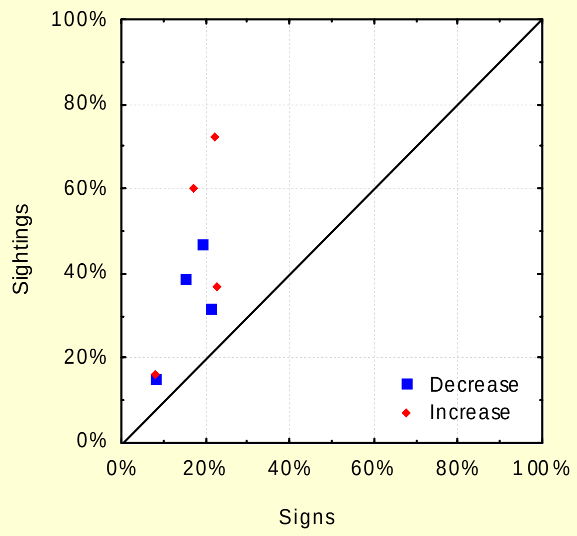


Fig. 31. The comparison of MDCs obtained (with 95% confidence) from samples of 500 foxes and rabbits. Paired and Independent analyses have both been used.

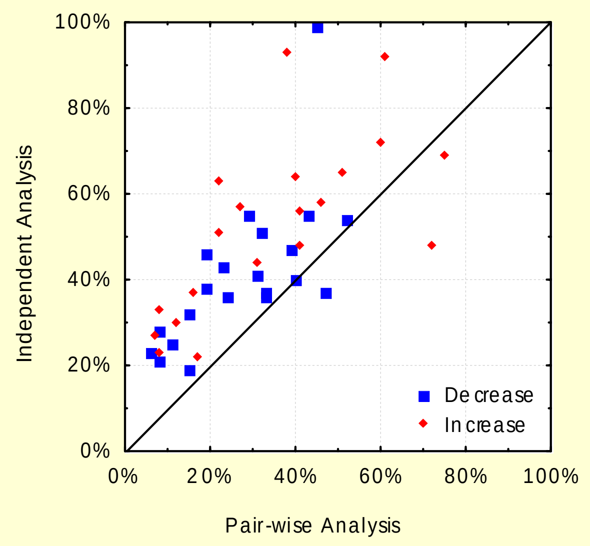


Fig. 32. The comparison of MDCs obtained (with 95% confidence) from samples of 500 sites. Sightings and signs have been combined.

small as 25% from sightings. Indeed, two of these could not even show a change of 50%. On the whole, signs appear to give a two to three-fold greater power to detect change than sightings.

The second comparison is between types of analysis – pair-wise versus independent samples. A total of 48 comparisons (including some where the MDCs did not converge) were made. Of these only three cases showed smaller MDCs from an independent than a pair-wise analysis (Fig. 32). Most importantly, 18 of the pair-wise MDCs were less than 25%, whilst only five of the independent analyses yielded MDCs less than 25%. However, in two cases (fox and rabbit) the pair-wise MDCs did not converge for sightings of animals, so should also be included with the three cases where independent analyses were superior.

Finally, a comparison has been made between the MDCs available from sightings when based on counts of animals versus the proportion of sections where animals were seen (Fig. 33). This was based on 34 comparisons (although again a few of the MDCs did not converge). In all but two cases the MDCs from the analyses by section were smaller than those from counts of animals. However, the proportionate differences were less than with the two previous analyses.

In summary, these power analyses have shown unequivocally that

a) signs are more powerful than sightings,

b) paired analyses are more powerful than independent analyses and,

c) for sightings, analysis of the proportion of sections is more powerful than counts of animals.

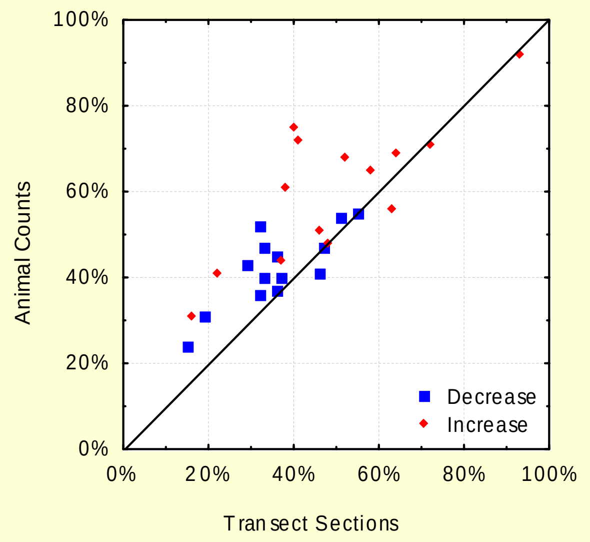


Fig. 33. The comparison of MDCs obtained (with 95% confidence) from samples of 500 animal counts versus proportions of transect sections. Only Sightings have been used.

Minimum Detectable Change from Binomial Data

Useful MDCs could not be calculated for 29 of the species recorded during the sighting surveys. Consequently, it is not possible to use the empirical data to give us any indication of how much change we might be able to distinguish in the future. However, reference to Fig. 6 shows that the majority of these species were found in very few sites. The most widely found species for which MDCs could not be calculated was weasel, found in 16 different site/visits. This represents almost exactly 1% of the 1,594 sightings/visits made during the three years.

Furthermore, less than one fifth of these 29 species were recorded in more than one section per site, and in only three cases were they recorded on more than one year in a site. So effectively, these data are simple presence / absence records.

As such, these are binomial data with very small proportions. One of the characteristics of binomial data is that if you know the sample size (n) and the number of positives (X – in our case presence) then you know everything about the distribution of the variable. Consequently, it is possible to calculate exact confidence limits, or the exact significance of a statistical test. From this, it is also possible to determine the exact MDCs from a binomial variable, with known n and X. It is, therefore, not necessary to carry out the type of empirical analyses described in the previous section for binomial data. Instead, we have calculated the theoretical MDCs for a range of sample sizes (from 50 to 2,000) for a small number of starting proportions (5% down to 1%) (Fig. 34).

These distributions allow us to determine exactly the proportionate changes which could be detected with different sample sizes. For example, take a species which was recorded on 5% of sites. (In the first year of this survey, this would equate to $803 \times 0.05 = 40$ sites.) Assuming a similar sample size in the second year, it would be possible to detect about 90% increase (*i.e.* an increase to 76 sites) or a reduction of about 65% (to about 14 sites) with 95% confidence. Any changes smaller than this, that is, within these bounds, would be considered non-significant. But, we have already ascertained that the 29 species with no empirical MDCs were found in around 1% or fewer sites. If we use the curves in Fig. 34a, we can see that the lower 95% limit is not even on the graph. In other words, with sample sizes of 2,000 or less, it is not even possible to detect a total extinction with 99% confidence. On the other hand, with a sample of 2,000 sites it would be possible to detect an increase of about 140%. For the 2001/2 sample of 800 sites, it would be possible to detect an increase of just over 250% with 95% confidence. This would be the equivalent of a change of from 8 sites to about 28 sites where the species was present.

This exploration of the MDCs from binomial data is based on the analysis of independent samples from each year. The previous calculation of MDCs from the empirical datasets utilised both independent and “paired” analyses, and showed that the latter analyses often required smaller samples to achieve given MDCs. However, with presence/absence data, there is no practical distinction between these two approaches. Although **theoretically,** repeated visits to the same sites would allow much greater power to detect change, in practice, the **average** power is the same as if the two years had been treated as independent samples.

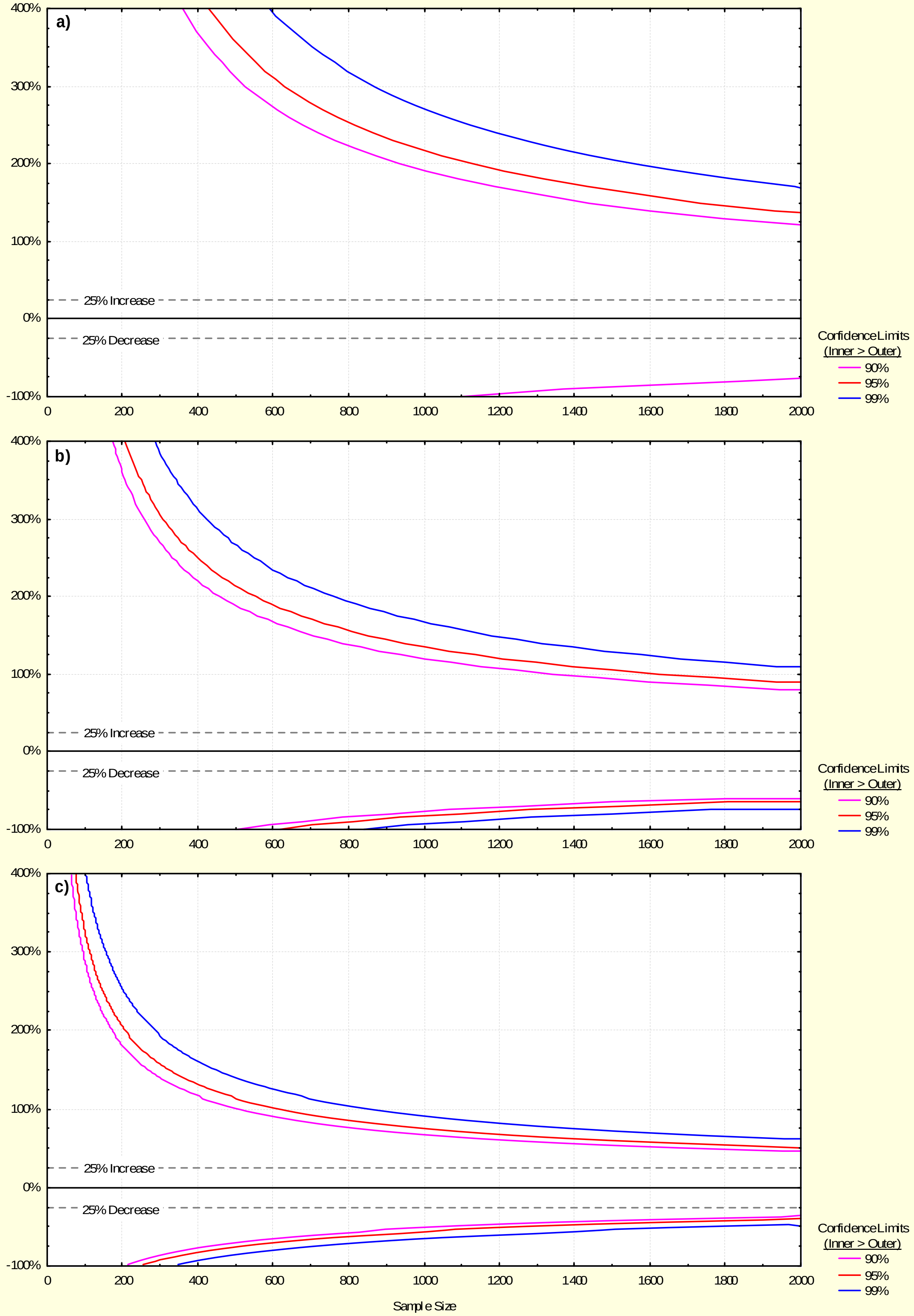


Fig. 34. The Minimum Detectable Changes (with three different Confidence Limits) for binomial response variables for a range of sample sizes. Starting proportions are a) 0.01, b) 0.02 and c) 0.05

Comparison of WMM with BBS

Introduction

The BTO/JNCC/RSPB Breeding Bird Survey (BBS) is the main national terrestrial bird monitoring scheme in the UK, a volunteer-based survey organised by the BTO in agreement with the other BBS partners, RSPB and JNCC, since 1994. In 1995 the BTO expanded the scope of BBS to collect information on mammals as well. 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. Although the focus was on medium to large sized, easily identifiable, species, observers recorded any mammal species they were able to identify. Approximately 85% of ca. 2000 participants have recorded mammals each year since 1995.

There are two major differences between the methodology of the WMM and the BBS. Firstly, BBS participants record mammal sightings and signs encountered on either of their two visits to the square each year, whereas WMM participants record sightings on one visit and field signs on another visit dedicated to this purpose. Secondly, the timing is different, with WMM participants recording mammals during the winter period (October to January) and BBS participants during the summer. The first BBS visit is usually carried out in April to mid-May and the second visit approximately four weeks later, between mid-May and the end of June.

Differences in timing and the number of visits aside, however, the methodology used for BBS mammal recording is very similar to that employed for the sightings phase of the WMM project. In both cases, the unit of sampling is a randomly selected 1-km OS grid square in which participants are asked to walk a transect route, following two approximately parallel, evenly-spaced lines and recording the total number of each mammal species encountered.

The methodology for recording mammal signs differed more between surveys. While WMM participants are asked to search for a restricted set of mammal signs, BBS participants record a range of different types of indirect evidence, including field signs, sightings of dead individuals, sightings of live individuals on additional visits and reports from other observers, for all species. In addition, BBS field signs data are recorded at the same time as sightings of both birds and mammals rather than during a separate visit. This may have a negative impact on detection rates, particularly for signs such as field vole runs which may only be located during intensive searches of suitable habitat, as carried out during the field signs phase of the WMM project. BBS field signs data also lack a quantitative element, with signs recorded only as present or absent at the surveyed sites, whereas the results for the WMM signs phase can be expressed as the proportion of transect sections in which at least one field sign was found. Finally, WMM participants are able to record which transect sections were searched for specific signs, whereas BBS participants are only asked to record whether the square was searched for mammal sightings or signs. Comparisons of field sign data for the two surveys should therefore be interpreted with care

Analytical methods

The primary aim of the analysis was to compare the data obtained from the two surveys. In addition, a number of different datasets were used to answer specific questions about the differences between the surveys. Three factors contributed to the definition of these datasets.

- Firstly, the Field signs and Sightings were analysed separately. This was largely because there were few species common to both methods, but also because this comparison has already been made in detail for the WMM data alone.

- Secondly, the data were analysed as records from individual years. The WMM data were collected in the winters of 2001/2, 2002/3 and 2003/4, with the BBS data collected in the subsequent summers of 2002, 2003 and 2004. These were classified into a three-level factor (Year) which matched WMM data from 2001/2 with BBS from 2002 (Year 1), etc.
- Thirdly, the data were treated as qualitative and, in some cases, quantitative. The BBS fieldsigns for each species were only recorded as present within the site. So to enable a comparison, the quantitative element in the WMM dataset (number of sections) had to be converted to simple presence/absence records (1 or 0).

  In both surveys, sightings were recorded as counts of individual animals. However, for most species the vast majority of site counts were zero. So, these data were analysed firstly as qualitative records and, secondly, for those sites where a sighting was made, as quantitative counts. This was equivalent to asking two different questions; "Was there a difference between the surveys in the occurrence of sightings?" and, for the latter dataset; "In those sites which had sightings, was there a difference in the magnitude of the counts?".

The summary of the datasets derived from these factors is given in Table 18. The ranges of sample sizes for field signs were due to a small number of recorders in the WMM survey opting not to record certain species. The large ranges in the quantitative datasets were due to the scarcer species having very few sites where they were recorded in at least one year.

Table 18. Summary of datasets with ranges of sample sizes used.

	Fieldsigns	*Sightings*
Qualitative	3036 - 3065	3329
Quantitative		78 - 1665

The BBS contributed a total of 2,580 sites to both methods. The WMM survey recorded field signs on 687 sites and sightings on 1,040 sites. However, relatively few sites were common to both surveys (199 field signs and 291 sightings). Although many sites had data from more than one year and, especially BBS, from both methods, this small overlap of site between surveys prevented a repeated-measures approach to the analysis. For example the analysis of sightings from individual years had a sample size of 3,329 sites, each contributing one datum. However, the equivalent full repeated-measures analysis would only have had 55 sites, although each would have contributed six data-points to give 330 records in total.

To avoid pseudo-replication, one data-point was randomly selected from the possible combination of year and survey. This was carried out independently by species so that sites which were common to both surveys might contribute a BBS record for one species, but a WMM record for another.

A further source of repetitive data was the BBS sightings, for which there were two visits to each site – one in late spring and the other about a month later in early summer. Correlations between the early and late visits in each of the three years showed extremely similar results, with approximately 50% of the variance in one visit explained by the variance of the other (r^2 = 47%, 50% & 56% in the three years). To avoid duplicating analyses, the maximum of the two counts was extracted as the single response variable. This also followed the same reasoning as the BBS field signs data, which were already recorded as a single record – present in either of the two visits.

Two different ANOVA models were applied to each of the six datasets. Firstly, a three-way, fully crossed model was constructed with Survey, Year and Species as the factors. For the individual year datasets, the year factor had three levels, but for change datasets, it had only two levels, representing the first and second changes. It should be pointed out that the inclusion of the species factor, which is actually a repeated-measure, artificially inflated the error degrees-of-freedom of the models. However, they were used primarily to explore the relationship between the surveys and species. Secondly, for each species in turn, two-way ANOVAs were used with just survey and year as fully-crossed factors.

Generalized Linear Models were used with three model-building procedures. Firstly, for the qualitative data from individual years, a binomial distribution was defined with a logit link-function. Secondly, for the quantitative data from individual years a poisson distribution was used with a log link-function. Finally, for all change data a normal error-term model was applied. In the case of the qualitative changes, which were trinomial data, a multinomial model was tested and gave identical results to the normal model. It should be pointed out that none of the models produced good fits to the data, but at least the normal-error models did not suffer from excessive heteroscedasticity. But, to be cautious in drawing conclusions, the alpha significance level was set at 0.01. Indeed, as many effects appeared to have significance levels less than 10^{-5}, it was clear that real effects could be identified even with this conservative alpha.

The species used in the comparison

The field signs of five species (badger, fox, mole, rabbit and brown rat) were recorded with sufficient regularity in both surveys to allow a comparison to be made. Of the eight field signs collected in all three years of the WMM survey, field vole runs and harvest mouse nests were recorded very infrequently during BBS surveys, largely because they require dedicated search effort to be found. Finally, badger setts and latrines were combined into a single field sign, based on the presence of either sign in the WMM data – in BBS only a general badger field sign was recorded.

The species lists and species frequency distributions from sightings were similar in the two surveys, although slightly more species were recorded in the WMM survey. In both cases ten species were recorded in more than 1% of site/visits (Table 19). Seven of these were common to both surveys and provided the basis of the comparison of sightings. Indeed, with the exception of feral cat in the BBS, these were the most ubiquitous seven species in both surveys. The only other significant effect in this model was a significant increase in proportion of sites with rabbit signs, which occurred consistently across both surveys. In the first year, the overall proportion of sites with rabbit signs was 21%, rising to 28% and 34% in the third year.

Table 19. Species recorded in more than 1% of the site/visits in the two surveys. Species marked in bold were common to both surveys.

BBS		*WMM*	
Species	*Proportion*	*Species*	*Proportion*
Rabbit	36.1%	**Rabbit**	32.1%
Brown hare	16.8%	**Grey squirrel**	23.0%
Grey squirrel	16.2%	**Brown hare**	11.7%
Roe deer	8.2%	**Roe deer**	10.2%
Feral cat	7.9%	**Fox**	7.8%
Fox	6.3%	**Fallow deer**	3.1%
Muntjac	1.6%	**Muntjac**	2.4%
Fallow deer	1.2%	Mole hills	1.2%
Mountain hare	1.2%	Brown rat	1.1%
Red deer	1.2%	Wild / Domestic cat	1.1%
19 other spp.	< 1.0%	24 other spp.	< 1.0%

Results

Field signs

The results of the three-way ANOVA of the presence of fieldsigns for all species is given in Table 20. The Wald's statistic showed that the strongest effect was that of survey. The model predicted 52% of WMM cases with field signs but only 10% of BBS sites. There was also a highly significant difference between species, ranging from only 12% of cases for brown rat, to 49% for mole. However, there was also a very highly significant interaction between species and survey (Fig. 3), but in every species the proportion of WMM sites with fieldsigns was several times greater than in BBS sites.

Table 20. Results of 3-way ANOVA of the presence of fieldsigns.

Effect	*DF*	*Wald*	*p*
Spp	4	492.222	<0.0001
Survey	1	1685.995	<0.0001
Year	2	1.059	0.5887
Species*Survey	4	138.920	<0.0001
Species*Year	8	24.338	0.0020
Survey*Year	2	7.709	0.0211
Species*Survey*Year	8	13.514	0.0953

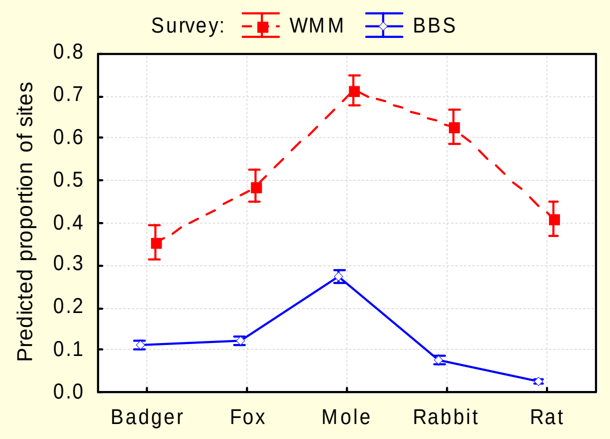


Fig. 35. The proportion of sites in which field signs were recorded for each species in each survey. Points represent predicted proportions and bars represent 95% C. I.

Consequently, the species were analysed individually using two-way ANOVA models (Table 21). Most importantly, in every case, the difference between the two surveys was very highly significant. Moreover, in only one species (mole) was there a marginally significant interaction with year (Fig. 36). Mean proportions of WMM sites with mole field signs did not differ across the three years (approximately 70%), but the proportion of BBS sites in year 3 was significantly lower (22%) than the previous two years (32%). Nevertheless, in each of the five species, the survey effect was still strongly evident in all years.

Table 21. The results of 2-way fully-crossed ANOVAs on presence of fieldsigns of individual species.

Effect:	Survey (DF = 1)			Year (DF = 2)			Survey x Year (DF = 2)		
	Wald's Statistic	*Likelihood Type III*		*Wald's Statistic*	*Likelihood Type III*		*Wald's Statistic*	*Likelihood Type III*	
Species:		χ^2	*p*		χ^2	*p*		χ^2	*p*
Badger	153.74	135.66	<0.0001	0.59	0.59	0.7441	3.56	3.53	0.1709
Fox	312.69	288.31	<0.0001	3.28	3.27	0.1952	1.91	1.92	0.3830
Mole	285.35	325.08	<0.0001	2.55	2.57	0.2771	9.01	9.37	0.0092
Rabbit	591.14	666.12	<0.0001	17.17	18.09	0.0001	4.37	4.37	0.1125
Rat	419.18	446.34	<0.0001	1.68	1.71	0.4249	1.41	1.43	0.4892

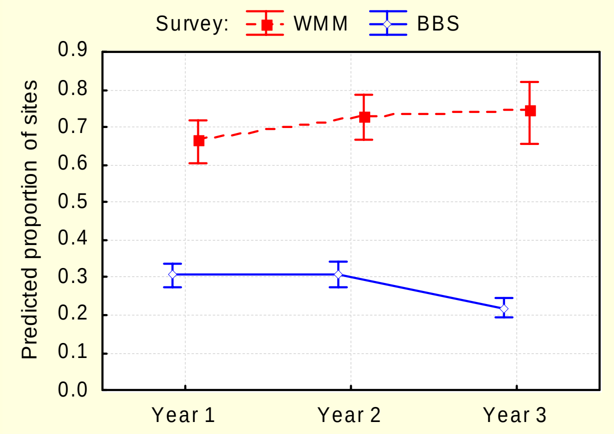


Fig. 36. The proportion of sites in which field signs were recorded for mole in each year across both surveys. Points represent predicted proportions and bars represent 95% C. I.

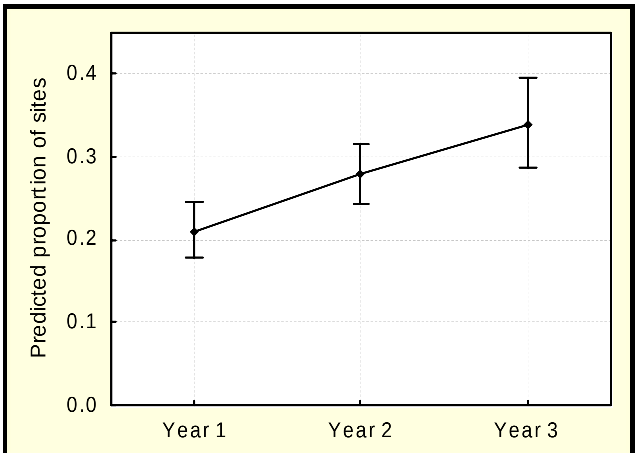


Fig. 37. The proportion of sites in which fieldsigns were recorded for rabbit across all years and both surveys. Points represent predicted proportions and bars represent 95% C. I.

The only other significant effect was an increase in proportion of sites with rabbit signs, which occurred consistently across both surveys. In the first year, the overall proportion of sites with rabbit signs was 21%, rising to 28% and 34% in the third year (Fig. 37).

Sightings

In contrast to field signs there was no overall difference between the surveys in the proportion of sites with sightings (Table 22). In both cases this averaged 11.8%. Inevitably however, there were large differences between species and there was a highly significant species x survey interaction (Fig. 38). In particular a significantly greater proportion of BBS sites had hare and rabbit sightings (26% & 54% respectively) than did WMM sites (15% & 42% respectively). In contrast though, fallow deer were seen more frequently on WMM sites (3.9%) than they were on BBS sites (1.6%).

Table 22. Results of 3-way ANOVA of the presence of sightings.

Effect	*DF*	*Wald*	*p*
Spp	6	1426.226	<0.0001
Survey	1	0.001	0.9749
Year	2	13.532	0.0012
Species*Survey	6	60.802	<0.0001
Species*Year	12	20.709	0.0548
Survey*Year	2	21.521	<0.0001
Species*Survey*Year	12	14.852	0.2496

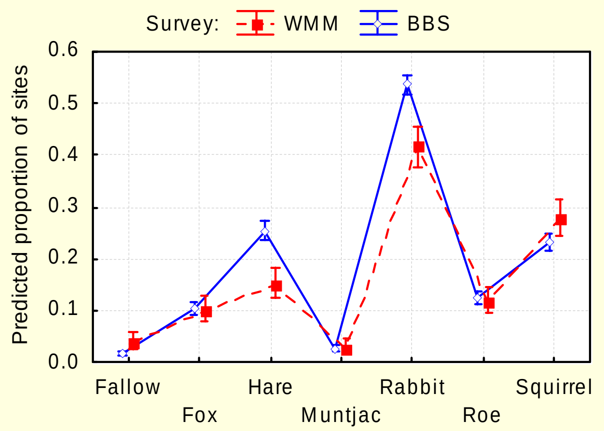


Fig. 38. The proportion of sites in which sightings were recorded for each species in each survey. Points represent predicted proportions and bars represent 95% C. I.

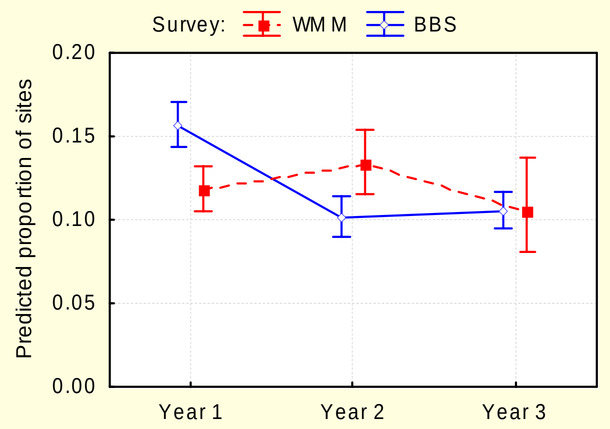


Fig. 39. The proportion of sites in which sightings were recorded during each year in each survey. Points represent predicted proportions and bars represent 95% C. I.

The other significant interaction was between survey and year (Fig. 39). There appears to be no significant difference between the means for the three years in WMM, although the means do vary between about 10.5% and 13.5%. However, the BBS annual means are highly significant different, being nearly 16% in year 1, falling to just over 10% in the subsequent two years.

The results for these three species were confirmed by the individual species analyses (Table 23). Furthermore, there were no significant interactions for these species showing that the differences were consistent across years. There was, however, one interaction which was significant. Although there were no differences between surveys in the mean occurrence of sightings of grey squirrels, this varied with year. There was no significant difference between the surveys in the first and third years, but in the second year, the proportion of WMM sites was significantly higher (34%) compared to BBS (20%).

Table 23. The results of 2-way fully-crossed ANOVAs on presence of sightings of individual species.

Effect:	Survey (DF = 1)			Year (DF = 2)			Survey x Year (DF = 2)		
Species:	*Wald's Statistic*	*Likelihood Type III* χ^2	*p*	*Wald's Statistic*	*Likelihood Type III* χ^2	*p*	*Wald's Statistic*	*Likelihood Type III* χ^2	*p*
Fallow deer	11.07	9.37	0.0020	7.12	7.45	0.0241	1.47	1.46	0.4830
Fox	0.06	0.06	0.7991	5.6	6.43	0.0403	3.64	3.56	0.1690
Hare	29.17	32.6	<0.0001	0.28	0.28	0.8710	4.97	4.94	0.0851
Muntjac	0.03	0.03	0.8702	1.70	2.00	0.3676	8.89	8.71	0.0134
Rabbit	27.58	27.63	<0.0001	6.16	6.21	0.0456	7.00	6.96	0.0313
Roe deer	0.12	0.13	0.7235	5.90	6.61	0.0371	0.51	0.51	0.7762
Squirrel	5.49	5.30	0.0210	1.78	1.83	0.4003	14.46	14.33	0.0007

The previous results related to the occurrence of sightings. In contrast, in those sites where sightings did occur, there was a highly significant difference in the mean counts of animals between the two surveys (Table 24). Overall there were more animals counted in BBS sites (mean = 3.3) than in WMM sites (mean = 2.1).

Table 24. Results of 3-way ANOVA of the counts of animals on sites where sightings occurred.

Effect	*DF*	*Wald*	*p*
Spp	6	1268.689	<0.0001
Survey	1	89.005	<0.0001
Year	2	4.977	0.0830
Species*Survey	6	397.277	<0.0001
Species*Year	12	50.385	<0.0001
Survey*Year	2	8.239	0.0163
Species*Survey*Year	12	84.420	<0.0001

However, the mean counts also differed greatly between species and there was a significant interaction (Fig. 40). Four species (fallow deer, fox, muntjac and roe deer) showed no differences at all between the surveys. However, brown hare, rabbit and grey squirrel mean counts were significantly greater in BBS sites than WMM sites. Indeed, rabbits showed a mean count nearly four times higher in the BBS squares.

