SCOTTISH BADGERS

Scottish Badger Distribution Survey 2006 – 2009

Estimating the density and distribution of badger main setts in Scotland

BioSS

Heritage LOTTERY FUNDED

SCOTTISH NATURAL HERITAGE

The Scottish Government

Scottish Badger Distribution Survey 2006 – 2009

- estimating the density and distribution of badger main setts in Scotland

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(Front cover photograph courtesy of Laurie Campbell).

Contents

1. EXECUTIVE SUMMARY

1. Until recently, estimates of the density and distribution of the Eurasian badger *(Meles meles)* in Scotland have relied on survey work carried out over ten years ago. The need was thus identified to obtain up-to-date estimates.

2. The Scottish Badger Distribution Survey was conducted by the charity Scottish Badgers. Funding was provided by The Heritage Lottery Fund, Scottish Government and Scottish Natural Heritage. Statistical input was provided by Biomathematics and Statistics Scotland (BioSS).

3. The aim of the survey was to provide an up-to-date estimate of badger main sett density and distribution and to provide information on the habitats in which badgers are present in Scotland. The survey was intended to act as a baseline from which future changes could be measured through repeat surveys every five to ten years.

4. The geographical scope of the survey included mainland Scotland, but excluded the islands (except for the Isle of Arran where badgers were known to be present). Certain areas of mainland Scotland were excluded from the sampling frame on the grounds of having known unfavourable habitat or because they were impractical to survey for reasons of safety or accessibility.

5. A stratified random sample of 1000 1km^2 squares was produced, with stratification by region and by habitat type. A reserve set of 1km^2 squares was also produced, using random stratified sampling, to allow for substitutions in situations where 1km^2 squares from the main dataset were deemed unsuitable for surveying, or for the addition of 1km^2 squares in areas where there were more volunteer surveyors than originally expected.

6. Data were collected on the presence or absence of badger setts and signs, the habitats contained within the 1km^2 survey squares and any evidence of human disturbance to badger setts. Using established field survey techniques, a network of trained volunteer surveyors collected data. Survey work was conducted during two main survey periods: September 2007 to May 2008 and September 2008 to May 2009.

7. Various quality assurance mechanisms were employed, including standardisation of recording procedures through the design of a standardised recording sheet, comprehensive surveyor training and the provision of survey packs to all surveyors. An audit of data quality was also conducted to check for the presence of recording errors, such as non-detection or misclassification. A total of 37 resurveys were conducted. One error was detected, but the circumstances associated with this were felt to be unique. Thus the evidence from the audit suggested that error rates were likely to be low enough to not have a material effect on the conclusions.

8. Over 570 volunteer surveyors took part in the survey, with a volunteer retention rate of over 90%. This was achieved through a variety of measures such as regular communication, face-to-face contact, expert-led refresher surveys, regular newsletters and incentives introduced for returning survey work.

9. Of the 1000 $1km^2$ survey squares available from the original sample, 994 $1km^2$ squares were offered to volunteer surveyors. 944 $1km^2$ squares were accepted for survey, representing an uptake rate of approximately 95%. Returns were monitored throughout the project to ensure that adequate coverage was achieved for each region and habitat, and to ensure that no significant gaps occurred within each geographical region.

10. 877 survey returns were received, representing a return rate of over 90%. Of the 877 squares surveyed, 585 squares were found to have no badger records of any kind, four squares recorded only a disused main sett, and the remaining 288 squares showed some evidence of current badger activity. 224 of these 288 squares contained an active badger sett of some kind, whilst 64 squares contained badger signs but no active setts. 136 squares contained an active badger main sett. A total of 170 main setts were found by the survey, with a maximum of four main setts being found in any single $1km^2$ square.

11. Access issues were encountered in approximately three percent of squares, with the majority of access restrictions encountered deemed reasonable. Evidence of human disturbance to badger setts was recorded in approximately two percent of the surveyed squares. No accidents or injuries were reported by fieldworkers in either of the two survey periods.

12. The data collected were used to generate a national estimate for the number of badger main setts and for the percentage of $1km^2$ squares containing badger activity. The results indicated that there are likely to be between 7300 and 11200 badger main setts in Scotland. It is estimated that between 7.1 and 10.4% of $1km^2$ squares in Scotland contain at least one main sett, that between 12.7 and 17.2% of $1km^2$ squares contain at least one active sett of some kind and that between 17.2 and 23.2% of $1km^2$ squares contain some form of current badger activity.

13. The standard errors associated with the estimates for individual regions and dominant habitat types are large relative to the sizes of the estimates themselves, indicating that there is a high degree of uncertainty when estimating densities at these scales.

14. The highest estimated densities were found in the Borders and Lothian regions, with moderately high estimated densities in Fife, Grampian and Dumfries and Galloway. Estimated densities in Central region, Highland and Tayside were much lower, with intermediate estimated densities in Strathclyde.

15. Estimates for finer scale geographical areas were also produced. The results provided some evidence that there may be substantial heterogeneity in badger densities within the larger regions studied but, since the sample sizes were small and thus the standard errors large, these differences could also have arisen by chance alone.

16. The highest estimated densities were for squares dominated by arable farmland, intensive grassland or deciduous woodland, with moderately high estimated densities for urban areas and much lower densities for squares dominated by coniferous woodland, natural grassland or acid grassland. The lowest estimated densities of all were for squares dominated by heather and bog.

17. A comparison was made between the dominant habitat types of the squares that contained main setts and the specific habitats in which main setts were located. Very little association between the broad-scale and fine-scale classifications of habitat was apparent: 126 setts (74%) lay in a square with a dominant habitat type that was either arable or intensive grassland, and only 25 setts (15%) lay in squares with deciduous or coniferous woodland as the dominant habitat type. In contrast, 98 of the 164 setts with known local habitat characteristics (60%) were either wholly within deciduous or coniferous woodland, and only 14 squares (9%) were located wholly within arable farmland or improved grassland. This apparent discrepancy may be explained by considering the differences in the habitat requirements for two key activities of the badger: sett building and foraging. Since a larger area is required for foraging than for sett building, the dominant habitat type of any square containing a main sett may thus be more reflective of preferences in the foraging habitat of badgers, rather than habitat preferences for sett location.

18. Statistical models were used to investigate the relationship between badger activity within a 1km² square and the environmental characteristics of that 1km² square. The results presented are preliminary and more detailed modelling would be required before conclusive inferences could be drawn. Nonetheless, the results suggested that the proportional land covers of deciduous woodland, arable farmland and improved grassland were important factors in explaining whether or not badgers (main setts / any setts / any badger activity) were present at a site.

19. The results of this survey were not directly comparable with the results of previous surveys of badger population in the 1980s and 1990s because of substantive differences in the designs of the surveys and the protocols used for data collection. In particular, the previous surveys were designed to estimate numbers of badger setts across the entire UK and do not provide a valid basis for estimating the population within Scotland. The raw results of the surveys suggest that there may have been a substantial increase in the number of setts within Scotland since the 1990s, but this apparent increase could also be due to differences in the methodologies used.

2. Introduction

The Eurasian badger (*Meles meles*) is an iconic species within the UK, being the UK's largest indigenous carnivore. Badgers are currently neither rare nor endangered in Scotland but in some areas they are under threat from human persecution, expansion of urban areas and changes in land use.

Current estimates of badger density and distribution in Scotland are based on survey work carried out over ten years ago (Wilson *et al.*, 1997), with the addition of patchy local knowledge, anecdotal reports and educated guesswork.

The need was identified to obtain an accurate, up-to-date estimate of badger density and distribution in Scotland. Should the increasing pressure on habitats suitable for badgers become more acute than at present, or should criminal activities such as badger baiting continue to be a high volume contributor to wildlife crime (Anon, 2009), information on the distribution and population density of the Scottish badger population could be used in planning conservation and crime prevention work. It is important that any future policies relating to badgers are based on sound scientific evidence.

The Scottish Badger Distribution Survey was set up by the charity Scottish Badgers, with the aim of providing an up-to-date estimate of badger main sett distribution and density and to provide information on the habitats in which badgers are present in Scotland. The collection of information on badger main sett presence or absence was the primary data requirement of the survey. The rationale behind collecting data on badger main setts, rather than collecting data on individual badgers, was due to the nocturnal and often elusive nature of the species making it difficult to locate and count individuals in the field, and on the scale required of this survey. Badger numbers are also known to fluctuate markedly, both throughout the year and from year to year (Rogers *et al.*, 1997), thus making this method much more sensitive to survey timing. It was deemed preferable, and much less onerous, to determine the presence of an active badger main sett, a relatively permanent and easily identifiable structure, which in turn would be indicative of the presence of a badger social group. Estimates of badger numbers could potentially then be produced, based on the mean social group size for different regions and habitat types. However, this was outside the scope of the survey and there are inherent problems associated with this task, due to the limited amount of appropriate and up-to-date data available on mean social group sizes for Scotland (see Section 8.3).

The survey was intended to act as a baseline from which future changes can be measured through repeat surveys every five to ten years. Finally, an important aim of the survey was to increase awareness of badgers amongst the general public. This was achieved through the use of a network of widely-recruited volunteer surveyors undertaking fieldwork in their local areas.

The project was funded through the Heritage Lottery Fund, Scottish Government and Scottish Natural Heritage. The project involved partnership working with Biomathematics and Statistics Scotland (BioSS) and benefited from the input of an advisory panel made up of representatives from The Scottish Government's Rural and Environment Research and Analysis Directorate, and Science and Advice for Scottish Agriculture (SASA).

3. Survey Methods and Organisation

3.1 Sampling strategy

3.1.1 Geographical scope

Certain areas of Scotland were excluded from the sampling frame from the outset, based on data from the Land Cover Map 2000 (LCM2000). Excluded areas were either (a) known to have unfavourable habitat, (b) known in advance not to support a badger population (i.e. all Scottish islands except Arran) or (c) were impractical to survey for reasons of safety or accessibility. 1km^2 squares that fulfilled any of the following criteria were automatically excluded:

- Squares relating to islands (except Arran)
- Squares containing more than 75% sea or other open water
- Squares with a mean height greater than 500m
- Squares with more than 50% bog, fen, marsh or swamp
- Squares in which littoral and supra-littoral areas together constituted the dominant habitat type

The total number of 1km^2 squares in Scotland is 83758. The areas excluded from the sampling frame are shown in Figure 1. The total number of 1km^2 squares after all exclusions was 59471, so that approximately 29% of the surface area of Scotland was excluded from the sampling frame.

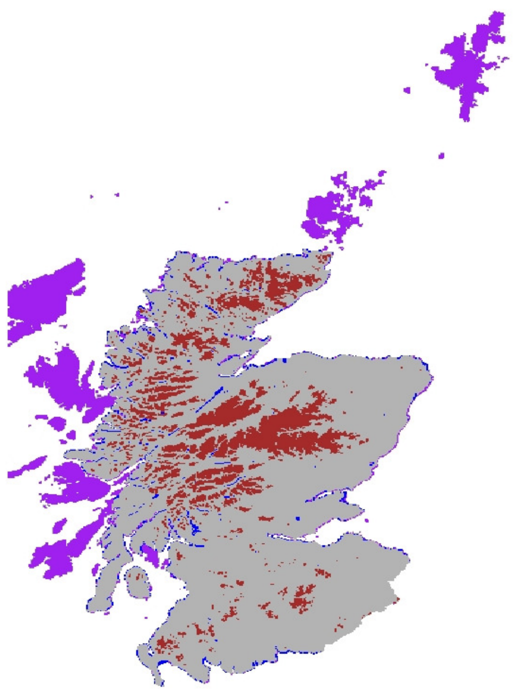

Figure 1. The areas of Scotland excluded from the sampling frame: squares lying on islands other than Arran (purple; 12625 squares), mainland squares with mean altitude over 500m or covered by more than 50% bog, or both (red; 10191 squares), mainland squares dominated by littoral areas or with more than 75% sea or both (blue; 1471 squares).

3.1.2 Stratification

Habitat strata were defined using factors that were expected to have an effect on badger density (Neal, 1972; Wilson *et al.,* 1997).

The 16 broadest target classes (Fuller *et al.*, 2002; Table 1) of the Land Cover Map 2000 (LCM2000) were divided into five broad habitat types:

1. Woodland (broadleaved, mixed, yew and coniferous)
2. Agricultural (arable & horticultural, improved grassland, neutral grassland, calcareous grassland)
3. Urban (built-up areas and gardens)
4. Upland (acid grassland; bracken; dwarf shrub heath; fen, marsh & swamp; bog; montane habitats)
5. Littoral (littoral, super-littoral)

Each 1km^2 square in Scotland was classified as belonging to one of the dominant broad habitat types, according to the broad habitat type which had the highest percentage cover within that square (after excluding sea/estuary, inland water and inland bare ground). This habitat selection was used because it was expected that main setts densities would differ between these broad habitat types (Wilson *et al.*, 1997).

The five main categories of broad habitat type were then sub-divided into nine dominant habitat types (DHTs). "Woodland" squares were allocated to be either deciduous (including mixed woodland and yew) or coniferous, depending on which of these two LCM2000 classes accounted for the higher proportion of land cover within that square. Similarly, "Upland" squares were allocated to be either heather and bog (including fen, marsh or swamp) or acid grassland, whilst agricultural squares were allocated to be either (a) arable and horticultural, (b) improved grassland or (c) natural (neutral or calcareous) grassland. "Urban" squares remained "urban" as no sub-classes were given within the target classes of LCM2000.

The number of 1km^2 squares assigned to the "littoral" (broad) habitat type was small (1264, of which only 473 are on the Scottish Mainland or Arran) and this habitat type was therefore not included within the survey design. Some of these squares were used within the analysis however (see Appendix O).

Scotland was also divided into nine different regions (Figure 2), based on amalgamations of Local Authority areas (as shown in Table 1). Stratification by region was used (a) to ensure good geographical coverage, (b) to allow for a potentially uneven spatial distribution in the numbers of volunteers available to conduct the survey and (c) to allow for regional comparisons to be made at the analytical stage.

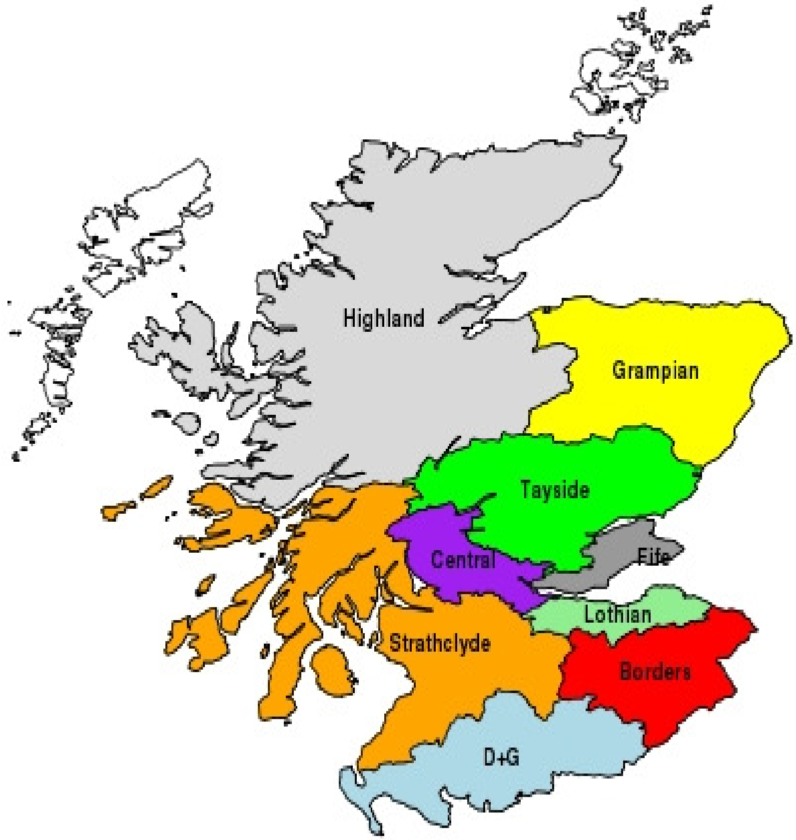

Figure 2. The nine regions used in the survey design.