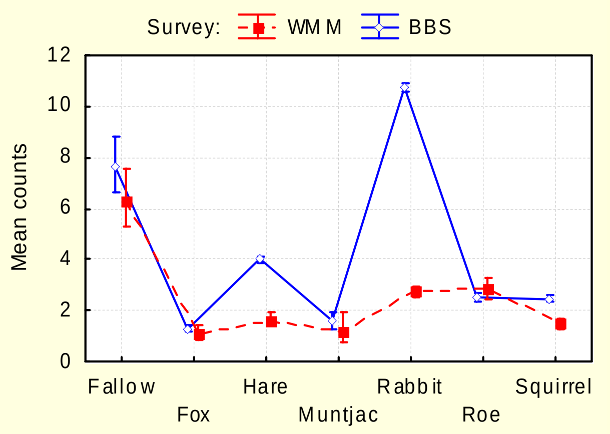


Fig. 40. The counts of animals in sites where sightings were recorded for each species in each survey. Points represent mean counts and bars represent 95% C. I.

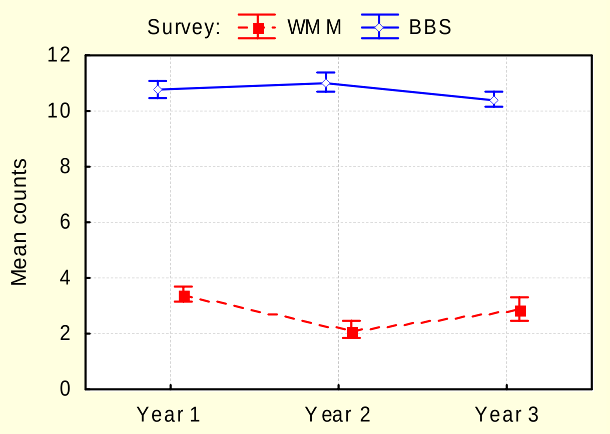


Fig. 41. The interaction between Year and survey in counts of rabbits in sites with non-zero counts. Points represent mean counts and bars represent 95% C. I.

The individual species analyses confirmed these findings and in addition, revealed a significant survey x year interaction for rabbits (Table 25). This showed that the mean counts in BBS sites (approx. 10.8) did not vary across the three years, but there were significantly fewer counts of rabbits in the second year in WMM sites compared to the other two years (Fig. 41).

Table 25. The results of 2-way fully-crossed ANOVAs on counts of individual species in sites where sightings were present.

Effect:	Survey (DF = 1)			Year (DF = 2)			Survey x Year (DF = 2)		
	Wald's	*Likelihood Type III*		*Wald's*	*Likelihood Type III*		*Wald's*	*Likelihood Type III*	
Species:	*Statistic*	χ^2	*p*	*Statistic*	χ^2	*p*	*Statistic*	χ^2	*p*
Fallow deer	2.73	2.80	0.0944	7.15	6.41	0.0405	55.03	72.61	<0.0001
Fox	1.12	1.19	0.2755	0.30	0.30	0.8595	1.55	1.55	0.4603
Hare	125.21	166.48	<0.0001	8.59	8.12	0.0172	0.50	0.50	0.7779
Muntjac	1.16	1.27	0.2595	0.65	0.59	0.7461	0.56	8.71	0.7569
Rabbit	1193.07	1987.90	<0.0001	28.69	30.36	<0.0001	33.99	36.71	<0.0001
Roe deer	2.21	2.14	0.1431	4.47	4.15	0.12557	1.31	1.30	0.5217
Squirrel	49.58	59.84	<0.0001	6.78	6.70	0.0351	4.12	4.45	0.1079

The individual analysis for fallow deer also showed a highly significant survey x year interaction. This showed that although there were marginally different mean counts over the three years in WMM squares, there were massive fluctuations in the mean counts in BBS sites (Fig. 42).

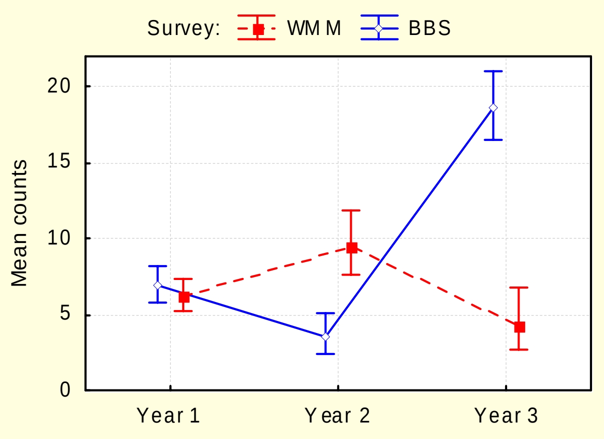


Fig. 42. The interaction between Year and survey in counts of fallow deer in sites with non-zero counts. Points represent mean counts and bars represent 95% C. I.

Discussion

These and supplementary analyses, clearly demonstrate that the two surveys (BBS and WMM) differ markedly in the type and amount of information collected by participants. The most noticeable difference, unsurprisingly, is that the WMM surveys detect the presence of field signs of five mammal species (rabbit burrows, molehills, rat runs, badger setts and latrines, and fox faeces) at considerably (and significantly) higher rates than BBS. Overall, WMM surveyors found field signs on five times as many sites as BBS surveyors, with rates of detection for the individual species varying from 30% (for badger) to about 70% (for mole) on WMM. This is unlikely to represent real differences in occurrence between summer and winter distributions (although there may be seasonal differences in activity) but is almost certainly a consequence of the considerably higher effort (on every transect section, focusing on a target suite of signs) in looking for field signs during WMM surveys.

The results for sightings were more mixed. Two of the more abundant and easily detected species, brown hares and rabbits, were found on a significantly higher proportion of sites, and in significantly greater numbers, during BBS surveys than on WMM. The differences is percentage occurrence were not as marked as for field signs (between ca. 40 and 50% of sites for rabbits, and between 15 and 25% for hares) but the counts on sites with these species exhibited more dramatic differences (4 hares in the summer compared to 1.5 in the winter, and more than 10 rabbits in the summer compared to only 3 in the winter). This may be a consequence of increased numbers (because of the presence of young animals in the spring) and/or increased activity levels during the summer.

Grey squirrel, another relatively abundant species, was found on a significantly higher proportion of WMM than BBS sites, but the difference was small (between 23% and 28%) and was reversed during the second year. In contrast, on sites where squirrels were present, summer counts were significantly higher (on average 2.5 individuals) than winter counts (on average 1.5 individuals). The only other species to show evidence of differences in detectability between surveys were fallow deer and muntjac. Fallow deer were seen on about twice as many WMM sites (albeit only 4%) as BBS, and there were significant differences between the BBS and WMM inter-annual patterns of counts. These effects may be due to seasonal changes in herding behaviour. The pattern for muntjac occurrence was the same as for squirrels but this species was seen on less than 3% of sites, and there were no differences in counts. Roe deer and fox showed no differences in occurrence, or abundance, between surveys.

During the course of the three-year WMM pilot, there was very little evidence of significant changes between years in percentage occurrence or abundance on sites. Of the species monitored by field signs, only rabbits showed a significant effect – a steady increase over the three years. However, this was not supported by the repeated measures analyses of a subset of sites monitored by both surveys in all three years.

Do BBS and WMM provide consistent information on changes in presence or numbers? It is important to distinguish here between detection of underlying trends – such as those associated with directional changes in land use, and the inter-annual changes – which may be more strongly influenced by current environmental conditions such as harsh or particularly wet winters. The year effects discussed in this study, *i.e.* the comparison of measures of abundance between adjacent summers and adjacent winters, are associated with the latter. Hence, the significant interaction for presence of mole signs (suggesting some decline on BBS and some increase on WMM) may reflect differences in the patterns of wet and dry summers compared to mild and harsh winters. The other important point is that consistency, or lack thereof, between the two surveys cannot necessarily therefore be used to validate the methods. For this, longer time periods would be required to compare underlying trends.

Two species were monitored by both sightings and field signs. Based on rates of detection of their burrows, rabbits increased in occurrence but the sightings data showed no significant declines in occurrence. However, there were declines in counts on sites with sightings between years 1 and 2, but these were almost entirely due to WMM counts. It is difficult to interpret these findings, but one possibility is that rates of detection of semi-permanent field signs such as burrows tend to increase over time as surveyors become more familiar with the site. This is particularly true for BBS observers, whose effort in recording field signs may have changed over the three years in response to new protocols introduced in 2002.

There was no evidence of inter-annual differences in the occurrence of foxes based on their field signs, but sightings data suggested a decline in occurrence. There was no evidence of inter-annual differences in counts. Taken together, these findings suggest that numbers of foxes did not change markedly over the three years, but perhaps fewer were seen in some years because of the timing and distribution of surveys in those years.

Value of repeated measures analyses

The key WMM/BBS analyses reported here make use of the full WMM and BBS datasets, but exclude multiple visits to sites to deal with the problem of non-independence. Nevertheless, some of the patterns may be influenced by changes in the distribution of sites between years and surveys. The repeated measures analyses were carried out to test for survey and year effects without this potential bias, but are inevitably conservative in the detection of effects because of the reduced sample size. These analyses confirmed the most robust findings, namely the significantly higher rates of occurrence of moles, foxes, rabbits and rats (although not badgers) detected by the WMM field signs survey, and the significantly greater rates of occurrence of rabbits and hares detected by the BBS sightings survey. No other significant effects were detected.

Conclusions

- The WMM protocols for field signs provide considerably more data on the presence of a suite of key species monitored by both WMM and BBS (mole, badger, brown rat, fox and rabbit) and hence are better able to detect changes in distribution. The WMM protocols also provide semi-quantitative information (% transect sections with field signs) for these species, and an additional species not monitored by the BBS (field vole). This is almost certainly due to the much greater effort, and more detailed information collected by volunteers carrying out WMM surveys.
- The WMM protocols for sightings found more evidence of the presence of species such as fallow deer, muntjac and grey squirrel, although the latter was actually detected in higher numbers on occupied sites during the summer than the winter. In contrast, the BBS protocols for sightings found considerably more evidence of the presence of hares and rabbits, and also found considerably larger numbers of these two species in the summer than in the winter. Because the sightings protocols do not differ greatly except in timing, these differences are most likely to reflect seasonal differences in the numbers of individuals, as well as possible seasonal differences in their distributions and behaviour. For two species – fox and roe deer – the surveys provide equivalent data.
- There was little evidence of year effects over the relatively short period of the pilot. Any year differences detected are most likely related to inter-annual changes in environmental conditions, rather than underlying trends. Badgers and brown rat (monitored solely by

their setts & latrines, and burrows) showed no evidence of inter-annual differences in occurrence. However, changes in the occurrence of moles (also monitored solely by field signs) differed between surveys – suggesting different factors operating in summer and winter.

- Based on rates of detection of their burrows, rabbits increased in occurrence, but the sightings data suggested declines in occurrence, and abundance. Moreover, there were differences in the inter-annual patterns between BBS and WMM surveys – which suggest different factors operating over these particular summers and winters. There was no evidence of inter-annual differences in the occurrence of foxes based on their field signs, but sightings data suggested a decline in occurrence, but not in numbers on those sites.

7. Individual Species

Introduction

One of the aims of the pilot Winter Mammal Monitoring was to assess methodological and geographical factors associated with the sampling protocols that could influence the estimated measures of changes in abundance. It is important to identify these variables so that subsequent trend analyses can take them into account, as necessary, or to consider modifications to the protocols to ensure collection of the best quality data. These are first considered at the species level – because the relationship between abundance and explanatory factors may differ across species. We then assess the influence of each factor overall, because winter mammal monitoring is a multi-species survey, and the protocols must be designed to collect good quality information for as many of the target species as possible. In the first sections, we report on the results of analyses of the data for each mammal species monitored by the sightings survey, the field signs survey, or both. A suite of key methodological, geographical, temporal and habitat-related factors are tested for the significance of their effect and interactions with other factors. Results are reported in detail under the individual species headings, and summarised in the conclusions of this chapter.

Analytical Methods

Datasets used in single species analyses

For the single species analyses, we used the full set of data – i.e. all sites surveyed by sightings or field signs in each year. This approach maximises sample size, allowing more complex models to be constructed, but means that data from some sites are included in the model in more than one survey year. It was not possible to control for pseudo-replication by incorporating a site identifier as a variable in the model, as this led to problems of model convergence. However, the inclusion of a large number of independent variables related to landscape and location should help to explain variance between sites as well as to reduce apparent variation in abundance resulting from annual turnover of sites. Moreover, the distribution of sites between Environmental Zones did not differ significantly between years. As an additional precaution, the models for two species (fox and rabbit) were re-run using a reduced subset of data containing only those sites that were surveyed by both methods in all three years and the results were compared to those of the models using the full dataset.

Dependent variables for the analyses of sightings data

Analyses of sightings data were performed using the GENMOD procedure in SAS v8.02, using the p-scale function to improve model fit. Two dependent variables were considered. The first was the total number of individuals (for each species) totalled across all transect sections at each site, with an offset incorporated to take account of the length of the transect, analysed using the GENMOD procedure with Poisson error and a log link function. The second was the proportion of transect sections in which at least one individual of the species was recorded, but that were identical in every other way. These models assumed a binomial error distribution and used a logit link. When the full set of independent variables (see below) was included, five out of seven binomial models converged, but only three out of seven Poisson models converged. The ratio of the Pearson's χ^2 value to the total degrees of freedom provides a crude assessment of the goodness of fit of these models. When the fit of the two model types was compared for the seven most frequently recorded species (Table 26), the fit of the binomial models was found to be superior on every occasion. Furthermore, the binomial models identified 14 of the 15 significant relationships found by the three Poisson models that converged, the exception being that between roe deer abundance and month, plus an additional 10 significant relationships which were not identified by the Poisson models. The final analyses were therefore preformed using binomial models.

Table 26. Comparison of model fit, as determined using the ratio of Pearson's χ2 to the degrees of freedom, for the binomial model using the proportion of positive transect sections as a dependent variable and the Poisson model using total counts across all transect sections as a dependent variable. The nearer the value of **χ**2/DF to 1.00, the better the fit of the model is to the data. The table also indicates which models converged (* indicates convergence if the term for Environmental Zone was removed fro the model) and presents the total number of significant relationships identified by each model.

Species	Binomial model			Poisson model		
	χ^2/DF	Model converged?	No. significant relationships	χ^2/DF	Model converged?	No. significant relationships
Rabbit	1.97	Yes	10	15.78	Yes	4
Brown Hare	1.50	Yes	11	3.35	No	-
Grey Squirrel	1.55	Yes	12	2.98	No	-
Red Fox	1.17	Yes	8	1.31	Yes	6
Fallow Deer	1.14	No*	-	10.73	No	-
Roe Deer	1.44	Yes	6	4.05	Yes	5
Muntjac	1.40	No*	-	1.44	No	-

All analyses of sightings took account of the fact that transect section length doubled after the first year of the survey, by treating consecutive pairs of 100m transect sections surveyed in the first year as the direct equivalent of 200m transect sections, as surveyed in later years. (Where only one half of the equivalent 200m section had been surveyed in the first year, the data were excluded as the probability of obtaining a positive result, e.g. seeing at least one individual of a species, is likely to have been significantly lower for these sections. Such sections accounted for less than 2% of the full dataset.)

If fewer than five 200m transect sections (or 10 of the 100m sections in the first year) were surveyed at a particular site (<50% of a 'standard' transect) then data from that site were excluded. The information about the number of transect sections was extracted from the habitat data, so an apparently 'short' transect could result from incomplete habitat recording. As the dependent variable used in analyses was the proportion of positive transect sections, the value of a single observation could be artificially inflated if the number of transect sections surveyed during the habitat phase was less than the number surveyed for sightings. For example, a single fox seen in a transect where only two sections were surveyed for habitat would result in a value of 0.50, whereas in reality 10 sections had been surveyed for sightings and the figure should have been 0.10.

Dependent variables for field signs analyses

Analyses of field signs data were performed using the GENMOD procedure in SAS v8.02, using the p-scale function to improve model fit. The dependent variable was the proportion of transect sections that were searched for each category of field sign in which at least one sign of that type was recorded. Participants were able to indicate on their survey forms which sections were searched for which signs. All models assumed a binomial error distribution and used a logit link. As with sightings data, field signs data from the first year had to be converted into equivalent 200m transect sections. This process is unlikely to have any influence on the detection rates of the majority of types of field sign. However, it is possible that the detection rate of field vole runs and harvest mouse nests, for which a five-minute searching limit was imposed per transect section, may have been higher in the first year of the survey, as the time spent searching two 100m sections would be twice that spent searching the equivalent 200m section in subsequent years. As participants cease their search efforts once a sign had been found in a section, the influence of changing transect section lengths should be minimal.

Dependent variables for combined analyses

For fox and rabbit, there were sufficient records of sightings and field signs to be analysed in the same model, with an additional independent, categorical variable indicating the survey type. There was a problem in that the proportion of visible transect sections, included as an independent variable in analyses of sightings-only data, could not easily be included in the joint models. The dependent variable for the field signs was calculated as the proportion of searched transect sections while the dependent variable for the sightings was calculated as the proportion of visible transect sections. This approach was not ideal for two reasons. Firstly, the classification of ‘visible’ by observers is likely to have varied. In some cases, sightings were recorded on transect sections marked as ‘not visible’. The other problematic aspect of this technique lies in the categorisation of partially-visible transect sections. Visibility is recorded for both the left- and right-hand sides of the transect, thus one side of a transect section could be recorded as ‘visible’ and the other as ‘not visible’. To further complicate matters, combining adjacent pairs of transect sections for first year data to make them equivalent to the longer second year transect sections means that visibility is a function of four separate measures of visibility. For the purpose of this analysis, transect sections that were equal to or greater than 50% visible were categorised as ‘visible’, even though they are unlikely to be exactly equivalent to 100% visible sections in terms of the probability of seeing an individual mammal.

Independent variables

All of the following independent variables were included in the full models used in the analysis of the sightings and field signs phase data, both phase-specific and combined.

- **Survey year –** included as a categorical variable - three years of data have been collected.
- **Survey month** – included as a continuous variable, with months re-numbered so that July became Month 1 and June became Month 12, allowing linear trends over the winter period to be investigated.
- **Number of observers –** included as a continuous variable. Participants were asked to record the number of observers taking part in the sightings phase. The number of observers taking part in the field signs survey was calculated by counting the number of names entered on each recording sheet.
- **Environmental Zone** – included as a categorical variable with six levels. As this variable is likely to be correlated with easting and northing, if either of these variables were not significant in the full model, Environmental Zone was removed and the model was re-run
- **Northing –** included as a continuous variable.
- **Easting –** included as a continuous variable.

- **Survey start time** – included as a continuous variable.
- **Survey duration** – included as a continuous variable indicating the total amount of time spent at the site during each phase of the survey.
- **Habitat types** – included as five separate continuous variables. The habitat types recorded by participants for each side of the transect in each section (27 in the first year, 23 in the second and third year) were combined into six broad habitat categories (Table 27). The number of transect sections assigned to each category (treating left-hand and right-hand sides as separate sections) was then expressed as a proportion of the total number of transect sections for which a habitat type was recorded.

Table 27. Habitat categories used in analyses of sightings and field signs

Code Year 1	Code Years 2 & 3	Description	Habitat Category
1	1	Broadleaved woodland	Woodland
2	2	Coniferous woodland	Woodland
3	3	Scrub	Woodland
4	4	Parkland	Woodland
5	5	Coniferous plantation	Woodland
6	6	Broadleaved plantation	Woodland
7	7	New plantation	Woodland
8	8	Recently felled woodland	Woodland
9	9	Dry semi-natural grassland	Grassland
10	10	Heaths and heather moorland	Grassland
11/12	11	Bogs, swamps, fens and marshes	Grassland
13	12	Bracken	Grassland
14/15	13	Grassland	Pastoral
16	14	Arable land with new sown crop	Arable
17	15	Arable land with mature crop	Arable
18	16	Arable land with stubble/weeds	Arable
19	17	Bare arable land	Arable
20/21	18	Coastal habitat	Other
22	19	Standing natural/semi-natural water bodies	Other
23	20	Standing man-made water	Other
25	21	Inland bare ground	Other
26	22	Built land	Urban
27	23	Amenity grassland	Urban

If the proportions of all six habitat categories were included in the model then problems would be encountered as the proportions of the first five categories would completely explain the variation in the proportion of the sixth. To overcome this problem, the proportion of the habitat category ‘Other’ was excluded from the model. *P* values obtained for each of the five remaining categories relate to the significance of their effect on the dependent variable relative to that of the missing category. In order to obtain a measure of the significance of habitat per se, the deviance of the model containing the habitat variables was compared with that of a model in which the five habitat variables had been removed according to the method developed by Manly (1990) as described in Crawley (1996) p.224.

- **Shannon-Wiener Diversity Index** – included as a continuous variable, this Index calculates the habitat diversity of each site as described in Chapter 6.

- **Linear features** – included as five separate continuous variables. The 11 types of linear feature recorded by participants were grouped into five broad categories (Table 6) and the proportion of transect sections containing a linear feature from each category was calculated. As multiple linear features can be recorded for each transect section, categories are not mutually exclusive and therefore all five proportions could be included as independent variables in the model.

Table 28. Linear feature categories used in analyses of sightings and field signs phase

Code	Description	Category
A	Small managed hedgerow	Hedge
B	Large managed hedgerow	Hedge
C	Unmanaged hedgerow	Hedge
D	Tree-line	Hedge
E	Fence/wall	Fence
F	Stream/river	Water
G	Canal	Water
H	Other boundary structure	-
I	Footpath	Path
J	Road	Road
K	Other boundary route	-

In addition, a further six independent variables were included in the models used to analyse the sightings data, but not in the field signs models:

- **Proportion of transect visible –** included as a continuous variable. Participants were asked to categorise the habitat to the left and to the right of the transect line as either visible or not visible. The proportion of transect sections recorded as visible was then calculated (treating left-hand and right-hand sides as separate sections).

- **Weather variables** – included as five continuous variables. Participants carrying out the sightings part of the survey were asked to record five weather variables – cloud cover, rainfall, wind, temperature and visibility – using a simple scoring system.

Interaction terms

Interaction terms were included in sightings, field signs and combined models. Due to the large number of independent variables in each model, it was necessary to select a subset of first-order interaction terms to include in each model. Interaction terms selected for inclusion in sightings and signs models were: interactions between year and month, duration, northing, easting, Environmental Zone, Shannon Wiener Index and all habitat variables, plus interactions between duration and northing, easting and Environmental Zone. Four of the nine models (e.g. muntjac sightings) would not converge even if a substantial proportion of these interaction terms were removed from the model. Models that did converge were simplified by removing non-significant interactions and were then re-run. This process was repeated until only significant interaction terms remained. For the combined models, the first order interactions between survey type and all other independent variables were included in the model. Models were simplified as above.

Badger (Meles meles)

As Badgers are generally inactive during daylight hours, the vast majority of the data collected for this species related to field signs rather than sightings. Over the three winters, badgers were seen on only seven sites (<1%) and the sightings data was not analysed. However, more than 95% of participants searched their transect routes for two types of badger field sign – recording setts on 23% of sites and latrines on 31% of sites. These percentages varied between 20% and 30% over the three winters. For the analyses for the effects of environmental and methodological factors, the two types were combined to produce a single variable. Thus, a transect section was recorded as ‘positive’ for signs of Badger if either a latrine or a sett (or both) were present.

Minimum Detectable Changes

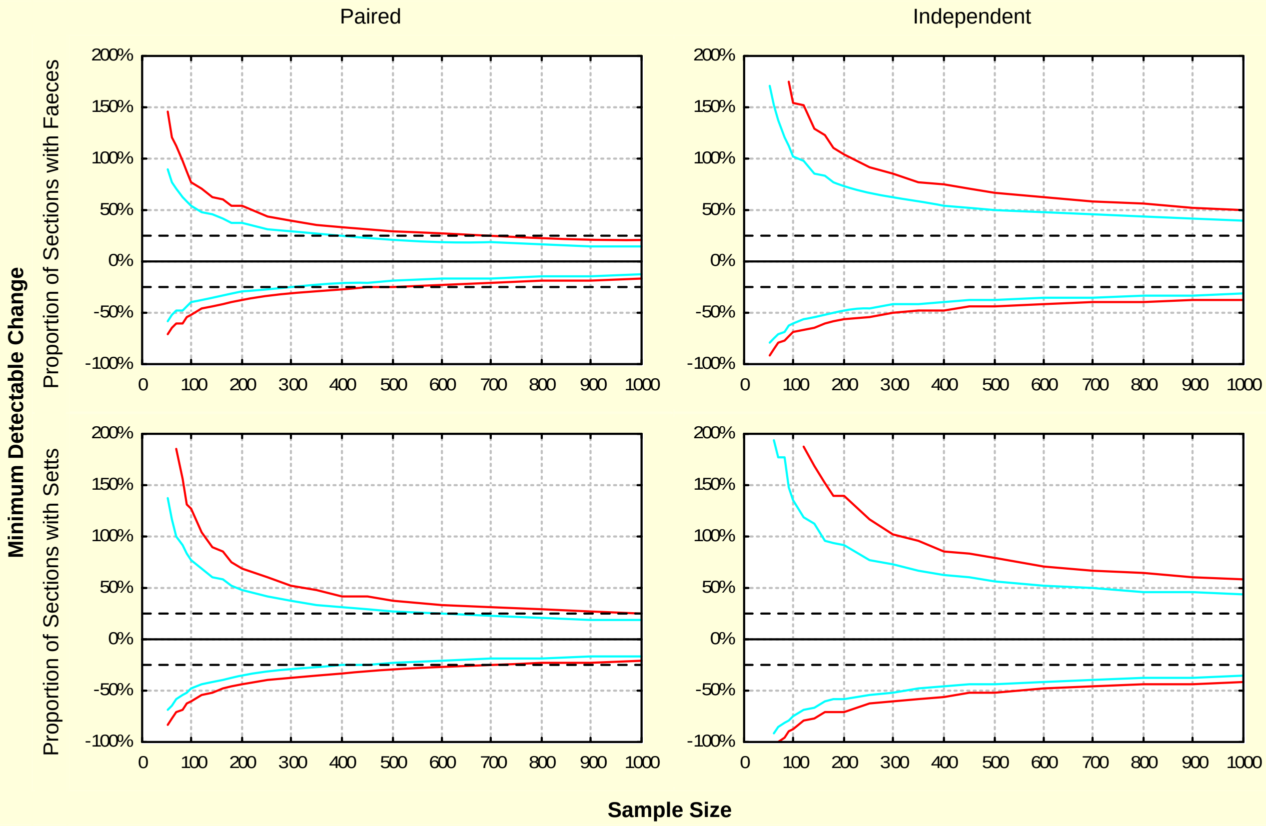


Fig. 43. Minimum Detectable Changes for Badger Faeces and Setts, at 95% (blue) and 99% (red) levels of confidence

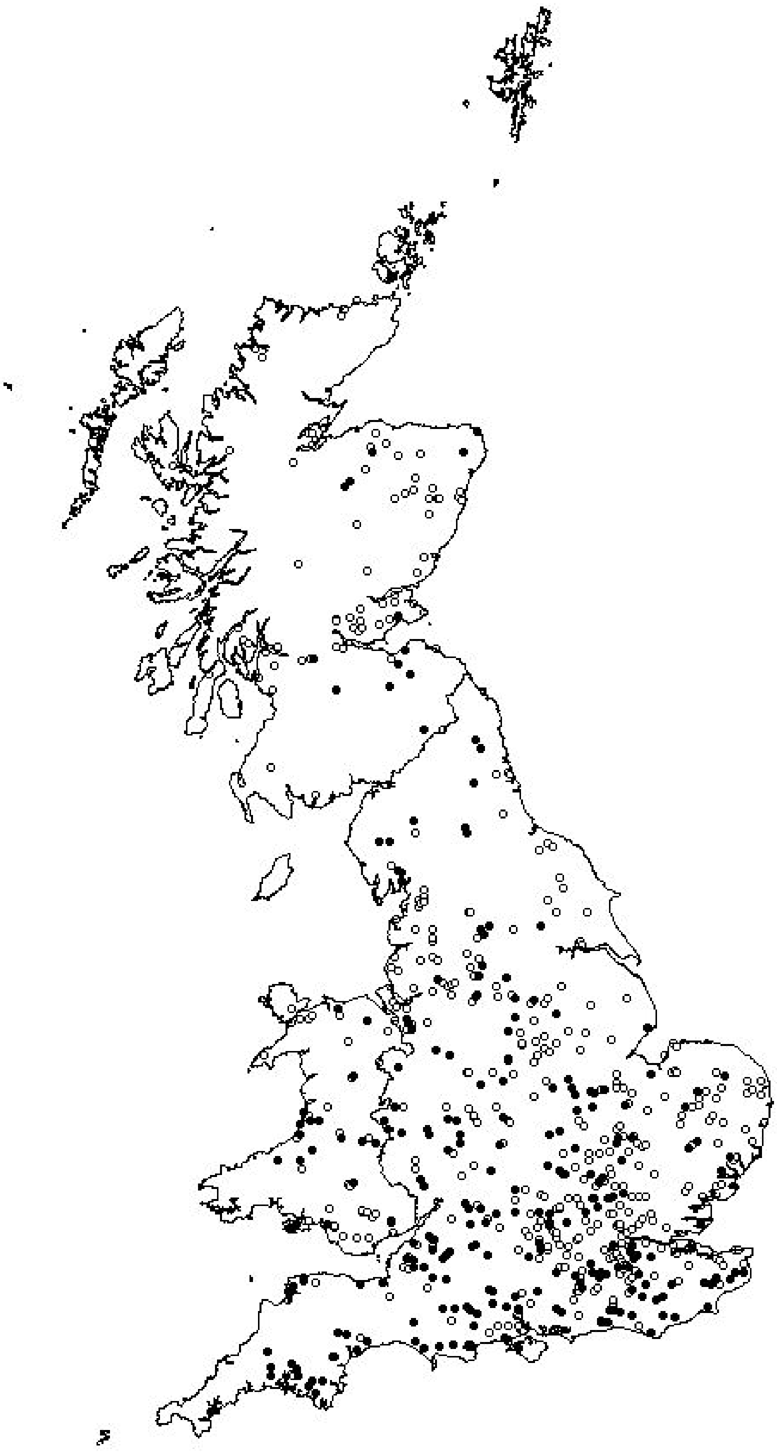
Badgers can be monitored using field signs. The plots above show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots).

By measuring the proportion of transect sections with badger latrines or faeces (upper two plots), a sample size of 400 sites would be sufficient to detect a significant change in abundance of 25% (based on the paired site analyses).

By measuring the proportion of transect sections with badger setts (lower two plots), a sample size of about 450 paired sites would be sufficient to detect a 25% decline, and a sample of 600 sites would be sufficient to detect a 25% increase. If both badger signs were combined into a single variable, a 25% change could probably be detected with a sample of 300 sites.

Distribution & Abundance

Distribution of Badger field signs on WMM sites. Open circles show sites surveyed for the species and closed circles indicate sites that recorded presence.