Table 1. Definitions of geographical areas used in the design and analysis of the survey. "Local authority areas" represent the unitary administrative areas in use since 1996, whilst "Regions" represent the administrative regions used from 1973-1996. "Sub-regions" divide three of the larger regions (Strathclyde, Tayside and Grampian) into smaller areas, and are used for reporting purposes.

Region	Local authority area	Sub-region
Grampian	Aberdeen City	Aberdeen-shire & City
	Aberdeenshire	
	Moray	Moray
Tayside	Dundee City	Angus & Dundee City
	Angus	
	Perth & Kinross	Perth & Kinross
Strathclyde	Argyll & Bute	Argyll & Bute
	East Ayrshire	Ayrshire & Arran
	South Ayrshire	
	North Ayrshire	
	Glasgow City	Clyde Valley
	Inverclyde	
	Renfrewshire	
	East Renfrewshire	
	South Lanarkshire	
	North Lanarkshire	
	East Dumbartonshire	
	West Dumbartonshire	
Central	Stirling	
	Falkirk	
	Clackmannanshire	
Lothian	City of Edinburgh	
	East Lothian	
	West Lothian	
	Midlothian	
Highland	Highland	
Borders	Borders	
Fife	Fife	
Dumfries & Galloway	Dumfries & Galloway	

3.1.3 The sampling strategy

A set of 1000 $1km^2$ squares was selected according to the method of stratified random sampling (Cochran, 1977; Barnett, 2003). A $1km^2$ sampling unit was chosen because the time required to survey a site of this size was considered appropriate for volunteer surveyors. A $1km^2$ sampling unit would also be relatively easy to locate, delineate and navigate through on the ground. A sample size of 1000 $1km^2$ squares was chosen as it was anticipated that this would be the maximum number of survey squares that volunteer surveyors could be expected to survey within the given timeframe.

Stratification allows control over the number of $1km^2$ squares sampled in each strata. A total of 72 strata were used in constructing the design, based on combinations of the eight DHTs and the nine regions.

Stratification allows intentional under-sampling of those strata that are of least interest and over-sampling of those strata that are of greatest interest, so that the number of surveyed $1km^2$ squares per stratum need not necessarily be proportional to the land area covered by that stratum. The primary aim of this survey was to obtain a precise estimate of the national population of badger main setts. The level of precision can be improved by under-sampling strata which would be expected in advance to have low badger sett densities. This is because strata with low sett densities make a relatively small contribution to the overall number of setts and because variability is relatively low in areas with low sett densities. The number of $1km^2$ squares within heather and bog, and acid grassland DHTs was therefore reduced on the grounds that badger sett densities might be expected to be several times lower in these habitats than in other habitat types (e.g. Wilson *et al.*, 1997, Table 3.1). The number of $1km^2$ squares assigned to Highland region was also reduced. These reductions allowed an increase in the number of $1km^2$ squares assigned to all other regions and strata. It was also predetermined that a minimum of 40 squares should be allocated to each region. The number of $1km^2$ squares assigned to each stratum is shown in Table 2, and a more detailed description of how these numbers were derived is given in Appendix A.

Table 2. Number of 1km^2 squares allocated to each stratum (combination of geographical region and DHT) within the original study design.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	9	28	11	1	8	25	7	0	89
Central	5	5	6	2	6	12	7	2	45
D+G	17	4	25	3	3	59	10	0	121
Fife	0	27	0	1	0	6	1	5	40
Grampian	2	68	24	4	17	32	5	5	157
Highland	13	7	31	11	84	21	9	1	177
Lothian	1	19	0	1	3	8	2	6	40
Strathclyde	16	5	41	8	29	63	37	20	219
Tayside	7	41	10	7	20	17	8	2	112
Total	70	204	148	38	170	243	86	41	1000

1km^2 squares were selected at random from within each stratum. Some slight adjustments were required due to discrepancies in the LCM2000 land cover data (Appendix B).

An additional nine 1km^2 squares in Highland region were subsequently also included in the design, selected from the reserve dataset, as there were higher than expected numbers of volunteers in some parts of this region.

3.1.4 Reserve dataset and substitutions

153 of the resulting 1009 1km^2 squares were found to be unsuitable prior to the commencement of the survey and were substituted (replaced) by another 1km^2 square. The decision to perform a substitution was taken by the Survey Coordinator, according to the following criteria:

- The decision to swap a square should not be influenced by the perceived likelihood of badger sett presence.
- Substitution was permissible only for the following reasons: (a) difficulties with access, (b) safety reasons and (c) no volunteers available to survey the original 1km^2 square.
- Substitutions were to be made within region and habitat type whenever possible.

The replacement squares were taken from a “reserve set” of 1km^2 squares, which were also generated by stratified random sampling. In practice, replacement squares always came from the same region as the original square and almost always also came from the same DHT and 100x100km grid box. Inevitably, there were some systematic differences between the squares that were substituted for and those that they were replaced with: the substitute squares tended to have lower mean altitude, less variation in altitude, higher landscape heterogeneity and a rather different composition of land cover types than the squares that they were designed to replace. Further details of the reasons for substitution, together with detailed comparisons of the characteristics of original and substitute squares, are given in Appendix C.

3.2 Survey methods

3.2.1 Data collection

Data on badger signs and badger setts present within survey squares were collected, along with information on the habitats occurring within the survey square. This was transcribed onto standardised recording sheets (Appendix D).

Badger sett data

Information was collected on all badger setts located within the survey square. For each sett located, confirmation was initially required to ensure that the mammal hole(s) located was that of a badger and not of another mammal. Thus, volunteers were required to locate at least one of the following at the locus: (a) badger spoil heap, (b) badger hair, (c) badger foot print or (d) bedding material used by a badger.

Once this had been confirmed, surveyors were required to count and classify each entrance located. Entrances were classified according to the usage categories of 'well used', 'part used' and 'disused' (Appendix E). Once all entrances had been located and their degree of usage determined, surveyors were then required to determine the category of each badger sett found using information on sett classification provided in the field guide (shown in Appendix F).

For the purposes of this survey, setts were classified into 'main sett' and 'other sett' only. The 'other sett' classification included setts normally classified as 'annexe', 'subsidiary' or 'outlier'. It was felt that this more-detailed sett classification system (Thornton, 1998; Kruuk, 1978; Roper, 1992a; Roper, 1992b) would be unnecessarily complicated for volunteer surveyors, since the key focus of the survey was the collection of main sett data.

For each sett found, volunteers were required to provide an 8-figure grid reference and detail the habitat in which the sett was directly found. Habitat mapping was conducted using habitat types and codes provided in the field guide (shown in Appendix G). Surveyors were also requested to check any badger setts located for evidence of human disturbance, such as digging or hole blocking, and to record this accordingly. Badger setts located were marked on a 1:10000 scale OS map.

Badger signs

The collection of data on the presence or absence of badger signs was deemed useful in order to provide an indication of badger activity levels at each site. Gross changes in activity levels between successive surveys could also be used to assess population change more accurately (Sadlier *et al.*, 2004).

It was considered that the detailed recording of badger signs would be too onerous for volunteers in the field and unnecessary in determining overall activity levels for each survey square. Thus the 1km^2 survey square was divided into nine sub-squares, similar to the system adopted in the previous national badger survey (Wilson *et al.,* 1997), and surveyors were required to record the presence or absence of specific badger signs within the sub-squares.