Factors Influencing Sightings and Signs

In this section, we identify all of the factors found to be significant in the full model (see Methods) for badger, where the measure of abundance is the proportion of transect sections scoring positively for either setts or latrines. The abundance of these badger signs did not vary significantly between years, nor did it show any significant effect of month (Table 29). Duration had a small, positive effect, indicating that signs were found in a greater number of transect sections if the observer(s) spent more time carrying out the survey, but neither number of observers nor start time had any significant effect.

Northing and easting were both significantly negatively related to the proportion of positive transect sections, indicating that badger signs are more frequently found in southern and western Britain. The effect of Environmental Zone was not significant (Table 29), but this may have been due to a correlation between this variable and both northing and easting. Habitat had a significant influence on the proportion of positive transects ($F=11.28$, $p<0.0005$), with signs recorded more frequently in woodland, pastoral and arable areas (Table 30). Habitat diversity, as measured by the Shannon –Wiener Index, also had a strong positive effect, indicating that badger signs were recorded on a greater proportion of transect sections at more diverse sites. None of the linear features recorded had a significant effect. When the interaction terms between year and month, duration, northing, easting, Shannon-Wiener Index and the habitat variables; and between duration and easting, northing and Environmental Zone were included in the model, Duration*Easting and Year* Easting were initially significant but became non-significant when the model was simplified by removing non-significant interaction terms.

Table 29 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections with Badger signs (either setts or latrines). Coefficients (parameter estimates) are estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic.

Variable	***df***	***Parameter Estimate***	X^2	***P***
Year	2	-	2.26	0.3225
Month	1	0.0326	0.32	0.5743
No. Observers	1	0.0701	0.40	0.5248
Start Time	1	0.0005	1.03	0.3104
Duration	1	0.0018	5.42	0.0199
Zone	5	-	8.77	0.1188
Northing	1	-0.2680	15.45	<0.0001
Easting	1	-0.2632	19.58	<0.0001
Shannon-Wiener	1	0.7249	17.18	<0.0001
% Hedge	1	0.9062	3.39	0.0657
% Water	1	0.9026	2.28	0.1309
% Fence	1	0.6339	0.76	0.3824
% Path	1	-0.0362	0.00	0.9602
% Road	1	-1.5277	2.48	0.1155

Table 30 Relative odds ratios for different habitat categories from the binomial model for badger. Ratios presented are relative to the category 'Other'. Variation between habitats was significant (p<0.0005, see text).

Habitat (%)	Odds (=P/1-P)
Woodland	148.41
Natural Grassland	49.40
Arable	129.02
Pastoral	141.18
Urban	16.95
Other	1.00

Conclusions

Badgers can be monitored using field signs. By measuring the proportion of transect sections with badger latrines or faeces, a sample size of 400 sites would be sufficient to detect a significant change in abundance of 25% (based on the paired site analyses). By measuring the proportion of transect sections with badger setts, a sample size of about 450 paired sites would be sufficient to detect a 25% decline, and a sample of 600 sites would be sufficient to detect a 25% increase. If both badger signs were combined into a single variable, a 25% change could probably be detected with a sample of 300 sites.

Brown hare (Lepus europaeus)

As brown hare is a relatively large species that is very active during daylight hours, sufficient data were collected during the sightings part of the survey to permit analysis of this dataset. Brown hare were recorded on 190 sites (17%) overall, although this percentage varied from about 13% in the first winter to 21% in the third winter. Brown hare is not a burrowing species and does not leave any field signs that can be easily identified, thus it was not included in the field signs part of the project.

Minimum Detectable Changes

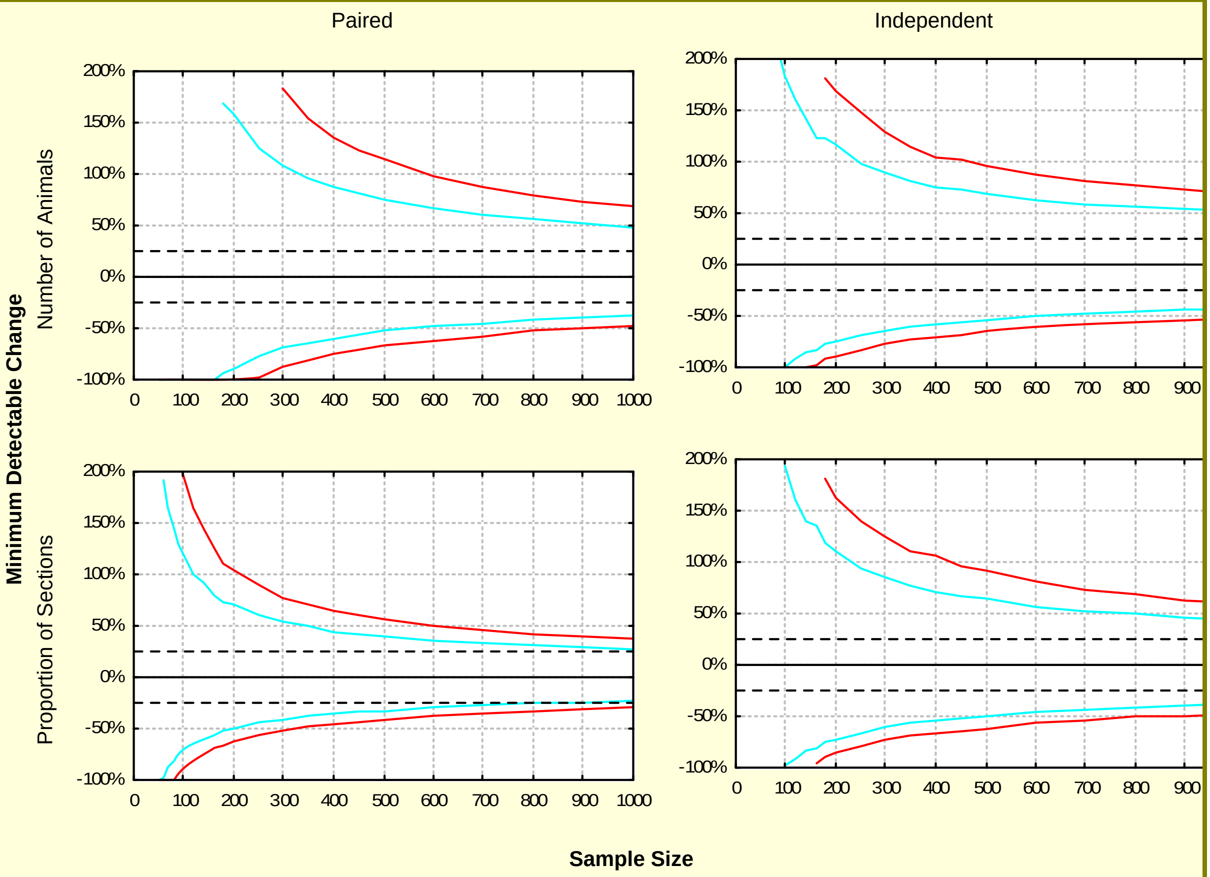
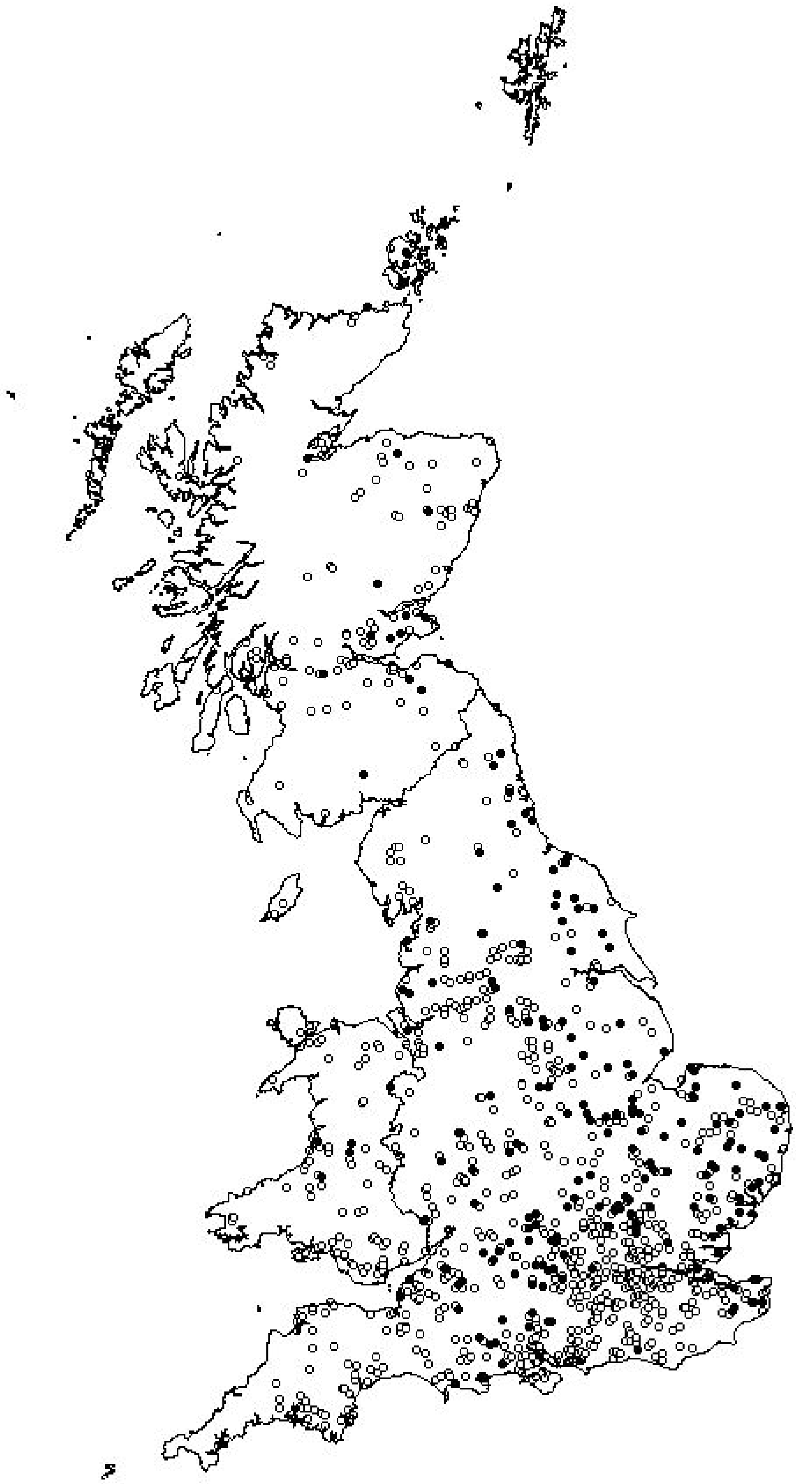


Fig. 44. Minimum Detectable Changes for Brown Hare Sightings, at 95% (blue) and 99% (red) levels of confidence

Brown hare can be monitored using sightings. The plots above show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots). By measuring the proportion of transect sections with hare sightings on paired sites, a sample size of between 100 and 200 sites would be sufficient to detect a significant decline in abundance of 50% or an increase of 100%, and a sample of between 700 and 1000 sites would be required to detect a significant change in abundance of 25%.

Distribution & Abundance

Distribution of Brown Hare sightings on WMM sites. Open circles show sites surveyed and closed circles indicate recorded sighting.



Factors Influencing Sightings and Signs

The proportion of transect sections in which brown hare was recorded varied significantly between years (Table 31 & Table 34), with hares seen on the greatest proportion of transect squares in the third year of the survey. The effects of month, start time and number of observers were all non-significant, but duration had a small, but significant, positive effect, indicating that hares were seen on a greater proportion of transect sections as the time taken to complete the survey increased. The influence of both rainfall and temperature was positive, indicating that brown hare were recorded on a greater proportion of transect sections on warmer and wetter days.

Environmental Zone significantly influenced the proportion of transect sections on which brown hare were seen (Table 31 & Table 33), hares were generally seen more frequently in England than in Scotland. Easting and northing were also highly positively significant, indicating that, within zones, hares were seen in a greater proportion of positive transect sections in the north and east. Habitat had a significant influence on the proportion of positive transects ($F=42.4$, $p<0.0005$), with sightings recorded on a greater proportion of transect sections in arable and pastoral areas (Table 33). Habitat diversity also had a strong positive effect. Of the linear features, only hedges had a significant effect.

When the interaction terms between year and month, duration, Environmental Zone, northing, easting, Shannon-Wiener Index and the habitat variables, and between duration and easting, northing and Environmental Zone were included in the model, it failed to converge.

Table 31 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections in which brown hares were seen. Coefficients (parameter estimates) estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic

Variable	***df***	***Parameter Estimate***	X^2	***P***
Year	2	-	7.86	0.0197
Month	1	0.1186	2.47	0.1158
No. Observers	1	0.0261	0.08	0.7722
Start Time	1	0.0012	1.63	0.2011
Duration	1	0.0042	4.24	0.0395
Zone	5	-	23.81	0.0002
Northing	1	0.4090	32.96	<0.0001
Easting	1	0.2341	11.49	0.0007
% visible	1	1.0754	6.87	0.0087
Cloud	1	-0.0042	0.00	0.9598
Rain	1	0.2904	4.27	0.0387
Wind	1	0.0421	0.19	0.6597
Temperature	1	0.3471	8.02	0.0046
Visibility	1	-0.2124	1.66	0.1979
Shannon-Wiener	1	0.4320	4.35	0.0396
% Hedge	1	2.0819	15.22	<0.0001

Variable	*df*	***Parameter Estimate***	X^2	***P***
% Water	1	0.4930	0.62	0.4294
% Fence	1	-0.3028	0.12	0.7293
% Path	1	0.9722	2.54	0.1112
% Road	1	0.6243	0.43	0.5121

Table 32 Relative odds ratios for different habitat categories from the binomial model for brown hare. Ratios presented are relative to the category 'Other'. Variation between habitats was significant (p<0.0005, see text).

Habitat (%)	**P / 1-P**
Woodland	2.88
Natural Grassland	2.21
Arable	46.48
Pastoral	13.30
Urban	0.01
Other	1.00

Table 33 Relative odds ratios for different Environmental Zones from the binomial model of Table 1 with a logit link function. Ratios presented are relative to Environmental Zone 6.

Zone	***Description***	***P / 1-P***
1	Easterly Lowlands (England/Wales)	2.60×10^9
2	Westerly Lowlands (England/Wales)	2.13×10^9
3	Uplands (England/Wales)	3.31×10^9
4	Lowlands (Scotland)	4.30×10^8
5	Intermediate Uplands and Islands (Scotland)	1.31×10^9
6	True Uplands (Scotland)	1.00

Table 34 Relative odds ratios for different years from the binomial model of Table 1 with a logit link function. Ratios presented are relative to the year '2003/04'.

Year	**P/1-P**
2001/02	0.01
2002/03	0.01
2003/04	1.00

Conclusions

Brown hare can be monitored using sightings. By measuring the proportion of transect sections with hare sightings on matched sites, a sample size of between 100 and 200 sites would be sufficient to detect a significant decline in abundance of 50% or an increase of 100%.

Brown rat (Rattus norvegicus)

Although brown rats can be active during daylight hours, most activity occurs at night. Moreover, rats are relatively small and are seldom seen out in the open preferring to remain in cover, such as vegetation or buildings. Rats were seen on only 23 sites (2%) over the three-year project, which was insufficient to allow analysis of the sightings data. However, more than 90% of observers searched their sites for the distinctive burrows constructed by rats, and these were recorded on 47% of sites overall. This percentage varied from 38% in the third year to 43% in the second year.

Minimum Detectable Changes

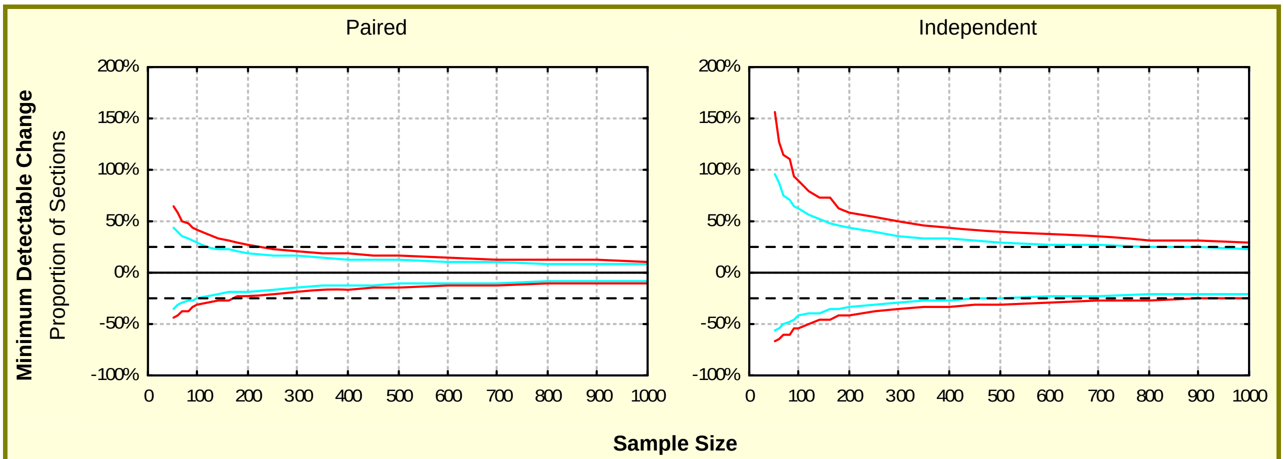
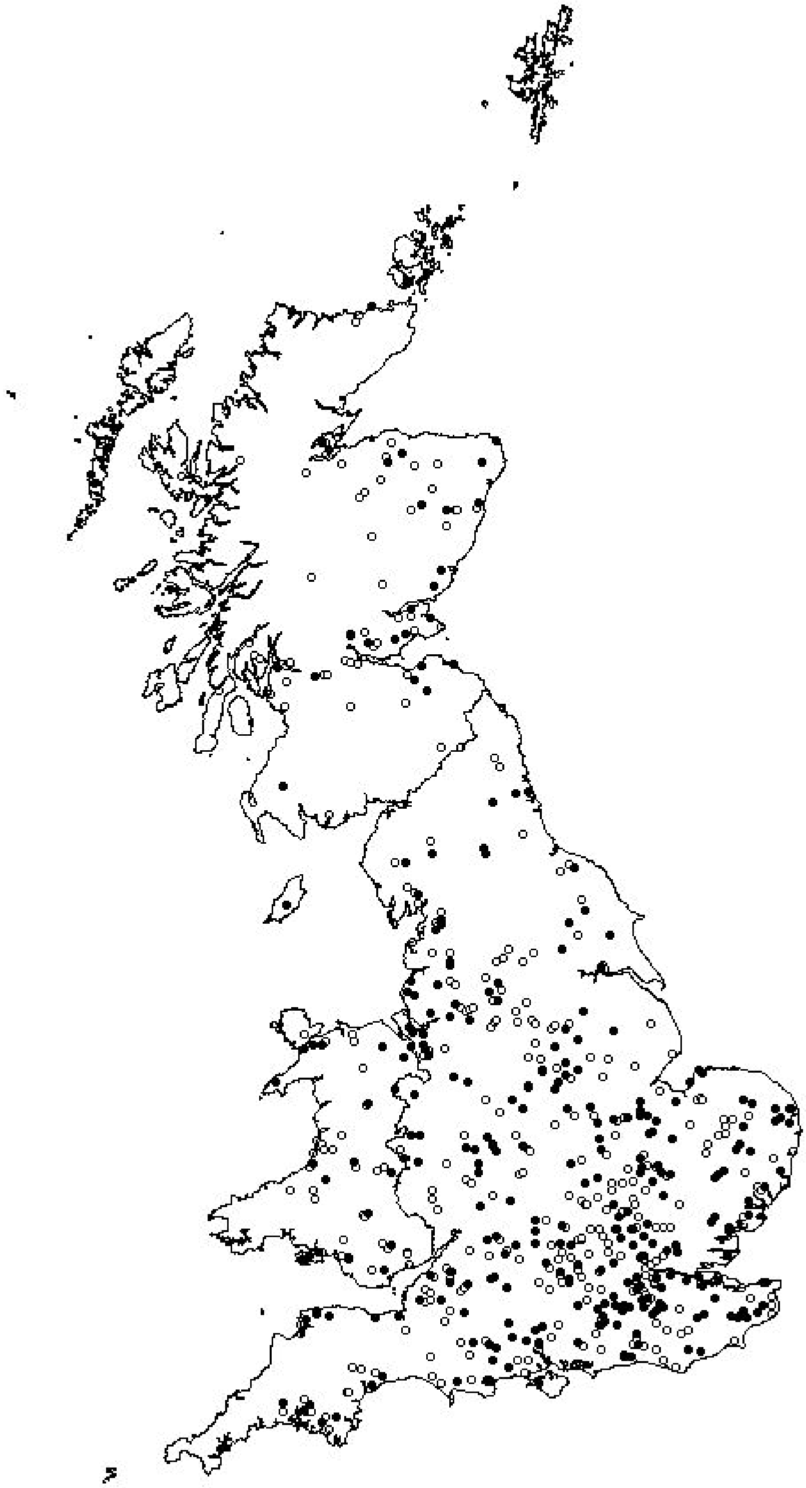


Fig. 45. Minimum Detectable Changes for Brown Rat runs, at 95% (blue) and 99% (red) levels of confidence

Brown rats can be monitored using the presence of active burrows on transect sections. The plots above show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots). Based on the paired analyses, a sample size of about 100 sites would be sufficient to detect a significant change in abundance of 25%.

Distribution & Abundance

Distribution of Brown Rat signs from recorded presence of signs on WMM sites. Open circles show sites surveyed for the species and closed circles indicate recorded presence.



Factors Influencing Sightings and Signs

The proportion of transect sections in which brown rat burrows were recorded did not vary with year or month, nor was it influenced by start time or the number of observers (Table 35). However, it was significantly positively related to duration, with rat burrows recorded in a greater proportion of transect sections during longer survey visits (Table 35).

Environmental Zone had a significant influence on the frequency of recording rat burrows (Table 35), with most signs recorded in sites categorised as Intermediate Uplands and Islands of Scotland (Table 37). Easting was also significant, with the proportion of transect sections containing rat burrows increasing towards the east of Britain (Table 35). Although northing was not significant in the full model (Table 35), when Environmental Zone, a potentially confounding variable, was removed and the model re-run, northing displayed a highly significant negative relationship with the dependent variable (Parameter Estimate = 0.0877, $X^2 = 4.12$, $P < 0.0427$). This indicates that the proportion of transect sections containing brown rat burrows increases towards the north. Habitat type also had a significant effect ($F=7.87$, $p<0.005$), with rat burrows most prevalent in arable areas (Table 36). The effect of hedges was also significantly positive. When the interaction terms between year and month, Environmental Zone, duration, northing, easting, Shannon-Wiener Index and the habitat variables, and between duration and easting, northing and Environmental Zone were included in the model, none were significant.

Table 35 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections in which brown rat burrows were recorded. Coefficients (parameter estimates) estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic.

Variable	***Num df***	***Parameter Estimate***	**X^2**	***P***
Year	2	-	2.76	0.2521
Month	1	0.0253	0.18	0.6717
No. Observers	1	0.1193	1.54	0.2141
Start Time	1	0.0008	2.93	0.0867
Duration	1	0.0021	6.40	0.0114
Zone	5	-	12.46	0.0290
Northing	1	0.0197	0.08	0.7791
Easting	1	0.1333	4.86	0.0274
Shannon-Wiener	1	0.5987	12.40	0.0004
% Hedge	1	1.4857	6.82	0.0090
% Water	1	0.6679	1.11	0.2928
% Fence	1	10467	1.79	0.1806
% Path	1	0.7849	1.09	0.2973
% Road	1	0.7021	1.11	0.4055

Table 36 Relative odds ratios for different habitat categories from the binomial model for brown rat. Ratios presented are relative to the category 'Other'. Variation between habitats was significant ($p<0.005$, see text).

Habitat (%)	P/1-P
Woodland	0.42
Natural Grassland	0.76
Arable	2.52
Pastoral	0.94
Urban	1.20
Other	1.00

Table 37 Relative odds ratios for different Environmental Zones from the binomial model for brown rat. Ratios presented are relative to Environmental Zone 6.

Zone	***Description***	***P/1-P***
1	Easterly Lowlands (England/Wales)	0.85
2	Westerly Lowlands (England/Wales)	0.74
3	Uplands (England/Wales)	0.77
4	Lowlands (Scotland)	0.82
5	Intermediate Uplands and Islands (Scotland)	2.85
6	True Uplands (Scotland)	1.00

Conclusions

Brown rats can be monitored using the presence of active burrows on transect sections. Based on the paired analyses, a sample size of about 100 sites would be sufficient to detect a significant change in abundance of 25%.

Fallow deer (Dama dama)

Fallow deer is a large, diurnal species that forms large herds and can therefore be easily detected during the sightings surveys. Over the three years of winter mammal monitoring, fallow deer were recorded on 48 sites (only 4.3%). This percentage varied little between years. The presence of deer slots and droppings (all species combined) was recorded during the first winter, but because these are difficult to identify reliably to species, deer signs were not included in the field signs survey in the subsequent two winters.

Minimum Detectable Changes

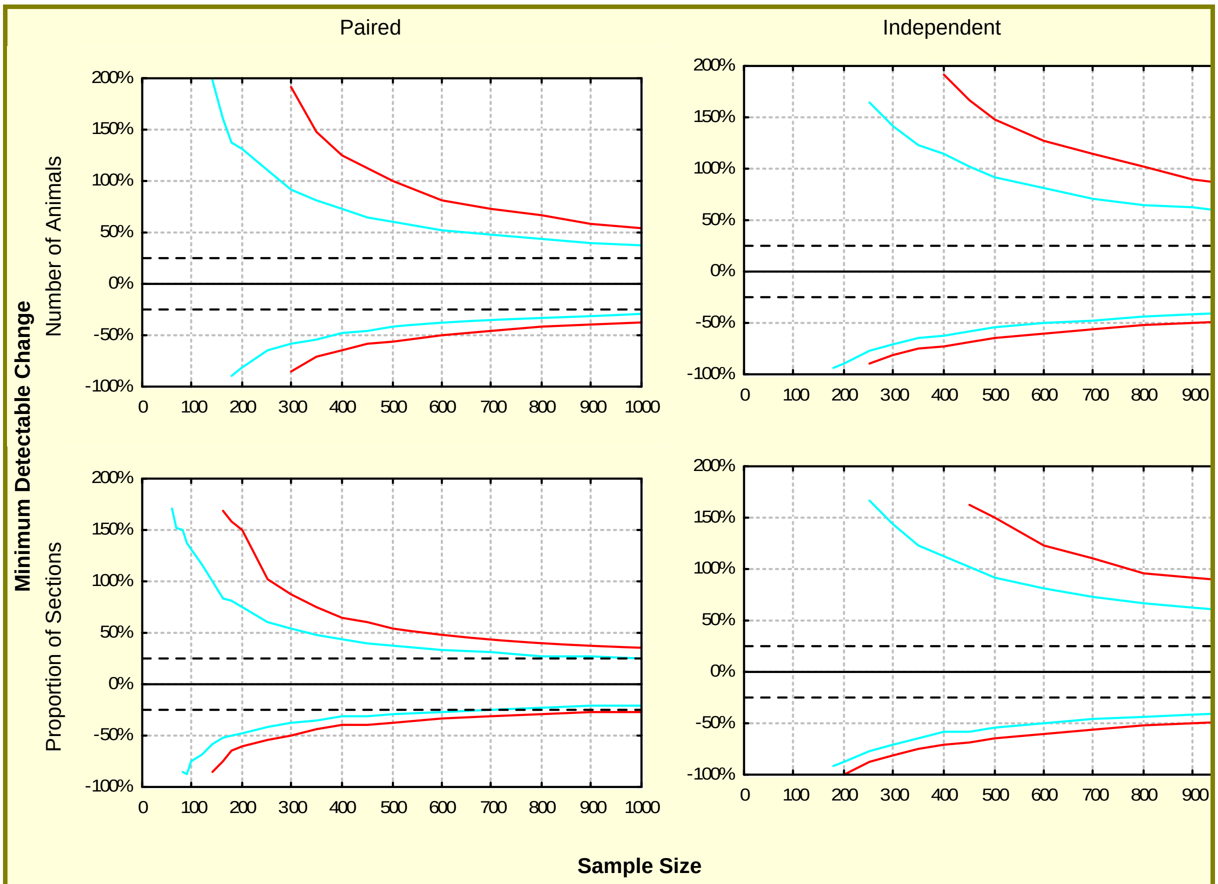
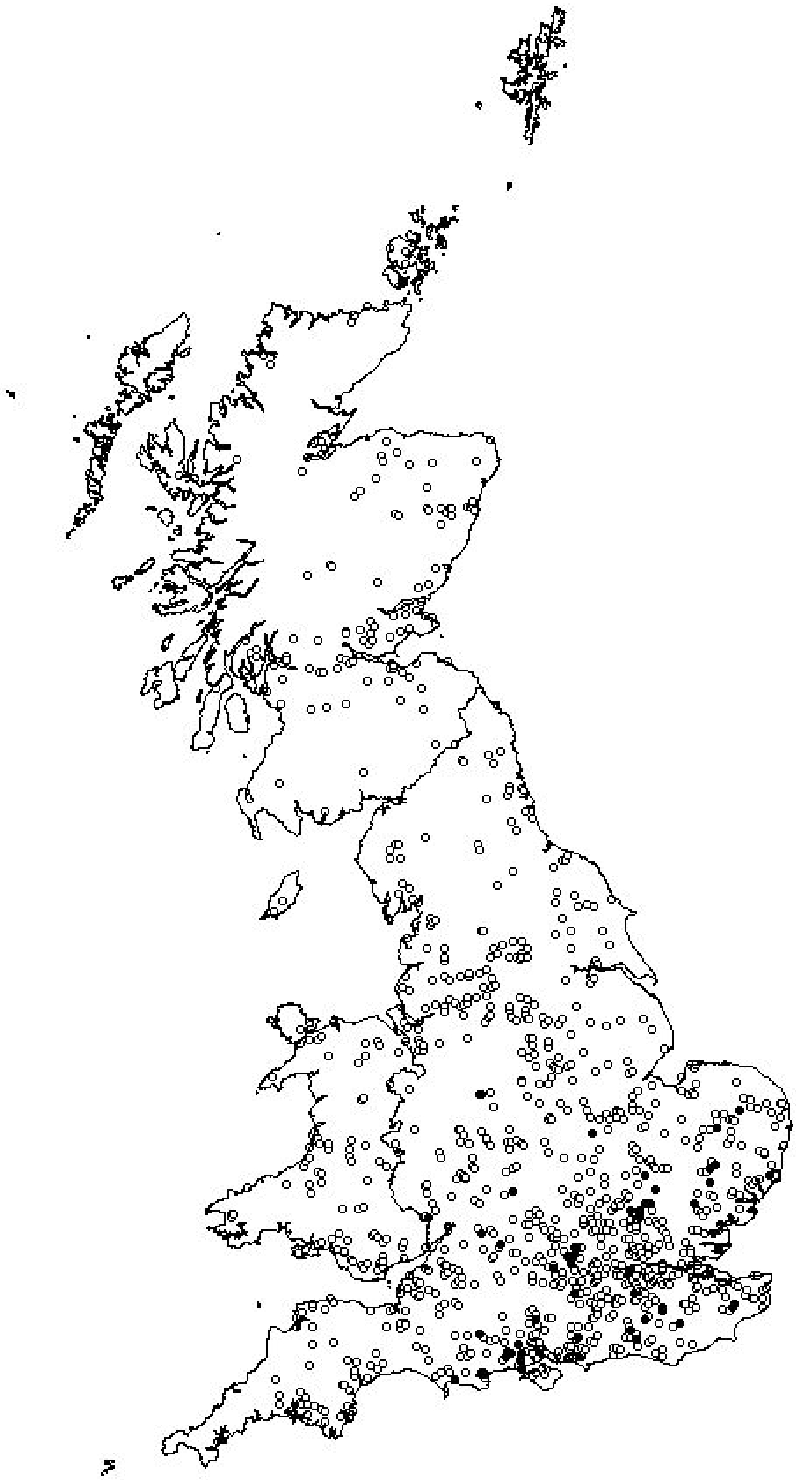


Fig. 46. Minimum Detectable Changes for Fallow Deer Sightings, at 95% (blue) and 99% (red) levels of confidence

Fallow deer can be monitored using the proportion of transect sections with sightings. The plots above show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots). A sample size of 700 matched sites would be required to detect a significant decline in abundance of 50%, and about 100 sites would be required to detect a doubling of the population.