Badgers signs recorded included badger paths, badger dung pits and latrines, badger hairs and badger prints. Badger foraging signs were not included as they were considered too difficult for volunteer surveyors to positively identify.

Habitat data

Although land cover information was available for each survey square through LCM2000, it was deemed useful for surveyors to also record habitat information in the field. This would allow any changes in land cover since the collection of data for LCM2000 to be identified, would provide information on the habitat(s) found in the immediate vicinity of badger setts and would generate more detailed information on habitat features specifically relevant to badgers (e.g. 'linear features' could be identified further in the field, with hedgerow habitat being particularly relevant to badgers).

Sixteen broad habitat types and their associated codes were used when recording habitat information, as adapted from Haines-Young *et al.* (2000) and shown in Appendix G. This recording scheme was detailed in the field guide provided to the volunteers. Some habitat types were grouped together for ease of recording. For example, grassland was categorised into 'improved grassland' and 'other grassland' only. It was felt that this level of detail was sufficient for the purposes of the survey and that surveyors may have found the more detailed classification of neutral, acid and calcareous grassland too complicated and time-consuming. Habitat information was recorded on 1:10000 scale OS maps, using instructions provided in the field guide.

Other information recorded

Surveyors were also requested to provide information on any Health and Safety or Access issues encountered, along with details of any areas of the survey squares not surveyed and the identification of any badger setts adjacent to the 1km^2 survey square. Surveyors were also required to expand on the details of any observations of human disturbance to badger setts and were given the opportunity to record information on other wildlife encountered during the course of their survey work.

3.2.2 Field survey technique

A systematic survey of each 1km^2 survey square was conducted in accordance with established standardised badger surveying techniques and as used in previous national surveys (Wilson *et al., 1997*). Surveyors were required to walk all linear features and habitat boundaries within their 1km^2 survey square, checking for badger signs such as badger paths, badger dung pits/ latrines, badger footprints and badger hair (e.g. badger hair caught on barbed wire fencing).

Where signs were present, surveyors were required to record the type and location of each sign (see Appendix D) and to investigate the site further in order to determine badger sett presence or absence. If a badger sett was located, volunteers were required to record details of the sett (see Appendix D) and continue with a full survey of the remainder of the survey square.

Habitat data were collected and recorded for each site. All volunteers were provided with two 1:10000 scale Ordnance Survey (OS) maps of their survey square, with the 1km^2 grid square highlighted in red. A full-colour copy of each map was provided for fieldwork purposes and a black and white copy was provided for detailed habitat mapping and marking the location of badger setts once the survey was completed.

All maps were created by the Survey Coordinator using OS digital tiles, obtained through a Digital Mapping Licence provided by Ordnance Survey.

3.2.3 Survey timing

The survey consisted of two main survey periods: the first from September 2007 to May 2008 and the second from September 2008 to May 2009. Survey work was not conducted over the summer of 2008 due to surveying restrictions created by increased vegetation growth at this time of year. Volunteers were requested to avoid surveying during the winter months of December and January as field signs are less abundant at this time of year due to badgers entering into a period of torpor or reduced activity (Fowler & Racey, 1998).

3.3 Quality assurance

3.3.1 Standardising recording procedures

As the survey involved a large number of surveyors, it was felt necessary to standardise recording procedures to ensure the data collected were of adequate quality. The first stage was to create a standardised and systematic surveying method as outlined above. Secondly, the following methods were employed in order to control the quality of survey work and the manner in which data were collected.

3.3.2 Design of recording sheets

Standardised recording sheets were designed to be simple to use and to follow logically the manner in which surveyors would locate recordable information in the field. For example, the first page of the recording sheet focused on the recording of badger signs, the first recordable finding which surveyors would be likely to locate in the field. The second page focused on the recording of badger setts, which would normally follow on from locating badger signs.

A blank section was also provided for recording any other relevant information. This provided surveyors with the opportunity to communicate clearly any areas within the survey square which were not surveyed. It was then possible for the Survey Coordinator to determine whether or not another full survey of the area would be required.

The standardised recording sheet is shown in Appendix D.

3.3.3 Surveyor training

In order to take part in the survey, volunteer surveyors were required to undertake a free one-day training course led by the Survey Coordinator. The training course was designed to provide new surveyors with the skills required to undertake a survey for the project and to provide information on the survey protocol for more experienced surveyors.

Each training event comprised a classroom-based theory session followed by a local fieldwork session. The theory training session provided a comprehensive overview of badgers and badger surveying, including information on health and safety, legal responsibilities, grid referencing and survey methodology. The fieldwork session provided surveyors with the opportunity to view badger setts and signs typical of their local area and to practice recording badger setts, signs and habitat data in the required format under expert supervision. The fieldwork sessions provided the Survey Coordinator with the opportunity to meet the surveyors and to identify individuals who would particularly benefit from further training and support.

The training package was piloted in late 2006 to a varied audience of 15 individuals. The purpose of the pilot training was to ensure that the training to be provided would be effective in producing competent surveyors. The pilot training session tested the contents, duration and delivery of the theory training. Furthermore, the fieldwork training was tested to ensure (a) that the format was appropriate, (b) that the time spent in the field was sufficient, (c) that the group size was appropriate and (d) that the recording process was practical in the field. To test the overall efficacy of the training package, participants were then taken to a further fieldwork site and asked to conduct a mock survey and record their findings, with a full feedback session and questionnaire at the end of the session. The pilot session was also attended by an experienced badger surveyor who acted as a silent observer and who also provided feedback. The pilot training session proved useful in providing feedback, leading to improvements in the overall training package.

Training events were held across Scotland in 42 locations from early 2007 until late 2008, with over 570 volunteers being trained to take part in the survey. The locations of training events are shown in Figure 3.

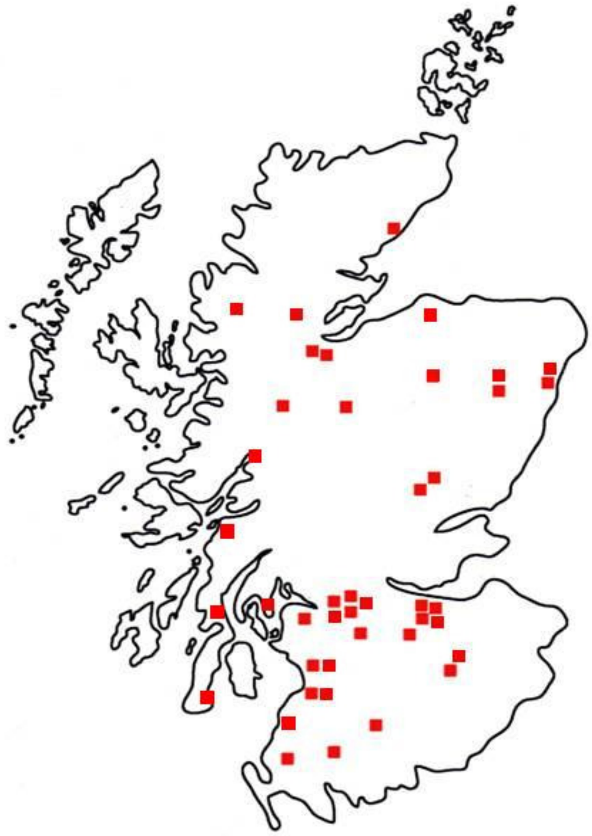

Figure 3. The locations of training events for the Scottish Badger Distribution Survey

3.3.4 Survey packs

At each training event, surveyors were provided with a take-home survey pack (as shown in Appendix H). The purpose of the survey pack was to supplement the information provided in the training events and to act as an aide-mémoire for surveyors prior to, and whilst undertaking, fieldwork.