Distribution & Abundance

Distribution of fallow deer sightings on WMM sites. Open circles show sites surveyed and closed circles indicate recording sighting.



Factors Influencing Sightings and Signs

The model for fallow deer would not converge unless the term for Environmental Zone was removed. Of the remaining variables, only northing, easting and habitat (F=52.3, p<0.0005) had a significant influence on the proportion of transect sections in which fallow deer were observed (Table 16). This was negatively related to northing and positively related to easting. Table 39 suggests that the significant influence of habitat resulted from greater proportions of transect sections containing fallow deer recorded in woodland and natural grassland areas. When the interaction terms between year and month, duration, Environmental Zone, northing, easting, Shannon-Wiener Index and the habitat variables, and between duration and easting, northing and Environmental Zone were included in the model, it failed to converge.

Table 38 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections in which fallow deer were seen. Coefficients (parameter estimates) estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic.

Variable	***Num df***	***Parameter Estimate***	**X^2**	***P***
Year	2	-	0.07	0.9672
Month	1	-0.1452	1.02	0.3134
No. Observers	1	0.2032	1.11	0.2913
Start Time	1	0.0009	0.13	0.7236
Duration	1	0.0011	0.07	0.7950
Northing	1	-0.5742	23.21	<0.0001
Easting	1	0.3356	11.23	0.0008
% visible	1	1.1105	3.54	0.0597
Cloud	1	-0.1061	0.42	0.5180
Rain	1	-0.2963	0.67	0.4123
Wind	1	-0.0081	0.00	0.9655
Temperature	1	-0.0238	0.01	0.9269
Visibility	1	0.0721	0.06	0.8062
Shannon-Wiener	1	0.4249	1.44	0.2296
% Hedge	1	-0.2034	0.04	0.8474
% Water	1	-0.3424	0.12	0.7292
% Fence	1	-2.9615	2.21	0.1372
% Path	1	-0.3934	0.17	0.6827
% Road	1	-2.2842	1.76	0.1842

Table 39 Relative odds ratios for different habitat categories from the binomial model for fallow deer. Ratios presented are relative to the category 'Other'. Variation between habitats was significant ($p<0.0005$, see text).

Habitat (%)	P/1-P
Woodland	42.35
Natural Grassland	41.60
Arable	4.39
Pastoral	4.15
Urban	0.12
Other	1.00

Conclusions

Fallow deer can be monitored using the proportion of transect sections with sightings. However, a sample size of 700 matched sites would be required to detect a significant decline in abundance of 50%, and 100 sites would be required to detect a doubling of the population.

Field vole (Microtus agrestis)

Peak field vole activity occurs at night, although some individuals may be active during daylight hours, and spend the majority of their time moving through dense vegetation, seldom emerging from cover. This species was seen and identified on only 12 sites (1%), too few to allow analysis of this dataset. However field voles create well-formed runs through the vegetative layer, which contain distinctive green, oval droppings if in use, and these were recorded by observers who searched in transect sections with suitable coarse grass habitat. About 85% of observers searched at least one transect section for field vole runs, and these were found on 68% of sites overall. These percentages varied between 63% and 70% over the three winters.

Minimum Detectable Changes

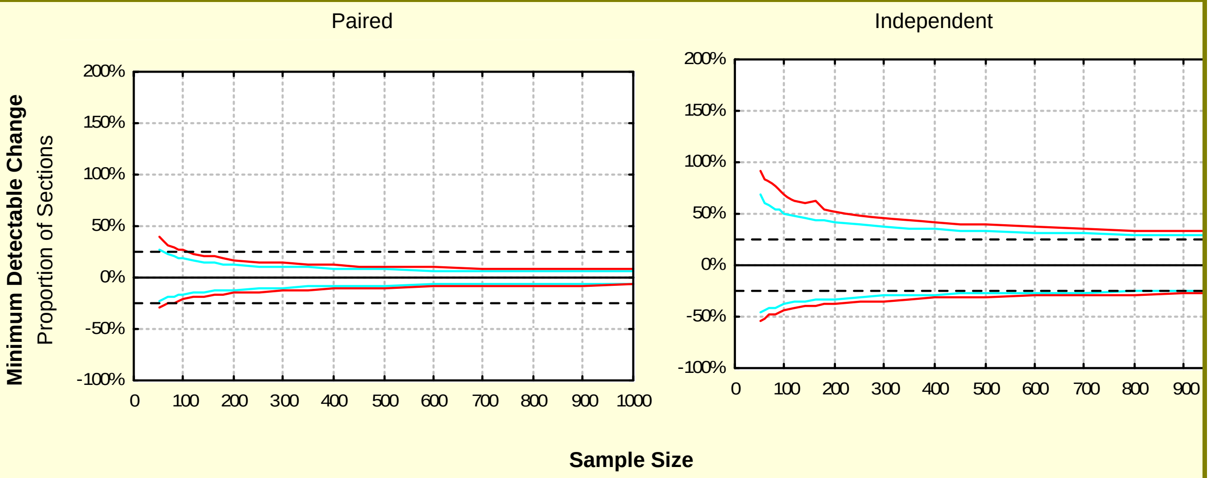
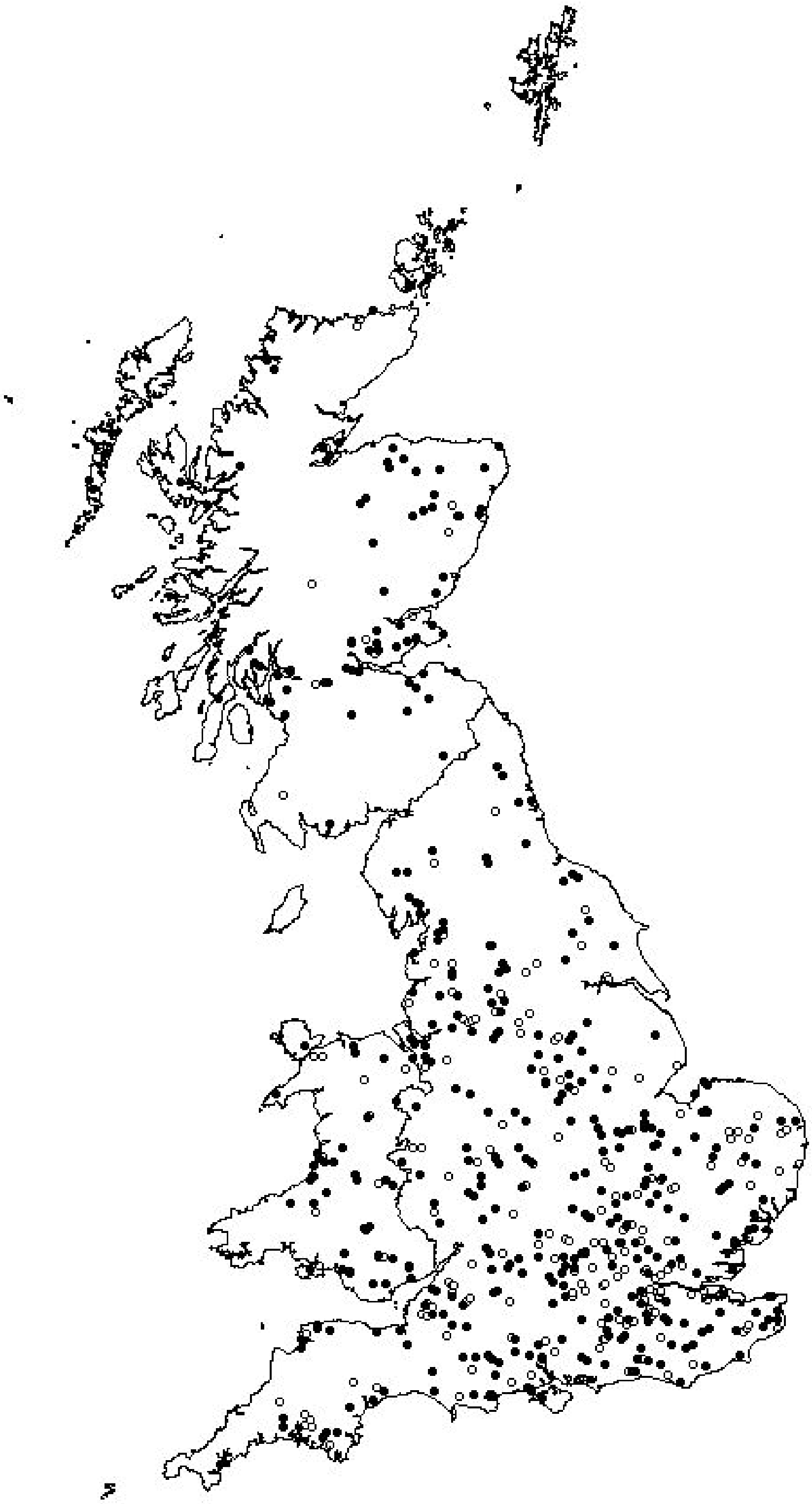


Fig. 47. Minimum Detectable Changes for Field Vole runs, at 95% (blue) and 99% (red) levels of confidence

Field voles can be monitored using the presence of runs in transect sections. The plots above show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots). A sample size of between 50 to 75 paired sites – in landscapes containing rough grassland - would be sufficient to detect a significant change in abundance of 25%.

Distribution & Abundance

Distribution of field vole signs from recorded presence of signs on WMM sites. Open circles show sites surveyed for the species and closed circles indicate recorded presence.



Factors Influencing Sightings and Signs

The proportion of transect sections in which field vole runs were recorded did not vary with year or month, observer number or the duration of the visit (Table 40). However, it did display a weak positive relationship with start time, suggesting that observers recorded field vole runs in a greater proportion of transect sections if they started surveying later in the day.

The prevalence of vole signs was significantly related to Environmental Zone, with the proportion generally greater in the Lowlands and True Uplands of Scotland (Table 42). However, while easting displayed a significant negative influence, suggesting that voles were more numerous at sites towards the west of Britain (Table 40), northing had no effect, even after Environmental Zone was removed from the model. Habitat diversity and habitat type (F=5.36, p<0.0005) had a significant effect on the proportion of transect sections in which field vole runs were recorded, with this proportion increasing at more diverse sites and at sites with a high percentage of arable or pastoral habitat (Table 41). The proportion of transects with vole runs decreased as the percentage of section containing roads increased.

When the interaction terms between year and month, Environmental Zone, duration, northing, easting, Shannon-Wiener Index and the habitat variables, and between duration and easting, northing and Environmental Zone were included in the model, the only interaction term which remained in the model after simplification was that between survey duration and easting.

Table 40 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections in which field vole runs were found. Coefficients (parameter estimates) estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic.

Variable	***Num df***	***Parameter Estimate***	**X^2**	***P***
Year	2	-	1.88	0.3906
Month	1	-0.0266	0.23	0.6278
No. Observers	1	0.0044	0.00	0.9596
Start Time	1	0.0021	20.88	<0.0001
Duration	1	0.0003	0.16	0.6916
Zone	5	-	17.70	0.0033
Northing	1	-0.1231	3.68	0.0551
Easting	1	-0.1187	4.03	0.0447
Shannon-Wiener	1	0.4035	6.34	0.0118
Habitat	5	-	-	<0.0005
% Hedge	1	-0.4050	0.66	0.4167
% Water	1	0.3085	0.35	0.5568
% Fence	1	0.0409	0.00	0.9485
% Path	1	0.1528	0.06	0.8183
% Road	1	-1.6929	4.43	0.0353

Table 41 Relative odds ratios for different habitat categories from the binomial model for field vole. Ratios presented are relative to the category 'Other'. Variation between habitats was significant (p<0.0005, see text).

Habitat (%)	P/1-P
Woodland	0.98
Natural Grassland	0.85
Arable	2.30
Pastoral	1.70
Urban	0.43
Other	1.00

Table 42 Relative odds ratios for different Environmental Zones from the binomial model for field vole. Ratios presented are relative to Environmental Zone 6.

Zone	***Description***	***P/1-P***
1	Easterly Lowlands (England/Wales)	0.29
2	Westerly Lowlands (England/Wales)	0.26
3	Uplands (England/Wales)	0.46
4	Lowlands (Scotland)	0.96
5	Intermediate Uplands and Islands (Scotland)	0.50
6	True Uplands (Scotland)	1.00

Conclusions

Field voles can be monitored using the presence of runs in transect sections. A sample size of between 50 to 75 paired sites – in landscapes containing coarse grassland - would be sufficient to detect a significant change in abundance of 25%.

Fox (Vulpes vulpes)

Foxes occur in relatively open habitats, thus increasing their detectability, and are also distinctive and therefore easily identified. Although principally nocturnal, a sufficient number of sightings of this relatively large, mobile species were reported to allow analysis. Overall, foxes were seen on 147 sites (13%). The percentage of sites where foxes were seen varied annually from about 7% in the third winter to 12% in the second winter, indicating that foxes were not always seen on the same sites. Fox scats are also very distinctive and the species was also monitored by the field signs surveys. More than 98% of sites were searched for fox signs, and signs were recorded in 61% of sites overall. This percentage varied between 45% in the second winter and 55% in the first winter.

Foxes can be monitored using field signs or sightings. The plots below show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots). By measuring the proportion of transect sections with fox faeces, a sample size of between 150 and 250 matched sites would be sufficient to detect a significant change in abundance of 25%. By measuring the proportion of transect sections with fox sightings, a sample size of 300 sites would be sufficient to detect a 50% decline, or a 100% increase.

Minimum Detectable Changes

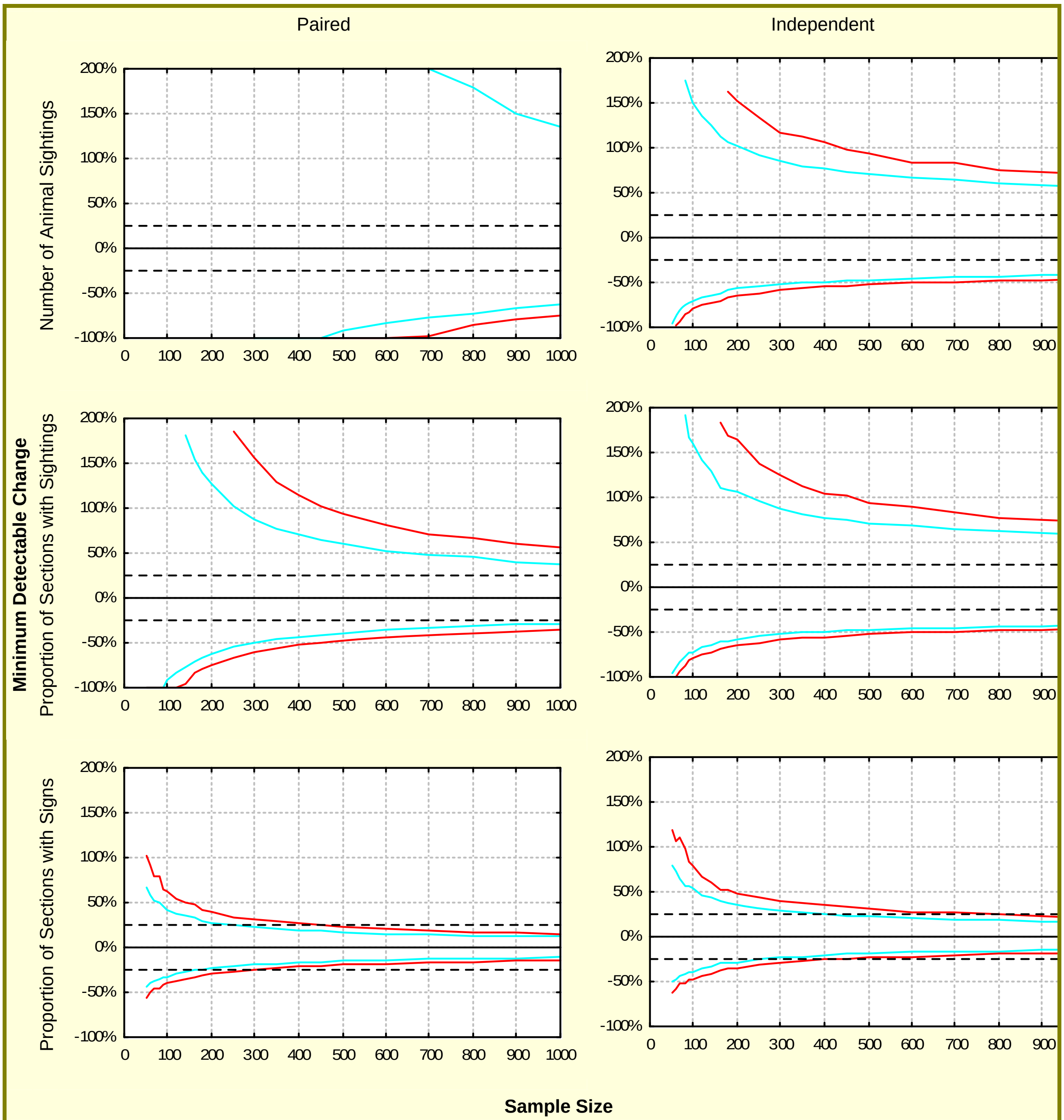
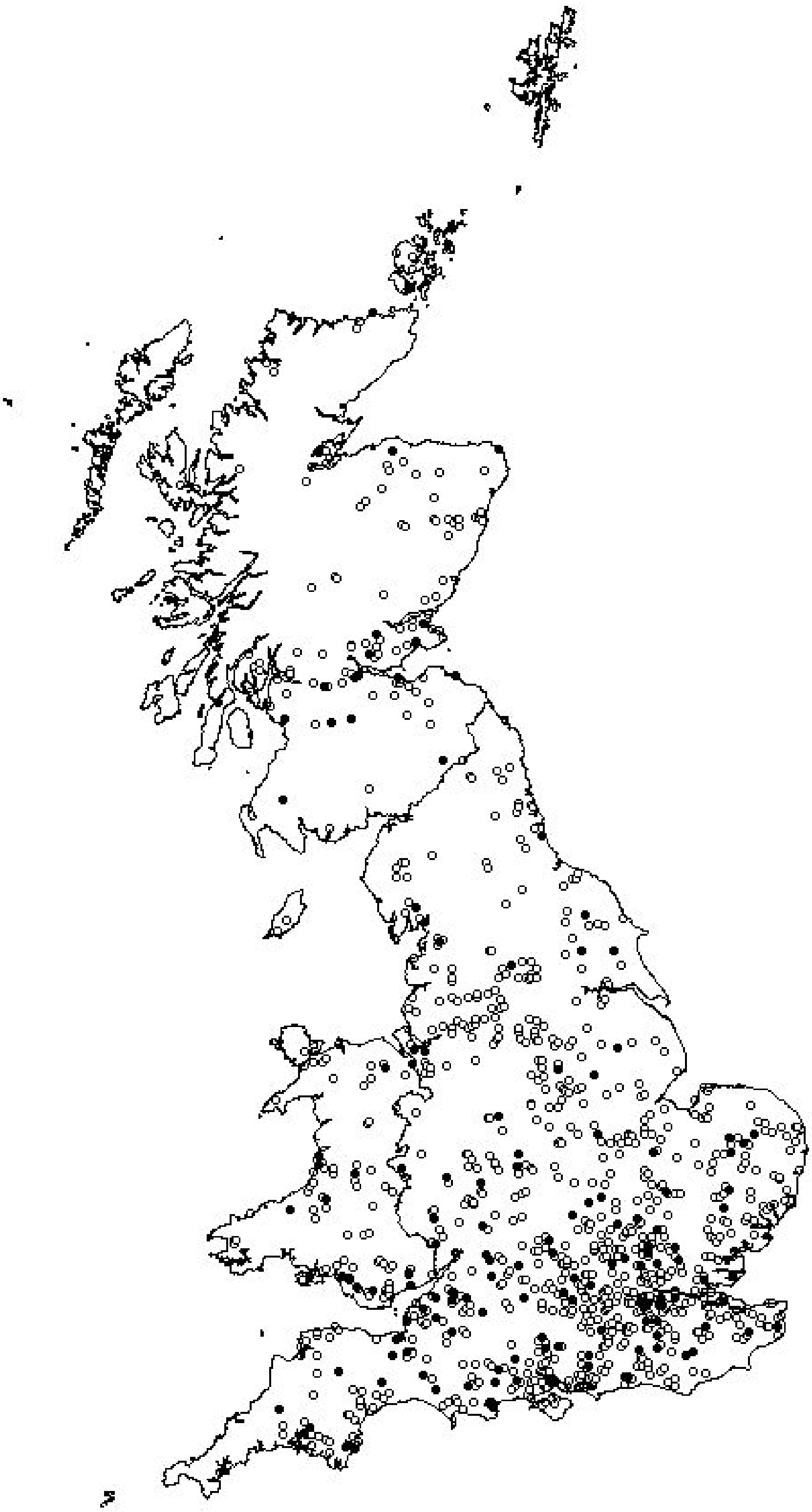


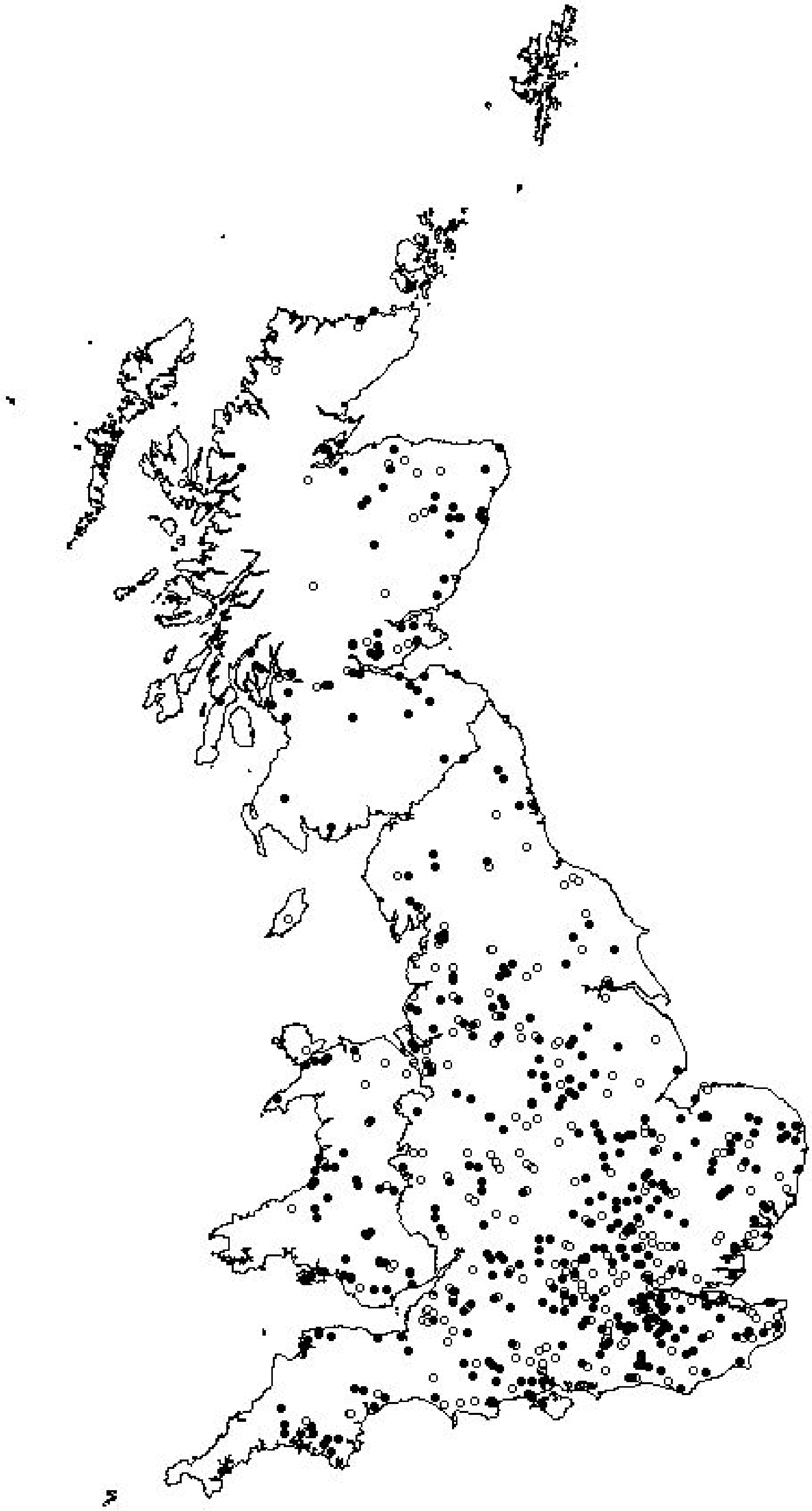
Fig. 48. Minimum Detectable Changes for Fox Sightings and Signs, at 95% (blue) and 99% (red) levels of confidence

Distribution & Abundance

Distribution of fox sightings on WMM sites. Open circles show sites surveyed and closed circles indicate recorded sighting.



Distribution of fox signs from recorded presence of signs on WMM sites. Open circles show sites surveyed for the species and closed circles indicate recorded presence.



Factors Influencing Sightings and Signs

The joint analyses of the fox sightings and field signs data revealed that survey type had a significant effect, with fox sightings recorded in a lower proportion of sections relative to fox signs (Table 43, parameter estimates: Sightings = -2.026, Signs = 0.000). Year had no significant influence but there was a weak significant effect of month, with the proportion of transect sections containing foxes or their signs increasing throughout the winter. Duration was positively related to the proportion of sightings and signs but there was no significant effect of either number of observers or start time A model containing sightings data only was run to investigate the influence of factors (proportion of visible transect section and weather variables) that were recorded only during the sightings survey. Of the weather variables, only temperature (parameter estimate = 0.3764, X^2 = 4.55, p = 0.0329) was significant, indicating that fox were seen more often on warmer days. The proportion of transect sections categorised by participants as 'visible' also had a significant effect, with foxes seen on a greater proportion of transect squares when a greater proportion were visible (parameter estimate = 1.1911, X^2 = 8.18, p = 0.0042). This relationship was controlled for in the combined sightings and signs model by using '#positive sections/#visible sections' as the dependent variable for the sightings survey and '#positive sections/#searched sections' as the dependent variable for the signs survey.

Environmental Zone also had a significant influence, with a greater proportion of positive transects in the lowland regions of England and Wales (Table 3). Northing was significantly negatively related to the proportion of positive transect sections, indicating that foxes and their signs were recorded in a greater proportion of sections in more southerly sites (Table 43). Easting was not significant.

Habitat diversity (Shannon-Wiener) had no significant influence on the proportion of sections containing fox signs or sightings (Table 43). Habitat type had a significant influence (F=4.21, p<0.001), however, with a greater proportion of positive sections at sites with high proportions of rough grassland or woodland habitat (Table 44). None of the linear features had any significant influence.

The interaction terms between survey type and all other variables were included in the model. The only interaction term remaining after simplification was that between survey type and year (X^2 = 7.77, p = 0.0205). Analysis of sightings and signs data separately indicated that the relationship between year and fox sightings was significant (X^2 = 7.39, P = 0.0248), with a greater proportion of positive transect sections in the first and second years of the survey, but that the relationship between survey year and field signs was not significant.

In order to investigate the influence of annual site turnover on the results of the analysis, the model for fox was re-run on a dataset containing only those sites that were surveyed in all three years of the survey (N = 252). The significance of survey year remained unaffected, but three other variables did differ in their significance from the results presented earlier. Month had a significant influence when analysing the full dataset, but not when analysing the reduced dataset containing sites visited in all years (parameter estimate = 0.1367, X^2 = 0.36, p = 0.5459), and the same was true for the influence of duration (parameter estimate = -0.0009, X^2 = 0.42, p = 0.5193) and northing (parameter estimate = 0.0499, X^2 = 0.29, p = 0.5881). Failure to detect these relationships in the dataset containing sites surveyed in all years may have been caused by the reduction in the sample size.

Table 43 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections in which foxes were seen or their signs were found. Coefficients (parameter estimates) estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic.

Variable	***Num df***	***Parameter Estimate***	**X^2**	***P***
Survey Type	1	-	262.81	<0.0001
Year	2	-	1.32	0.517
Month	1	0.0698	4.03	0.045
No. Observers	1	0.0301	0.23	0.633
Start Time	1	-0.0000	0.00	0.961
Duration	1	0.0023	18.57	<0.0001
Zone	5	-	45.47	<0.0001
Northing	1	-0.1198	6.95	0.0084
Easting	1	-0.0066	0.03	0.868
Shannon-Wiener	1	0.0458	0.18	0.671
% Hedge	1	0.2262	0.41	0.522
% Water	1	-0.2740	0.54	0.463
% Fence	1	0.6513	2.23	0.135
% Path	1	0.7454	3.36	0.067
% Road	1	-1.0677	3.54	0.060

Table 44 Relative odds ratios for different habitat categories from the binomial model for fox. Ratios presented are relative to the category 'Other'. Variation between habitats was significant (p<0.001, see text).

Habitat (%)	**P/1-P**
Woodland	1.87
Natural Grassland	2.44
Arable	1.23
Pastoral	1.53
Urban	0.99
Other	1.00

Table 45 Relative odds ratios for different Environmental Zones from the binomial model for fox. Ratios presented are relative to Environmental Zone 6.