The survey pack consisted of the following information:

- A5 splash-proof field-guide including information on badger habitats, setts and signs; signs of other mammals; recording and classifying badger setts; human disturbance to badger setts; habitat types including descriptions and photographs; instructions for habitat mapping and a checklist for use prior to undertaking fieldwork
- Ordnance Survey leaflet 'Map reading made easy'
- Scottish Outdoor Access Code 'Know the Code before you go' leaflet
- Health and Safety advice
- Landowner information sheet
- Recording sheet
- Grid referencing overlay
- Badger information leaflet

3.3.5 Audit of data quality

The final stage of the quality assurance procedures involved the checking of a sample of data at the end of the survey period to assess the accuracy of data collected. The main types of errors associated with this type of recording are false positives and false negatives. False positives would occur in situations where surveyors had classified a hole of another mammal as that of a badger or where surveyors had classified an 'other' category of badger sett as a main sett. False negatives would occur when surveyors had not detected a main sett when a main sett was in fact present.

Resurvey squares were selected by the Survey Coordinator to cover all the regions and DHTs. They were selected to ensure that a range of volunteer surveyors were covered, classified by the season when they were trained and when they carried out the survey. Care was taken to include surveys from situations where volunteers were trained during the first survey season but subsequently carried out their survey work during the second survey season. This was to ensure that the time gap that occurred for some surveyors between training and surveying had not affected the quality and accuracy of the data collected.

The auditing process was conducted in three stages: one stage to assess false positives and two stages to assess false negatives.

Firstly, to assess the extent of false positives present, expert resurveys were conducted in a sample of 22 survey squares where the original surveyor had recorded a main sett. Resurveys of the 22 survey squares selected were undertaken by experienced badger surveyors. They were given details of the exact location of all setts recorded (both marked on maps and as an eight-figure grid reference).

Experienced badger surveyors were selected by the Survey Coordinator as being suitably skilled to identify a badger main sett in their local area. Experienced badger surveyors were requested to visit the sites to confirm whether an active badger main sett was present in the location stated by the original surveyor. The findings of the original surveyor were confirmed by the experienced badger surveyors in all but one of the 22 cases. The one exception was in the Highland region, where a surveyor who lived and had been trained outwith the region had misclassified what the experienced badger surveyor deemed to be an 'other' badger sett as a badger main sett. This was considered a unique situation which was not representative of the majority of survey work conducted.

Secondly, to assess the extent to which surveyors missed a main sett when a main sett was in fact present, 15 squares were resurveyed by experienced badger surveyors. These surveys were specifically targeted at areas in which the preliminary survey results appeared to show lower badger densities than might have been expected. The findings of the original surveyor were confirmed in all 15 cases.

Finally, a very small number of blind resurveys (four) were also conducted. In this instance, a second surveyor surveyed a square that had already been surveyed by both a volunteer surveyor and an experienced badger surveyor, without knowing the results of either of these surveys (and without knowing that these squares had already been surveyed). Three of these blind resurveys were conducted in squares for which the experienced badger surveyor and original surveyor had both found a main sett. In all three of these cases the resurvey volunteer also found a main sett. The remaining blind resurvey was taken at the square in which the resurvey by the experienced badger surveyor disagreed with the original volunteer survey. In this case the resurvey volunteer was in agreement with the experienced badger surveyor that no main sett was present. The blind volunteer resurveys therefore found no additional evidence of any non-detection or misclassification.

The scope of the survey squares selected for the audit is given in Table 3 and a summary of the results of the audit of data quality is given in Table 4.

Table 3. Numbers of 1km^2 squares within each stratum that were covered by a resurvey (audit). Black: squares in which the original (volunteer) survey identified at least one main sett as being present, red: squares in which the original volunteer identified no main sett as being present, blue: a mixture of the two.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	1		3	1	3				8
Central						1			1
D+G	1		1	1					3
Fife		1				1			2
Grampian		1	1			1			3
Highland	1			2					3
Lothian						2		2	4
Strathclyde		1				1	1	2	5
Tayside		5	1	1		1			8
Total	3	8	6	5	3	7	1	4	37

Table 4. Summary of the results of the first two stages of the audit.

Main sett records at present? Volunteer	Main sett records at present? Expert	Status of volunteer record	Volunteer error?	Number of Squares
Yes	Yes	True presence	No	21
	No	False presence	Yes	1
No	Yes	False absence	Yes	0
	No	True absence	No	15

3.4 Data management

3.4.1 Datasets employed

The data transfer to electronic format was comprehensively checked and the main dataset was stored in an Excel® spreadsheet, with an additional spreadsheet providing more detailed information from the results of the survey. Both datasets were password-protected to comply with Data Protection Act.

The purpose of the main dataset was to act as an administrative tool in managing volunteers and square allocations and for monitoring progress towards achieving adequate survey coverage. The main dataset included:

- a unique identification number for each $1km^2$ survey square,
- the 4-figure grid reference, region and DHT for each $1km^2$ square,
- details of any substitutions, including reasons for substitution and the grid reference of the newly allocated $1km^2$ survey square,
- the name of the proposed surveyor for each square including whether the square had been accepted for survey and whether the necessary information had been provided to the surveyor,
- whether the survey had been completed, including details of when the surveyor had agreed to complete the survey,
- whether badger setts or signs were recorded in the square, including the highest category of sett found in each survey square.

The purpose of the results database was to collate the field data in one location, in a format that would be amenable to analysis. The results dataset included:

- the unique identification number for each $1km^2$ survey square,
- the 4-figure grid reference,
- the date(s) visited,
- the activity scores for each of the badger signs recorded (paths, prints, dung pits/latrines and hairs),
- a separate field for each sett located within each survey square including the category of sett, the number of entrances and their individual degree of usage, and an 8-figure grid reference,
- the habitat in which the sett was directly located,
- any evidence of human disturbance and any supplementary information provided by the surveyor.

3.4.2 Square allocation

Survey squares were allocated to individuals and groups by the Survey Coordinator. This process involved matching surveyor home postcodes with the nearest available survey squares. Priority was given to surveyors who were reliant on public transport, either by allocating the closest or most accessible survey square. Surveyors were offered a number of survey squares, with the exact number offered depending on their individual time commitment (as stated at point of registration) or the number of available squares and/or surveyors in their area.

All surveyors were provided with a grid reference of their proposed allocation(s) and a location map highlighting the proposed survey square(s). Surveyors were requested to accept or decline their proposed allocation(s) within a set timescale. This process was fully recorded by the Survey Coordinator in the main survey database. On acceptance, surveyors were issued with 1:10000 scale OS maps of their survey squares, including one colour copy for use in the field and one black and white copy for marking final habitat information and the location of badger setts. Surveyors were also provided with prepaid, pre-addressed envelopes in which to return the results of their survey work to the Survey Coordinator. This step was taken to reduce the time taken to return results once surveys were completed.

In total, 994 survey squares were allocated to volunteer surveyors, with an uptake of 944 survey squares. This represented an uptake rate of approximately 95%.

3.4.3 Data checking

On receipt of each survey return, the Survey Coordinator checked each map and recording sheet for any obvious errors before acknowledging receipt either by post or email, entering basic data into the main database and scanning each map and recording sheet to create a back-up of image files in jpeg format for all data received.

Prior to entering data into the more detailed results database, a comprehensive check of each return was conducted, including the checking of any grid references and habitat information provided by the surveyor. The relevant surveyors were contacted to clarify any questions arising from the data checks and a decision was made by the Survey Coordinator as to whether a repeat survey was required for any of the survey squares.

3.5 Monitoring progress

Regular contact was maintained with surveyors throughout the survey period to keep track of when and where survey work was taking place and to establish in advance areas of potential low coverage. Targets were agreed between Scottish Badgers, BioSS and the Scottish Government for the total number of 1km^2 squares to be surveyed at key points throughout the project.

3.5.1 Monitoring coverage across region and habitat strata

In addition to the general targets set with regard to the overall number of survey returns, targets were also set to ensure that adequate coverage was achieved within each of the DHTs, geographical regions and region-by-DHT combinations. Using the original dataset of 1000 survey squares, a minimum target of 67% coverage for each DHT within each region was set. Levels of coverage were calculated by Biomathematics and Statistics Scotland (BioSS) at various points through the survey and strata with relatively poor coverage were identified. The Survey Coordinator then worked on either allocating squares within these strata to existing surveyors or on recruiting and training new volunteers to survey them.