Zone	***Description***	***P/1-P***
1	Easterly Lowlands (England/Wales)	0.47
2	Westerly Lowlands (England/Wales)	0.39
3	Uplands (England/Wales)	0.29
4	Lowlands (Scotland)	1.23
5	Intermediate Uplands and Islands (Scotland)	0.54
6	True Uplands (Scotland)	1.00

Conclusions

Foxes can be monitored using field signs or sightings. By measuring the proportion of transect sections with fox faeces, a sample size of between 150 and 250 matched sites would be sufficient to detect a significant change in abundance of 25%. By measuring the proportion of transect sections with fox sightings, a sample size of 300 sites would be sufficient to detect a 50% decline, or a 100% increase.

Grey squirrel (Sciurus carolinensis)

Grey squirrels are predominantly diurnal and often extremely active, and were recorded on 361 sites (32%), in sufficient numbers to permit analysis. The percentage of sites where grey squirrels were seen varied from about 28% in the first winter to 34% in the second winter. The recording of squirrel dreys was trialled during the first year and more than 50% of observers searched for dreys and 8% reported them on their site. However, although dreys or chewed pine cones provide good evidence of the presence of squirrels, it is not possible to distinguish between the native red squirrel and the introduced grey squirrel on the basis of these field signs alone, and the recording of squirrel dreys was discontinued after the first season.

Minimum Detectable Changes

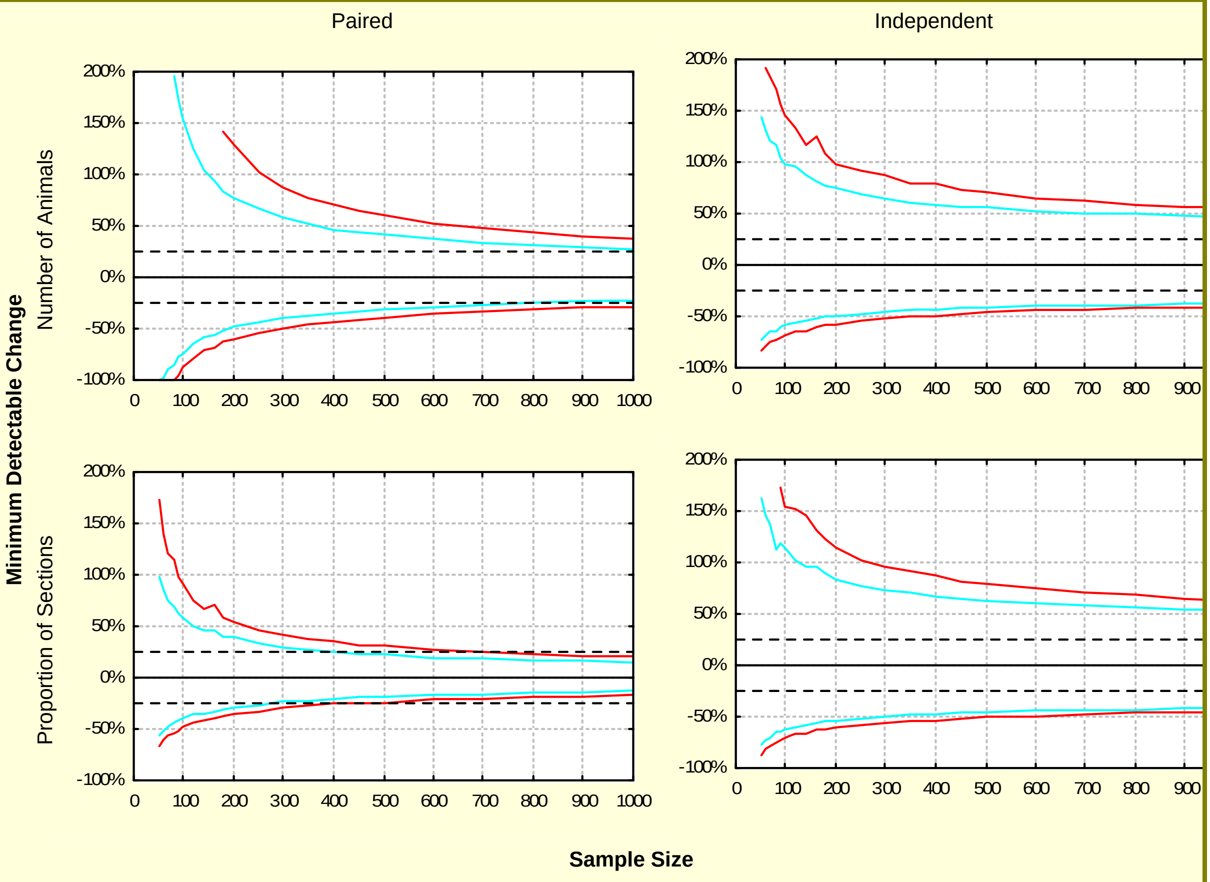
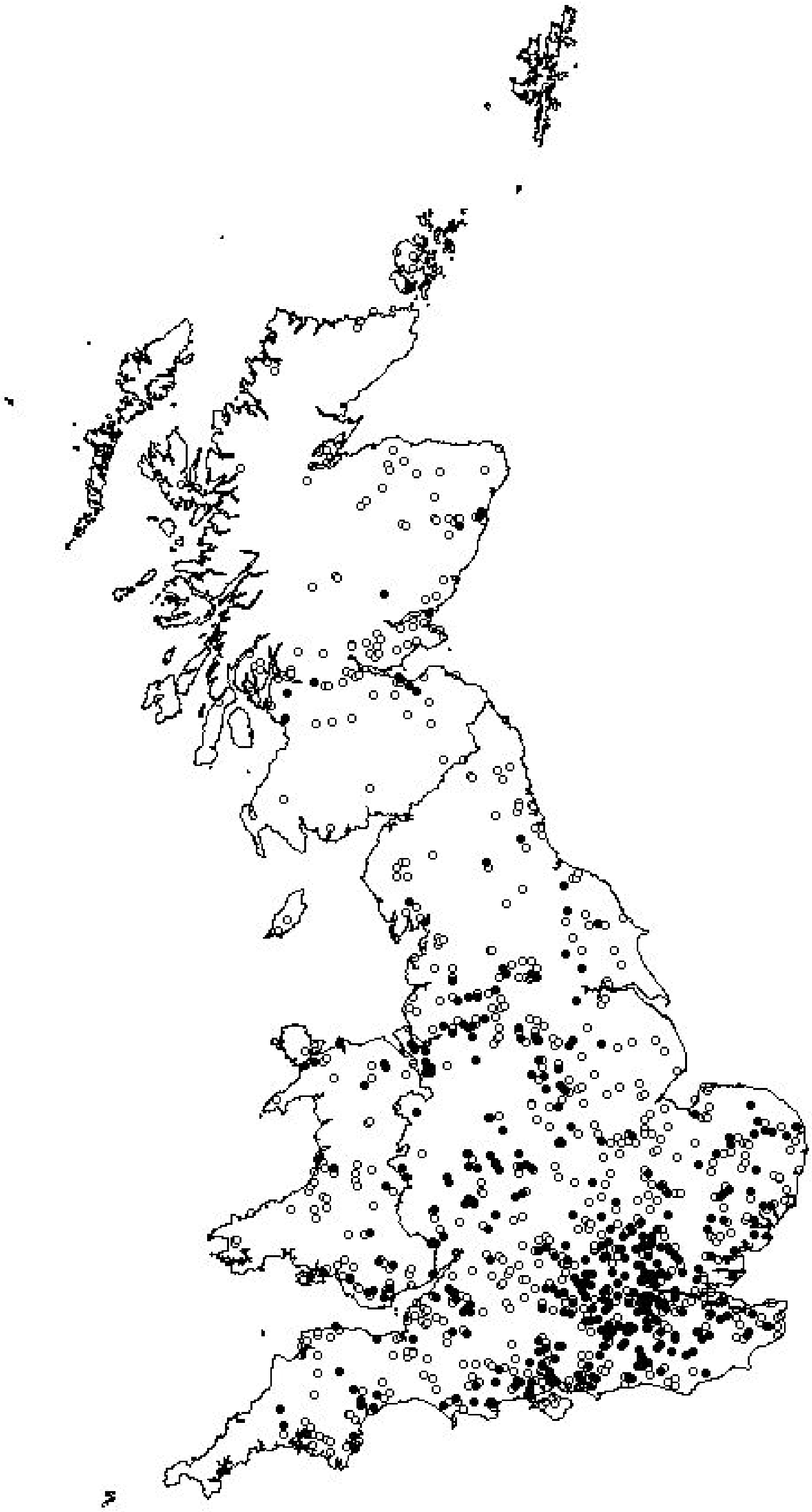


Fig. 49. Minimum Detectable Changes for Grey Squirrel Sightings, at 95% (blue) and 99% (red) levels of confidence

Grey squirrels can be monitored using sightings. The plots above show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots). By measuring the proportion of transect sections with grey squirrel sightings, a sample size of between 300 and 400 paired sites would be sufficient to detect a significant change in abundance of 25%. A sample size of 50 to 75 sites would be sufficient to detect a 50% decline or an increase of 100%.

Distribution & Abundance

Distribution of grey squirrel sightings on WMM sites. Open circles show sites surveyed and closed circles indicate recording sighting.



Factors Influencing Sightings and Signs

The proportion of transect sections in which grey squirrels were recorded varied significantly with year (

Table 46), being highest during the second year and lowest during the first year (Table 49). Month had a significant negative effect, indicating that squirrels were recorded less frequently at the end of the winter period than at the beginning. Duration was significantly positively related to the proportion of positive transect sections and the proportion of visible transect sections also had a significant positive influence. Of the weather variables, both cloud cover and temperature exhibited a significant negative effect, indicating that squirrels were recorded on more transect sections when sites were surveyed on clear, cold days.

The proportion of positive transect sections was significantly related to Environmental Zone with grey squirrel seen a lower proportion of sites in areas of True Upland (Table 48). Easting was also significant, with the proportion of transect sections containing squirrels increasing towards the east. Although northing was not significant in the full model, when Environmental Zone, a potentially confounding variable, was removed and the model re-run, northing had a highly significant negative effect (parameter estimate = -0.1185, X^2 = 28.54, $p < 0.0001$). This indicates that more grey squirrels were counted in the south of Britain. Both habitat diversity and habitat type (F=49.3, p<0.0005) were significantly related to the proportion of transect sections in which squirrels were recorded, increasing at sites containing diverse habitat types and those containing a greater proportion of woodland, and to a lesser extent, urban habitat (Table 47). The proportion of sections containing hedges and paths also had a positive effect on squirrel records.

When the interaction terms between year and month, duration, Environmental Zone, northing, easting, Shannon-Wiener Index and the habitat variables, and between duration and easting, northing and Environmental Zone were included in the model, it failed to converge.

Table 46 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections in which grey squirrels were seen. Coefficients (parameter estimates) estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic.

Variable	***Num df***	***Parameter Estimate***	**X^2**	***P***
Year	2	-	26.27	<0.0001
Month	1	-0.2326	18.06	<0.0001
No. Observers	1	0.0447	0.30	0.5830
Start Time	1	0.0005	0.26	0.6071
Duration	1	0.0042	6.33	0.0019
Zone	5	-	24.24	0.0002
Northing	1	-0.1005	3.17	0.0749
Easting	1	0.1316	8.51	0.0035
% visible	1	0.4345	4.78	0.0288
Cloud	1	-0.1335	4.28	0.0386
Rain	1	-0.0933	0.49	0.4846
Wind	1	-0.1020	1.73	0.1890
Temperature	1	-0.3298	9.43	0.0021
Visibility	1	0.0507	0.20	0.6548
Shannon-Wiener	1	0.5892	19.32	<0.0001
Habitat	5	-	-	<0.0005
% Hedge	1	1.7211	15.97	<0.0001
% Water	1	0.2048	0.22	0.6422
% Fence	1	0.7862	1.87	0.1712
% Path	1	1.0430	5.28	0.0216
% Road	1	0.9790	2.84	0.0922

Table 47 Relative odds ratios for different habitat categories from the binomial model for grey squirrel. Ratios presented are relative to the category 'Other'. Variation between habitats was significant (p<0.0005, see text).

Habitat (%)	**P/1-P**
Woodland	8.28
Natural Grassland	0.56
Arable	0.41
Pastoral	0.60
Urban	2.59
Other	1.00

Table 48 Relative odds ratios for different Environmental Zones from the binomial model for grey squirrel. Ratios presented are relative to Environmental Zone 6.

Zone	***Description***	***P/1-P***
1	Easterly Lowlands (England/Wales)	2.85×10^9
2	Westerly Lowlands (England/Wales)	3.41×10^9
3	Uplands (England/Wales)	1.41×10^9
4	Lowlands (Scotland)	1.89×10^9
5	Intermediate Uplands and Islands (Scotland)	3.19×10^8
6	True Uplands (Scotland)	1.00

Table 49 Relative odds ratios for different years from the binomial model for grey squirrel. Ratios presented are relative to the year '2003/04'.

Year	**P/1-P**
2001/02	0.62
2002/03	1.26
2003/04	1.00

Conclusions

Grey squirrels can be monitored using sightings. By measuring the proportion of transect sections with grey squirrel sightings, a sample size of between 300 and 400 paired sites would be sufficient to detect a significant change in abundance of 25%. A sample size of 50 to 75 sites would be sufficient to detect a 50% decline or an increase of 100%.

Mole (Talpa europaea)

Moles are clearly not good candidates for the sightings survey as they spend the vast majority of their lives underground. This species was apparently seen on 24 sites (2%) but it seems likely that some of these records are based on indirect evidence such as dead animals or mole diggings. Molehills provide a very distinctive field sign by which the presence of moles can be judged. Almost all sites (99%) were searched for molehills and they were recorded on 75% of them. These percentages varied from 68% in the first winter to 75% in the third winter.

Minimum Detectable Changes

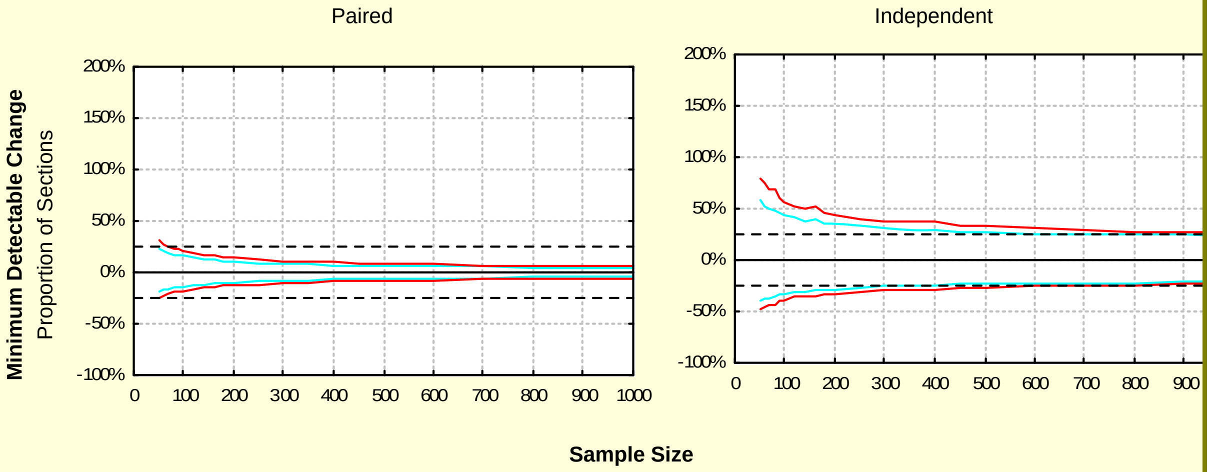


Fig. 50. Minimum Detectable Changes for Mole Hills, at 95% (blue) and 99% (red) levels of confidence

Moles can be monitored using field signs. The plots above show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots). By measuring the proportion of transect sections with molehills, a sample size of 50 paired sites would be sufficient to detect a significant decline in abundance of 25% or a 25% increase.

Distribution & Abundance

Distribution of mole signs from recorded presence of signs on WMM sites. Open circles show sites surveyed for the species and closed circles indicate recorded presence.

Factors Influencing Sightings and Signs

Analyses of the mole data revealed no effect of survey year or month, nor was it influenced by start time or the duration of the survey visit (Table 50). However, molehills were positively related to observer number (Table 50). Environmental Zone had a significant (Table 50), with the proportion of transect sections containing molehills generally greater in England than in Scotland (Table 52). Northing was also negatively related to the presence of molehills, with the proportion of positive transects increasing towards the south. Although easting was not significant in the full model, when Environmental Zone, a potentially confounding variable, was removed and the model re-run, easting displayed a significant positive relationship with the dependent variable (parameter estimate = 0.1134, X^2 = 9.82, *p* = 0.0017). This indicates that the prevalence of molehills increases towards the east of Britain. Habitat had a significant influence on the proportion of transect sections containing molehills (F=16.1, p<0.0005), with the proportion greatest in arable and pastoral areas. Of the linear features, only fence displayed a significant relationship, with the proportion of positive transect sections increasing as the proportion of sections containing fences increased. None of the tested interaction terms - between year and month, Environmental Zone, duration, northing, easting, Shannon-Wiener Index and the habitat variables, and between duration and easting, northing and Environmental Zone had a significant influence on the proportion of transect sections containing molehills.

Table 50 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections in which molehills were observed. Coefficients (parameter estimates) estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic.

Variable	***Num df***	***Parameter Estimate***	**X^2**	***P***
Year	2	-	5.54	0.0626
Month	1	-0.0573	0.68	0.4101
No. Observers	1	0.2217	6.95	0.0084
Start Time	1	0.0007	3.55	0.0597
Duration	1	0.0010	2.64	0.1043
Zone	5	-	18.43	0.0025
Northing	1	0.2240	20.60	<0.0001
Easting	1	0.0563	1.55	0.2139
Shannon-Wiener	1	0.4019	10.69	0.0011
% Hedge	1	0.1847	0.20	0.6510
% Water	1	0.4433	1.08	0.2989
% Fence	1	1.5373	9.35	0.0022
% Path	1	0.6926	1.82	0.1775
% Road	1	0.0172	0.00	0.9779

Table 51 Relative odds ratios for different habitat categories from the binomial model for mole. Ratios presented are relative to the category 'Other'. Variation between habitats was significant ($p<0.0005$, see text).

Habitat (%)	**P/1-P**
Woodland	1.89
Natural Grassland	2.34
Arable	5.84
Pastoral	7.33
Urban	1.07
Other	1.00

Table 52 Relative odds ratios for different Environmental Zones from the binomial model for mole. Ratios presented are relative to Environmental Zone 6.

Zone	***Description***	***P/1-P***
1	Easterly Lowlands (England/Wales)	2.66
2	Westerly Lowlands (England/Wales)	2.07
3	Uplands (England/Wales)	2.97
4	Lowlands (Scotland)	1.18
5	Intermediate Uplands and Islands (Scotland)	0.41
6	True Uplands (Scotland)	1.00

Conclusions

Moles can be monitored using field signs. By measuring the proportion of transect sections with molehills, a sample size of 50 paired sites would be sufficient to detect a significant decline in abundance of 25% or a 25% increase.

Muntjac (Muntiacus reevesi)

Muntjac are active throughout the day and night, although they tend to become increasingly active at dusk, and are relatively large and mobile. During this project, muntjac were seen on 43 sites (3.8%), which was sufficient to allow some analyses of this dataset. This percentage was about the same in all three winters. As with other deer species, the slots and droppings produced by muntjac are difficult to identify to species and therefore were not recorded. The presence of deer slots was recorded during the first season, but not at the species level, and this was discontinued after that season.

Minimum Detectable Changes

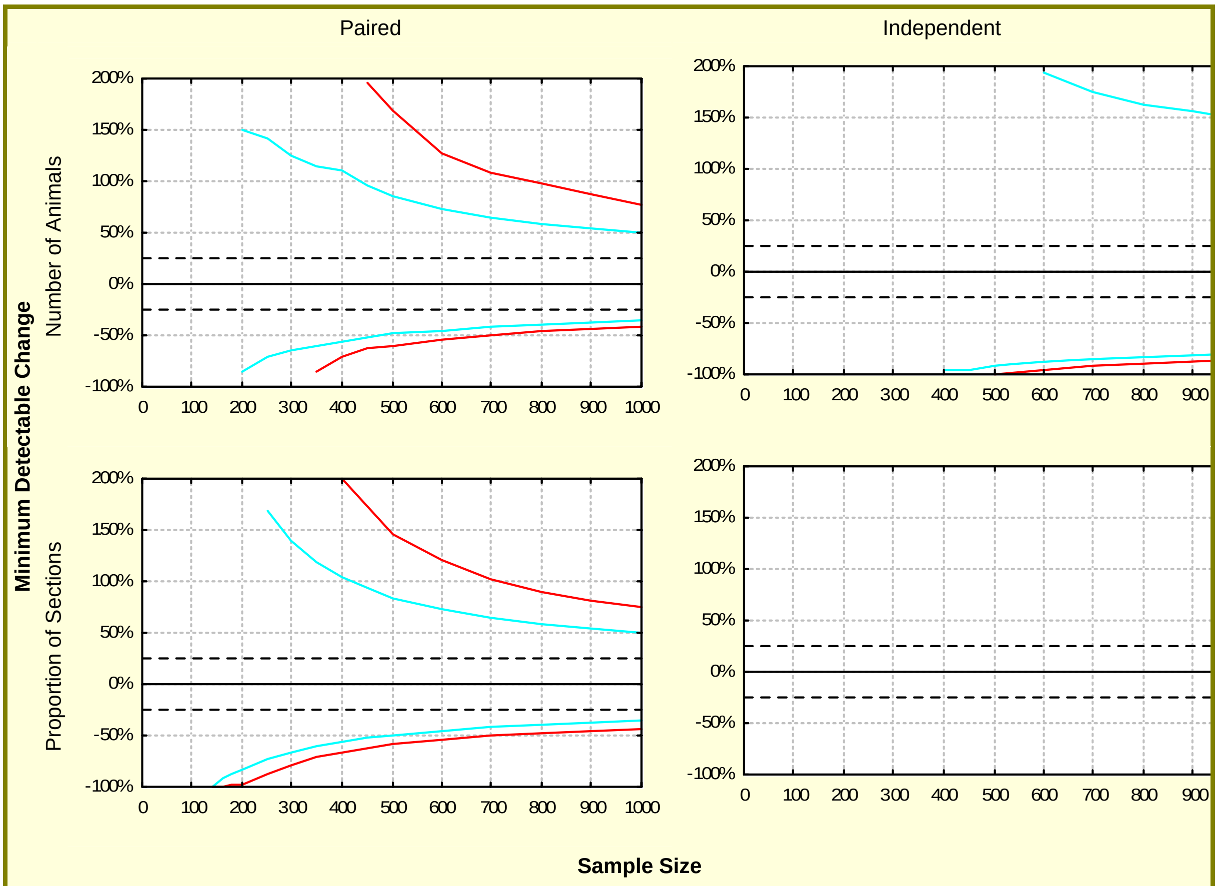
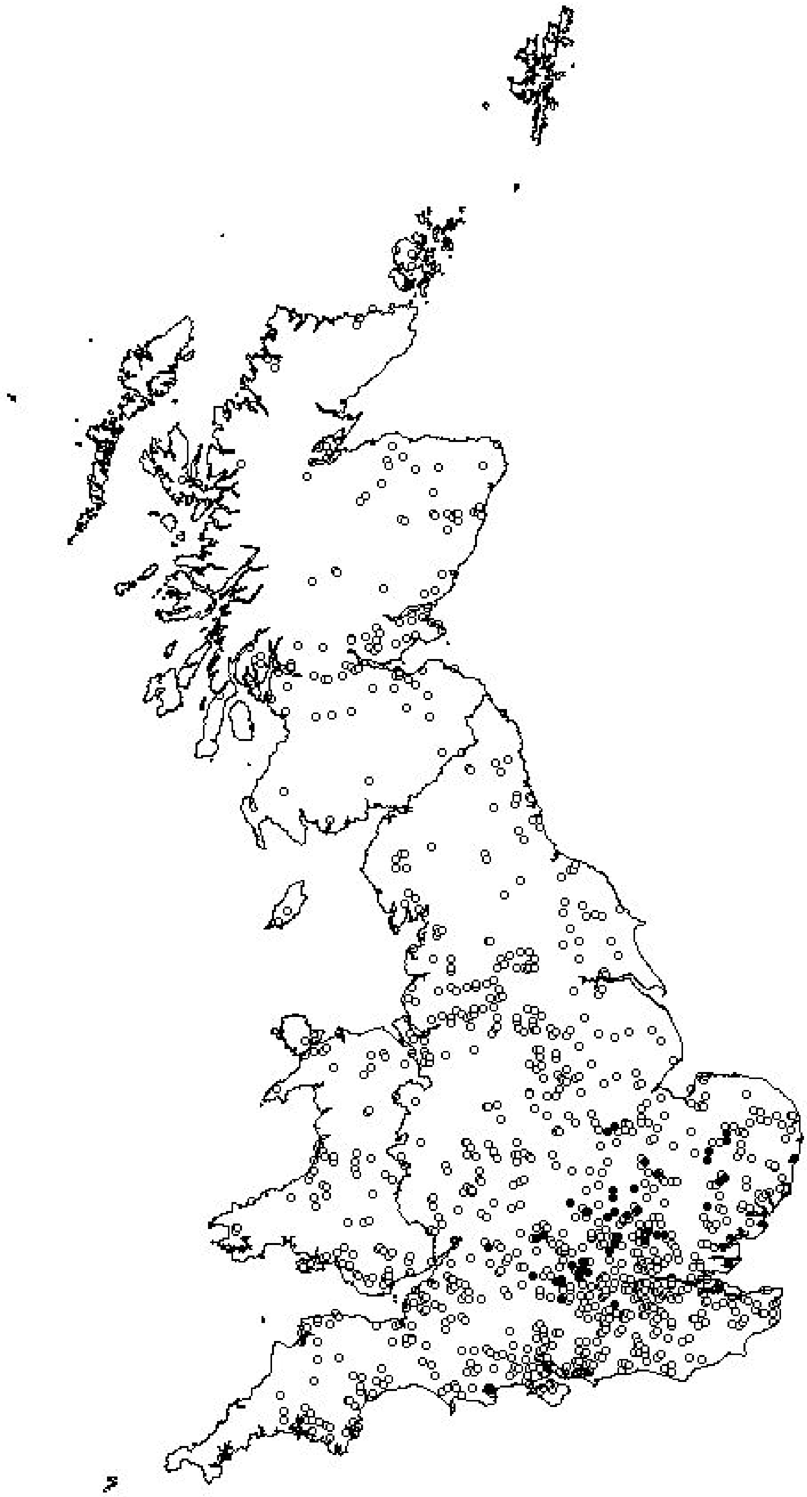


Fig. 51. Minimum Detectable Changes for Muntjac Sightings, at 95% (blue) and 99% (red) levels of confidence

Muntjac can be monitored using sightings. The plots above show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots). By measuring the proportion of transect sections with muntjac sightings, a sample size of between 300 and 400 paired sites would be sufficient to detect a significant decline in abundance of 50% or a 100% increase.

Distribution & Abundance

Distribution of muntjac sightings on WMM sites. Open circles show sites surveyed and closed circles indicate recorded sighting.



Factors Influencing Sightings and Signs

The proportion of transect sections in which muntjac was recorded did not vary significantly between years or months, nor was it significantly related to start time or duration (Table 53). However, observer number had a significant positive effect. Rainfall also influenced the number of muntjac sightings, with fewer reported as the weather became wetter (Table 53). Easting was significantly negatively related to muntjac sightings, indicating that this species is more common in the east of England (Table 53). Sightings were also significantly related to habitat diversity, with the proportion of positive transects greatest at more diverse sites. Habitat type was also significant (F=24.6, p<0.0005), with the highest proportion of sections in which muntjac were recorded in habitat categorised as ‘woodland’ or ‘pastoral’. Linear features had no significant influence. When the interaction terms between year and month, duration, Environmental Zone, northing, easting, Shannon-Wiener Index and the habitat variables, and between duration and easting, northing and Environmental Zone were included in the model, it failed to converge.

Table 53 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections in which muntjac were observed. Coefficients (parameter estimates) estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic.

Variable	***Num df***	***Parameter Estimate***	X^2	***P***
Year	2	-	2.84	0.2423
Month	1	0.2041	1.62	0.2037
No. Observers	1	0.4351	5.00	0.0253
Start Time	1	0.0002	0.00	0.9549
Duration	1	0.0053	1.10	0.2936
Northing	1	-0.0169	0.02	0.8963
Easting	1	0.6816	33.95	<0.0001
% visible	1	-0.5609	0.72	0.3951
Cloud	1	0.2661	2.43	0.1189
Rain	1	-1.2061	6.61	0.0101
Wind	1	-0.0459	0.05	0.8277
Temperature	1	-0.0711	0.06	0.8029
Visibility	1	-0.3362	0.99	0.3195
Shannon-Wiener	1	1.6906	15.46	<0.0001
% Hedge	1	0.4985	0.16	0.6902
% Water	1	0.6955	0.32	0.5691
% Fence	1	-0.7971	0.10	0.7576
% Path	1	0.9956	0.55	0.4602
% Road	1	-0.7268	0.19	0.6623

Table 54 Relative odds ratios for different habitat categories from the binomial model for muntjac. Ratios presented are relative to the category 'Other'. Variation between habitats was significant ($p<0.0005$, see text).

Habitat (%)	P/1-P
Woodland	18657.43
Natural Grassland	4072.45
Arable	4651.76
Pastoral	9452.17
Urban	127.87
Other	1.00

Conclusions

Muntjac can be monitored using sightings. By measuring the proportion of transect sections with muntjac sightings, a sample size of between 300 and 400 paired sites would be sufficient to detect a significant decline in abundance of 50% or a 100% increase.

Rabbit (*Oryctolagus cuniculus*)

Rabbits are principally crepuscular and nocturnal, but are diurnal in undisturbed areas. The species is medium-sized and mobile and also tends to spend much of the time grazing in open areas and was recorded frequently during the sightings surveys. Overall, rabbits were seen at 491 sites (44%) and this percentage varied from about 40% in the first two winters to just over 50% in the third winter. Rabbits were also monitored by the recording of their distinctive burrows. Virtually all observers searched their transect routes for rabbit burrows, and overall, active burrows were recorded on 655 of sites. This percentage varied from about 60% in the first two winters to almost 68% in the third winter.