3.5.2 Monitoring coverage within regions

Coverage was also monitored on a finer scale within geographical regions to ensure that there were no significant gaps in recording effort within any one region. An analysis was conducted to identify the location of any particularly isolated un-surveyed squares. Information was produced at various stages of the project on the location of un-surveyed squares from the original dataset that were located more than (a) 25-km and (b) 10-km from the nearest surveyed square. In mid 2008 these analyses identified three geographical clusters containing a significant gap in recording effort (Figure 4). The Survey Coordinator used this information to conduct a targeted recruitment drive, further training events and square allocations in the required areas in the autumn of 2008 and as a result the gap was filled by early 2009.

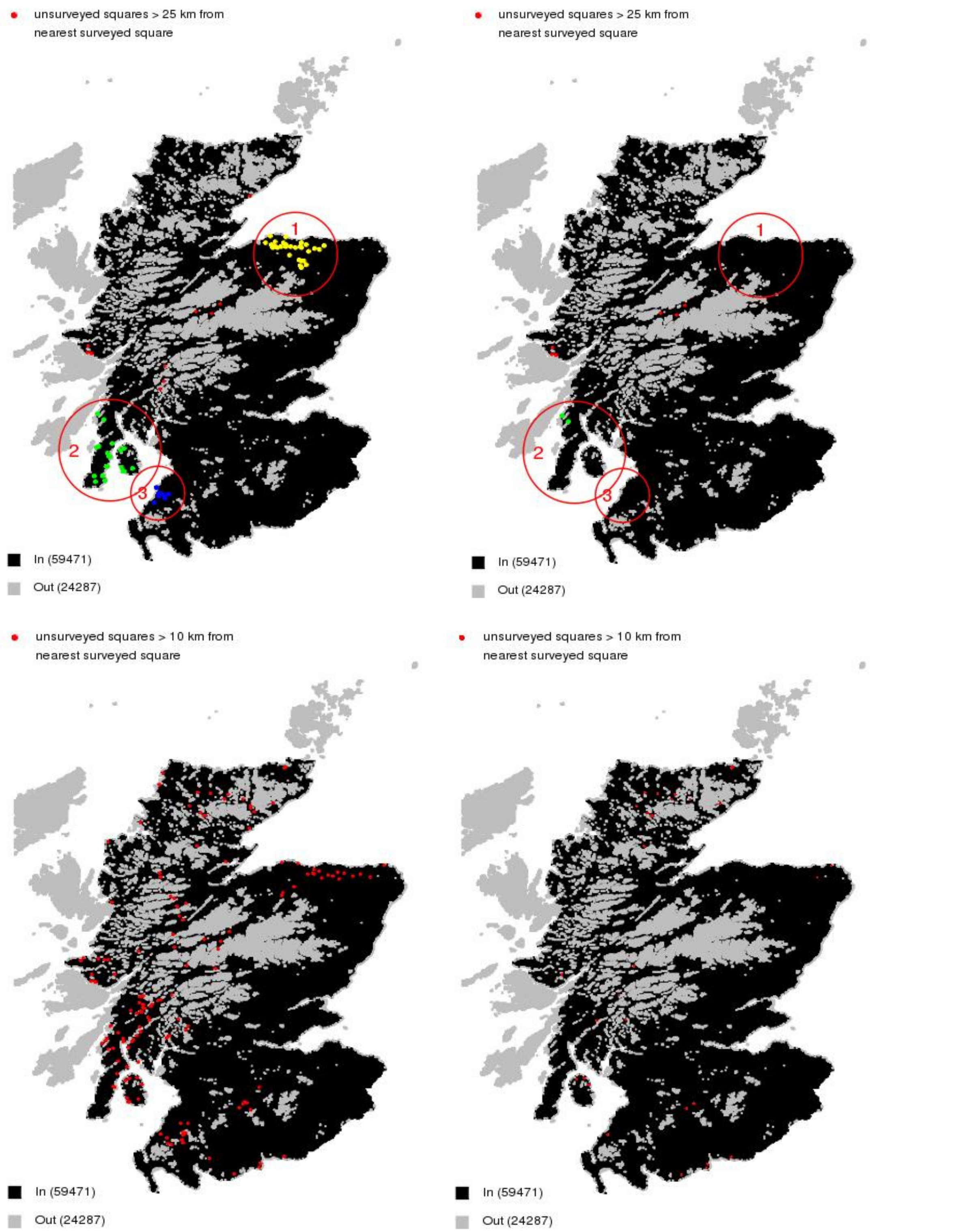

Figure 4. The location of un-surveyed squares that were located more than 25 km (top) or more than 10km (bottom) from the nearest surveyed square in mid 2008 (left) and early 2009 (right).

3.6 Unsurveyed squares

Data were received for 877 of the 1009 squares in the final design (Figure 5) with no data available for the remaining 132 squares. Thus, the proportion of missing data was relatively low (13.1%). The exact reasons for data being missing were variable and not always known. However, the continual monitoring of progress and appropriate reallocation of resources by the Survey Coordinator (Section 3.5) ensured that

(a) no more than one-third (33%) of the data were missing within any individual stratum (Table 5);

(b) at least 40 squares were surveyed within each region; and

(c) no unsurveyed square was more than 15km from the nearest surveyed square.

There were inevitably, however, still some systematic differences between the characteristics of surveyed and unsurveyed squares; full details of these comparisons are given in Appendix I.

Table 5. Number of $1km^2$ squares actually surveyed in each stratum.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	8	28	8	1	8	24	7	0	84
Central	4	5	5	2	5	11	6	2	40
D+G	17	3	20	3	3	54	10	0	110
Fife	0	27	0	1	0	6	1	5	40
Grampian	2	54	20	5	16	25	4	5	131
Highland	12	8	25	11	68	23	9	1	157
Lothian	1	19	0	1	3	8	2	6	40
Strathclyde	11	4	29	6	21	48	27	19	165
Tayside	7	41	9	8	19	17	7	2	110
Total	62	189	116	38	143	216	73	40	877

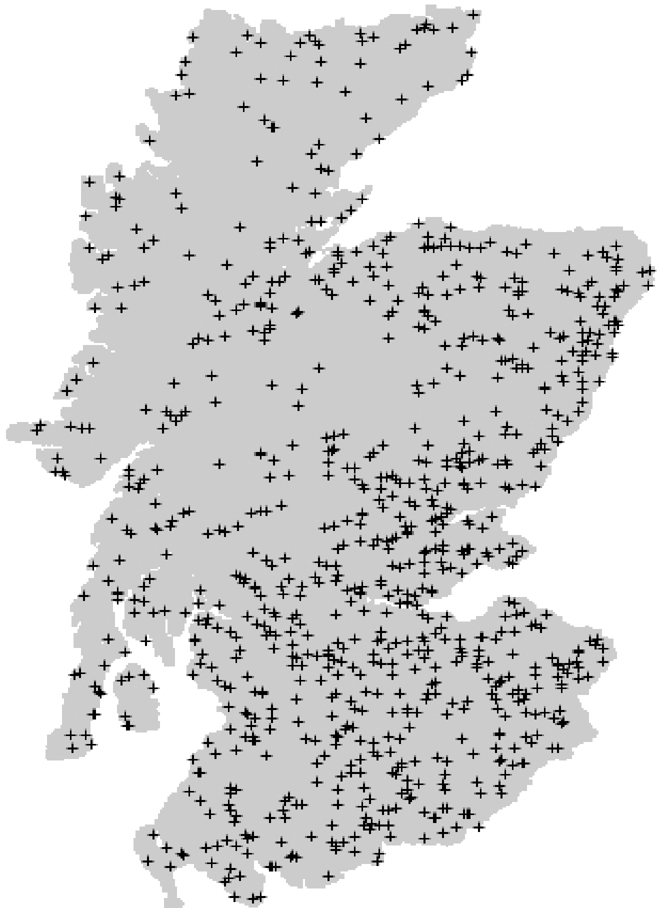

Figure 5. Map showing the geographical distribution of the 877 squares that were surveyed.

4. Volunteer involvement

4.1 Volunteer recruitment

Obtaining a large network of competent and reliable surveyors was essential to the success of the survey. Publicity was initially targeted towards those with an existing interest in wildlife. Simple eye-catching survey posters were created and forwarded to the main country parks and countryside visitor centres across Scotland. Press releases and project information was issued to a wide range of organisations and magazines including BBC Wildlife Magazine, Scottish Wildlife Trust, Forestry Commission Scotland, Local Authority Ranger Services, National Trust for Scotland, RSPB Wildlife Explorers, IEEM, SCENES, John Muir Trust, Trees for Life, Reforesting Scotland, Woodland Trust, BTO, The Mammal Society, Mammals Trust UK, Scottish Countryside Rangers Association, Community Woodlands Association, Biological Recording in Scotland and various local wildlife and biological recording groups and newsletters. The survey was publicised through BBC Radio Scotland's 'Out of Doors' programme. Several public talks and conference presentations on the survey were held throughout Scotland and the Survey Coordinator attended various wildlife and countryside events and open days.

Alongside the publicity drive, a survey factsheet was produced (Appendix J) together with a sign-up sheet for potential surveyors to register their interest in taking part in the project (Appendix K). The purpose of the survey factsheet was to provide prospective surveyors with information on: the purpose of the project; what their role would be; the expected time commitment; the timescale of the project; the level of experience required; the level of training provided; what would be done with the data collected and how to register as a volunteer. Clear communication from the outset, in terms of what would be required from a volunteer surveyor, assisted in managing volunteer expectations and in reducing the potential for volunteer drop-off once the project was underway.

The volunteer sign-up sheets contained a tear-off section for volunteers to return to the Survey Coordinator, providing contact information and details of any previous experience. On receipt of sign-up sheets, the Survey Coordinator contacted the sender to acknowledge and thank them for their interest, and to inform them when they would next be contacted with regard to training and subsequent survey work. The information from all the registrations of interest was collated in Access® format. Over 600 expressions of interest were obtained over the course of the survey.

4.2 Volunteer support and communication

A determined effort was made at every stage of the project to ensure that the volunteer network was provided with sufficient information, training, support and feedback on the progress of the survey. This would ensure that volunteers felt confident in conducting their survey work, that they were motivated and felt included in the survey and that they were aware of the importance of their contribution towards the progress and success of the survey.

The training sessions were an excellent tool in achieving confidence within the volunteer base and in assisting the Survey Coordinator in building good relationships with the volunteer network. Group sizes were purposely kept small at the training events to ensure that the Survey Coordinator could dedicate individual time to each volunteer and gain an understanding of how best to support each individual in their survey work. The survey packs were also a useful tool in communicating information to volunteers. To ensure that volunteers were provided with ongoing support and information following the training events, a range of measures were employed:

A series of expert-led group surveys were arranged during the two main survey periods, whereby volunteers who were lacking in confidence or unable to recall certain elements of the original training programme could benefit from the provision of further training and field experience. In addition, a network of Regional Coordinators was available to provide support and assistance at a local level. The Survey Coordinator was on-call throughout to answer any volunteer queries. This operated effectively, with many volunteers providing regular feedback and updates to the Survey Coordinator.

Ongoing communication with the volunteer network was achieved through regular emails from the Survey Coordinator, providing clear information on survey timing and deadlines, and requesting specific information from volunteers about their survey plans. Care was taken to ensure that all correspondence was conducted politely and in a manner which provided volunteers with the opportunity to easily express any personal concerns (over meeting deadlines, for example).

A survey e-newsletter was also produced on a monthly basis during the main survey periods and on a bi-monthly basis in the interim periods (Appendix L). The purpose of the newsletter was to provide volunteers with further support and motivation and to communicate on the progress of the survey. The newsletter included further advice on carrying out a badger survey, information on survey coverage and a section where volunteers were encouraged to share their experiences and ask questions of the Survey Coordinator.

An additional benefit of the regular newsletters was the opportunity provided to inform volunteers of any areas of poor coverage and to request assistance in these areas. This approach proved very successful and many volunteers came forward to assist with further survey work as a result.

4.3 Volunteer retention

Low drop-off rates were recorded in the time period between prospective volunteers registering interest and subsequently signing up to attend a training event. Following training, a volunteer retention rate of over 90% was achieved (i.e. over 90% of all volunteers who attended a training session then proceeded to accept, complete and return at least one survey). In the small number of situations where volunteers were unable to accept or complete a survey, the majority of volunteers contacted the Survey Coordinator to inform Scottish Badgers of their situation. The Survey Coordinator then marked this information alongside the relevant survey squares in the main database and the survey square was then deemed available for re-allocation.

Further to the support and communication detailed above, various measures were adopted to reduce volunteer drop-off throughout the survey and to maximise survey returns. All volunteers who returned their survey results by the agreed deadlines were entered into a free prize draw to win a range of prizes. Volunteers were further encouraged to submit survey returns with an offer of one year of free membership to Scottish Badgers and the option of further free training.

5. Statistical methods

5.1 Estimating the total number of badger main setts in Scotland

One of the key objectives of the survey was to produce an estimate of the total number of badger main setts within the whole of Scotland. This in turn would provide a measure of badger distribution across Scotland and a crude indication of badger density.

A simplistic way to achieve this would have been to divide the number of badger main setts located by the number of $1km^2$ squares surveyed and then multiply this by the total number of $1km^2$ squares that could conceivably contain badgers. However, this approach would over-estimate the total number of badger main setts because it ignores the fact that the survey design deliberately under-sampled certain strata (regions and DHTs) that were believed to have relatively low badger densities and subsequently over-sampled certain strata that were believed to have relatively high badger densities.

Estimating the total number of main setts separately for each stratum and then adding across strata eliminates this potential problem. This is the standard statistical approach for analysing data that have been collected via stratified random sampling. In addition, standard errors and confidence intervals, which enable us to quantify the uncertainty involved in estimating the total number of main setts, can be computed using standard formula (full technical details of this process are detailed in Appendix M).

Two complications arose in this process. Firstly, the strata that were used for the calculations should, ideally, have been identical to those that were used in the design of the sampling strategy. Secondly, the calculations also relied on there being at least two surveyed squares within each stratum. In practice, however, six of the 72 strata only contained one surveyed square and a further six strata contained no surveyed squares whatsoever. Strata therefore needed to be merged or pooled in some way before estimates and standard errors could be derived. The impact of different strategies for merging strata is explored in Appendix N. It was concluded that all approaches which retain an eight group classification of DHTs lead to very similar estimates and that the exact details of the rules used to merge strata were consequently of minor importance. Thus stratification was conducted using DHT-by-region combinations when calculating the national estimates as these were most closely related to the strata used in constructing the design. Strata with sparse data were merged with strata that corresponded to the same DHT and a neighbouring region so that there were a total of 60 strata.

It was assumed that squares relating to islands other than Arran would not be included in the calculation of “the total number of $1km^2$ squares that could conceivably contain badgers” since these islands were already known not to support badger populations. It was, however, less clear how squares that were excluded from the sampling frame on other grounds (high altitude, bogginess, dominated by littoral habitats, predominantly sea or open water) should be treated.

Thus, the following two possible scenarios were considered in the analysis:

Scenario A. Badger densities were taken as zero for all excluded squares.

Scenario B. Badger densities for excluded squares on the Mainland and Arran were considered to be equal to the density of the stratum to which they belong (and excluded squares were thus treated in the same way as included squares). Slight modifications were needed in order to deal with squares for which the DHT was littoral (as detailed in Appendix O).