Minimum Detectable Changes

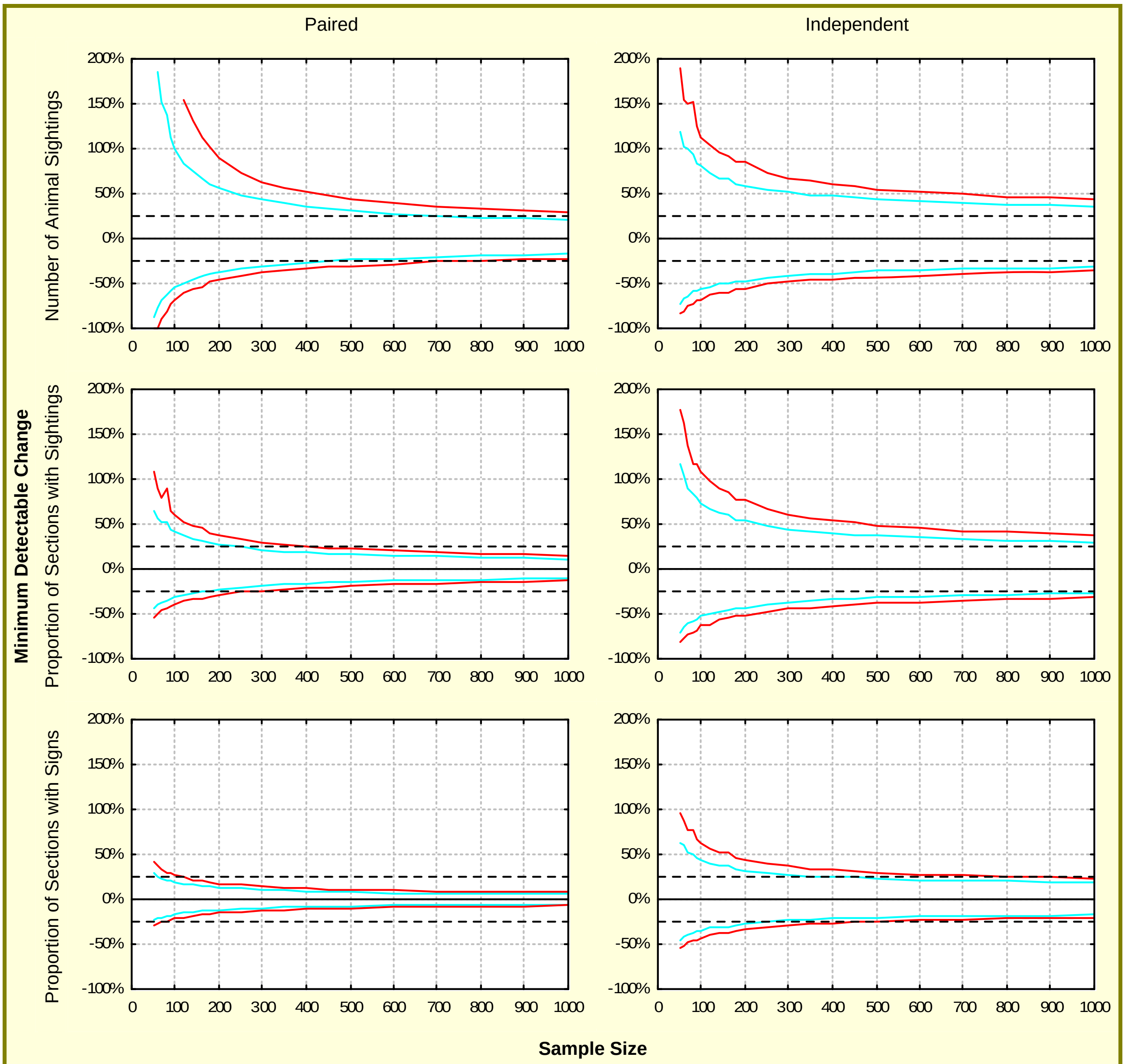
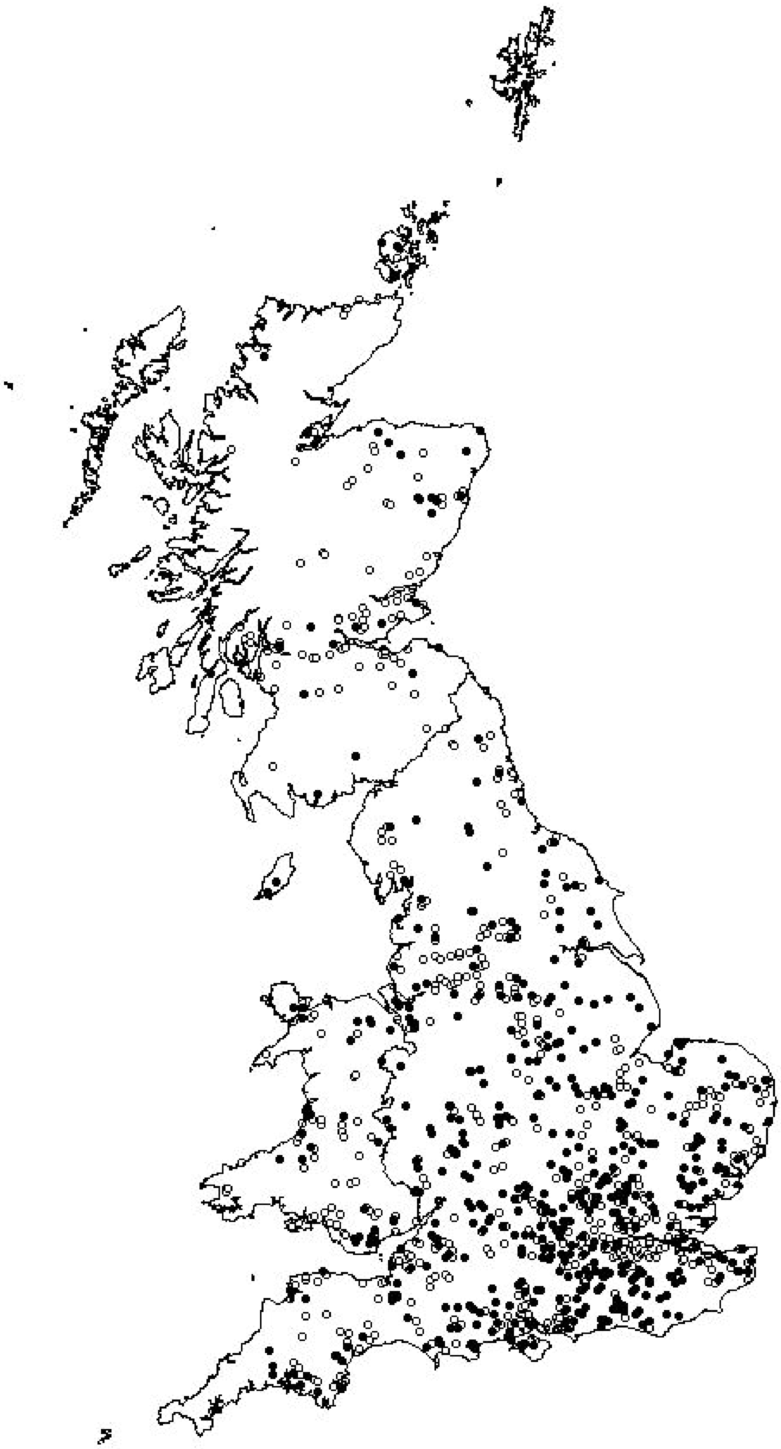


Fig. 52. Minimum Detectable Changes for Rabbit Sightings and Signs, at 95% (blue) and 99% (red) levels of confidence

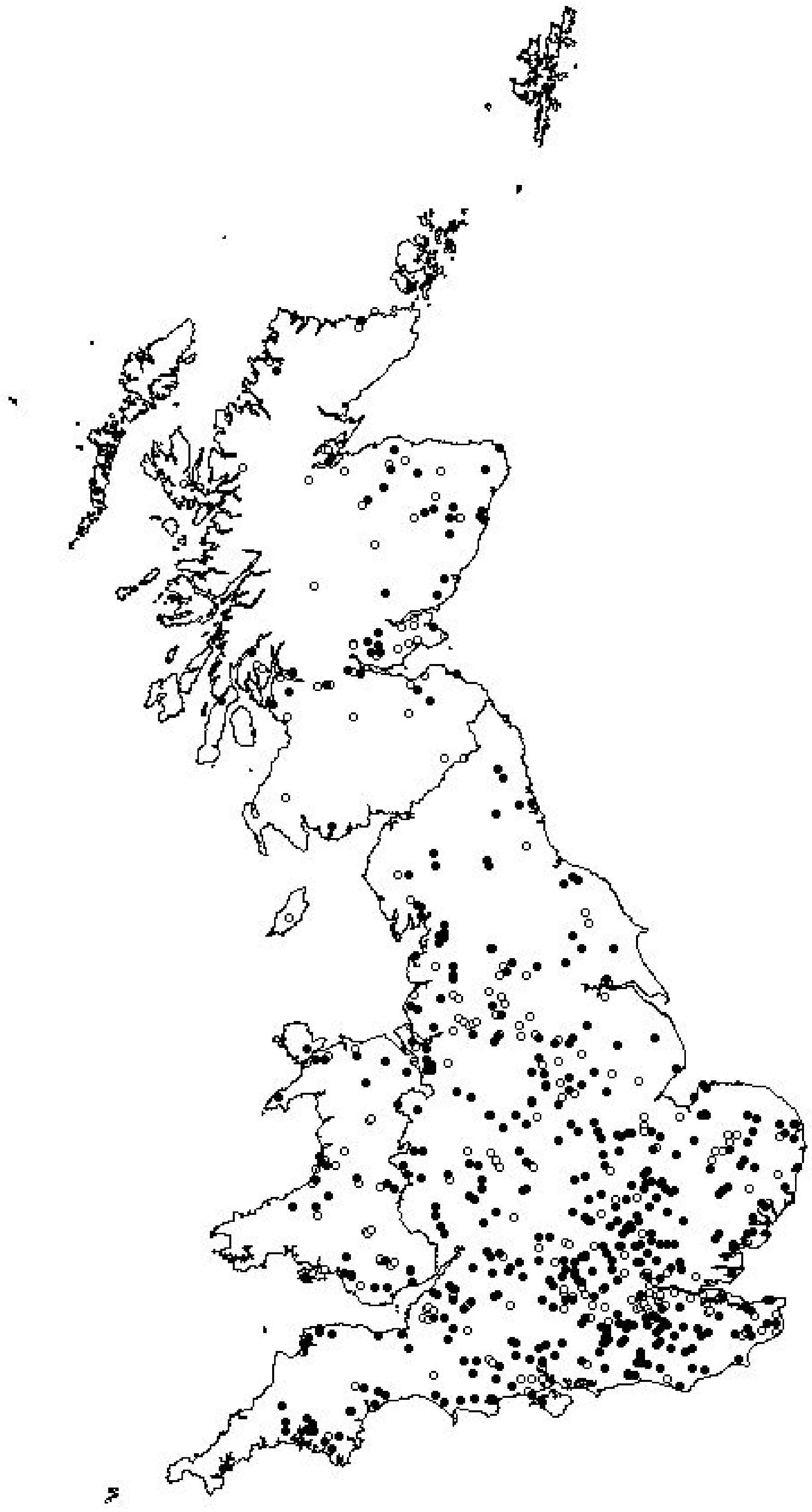
Rabbits can be monitored using sightings or field signs. The plots above show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots). By measuring the proportion of transect sections with sightings, a sample size of between 150 and 250 paired sites would be sufficient to detect a significant change in abundance of 25%. A sample size of only 50 paired sites would be required to detect a decline of 50% or an increase of 100%. By measuring the proportion of transect sections with active rabbit burrows, a sample size of between 50 and 75 sites would be sufficient to detect a 25% decline, or a 25% increase.

Distribution & Abundance

Distribution of rabbit sightings on WMM sites. Open circles show sites surveyed and closed circles indicate recorded sighting.



Distribution of rabbit signs from recorded presence of signs on WMM sites. Open circles show sites surveyed for the species and closed circles indicate recorded presence.



Factors Influencing Sightings and Signs

Survey type had a significant influence on the number of positive transect sections, with rabbit sightings recorded in a lower proportion of sections than burrows (

Table 55, parameter estimates: Sightings = -0.9510, Signs = 0.0000). Neither year, month, start time or number of observers had a significant influence but duration had a significant effect, with rabbit sightings and signs recorded in a greater proportion of transect sections during longer survey visits (

Table 55). A model containing sightings data only was also run to investigate the influence of factors (proportion of visible transect section and weather variables) that were recorded only during the sightings survey. Of these, both cloud (parameter estimate = -0.2238, X^2 = 16.22, p < 0.0001) and temperature (parameter estimate = -0.2362, X^2 = 6.90, p = 0.0086) were significant, indicating that rabbits were seen in a greater proportion of transect sections on clearer, colder days

Environmental Zone also had a significant influence, with a greater proportion of transects containing sightings or signs in the lowland regions of England and Wales (

Table 57). Neither northing nor easting displayed a significant relationship in the full model but when Environmental Zone, a potentially confounding variable, was removed and the model re-run, easting displayed a significant positive effect, indicating that rabbit abundance increased towards the east of England (parameter estimate = 0.1000, $X^2 = 14.59$, $p = 0.0001$).

Habitat diversity had a significant positive influence on the proportion of sections with signs or sightings (

Table 55). Habitat type also had a significant influence (F=22.07, p<0.0005), with a greater proportion of positive sections as the proportion of arable, pastoral or 'other' habitat at the site increased (Table 56). Of the linear features, only hedges had a significant effect (

Table 55).

The interaction terms between survey type and all other variables were included in the model. The only interaction term which remained in the model after simplification was that between survey type and start time (X^2 = 9.06, p = 0.0026). Analysis of sightings and signs data separately indicated that the relationship between start time and the proportion of sections containing rabbits was significant (parameter estimate = -0.0019, X^2 = 4.84, p = 0.0277), with a greater proportion of transect sections containing rabbits in surveys that were started later in the day, but that the relationship between start time and the proportion of sections with burrows was not significant.

In order to investigate the influence of annual site turnover on the results of the analysis, the model for rabbit was re-run on a dataset containing only those sites that were surveyed in all three years of the survey (N = 252). The significance of survey year remained unaffected, but two other variables did differ in their significance from the results presented earlier. Hedgerows had a significant effect when analysing the full dataset, but were not significant when analysing the dataset with repeated visits (parameter estimate = -0.3454, X^2 = 0.36, p = 0.5459), whereas the opposite was true for the effect of roads (parameter estimate = 0.0544, X^2 = 3.87, p = 0.0493). Failure to detect the relationship between rabbit abundance and hedgerow presence in the repeated visits dataset may have been caused by the reduction in the sample size, or differences in other aspects of these sites. It is more difficult to explain the change in significance of the presence of roads, but this may have been due to the increased influence of small numbers of unrepresentative sites in a smaller dataset.

Table 55 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections in which rabbits were seen or rabbit burrows were observed. Coefficients (parameter estimates) estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic.

Variable	***Num df***	***Den df***	***Parameter Estimate***	**X^2**	***P***
Survey Type	1	2337	-	110.21	<0.0001
Year	2	2337	-	4.04	0.1325
Month	1	2337	-0.0077	0.09	0.7701
No. Observers	1	2337	-0.0333	0.35	0.5559
Start Time	1	2337	0.0003	0.79	0.3748
Duration	1	2337	0.0022	19.48	<0.0001
Zone	5	2337	-	38.37	<0.0001
Northing	1	2337	0.0345	0.95	0.3286
Easting	1	2337	0.0489	2.41	0.1209
Shannon-Wiener	1	2337	0.8048	78.46	<0.0001
% Hedge	1	2337	0.7648	7.14	0.0076
% Water	1	2337	0.5578	3.10	0.0785
% Fence	1	2337	-0.6977	2.00	0.1576
% Path	1	2337	-0.1406	0.15	0.6974
% Road	1	2337	0.5448	2.18	0.1400

Table 56 Relative odds ratios for different habitat categories from the binomial model for rabbit. Ratios presented are relative to the category 'Other'. Variation between habitats was significant (p<0.0005, see text).

Habitat (%)	**P/1-P**
Woodland	0.39
Natural Grassland	0.40
Arable	0.71
Pastoral	0.81
Urban	0.11
Other	1.00

Table 57 Relative odds ratios for different Environmental Zones from the binomial model for rabbit. Ratios presented are relative to Environmental Zone 6.

Zone	***Description***	***P/1-P***
1	Easterly Lowlands (England/Wales)	1.68
2	Westerly Lowlands (England/Wales)	1.38
3	Uplands (England/Wales)	0.75
4	Lowlands (Scotland)	0.58
5	Intermediate Uplands and Islands (Scotland)	1.30
6	True Uplands (Scotland)	1.00

Conclusions

Rabbits can be monitored using sightings or field signs. By measuring the proportion of transect sections with sightings, a sample size of between 150 and 250 paired sites would be sufficient to detect a significant change in abundance of 25%. A sample size of only 50 paired sites would be required to detect a decline of 50% or an increase of 100%. By measuring the proportion of transect sections with active rabbit burrows, a sample size of between 50 and 75 sites would be sufficient to detect a 25% decline, or a 25% increase.

Roe deer (Capreolus capreolus)

Roe deer are active during the day, are large and mobile and may form small herds. They are therefore highly visible and frequently recorded during the sightings surveys. Over the three winters, roe deer were seen on 168 sites (15%), with the annual percentage of sites with sightings varying little between 12% and 13%. As with other deer species, the slots and droppings produced by roe deer are difficult to identify to species> Although the recording of deer slots (all species combined) was tested during the first winter, this was discontinued for the second two seasons.

Minimum Detectable Changes

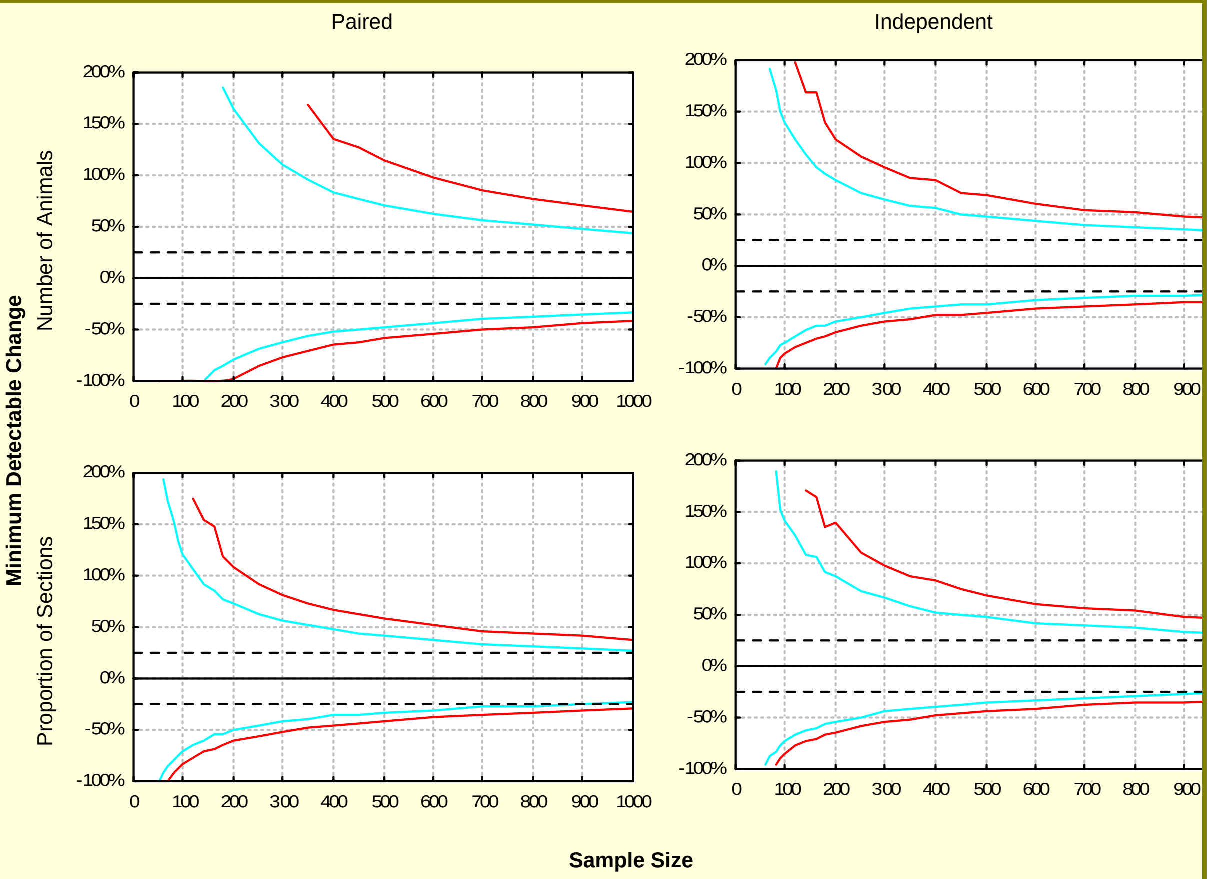
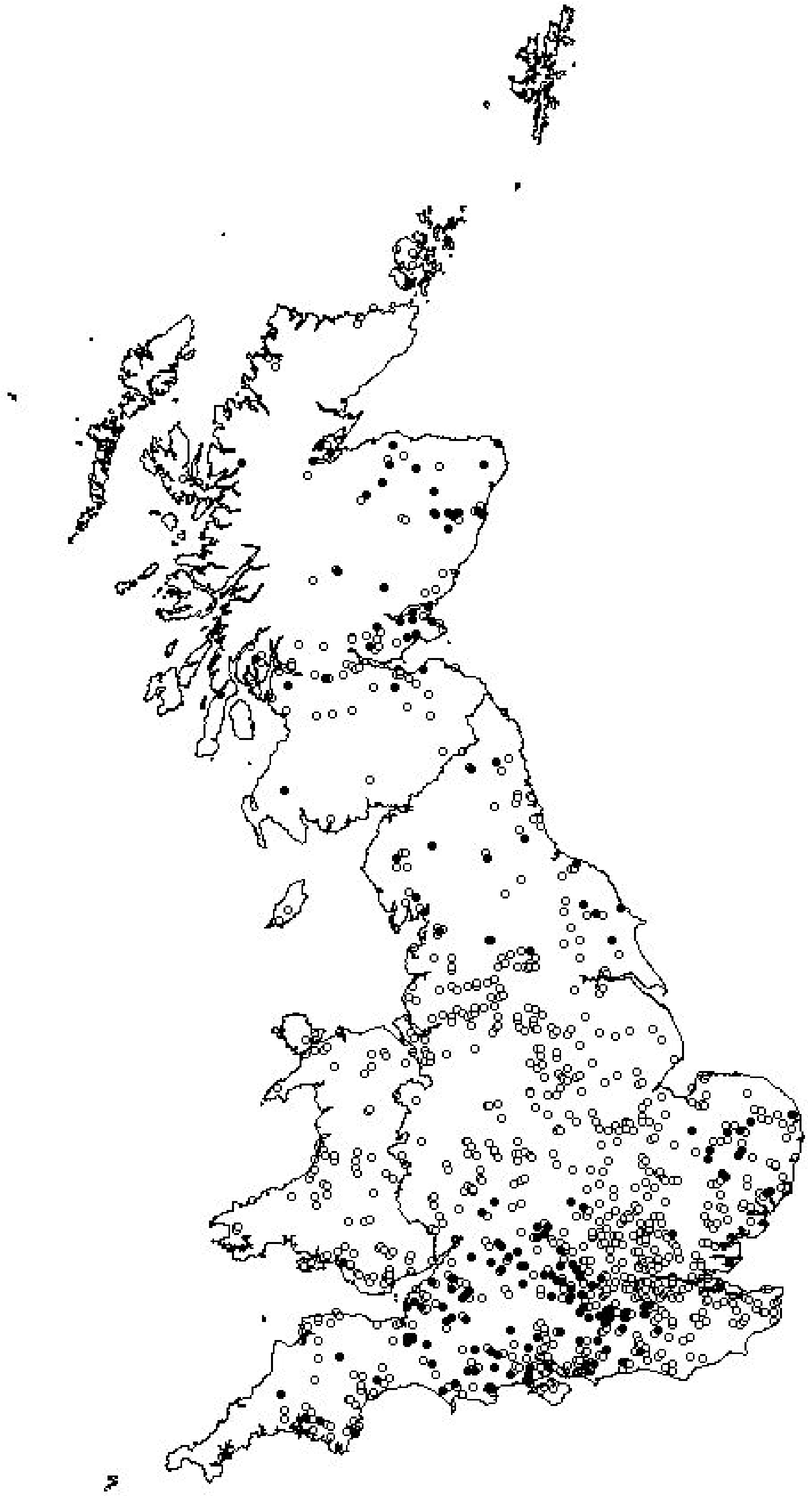


Fig. 53. Minimum Detectable Changes for Roe Deer Sightings, at 95% (blue) and 99% (red) levels of confidence

Roe deer can be monitored using sightings. The plots above show the predicted relationship between sample size and the minimum detectable change for paired sites (left set of plots) and for independent sites (right set of plots). By measuring the proportion of transect sections with sightings, a sample size of between 800 and 1000 paired sites would be sufficient to detect a significant change in abundance of 25%. However, a sample size of 200 paired sites would be sufficient to detect a decline of 50% or an increase of 100%.

Distribution & Abundance

Distribution of roe deer sightings on WMM. Open circles show sites surveyed and closed circles indicate recorded sighting.



Factors Influencing Sightings and Signs

The proportion of transect sections in which roe deer was recorded did not vary significantly with year, month, number of observers, start time, survey duration or the majority of weather variables, although there was a significant negative effect of visibility, indicating that roe deer were recorded in a reduced proportion of transect sections in poor visibility (Table 58). Sightings were also positively related to the proportion of transect sections classed as 'visible', with roe deer sighted in more sections if more were classed as 'visible' (Table 58).

The proportion of positive transect sections was significantly related to Environmental Zone, with roe deer seen in a greater proportion of transect sections in England (Table 60). Northing was also significant, with the proportion of transect sections containing roe deer increasing towards the south of Britain (Table 58). Easting had no significant influence even when Environmental Zone was removed from the model.

Habitat type, but not habitat diversity, was significantly related to the proportion of transect sections in which roe deer was recorded (F=21.2, p<0.0005), with the proportion increasing at sites containing a greater proportion of woodland, grassland and pastoral habitat (Table 59). None of the linear features recorded had a significant effect. The interaction terms between year and month, Environmental Zone, duration, northing, easting, Shannon-Wiener Index and the habitat variables, and between duration and easting, northing and Environmental Zone were included in the model. None of the interaction terms had a significant influence.

Table 58 The effects of geographical, temporal, habitat and methodological variables on the proportion of transect sections in which roe deer were seen. Coefficients (parameter estimates) estimated from a binomial model with a logit link function, Standard Errors adjusted for over-dispersion using the Pearson Chi-Square statistic.

Variable	***Num df***	***Parameter Estimate***	X^2	***P***
Year	2	-	0.59	0.7434
Month	1	0.1499	3.18	0.0747
No. Observers	1	0.1682	2.64	0.1044
Start Time	1	-0.0029	3.33	0.0680
Duration	1	0.0002	0.00	0.9560
Zone	5	-	23.51	0.0003
Northing	1	-0.3637	15.63	<0.0001
Easting	1	-0.0227	0.09	0.7643
% visible	1	0.7504	4.44	0.0351
Cloud	1	0.0065	0.01	0.9213
Rain	1	-0.0671	0.11	0.7383
Wind	1	-0.1716	2.23	0.1353
Temperature	1	-0.0203	0.02	0.8944
Visibility	1	-0.4019	4.12	0.0424

Variable	***Num df***	***Parameter Estimate***	**X^2**	***P***
Shannon-Wiener	1	0.3580	2.75	0.0973
% Hedge	1	0.5359	0.70	0.4030
% Water	1	-0.3346	0.22	0.6389
% Fence	1	0.9948	1.43	0.2315
% Path	1	0.1787	0.06	0.8108
% Road	1	0.2356	0.05	0.8294

Table 59 Relative odds ratios for different habitat categories from the binomial model for roe deer. Ratios presented are relative to the category 'Other'. Variation between habitats was significant (p<0.0005, see text).

Habitat (%)	**P/1-P**
Woodland	19.45
Natural Grassland	12.74
Arable	3.96
Pastoral	8.55
Urban	0.48
Other	1.00

Table 60 Relative odds ratios for different Environmental Zones from the binomial model for roe deer. Ratios presented are relative to Environmental Zone 6.

Zone	***Description***	***P/1-P***
1	Easterly Lowlands (England/Wales)	0.08
2	Westerly Lowlands (England/Wales)	0.09
3	Uplands (England/Wales)	0.08
4	Lowlands (Scotland)	0.73
5	Intermediate Uplands and Islands (Scotland)	0.52
6	True Uplands (Scotland)	1.00

Conclusions

Roe deer can be monitored using sightings. By measuring the proportion of transect sections with sightings, a sample size of between 800 and 1000 paired sites would be sufficient to detect a significant change in abundance of 25%. A sample size of 200 paired sites would be sufficient to detect a decline of 50% or an increase of 100%.

Summary and Conclusions

Winter mammal monitoring is designed to be a multi-species survey and it is therefore important to assess the importance of methodological and other factors across all species. In this section, we summarise the results of the single-species analyses of factors influencing abundance, and review the importance of each factor across species. Only factors found to be significant in the single species analyses are discussed, but it is important to note that for species with fewer data, it is more difficult to detect significant effects.

Month

Two species, grey squirrel and fox, displayed significant seasonal variation in the proportion of transect sections in which they were recorded. The proportion in which grey squirrel were observed declined significantly over the winter period. Although this species does not truly hibernate, it is possible that they spend more time in their nests as mean temperatures fall. Conversely, fox abundance appeared to increase during the winter period, possibly because individuals become more active during daylight hours as food availability decreases.

Weather

Weather conditions on the day of the survey influenced the rate of sightings of six species (brown hare, rabbit, fox, grey squirrel, roe deer and muntjac). However, the nature and direction of the observed relationships was variable, making interpretation difficult. Sightings of fox and brown hare increased with temperature, which could be interpreted as individuals trying to minimise heat loss by taking shelter during periods of adverse weather conditions. In contrast, sightings of rabbit grey squirrel decreased with temperature (and cloud cover). Muntjac were seen less frequently as rainfall increased (suggesting that individuals were sheltering or more difficult to see) but brown hare were seen more frequently as rainfall increased. Visibility, as recorded by observers had no significant effect on the sightings of any species except roe deer, for which fewer sightings were recorded on days of poorer visibility.

Number of observers

The number of observers present during a visit was positively correlated with sightings of muntjac and the recording of molehills, but had no effect on any other species. Although we had expected to find a stronger effect for the recording of field signs (particularly the more cryptic signs where an increase in effort might increase rates of detection) predictions of this effect on sightings is more complicated, as having a larger group of observers may also increase the risk of disturbing mammals before they are recorded.

Start time

Start time did not influence sightings (measured as the proportion of transect sections in which a species was seen) of any species except rabbit, or any field signs except for field voles, in which the proportion of transects in which field vole runs was observed increased later in the day. The increase in rabbits seen on surveys conducted later in the day may reflect movement away from cover but it is difficult to find a biological explanation for the relationship between vole runs and start time. However, as field vole runs can be quite difficult to detect and must be searched for intensively, it is possible that the rate of detection may increase as the quality of daylight improves.

Duration

Visit duration was positively related to the proportion of transect sections with sightings of four species (rabbit, brown hare, grey squirrel and fox) but not for any of the deer species. Duration was also positively related to the rates of detection of two of the field signs (rat burrows and badger setts and latrines). This shows that for at least some of the species, more time spent at the site will increase the probability of encountering the species, by sight or by finding field signs, the latter probably due to increased time searching.

Geographical Distribution

All species and/or their field signs recorded displayed significant geographical variation in the proportion of transect sections in which they were recorded. Northing and easting were clearly important, reflecting both east-west and north-south gradients in abundance known from other sources of information such as national surveys. Hence, roe deer and fox were recorded more frequently in the south of England, badger signs were most abundant in the lowlands of southwest England and Wales, and fallow deer and grey squirrel were seen in the greatest proportion of transect sections in the lowlands of southeast England. Rabbit was most frequently recorded in the east of England, molehills were most abundant in the north of England and brown hare were most often sighted in the northeast. Field signs of both field vole and brown rat were recorded on the greatest proportion of transect sections in western parts of the country and north-eastern Scotland, respectively.

Habitat Type

Habitat was also a significant predictor of the abundance of both sightings and field signs of all species. Sightings of rabbit and brown hare, molehills, field vole runs and brown rat burrows were more frequent on sites in agricultural land, the latter specifically in arable areas. Grey squirrel, badger signs, muntjac, roe deer and fallow deer were most frequently found in woodland, although the two larger deer species also favoured areas of rough grassland and, in the case of roe deer, pastoral land. Muntjac and signs of badger were also often recorded on agricultural land. Data for fox suggested that this species is most abundant in areas of rough grassland, but that it also often utilises woodland areas.

Habitat Diversity

Habitat diversity appeared to be an important positive influence on the abundance of most species and their field signs, with the exception of fallow and roe deer, and fox.

Linear features

There was relatively little evidence of the importance of linear features, the possible exception being the proportion of transect sections containing hedges which was positively correlated to the abundance of brown hare, rabbit, grey squirrel and brown rat burrows. All four of these species may use hedges to provide cover in otherwise open environments, and both grey squirrel and brown rat may also utilise them as a feeding habitat. Only three other significant relationships between a type of linear feature and mammal abundance were identified, all of which relate to man-made structures such as paths, fences and roads. There is unlikely to be a direct relationship between these structures and the ecology of the species involved – grey squirrel, mole and field vole respectively. A more likely explanation is that the presence of man-made structures is related to the type(s) of habitat present and therefore to the suitability of the site for the relevant species.

Year

Only one species, brown hare, displayed significant inter-annual variation in abundance over this period, with the proportion of transect sections in which individuals were observed increasing over the two-year period between 2001/2002 and 2003/2004. This is too short a period to assess long-term trends, and there are no particular reasons to expect large changes in abundance between years. It is, however, possible that models that do not include as many environmental variables would be more likely to reveal a year effect.

8. Conclusions and Recommendations

The main aims of the Winter Mammal Monitoring project were to:

- to design and pilot a volunteer-based winter mammal monitoring survey for the UK
- to assess the scale of monitoring needed to detect significant long-term changes in abundance and distribution of as many mammal species as possible across the UK
- to assess the feasibility of this scheme, including the accuracy and repeatability of the results, and to provide clear recommendations for its implementation, including detailed costings.

Conclusions

Species Monitored

Table 61. Species that can be successfully monitored with Winter Mammal Monitoring.

	25% increase or 25% decline	*50 % decrease or 100% increase (halving or doubling)*
Sighting	Grey Squirrel Rabbit Fallow deer	Brown hare Roe deer Feral cat Free roaming dog Fox
Field Signs	Badger Brown rat Field vole Fox Mole Rabbit	

- With Winter Mammal Monitoring, we can monitor ten species of wild mammals reliably enough to detect declines in abundance of between 25% and 50%, and increases in abundance of between 25% and 100% - as measured by the proportion of transect sections with positive records of sightings or signs (Table 61). This assessment is based on an analysis of repeat visits to the same square, and, with the exception of at least 700 sites required to detect a 25% change in fallow deer, is based on sample sizes that were achieved in the 3 year pilot project (ca 500). For nine species monitored using Sightings, a halving or doubling of the measure could be detected with samples of 50 to 500, and for three species, a 25% change could be detected with samples of 150 to 1000. For the Field Signs, a 50% decline or doubling could be detected for all species except harvest mouse, and for five of the signs, a 25% change could be detected with a sample of 250, or less.
- Three species (brown rat, field vole and harvest mouse) were added to the list of target species for the Field Signs survey and recording protocols were developed for them. Brown rat and field vole can be monitored by these methods but harvest mouse signs (nests) were detected at too low frequencies.
- Significantly more information was collected in the Field Signs part of Winter Mammal Monitoring than the Sightings component. The power analyses showed that for fox and

rabbit (two species for which both signs and sightings information were available), the sample of sites required to detect the same magnitude of change in abundance was 2-3 times smaller for signs than for sightings. However, the species monitored by each method are different and hence sightings data are essential for monitoring some key target species (such as roe deer and brown hare). For Sightings data, the proportion of transect sections that were positive proved to be more powerful than the total number of animals counted.

- The fact that fox and rabbit are monitored by both sighting and field signs will provide a useful internal check for the project (i.e. that the trends identified by the Sighting and Field Sign surveys are the same).
- The ability of the Winter Mammal Monitoring methods to monitor mammal species was tested by calculating Minimum Detectable Change (MDC). Confidence limits were set at 90% and 95% for a range of sample sizes from 50 to 1000. As sample size can be controlled by project organisation, the likely MDCs for any level of confidence can be easily acquired. Furthermore, MDCs were calculated for paired (visits to the same site in different years) and independent analytical approaches, showing that the former were always more powerful.
- As more years of data are added, the predictive power of the models will increase. This also gives a strong indicator of the value of a multiyear baseline as a starting value against which to measure change, as there is then some indication of the inherent variation in the baseline.
- The analysis showed that duration has a significant effect on the response variable. For example, on Field Signs surveys of a duration of less than 2 hours, evidence of mammals were found in 56% of sections, on average, whereas on surveys with durations exceeding 4 hours, 78% of sections were positive.
- The time since the beginning of the season (month of survey in these analyses) had no influence on the recording of field signs of the seven focal species, but there was a seasonal effect on sightings of grey squirrel. The effect of season (month) on survey should be re-assessed when more data are available, to ensure that there is no interaction with longer-term change, but we see no reason to change the recommended timing of the field season.

Sites and Volunteers

- In the 3 year pilot project 1,886 people expressed an interest in the project, and 907 became active volunteers, completing at least one part of the project. 176 volunteers surveyed more than one site.
- In all 1,121 sites were visited at least once; 1,043 for Sightings and 690 for Field Signs, with both methods being used on 612 sites.
- Despite the random allocation of sites, their final distribution reflects the distribution of volunteers, with more sites taken up in areas of high human populations. However, our measures of changes in the abundance of mammals could be corrected by *post hoc* stratification that takes into account differences in observer effort in different strata, such as landscape types.
- Depending on the analytical model employed, observer effects may have a significant effect on the results. The pilot study, covering only three years and with relatively few cases of visits by different observers to the same site, does not allow an assessment of observer variability, but we consider it an important factor to investigate in the long-term

scheme. Nevertheless, its effect on temporal trends will be negligible if observers do not survey the same sites.

Turnover

- The turnover rate for both sightings and field signs surveys was high. For sighting surveys, the proportion of sites revisited was 36% between the first and second winters and 49% between the second and third winters. For the field signs survey, the proportion of sites revisited was 44% between the first and second winters and 47% between the second and third winters. A large part of this turnover will be due to the lateness of the contract extensions, which meant that communicating with volunteers did not happen until the field season was already underway.
- Analyses of turnover revealed that one of the significant factors influencing whether a site would be resurveyed in the following year was whether the site had been visited in the previous year. This strongly suggests that if sites are surveyed as part of a long-term scheme, turnover would be much less than was found in this pilot. In other words, more volunteers would be retained if they were allowed to resurvey the same site. This sampling design can be analysed using existing statistical models with site effects (or an equivalent) and would be easier to manage for a number of reasons. Firstly, many observers find that organising access to their selected route (by finding and contacting potential land-owners) is the least enjoyable and most time-consuming aspect of the survey. Second, observers may have to drop a year for a variety of reasons (e.g. illness or vacation) and may wish to take up the survey again in the following year, on the same site. Thirdly, it would mean that land-owners being approached for access to land would have to deal with fewer people.
- Turnover was also high if the response variable was low (i.e. if the volunteers didn't see anything, or found very few field signs). This behaviour by volunteers must be dealt with in subsequent sampling and analyses to minimise the effect on the calculated trends, and the importance of surveying squares even when no data are collected is a key message to communicate in a long term monitoring scheme.
- Sites with certain types of habitat (woodland, grassland or water) had higher rates of sightings and signs, which generate more interest for the observer, which in turn encourages them to re-visit the site.
- The high dropout of urban sites after the first year could mean that urban sites are not well covered by Winter Mammal Monitoring. Indeed Winter Mammal Monitoring is probably not a useful method to monitor mammals in urban areas. These areas are, however, being monitored by other surveys within the Tracking Mammals Partnership.

Analytical Methods

- Based on analyses of the proportion of sections in which mammal sightings or signs were recorded, a full repeated measures model had the best fit to the data collected during this pilot study, but only used a small percentage (about 15-20%) of the data. A model using the entire dataset, resulted in detection of a greater number of significant factors, but this was achieved by ignoring the non-independence of repeated visits to the same sites. A random sub-set model, which used only one randomly-selected data point in the time series for each site was considered to be the best compromise for analysing the pilot study dataset because there is no problem with non-independence, and uses a larger proportion (ca 40%) of the data. However, the analyses of results for single species, because they were based on much fewer data than the measure of all mammal records, used the full dataset (see Chapter 7). It is important to note that the comparison of statistical models was intended to determine the most effective method for analysing the data collected. Longer-term data sets are likely to differ in various parameters, such as the rate of turnover and the number of sites with visits repeated in other years, and hence the best statistical model may differ. The other important consideration is volunteer management. The sampling design and analyses of long term volunteer-based surveys should be designed to make maximum use of the data collected, taking into account the behaviour of volunteers. Further, we make recommendations for improving the retention of volunteers.

Comparison with other national surveys of mammals

- Single species models using data from all sites over all three field seasons provided information on environmental parameters that influenced measures of abundance. The results of these analyses can be used to help validate the Winter Mammal Monitoring methodology.
- Geographical location (northing and easting) were important explanatory factors for most species – reflecting both east-west and north-south gradients in abundance. In general, these confirm the spatial patterns of abundance revealed by other national surveys of these species, such as for brown hare and badger, or in comparison with the known distributions of the species (for example muntjac).

Comparison of Winter Mammal Monitoring and the Breeding Birds Survey (BBS)

- The methods for Sightings used in these two surveys are very similar. The BBS currently has an annual coverage of about four times as many sites as Winter Mammal Monitoring, and hence more data are collected. However, BBS mammal recording differs from WMM in several important ways. On BBS, mammal sightings are collected during bird counting visits, and the recording of evidence of presence based on field signs is combined with the recording of presence based on other criteria such as dead animals or local knowledge. Moreover, BBS mammal data are recorded at the spatial resolution of the 1 km square (not the transect section) and there is no quantification of the field signs data (i.e. just presence or absence in the square). Even for sightings data, analyses of WMM have shown that the proportion of transect sections with sightings is a more powerful measure than absolute counts (although the latter are more directly related to abundance). This is likely to be particularly true for species that aggregate in herds (the deer for example) and hence BBS trends for the herding deer species are probably the least reliable.
- BBS and WMM surveys are conducted at different times of the year so they monitor different components of the population. BBS takes place from April to July, so the population will include many young-of-the-year and, consequently, is likely to be highly variable. On the other hand, WMM takes place from October to March and so the monitored population comprises largely over-wintering adults, which will form the breeding population in the following spring. Depending on the life history parameters of the species, this is likely to be a more useful measure of population change as it is less influenced by summer recruitment. These differences could explain some of the differences in the inter-annual results between the two surveys.
- We recommend, therefore, that Winter Mammal Monitoring is taken forward as a long-term monitoring scheme to provide different data to BBS. It will, however, be useful to compare trends identified by Winter Mammal Monitoring and BBS over the longer term,

to use as a validation tool. It is only after several years of data collection that we will be able to see if the trends identified from each survey are different.

Recommendations

The methods and volunteer organisation of Winter Mammal Monitoring have been shown to work and we recommend that the future long term monitoring scheme is set up on similar lines. However we feel that the project organisation should be altered to benefit the project. These recommendations are outlined below:

Project Organisation

- The three-year pilot project has been carried out by a partnership between the BTO and The Mammal Society. The BTO has been the lead organisation although in practise the work has been split approximately 50:50. This has been useful for the pilot and each organisation has brought its own strengths and expertise to the partnership.
- However, working in partnership has costs and can be time consuming - in liaison between project partners and overcoming the organisational and cultural differences between organisations. The fact that organisations have different financial year ends means they are often working to different reporting schedules, and there are differences in the timing of other organisational commitments (e.g. both the BTO and The Mammal Society have annual conferences where staff are expected to be present and/or deliver presentations on current activities). This means that staff working in partner projects may be away from the project at different times.
- We recommend that one organisation takes a strong lead on the project – with the other partner contributing less, perhaps 15-20% of the time and work. This will ensure that combined organisational strengths and expertise are maximised but that there is one lead organisation for the volunteers, media and funders to contact. Recruiting and liaising with volunteers, sending out information packs, producing and sending out newsletters could be more efficient if carried out by one organisation, and this is partly reflected in the division of work we adopted in the latter years of the pilot. Nevertheless, we consider it an advantage to have additional partners involved in the project, contributing expertise in particular components (for example data analysis) as well as experience with other data sets that can be used in validation This is the approach being taken by the Tracking Mammals Partnership.

Project Scope

- We recommend that Winter Mammal Monitoring be expanded to specifically cover Northern Ireland. It is important that we can report at a UK level. This will require more investment on part of the funders and we hope that Northern Ireland funding bodies will recognise the importance of this work.
- We recommend that training be an explicit part of this project. Training is an important mechanism for recruiting and enthusing volunteers. It also ensures that the data collected are of sufficient quality. Training may also encourage people not to opt out of surveying for particular field signs such as field vole runs. We recommend that the training part of the project is carried out by an organisation that already runs a training programme to take advantage of expertise and to piggyback on procedures and processes that are already set up. We recommend that the volunteers pay a nominal cost to attend the Training Course, as this encourages them to value the training and helps to ensure that people book and actually attend the course. However, we recommend that the full cost of

running the Training Course is subsidised so that the volunteers are just paying a nominal fee.

Sampling Strategy

- In the following recommendations of the most appropriate sampling design, we have assumed that the primary aim of the monitoring programme is to detect changes in populations over time, and the ability to assess confidence in these measures.
- We believe that turnover is best handled by targeting volunteer management effort towards a group of dedicated volunteers that are likely to continue surveying their allocated site for many years. This would be much easier to manage than a system in which a new set of sites is selected every year (see below). We predict that turnover will be much less anyway, than during the pilot, once a long-term monitoring programme has been established. If observer effects (as yet unquantified) are found to be minimal, new recruits could be encouraged to take up sites that had been dropped. Another option might be to modify the analytical model by incorporating an interaction term to test for a difference between current and new sites in the estimate of the year effect. If this is non-significant, it may not be necessary to correct for this effect.
- The importance of surveying squares even when no data are collected is a key message to communicate in a long term monitoring scheme. If volunteers are encouraged to spend longer carrying out their survey (and hence increasing their chance of seeing mammals or finding field signs, as revealed by the influence of duration), this could also reduce turnover.
- We recommend, therefore, that future winter mammal monitoring employs a programme of repeat visits by the same observer to the same sites in as many years as possible, analysed using models with site effects to account for the non-independence of repeat visits to the same sites. There are a number of procedures for analysing data collected from many locations and over many years, and statistical techniques have been developed to handle the gaps in the time series that are a feature of these datasets. This design is the most powerful for equivalent sample sizes, and temporal gaps in coverage can be handled.
- We considered an alternative sampling approach of generating a completely new random set of 1km squares each year. This has the advantages of being able to utilise all of the data collected (even from single visits) and to avoid the need to incorporate site effects in the analyses. However, a disadvantage of this model is in the management of volunteers, because those who continued to participate in the survey would have to be assigned new sites. This requires considerably more effort for volunteers (in order to find the site, select a route and organise access to land) and is likely to be unpopular with regular participants. Although turnover was high during the pilot, we anticipate that it will be considerably reduced once the scheme has been established. We also considered whether a joint approach in which this ‘new random site’ model might be suitable for a subset of volunteers that wish to participate in Winter Mammal Monitoring for only one year. This is feasible, but would be complicated by the fact that analyses would probably have to carried out separately from those involving repeat visits, and that the decision on whether to include the site in the ‘new random set’ or the ‘repeated visit set’ would have to be made before the survey was carried out. This is due to the bias that would be caused by observers dropping sites with fewer mammals. Nevertheless, it would be advisable to explore these options if future recruitment and turnover rates suggest it is feasible.

Methods and Volunteer Organisation

- A Sightings and a Field Sign survey should be carried out separately within a winter field season (October to April). The volunteers would be asked to carry out both surveys, but if they prefer to just do one type, then they would be encouraged to carry out that survey on more than one square.
- That habitat data continues to be collected in order to investigate associations between mammal trends and habitat change. This may change in the future if it is decided that remote-sensed data, such as provided by the Countryside Survey can be used for this purpose.
- Square allocation continues to be done on a random basis allowing for volunteer location. i.e. 1km square selected at random from an area within 10kn of their home. Squares are checked for suitability before being sent to the volunteers.
- The same instructions will be given for deciding on a transect route and suitable length. The transect will be divided into 200m sections. Field protocols for collecting the Sighting and Field Sign data will also be the same – with duration being stressed as a factor that will help the observer collect more data.
- Health and safety guidance will be modified in line with that discussed at the Tracking Mammals Partnership workshop held in March 2004.
- Details on all the survey methods will be sent out prior to the beginning of the fieldwork season. Each volunteer will be sent a postcard acknowledging receipt of their data.
- One newsletter will be produced each year – at the end of the summer, once the data for that year has been input and analysed. The newsletter will also act as a reminder of the forthcoming field season and advertise any changes to protocols etc.
- That the database is held, maintained and developed by the lead project partner. The data can be extracted from this and sent to the other project partner at the analysis stage as needed. We also recommend that the database is integrated within the main database of the lead project partner, to ensure full CRM and to simplify updating address details, etc.
- Although the main organisation and field protocols for the project are the same, we strongly recommend that the project is re-launched. This will emphasise the start of the long term monitoring project as opposed to the pilot project. We recommend that all the project materials are thoroughly revised and updated, giving them a new look to emphasise the launch of the new project and making them more user friendly.
- The most important recommendation is for the allocation of long-term project funds (rather than a year-to-year basis) and for a long lead time in which to re-launch the project. Problems in the pilot were caused by the lack of funding commitments for Years 2 and 3 until the start of the fieldwork season. Funds must be allocated for three-year (ideally five-year) periods and allocated far enough in advance for organisational plans to be made and material prepared to send to the volunteers.

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10. Appendices

Appendix 1 - Assessment of distance sampling

Distance sampling is the accepted analytical method for estimating species density and abundance (Buckland *et al*., 2001) from line or point transect surveys. It works on the principle that as distance increases from a transect line (or point) the proportion of individuals that are detected by an observer will decline. Distance sampling models this decline in detectability with distance to produce an estimate of undetected individuals, which is subsequently used to estimate real density and hence abundance.

There are a number of assumptions associated with distance sampling. The most important of these are:

- that all animals along the transect line are detected
- that individuals are randomly (uniformly) and independently distributed in the survey area
- that animals do not move in response to the observer prior to detection
- that distances are measured accurately
- that transect lines are randomly, or systematically, located
- that the detection curve has a shoulder, i.e. detection rates are high at first but then decline.

The extent to which the Winter Mammal Monitoring survey data meets these assumptions for particular species is examined below. In this study, distance sampling software developed by Buckland *et al*. (2001) (DISTANCE, Version 4.0; Thomas *et al*., 2002), is used to explore the sightings data and to fit detection curves.

The first step in assessing whether distance sampling can be used to estimate densities and abundance is to establish whether there is an adequate number of observations of that species. For distance sampling, 60-80 observations of each species are recommended for analysis (Buckland *et al*., 2001). For species that occur in clusters, for example herding deer, large groups are more likely to be detected than single animals. To correct for any bias that this might introduce, the probability of detection of these species should be modelled using cluster size as a covariate. However, a problem may arise where a species occurs in a loose aggregation rather than a distinct group, such as rabbit in this study. In which case, it may be most appropriate to compare estimates from two detection functions treating individuals in groups as individuals and as groups. Of the 27 wild mammal species recorded in the Winter Mammal Monitoring project pilot year of 2002, the sample sizes were approximately appropriate to try and model the detection functions of 6 of these species, which includes brown hare, rabbit, red fox, grey squirrel, fallow and roe deer (Table 62). Obviously, the detection function of a species in different habitats is likely to vary, for example roe deer in farmland is likely to have higher detectability than roe deer in woodland. Therefore, detection functions should ideally be calculated within all habitats in which detectability is likely to differ. However, provided the assumption that all animals are detected along the transect line, distance sampling estimators are pooling robust. That is, no bias is introduced by pooling data from animals with different detection probabilities. This is a particularly important feature of distance sampling methods because animal populations are almost always heterogeneous and modelling this can be difficult.

The second step in assessing whether distance sampling can be used on data collected through the Winter Mammal Monitoring survey is to plot the distribution of the sightings data for those species where there is an adequate sample size (brown hare, rabbit, red fox, grey squirrel, fallow and roe deer) with lots of cutpoints (25) to examine how well the data meets the above assumptions of distance sampling. In diagnosing these data, it is important to examine the distributions with the behaviour of the species in mind. In other words, does the distribution of the data reflect the known behaviour of the species or is it obviously biased by failure to meet the assumptions of distance sampling? The effect of failure to meet each of main assumptions of distance sampling is discussed in detail in Borchers *et al*. (2002), but is discussed, where relevant to this study, for the six species below. Where there is little or minor violation of the above assumptions, exploratory analyses is used to examine how best the data can be modelled in DISTANCE by fitting a small number of key/adjustment combinations to the data (e.g. Uniform + cosine, Half-normal + Hermite polynomial and Hazard-rate + cosine) and grouping data into distance bands and perhaps truncating to remove outliers to provide the best model fit possible to the data. From these, the 'best' model is chosen as the one with the lowest AIC value, which provides a relative measure of fit from between models, whilst the absolute measure of fit can then be examined on the chosen model by performing a goodness-of-fit test.

Species-specific detectability

a) Brown hare

The distribution of brown hare sightings is shown in Fig. 54. The first problem that is apparent with these data is that they are heavily spiked at 60-70 m. This spike could be related to the behaviour of brown hare avoiding field margins, but could equally be explained by movement of hares in response to the observer prior to detection or observers not recording hare where first sighted. However, whatever the reason for this spike, whether or not it explains the real distribution of brown hare, this spike it likely to reduce the probability of finding a model that provides an adequate fit to this distribution and is likely to bias any confidence intervals. The rounding of distances by observers to convenient values (100, 150, 200, 250 m) is also evident in Fig. 54 and heaping could have contributed to the observed spike. Because, goodness-of-fit tests are very sensitive to heaping, where heaping is apparent it is important to group distance data into bands, so that 'heaps' fall at approximate midpoints of the groups. Exploratory model fitting to the brown hare data, found that a Uniform key with cosine adjustment term and data grouped into five distance bands and no truncation, produced the best fit to the data, although the absolute fit to the data was very poor (goodness-of-fit test: χ_3= 43.63, P <0.00001: Fig. 55)

b) Rabbit

The distances that rabbits were observed in this study are shown in Fig. 56. This data shows a heavy spike at zero distance (i.e. along the transect line). This distribution could reflect the real distribution of rabbits, with rabbits preferentially occurring along the linear feature/s that the observer walks. However, a similar distribution could result if detectability of rabbit is very small away from the transect line, or if observers heap all close sightings of rabbit into the zero distance category. Because the spike is so large, the choice of 'best' model, not only depends on the best relative fit between different models (comparisons of AIC values), but also on whether the spike is real of not. For example, if the spike is real, a Hazard rate model that fits the model to the spike may be most appropriate, but if the spike is not real, other models that average out the spike may be a better choice. Although not necessarily the most appropriate model for the reasons above, a Hazard rate key with cosine adjustment provided the best fit to the data, with the data grouped into nine distance bands and right truncated to remove the largest 5% of distances data as routinely recommended for distance analyses by

Buckland *et al*. (2001). However, this model was significantly different from the distribution of the data (goodness-of-fit test: χ_5= 36.78, P <0.00001: Fig. 57) and hence likely to produced biased estimates of density and abundance.

Another problem particularly related to the surveying of rabbits, is that rabbits occur in burrows and at any point in time, a certain proportion of the population is likely to be underground. This means that detection along the transect line walked is unlikely to be 100%, which invalidates this assumption of distance sampling. Excluding the other problems associated with the rabbit data, if this is not controlled for, the true estimate of density and hence abundance is likely to be underestimated by some unknown amount. There are methodological ways of changing the survey design to deal with this problem, for example, using a double platform approach requiring two separate observers to walk the transect line, although this is likely to be beyond the protocol of this survey. A further problem with rabbits is that they occur in groups of often many individuals associated with a single burrow system. Large groups are more likely to be detected than small groups or individuals, and this should be corrected for in the analyses. However, rabbits often occur in loosely aggregated clusters and it may be difficult to decide where one group starts and another one ends.

c) Fox

The distribution of fox sightings is shown in Fig. 58. This shows two spikes, one at zero distance (i.e. along the transect line) and one at 50 m, with very few sightings at distances other than these. The large spike at zero distance may represent, to some degree, convenient grouping of sightings by the observers close to the transect line, but may also represent the behaviour of foxes, which like observers tend to use linear features along which to travel. If this is the case, this violates the assumption that the species is randomly and independently distributed in the survey area. The relatively high proportion of sightings at 50 m is likely to be due to observers heaping a large proportion of sightings away from the transect line into the 50 m category for convenience. As discussed above, to deal with the problem of heaping, one normally groups distance data, so that ‘heaps’ fall at approximate midpoints of the groups. However, there are such few data in other distance categories that exploratory analyses found no model that provided an acceptable fit to these data. For this reason, the model fitting process was not examined further for this species.

d) Grey squirrel

The perpendicular distances from the transect line that grey squirrel are observed in this study are shown in Fig. 59. This shows obvious outliers at distances of over 50 m from the transect line, so as recommended for this type of data, it is truncated, with 50 m as the cutpoint in this case as shown in Fig. 60. Examining the distribution of Fig. 60, it is clear that observers are heaping the distance of observations to the nearest 5 m, but there is no gross heaping as observed in the fox example. This is not a great problem and can be dealt with by grouping data into distance bands, using approximate midpoints between heaps as cutpoints as shown in Fig. 61. Fitting a number of standard models to these grouped data, it was found that a model with half-normal key, with cosine adjustment, provided a reasonable fit that was not significantly different from the distribution of the data (goodness-of-fit test: χ_3= 6.81, P = 0.08) and could be used to produce reasonable estimates of density and abundance.

e) Fallow deer

The distribution of fallow deer sightings is shown in Fig. 62. This distribution suggests that observers are not providing an accurate estimate of distance and are grossly heaping distances away from the transect lines to 100 m. In addition to heaping, the particularly large proportion of sightings at 100 m, may suggest that animals are moving in response to the observer prior to detection or that observers are not recording distance where first sighted. Whatever the reason, this data is very poor and cannot be used to provide reliable estimates of density and abundance. Problems with the surveying of deer are well known (Buckland *et al*., 2001) and alterative methods that may improve the data are not feasible for a survey of this type, e.g. thermal imaging at night or recording dung in distance categories. However, this second method would assume that volunteer observers could correctly identify deer dung at the species level and further work would be needed to calculate defecation rates and dung decay rates, which are both likely to be confounded by habitat, season and weather conditions. If reliable distance sampling data were available for the fallow deer, other problems that would need to be addressed are the problem of correcting for large herd sizes using herd size as a covariate in the model fitting process and reducing bias in confidence intervals, if fallow deer are preferentially using linear or edge features along which to travel.

f) Roe deer

The distribution of roe deer sightings in this study is shown in Fig. 11.10. This distribution shows a spike at zero distance and the heaping of distances to the nearest 50 m (i.e. heaping at 100, 150, 200 and 250 m). Grouping distances into appropriate bands, it was examined whether a model could be fitted to such data. The best model, a Hazard rate key with cosine adjustment and data grouped into six distance categories (45, 100, 120, 175, 245 and 294), provided a reasonable fit to the data that was not significantly different from the distribution of the data (goodness-of-fit test: χ_1= 3.81, P = 0.08; Fig. 64). The majority of roe deer were recorded as individuals or as pairs, so the problem of bias due to greater detection of large herd sizes is likely to be less of a problem than would be the case with say fallow deer. In further analyses, it may, however, be interesting to examine the effect of group size in roe deer on resulting estimates. Assuming all roe deer are detected at zero distance, distance-sampling estimators are pooling robust. In other words, no bias is introduced by pooling data from animals with different detection functions. However, because roe deer occur in both woodland and farmland, in which detectability is likely to be different, it may be interesting to expand the above analyses to calculate separate detection functions for both broad habitat classes. Depending on the fit of the resulting models, this may improve the reliability of density and abundance estimates.

Table 62 Number of observations of each species in each group size**.**

	Species count per 100 meter transect section																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	21	25	27	35	41	80	146	Total
Badger	2	1																						3
Bank vole	1																							1
Brown hare	168	22	12	2	4		1	1																**210**
Brown rat	12	1	1																					14
Common dormouse		1																						1
Common shrew	2																							2
Fallow deer	10	15	5	6	4	7		3	1	1				1		1		1		1	1			**57**
Field vole	2																							2
Fox	96	4																						**100**
Grey squirrel	366	61	19	4	1	1			1		1													**454**
Hedgehog	3																							3
House mouse	1																							1
Mink	3																							3
Mole	9	2	3			1																		15
Mountain hare/Irish hare	8																							8
Muntjac	29	1	2																					32
Polecat/ferret	1																							1
Rabbit	444	173	75	38	26	12	6	6		3	3	3	1	2	3								1	**796**
Red deer	8	2	5	2	1	1	1	1		2		1					1							25
Red squirrel	6																							6
Roe deer	64	50	25	8	3	3						1												**154**
Sika deer	4	3	1	1																				9
Stoat	4	1																						5
Vole	2																							2
Water vole	2																							2
Weasel	3																							3
Wildcat	1																							1

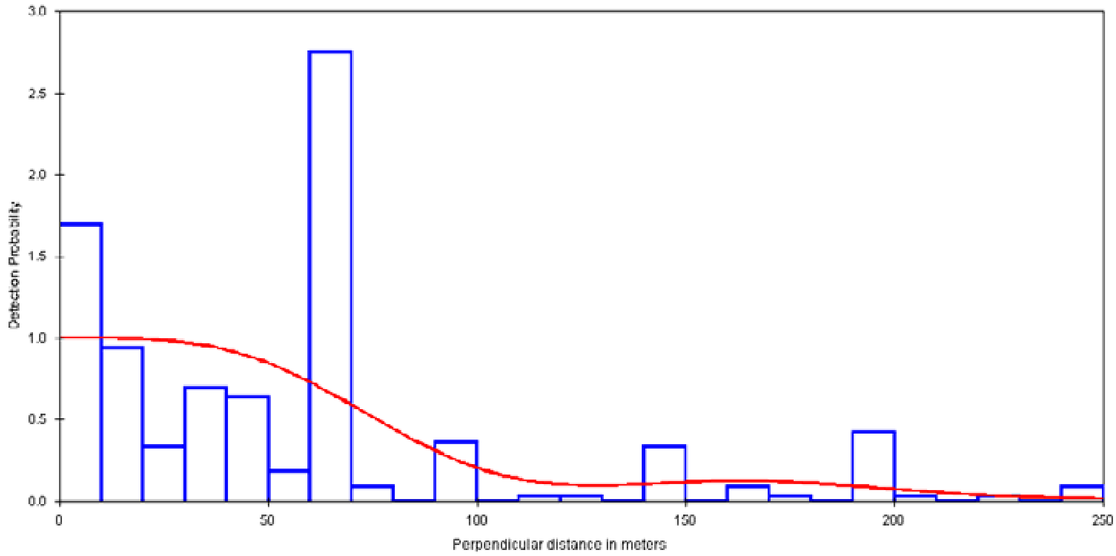

Fig. 54 The distribution of perpendicular distances of observed brown hare from transect lines for all sightings in 2002. The red line shows a default model (uniform key with Hermite polynomial adjustment) and can be ignored here.

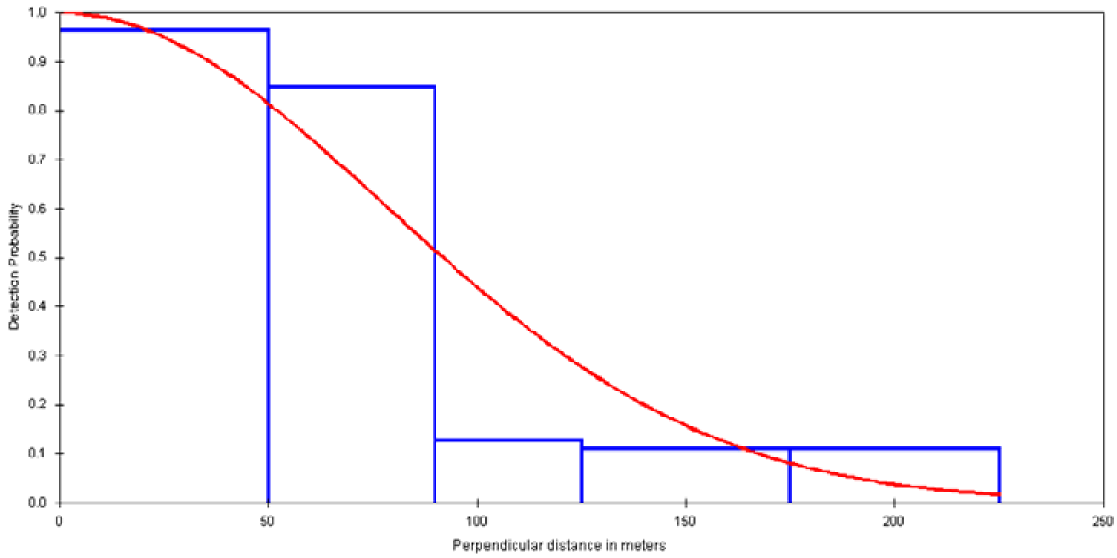

Fig. 55 The distribution of perpendicular distance of observed brown hare from transect lines for all sightings in 2002, grouped into five distance bands with cutpoints of 50, 90, 125, 175 and 225 m and fitted with a Uniform key and cosine adjustment term.

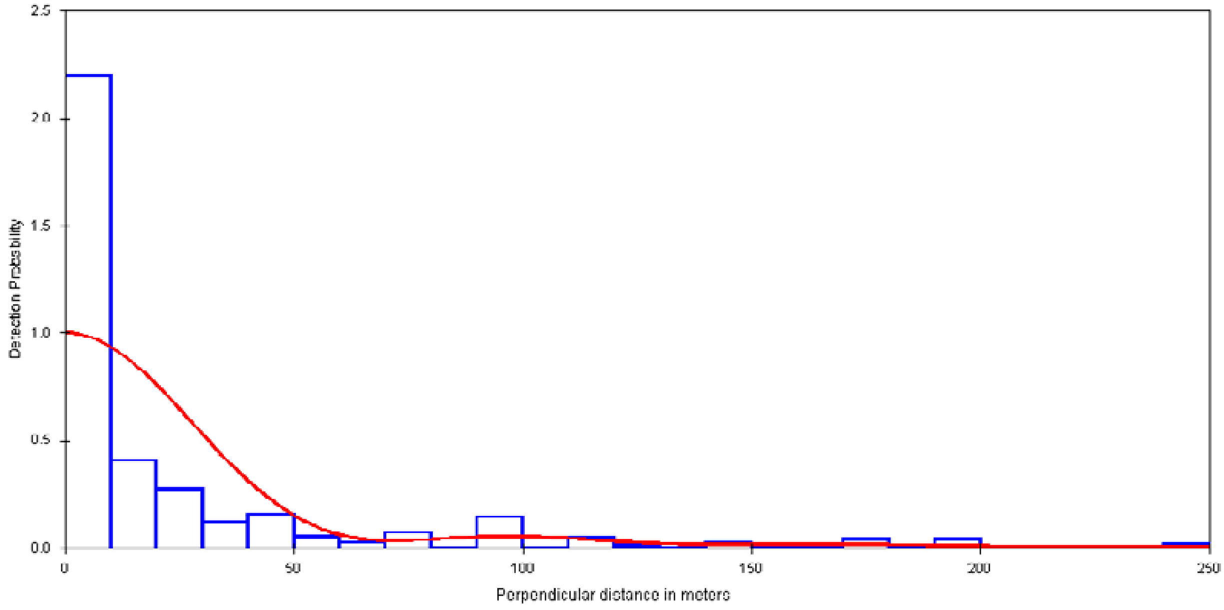

Fig. 56 The distribution of perpendicular distances of observed rabbit from transect lines for all sightings in 2002. The red line shows a default model (uniform key with Hermite polynomial adjustment) and can be ignored here.

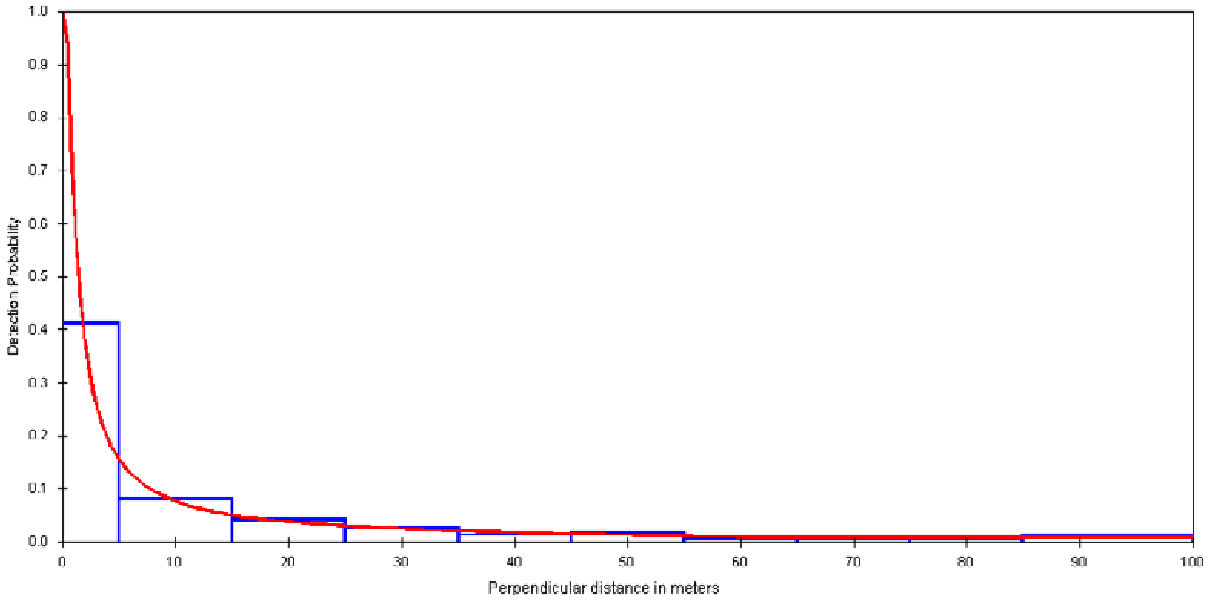

Fig. 57 The distribution of perpendicular distance of observed rabbit from transect lines for all sightings in 2002, grouped into nine distance bands with cutpoints of 15, 25, 35, 45, 55, 65, 75, 85 and 100 m, with the largest 5% of largest observation truncated and fitted with a Hazard rate key and cosine adjustment term.

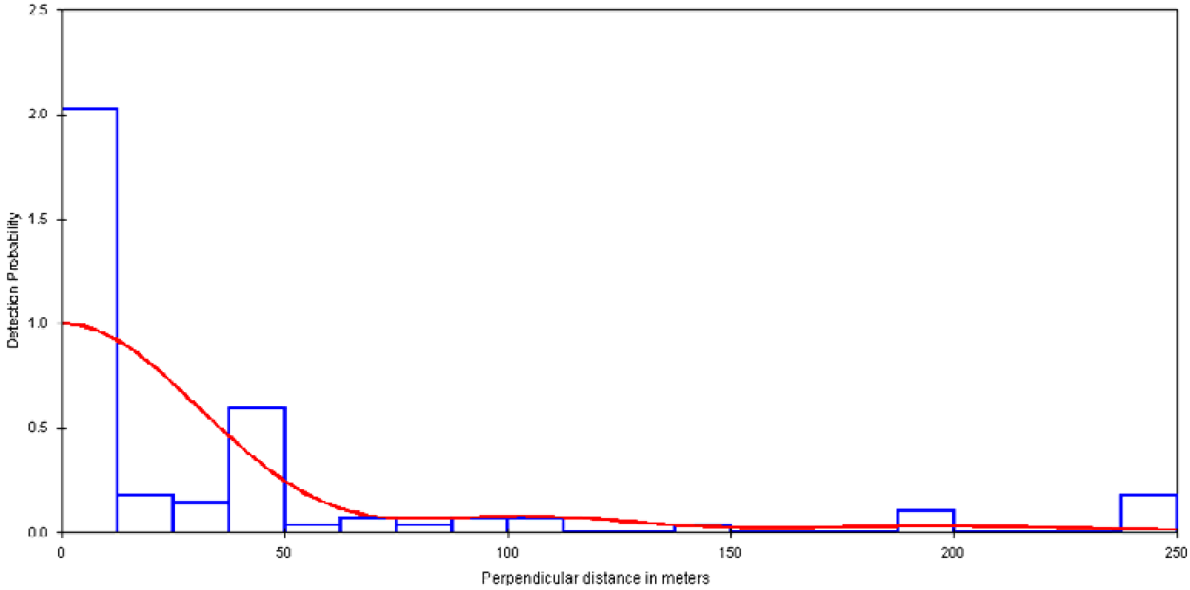

Fig. 58 The distribution of perpendicular distances of observed fox from transect lines for all sightings in 2002. The red line shows a default model (uniform key with Hermite polynomial adjustment) and can be ignored here.

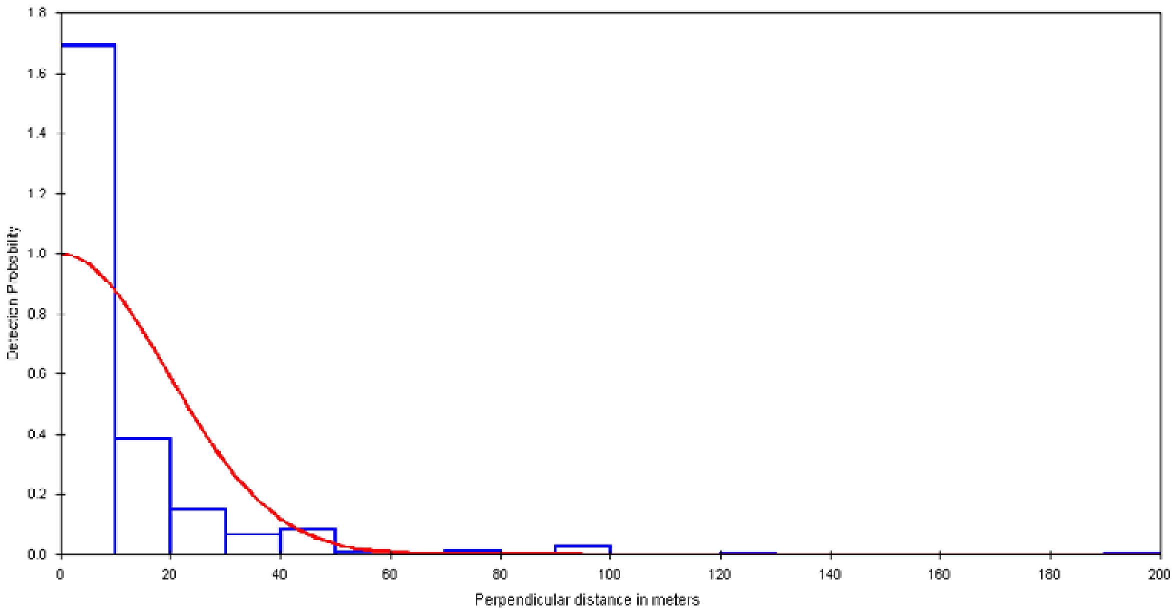

Fig. 59 The distribution of perpendicular distances of observed grey squirrel from transect lines for all sightings in 2002. The red line shows a default model (uniform key with Hermite polynomial adjustment) and can be ignored here.

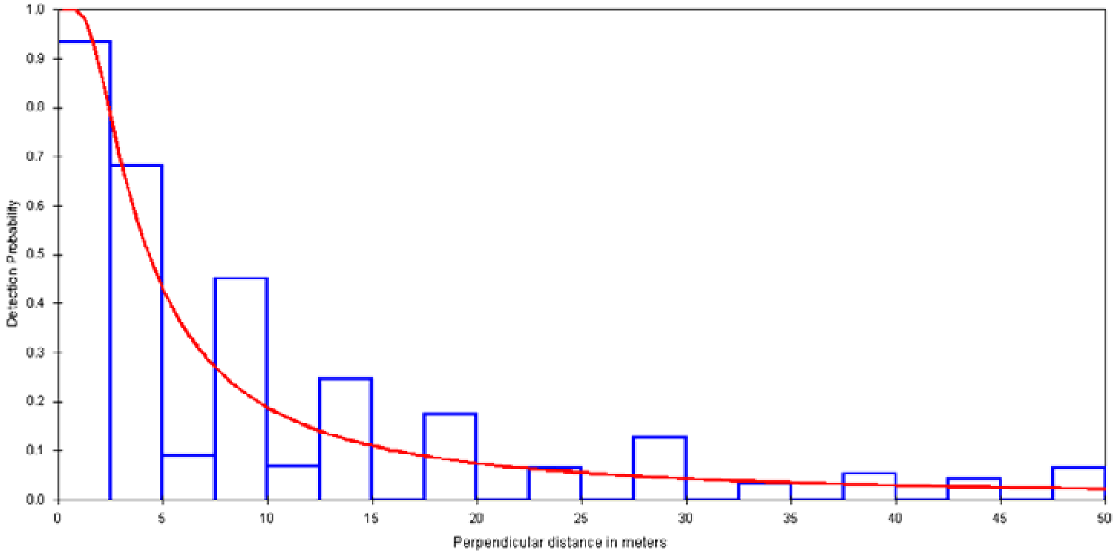

Fig. 60 The distribution of perpendicular distances of observed grey squirrel from transect lines for all sightings in 2002, truncated at 50 m. The red line shows a default model (uniform key with Hermite polynomial adjustment) and can be ignored here.

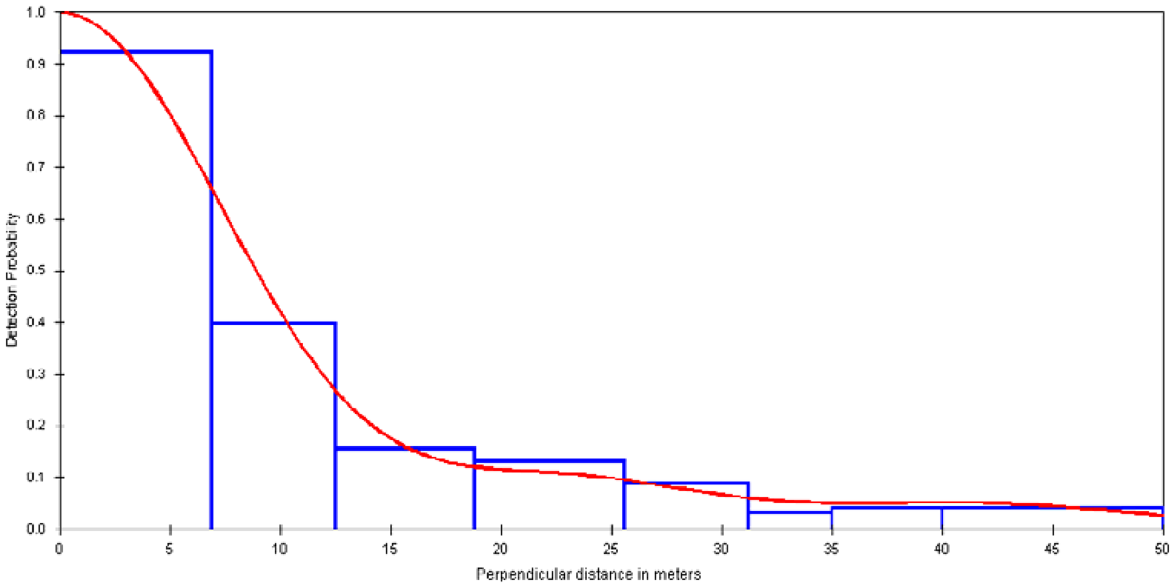

Fig. 61 The distribution of perpendicular distance of observed grey squirrel from transect lines for all sightings in 2002, grouped into eight distance bands with cutpoints of 6.9, 12.5, 18.8, 25.6, 31.2, 35, 40, 50 m, truncated at 50 m and fitted with a Half normal key and cosine adjustment term.

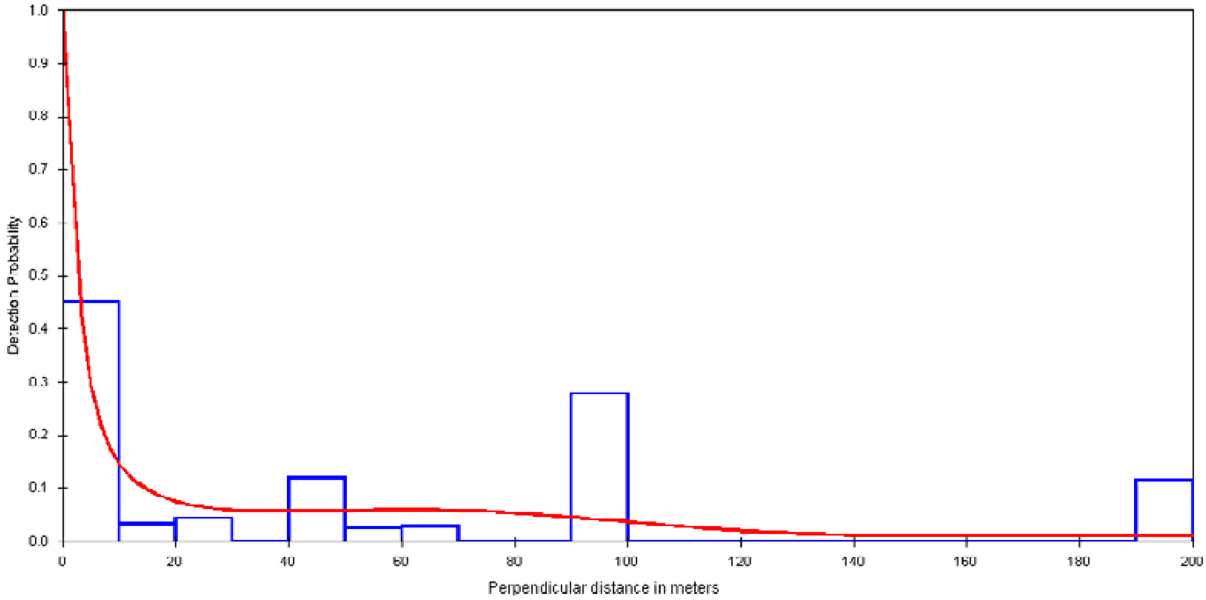

Fig. 62 The distribution of perpendicular distances of observed fallow deer from transect lines for all sightings in 2002. The red line shows a default model (uniform key with Hermite polynomial adjustment) and can be ignored here.

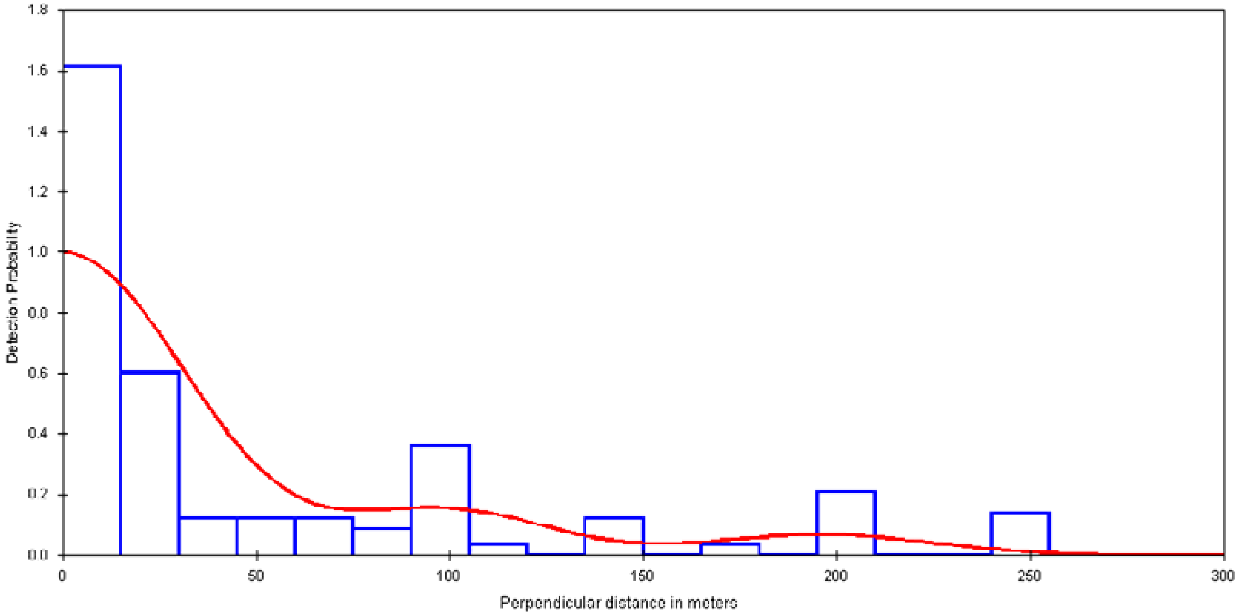

Fig. 63 The distribution of perpendicular distances of observed roe deer from transect lines for all sightings in 2002. The red line shows a default model (uniform key with Hermite polynomial adjustment) and can be ignored here.

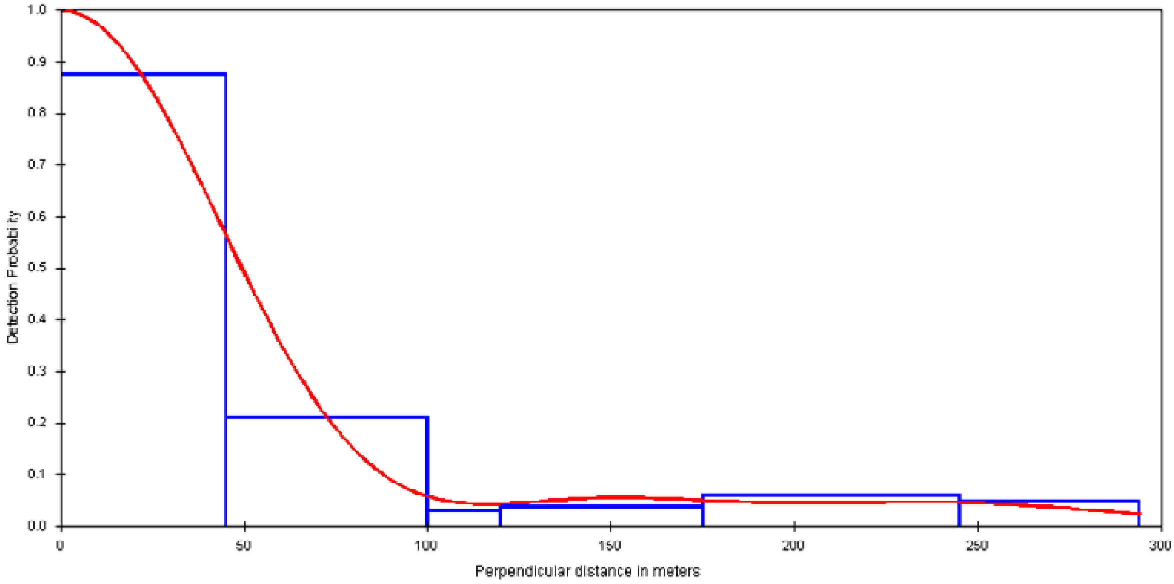

Fig. 64 The distribution of perpendicular distance of observed roe deer from transect lines for all sightings in 2002, grouped into six distance bands with cutpoints of 45, 100, 120, 175, 245, 294 m, truncated at 300 m and fitted with a Hazard rate key and cosine adjustment term.

Appendix 2 – Questionnaire results

Question 6: Are you male or female?

258 males (60.7%) and 167 females (39.2%) took part in the surveys.

Question 7: Which age bracket do you fall in to?

Under 18	5
18-24	15
25-34	56
35-44	66
45-54	99
55-64	108
65-74	50
75+	7

Question 8: Have you taken part in a similar survey before?

	For The Mammal Society	*For the BTO*	*Other organisations*
Frequently	15	173	91
Occasionally	72	54	188
Never	338	198	146

Question 9: Have you attended a *Look Out for Mammals* mammal ID course run by The Mammal Society?

Yes	61
No	364

Question 10: Which one of the following categories best describes you?

Student	20
Academic	24
Countryside worker	85
Mammal interest	19
General natural history interest	265
Other	9

Question 11: Are you a member of

	The Mammal Society?	*The BTO?*
Yes	113	167
No	312	258

Question 12: Were the instructions and information packs easy to understand?

Score rating	Number of people giving each score rating for:		
	Part 1 sightings	*Part 2 signs*	*Habitat data*
1	4	6	7
2	16	27	23
3	63	77	88
4	136	126	146
5	152	86	106

Question 13: Were the forms easy to complete?

Score rating	Number of people giving each score rating for:		
	Part 1 sightings	*Part 2 signs*	*Habitat data*
1	6	8	11
2	25	26	38
3	59	49	82
4	137	112	114
5	124	81	100

Question 14: Which form of support did you make use of?

Web site	32
Telephone	47
Laminated mammal keys	127
Mammal ID workshop	28
Mammal monitoring workshop at Chilbolton, Hampshire	15
Local support	21

Question 15: Did you feel that there was adequate support for the project in terms of help lines, advice etc.?

Score rating	*Number of people giving each score rating*
1	9
2	19
3	90
4	103
5	73

Question 16: Were you happy with your square?

Yes	247
No	178

Question 17: If no, was this because: (participants were asked to tick as many answers as applied).

Too far away	46
Too boring/dull	39
Few or no mammals	80
Contained too much urban habitat	54
Terrain was too difficult	23

Question 18: Did you encounter any access problems with your square?

Yes	101
No	324

Question 19: If yes, was this due to: (participants were asked to tick as many answers as applied)

Reservations about Foot and Mouth	21
Disturbance to game	8
Disturbance to livestock	10
Other issues with a farmer	14
Safety	9
Square contained too much urban or industrial private property	33
Other	52

Question 20: How easy was it for you to select a transect route in your allocated square?

Score rating	*Number of people giving each score rating*
1	39
2	31
3	69
4	91
5	144

Question 21: How easy was it for you to estimate distance in Part 1 (Sightings) of the project?

Score rating	*Number of people giving each score rating*
1	9
2	27
3	80
4	125
5	87

Question 22: How easy did you find each of the following species to identify? (answers given as % of those who answered the question)

Score rating	*Lagomorphs*	*Squirrels*	*Deer*	*Large carnivores*	*Small carnivores*
1	2.2	3.7	4.2	6.5	13.8
2	0.3	0	4.2	2.2	14.3
3	2	2.9	17.6	11.7	21.6
4	11.8	7.7	24.5	16.8	22.2
5	83.7	85.7	48.5	63.5	28.1

Question 23: How easy did you find each group of signs to identify?

Score rating	*Badger setts*	*Squirrel dreys*	*Field vole signs*	*Dormouse nuts*	*Harvest mouse nests*	
1	4.7	5.4	28.3	29.7	44.9	
2	1.7	9.8	21.2	15.2	19.1	
3	16.6	15.3	25.6	30.3	19.8	
4	22.6	30.5	12.2	11.6	6.2	
5	54.1	39	12.7	13.2	11.8	
Score rating	*Deer slots*	*Rat burrows*	*Rabbit burrows*	*Molehills*	*Fox faeces*	*Badger faeces*
1	7.6	19.5	1.9	0.9	8.9	16.1
2	13	16.5	0.9	0	10.8	11.5
3	13	32.1	6.9	0	18.5	17.9
4	21.4	18.5	26.1	4.3	22.2	16.1
5	45	13.4	64.2	94.8	39.6	38.4

Question 24: Did you find the survey interesting and enjoyable to complete?

	Number of people giving each score rating	
Score rating	*Sightings*	*Signs*
1	15	14
2	45	30
3	62	36
4	110	73
5	102	86

Question 25: Which of the following factors influenced you to take part in this survey? (respondents were asked to tick as many as applied)

Mammal specific	166
Range of mammal species	143
Local squares allocated	208
Run by the Mammal Society	107
Run by the BTO	167
Timing of survey	97

Question 26: Would you be interested in collecting other information at the same time as you carry out your mammal survey (e.g. wintering birds)?

Yes	287
No	138