Scenario A clearly placed a lower bound on the badger densities for the excluded squares, and Scenario B probably also placed an upper bound on these densities (since the densities in excluded squares were believed to be lower than that in similar squares that were included in the survey).

5.2 Other quantities

Identical methods to those outlined above were also used to produce estimates for individual regions and individual DHTs, and similar methods were also used to produce estimates for the percentage of $1km^2$ squares that (a) contain an active main sett (b) contain any active sett (either main setts or other setts) or (c) contain current badger activity (either active setts or signs).

For three regions (Strathclyde, Tayside and Grampian) estimates were also produced for sub-regions, based on amalgamations of local authority areas (Table 1). The rationale behind this decision was that the three larger regions detailed above were relatively heterogeneous and as such would benefit from analysis on a finer geographical scale. The above areas were also deemed relatively straightforward to divide into smaller geographical areas based on administrative units. The sub-regions were chosen in such a way that they were based on grouping adjacent local authority areas and that they contained at least 30 surveyed squares, since it was considered not meaningful to produce estimates for areas that contained very little data. This requirement led to there being three sub-regions within Strathclyde, two sub-regions within Grampian and two sub-regions within Tayside. The Highland region was not divided into sub-regions.

5.3 Statistical Software

All analyses were performed using Version 2.8.1 of the R statistical programming environment (R Development Core Team, 2009).

6. Results

6.1 Data collected on badger setts and signs

In total, 877 survey returns were received by the end of the final survey period on 31st May 2009. This represented a return rate of over 90%. Of the 877 squares surveyed, 585 squares (66.7%) were found to have no badger records of any kind, 4 squares recorded only a disused main sett, and the remaining 288 squares (32.8%) showed some evidence of current badger activity. 224 squares (25.5%) contained an active badger sett of some kind (64 squares contained badger signs but no actual setts), and 136 squares (15.5%) contained an active badger main sett.

A total of 169 active badger main setts were identified by the survey, within 135 individual 1km^2 squares (there was one further square in which main setts were identified but the number of main setts was not recorded so this record has been excluded from analyses of main sett numbers). The majority of the 135 squares (109 squares, corresponding to 81%) contained a single main sett, with 20 squares containing two setts and just 6 squares containing more than two setts. The maximum number of main setts within any square was four.

6.2 Access issues encountered

Access issues were reported by surveyors in 29 out of the 877 survey squares (corresponding to approximately three percent of sites surveyed).

Two incidents were reported in the Scottish Borders, two in Central region, five in Dumfries and Galloway, two in Fife, one in Grampian, four in Highland, two in Lothian, four in Strathclyde and seven in Tayside.

The majority of access restrictions were deemed reasonable e.g. bull or lambs in fields, construction/forestry work, shoots taking place or the presence of working quarries or airfields.

A small number of access restrictions enforced were felt to be unreasonable but for the majority of survey squares, landowners were fully cooperative with surveyors. In many cases, landowners showed interest in the survey and assisted surveyors by providing useful information.

6.3 Health and Safety incidents reported

No accidents or injuries incurred whilst undertaking fieldwork were reported by surveyors during the course of the two survey periods.

6.4 Evidence of human disturbance to badger setts encountered

Evidence of human disturbance to, or in the vicinity of, badger setts was reported in 17 out of the 877 survey squares (corresponding to approximately two percent of sites surveyed). Human disturbance ranged from the presence of old crowning down holes (a typical sign of badger digging activities) to hole blocking, snares at setts, trees felled on top of setts and the presence of a live badger in a cage in one instance. All incidents were reported to the Species Protection Officer at Scottish Badgers and to the relevant authorities where necessary.

6.5 Scotland-wide estimates of badger activity

Table 6 shows estimates for (a) the overall number of badger main setts within Scotland, (b) the mean number of main setts per $1km^2$ square, (c) the total number and percentage of $1km^2$ squares that contain at least one main sett, (d) the total number and percentage of $1km^2$ squares that contain at least one sett of any kind and (e) the total number and percentage of $1km^2$ squares that contain any form of current badger activity (either badger setts or signs). The differences between Scenarios A and B were fairly small, relative to the uncertainty associated with the estimates under each scenario (i.e. the estimate under Scenario B always lay well within the 95% confidence interval about the estimate under Scenario A, and vice versa). When reporting the results, the lower limit of the 95% confidence interval under scenario A and the upper limit of the 95% confidence interval under scenario B were given on the grounds that this range reflects both sampling uncertainty (resulting from the fact that only approximately 1% of $1km^2$ squares within Scotland have actually been surveyed) and uncertainty about the habitat suitability of squares that were excluded on the grounds of health and safety (e.g. the difference between scenarios A and B). The results suggest that there were likely to be between 7.1% and 10.4% of $1km^2$ squares that contain at least one main sett, between 12.7% and 17.2% of $1km^2$ squares that contain at least one active sett of some kind and between 17.2% and 23.2% of $1km^2$ squares contain some form of current badger activity, and that there were a likely to be a total of between 7300 and 11200 main setts within Scotland.

Table 6. Estimates for the total number of main setts and the number of 1km^2 squares containing a main sett / any active sett / current badger activity within Scotland, based on stratifying by DHT-by-region (and merging regions as appropriate in order to remove sparse strata) and under two different scenarios concerning the treatment of excluded areas. Standard errors and approximate 95% confidence intervals are also shown.

		Excluded areas	Estimate	Standard error	95% confidence interval
Total number of main setts		A	8955	849	(7284, 10625)
		B	9370	925	(7549, 11191)
Mean number of main setts per 1km^2 square		A	0.1069	0.0101	(0.0870, 0.1269)
		B	0.1119	0.0110	(0.0901, 0.1336)
Total number of 1km^2 squares	containing a main sett	A	7069	574	(5942, 8196)
		B	7409	640	(6152, 8666)
	containing any sett	A	12092	724	(10669, 13514)
		B	12748	832	(11111, 14385)
	containing any activity	A	15950	798	(14381, 17519)
		B	17488	982	(15558, 19419)
Percentage of 1km^2 squares	containing a main sett	A	8.44	0.69	(7.09, 9.79)
		B	8.85	0.76	(7.34, 10.35)
	containing any sett	A	14.44	0.86	(12.74, 16.13)
		B	15.22	0.99	(13.27, 17.17)
	containing any activity	A	19.04	0.95	(17.17, 20.92)
		B	20.88	1.17	(18.57, 23.18)

6.6 Estimates for each dominant habitat type

Basic summary statistics for each DHT are given in Table 7. The majority of setts and signs were found within squares dominated by arable farmland or intensive grassland (with 74% of main setts lying within squares having one of these two DHTs). It should be noted that this arises partly because more squares were surveyed in these areas than in the remaining DHTs.

Table 7. Summary of raw survey results for each DHT.

DHT	All squares	Squares surveyed	Number of main setts	Number of 1km^2 squares containing		
				main setts	any setts	any activity
Acid grassland	9227	62	4	4	10	11
Arable	9308	189	57	50	71	90
Coniferous	9134	116	12	8	14	24
Deciduous	895	38	13	9	13	15
Heather & bog	34843	143	5	3	6	11
Intensive grassland	13253	216	68	52	89	111
Natural grassland	5527	73	4	4	9	13
Urban	1356	40	6	6	12	13

Estimated main setts densities are shown in Table 8. Substantial differences between different DHTs were evident but the standard errors were large (relative to the sizes of estimates themselves) indicating a high degree of uncertainty in estimating badger densities for individual habitat types. Comparisons between habitat types should therefore be interpreted with caution. The results suggest, however, that the highest densities were found in squares dominated by arable (an estimate of 0.29 main setts/km^2 under scenario A), intensive grassland (0.27 main setts/km^2) or deciduous woodland (0.30 main setts/km^2), with moderately high densities in urban areas (0.14 main setts/km^2). Estimated densities were much lower in the remaining areas, with 0.09 main setts/km^2 in coniferous woodland, 0.04 main setts/km^2 in natural grassland and 0.04 main setts/km^2 in acid grassland, and the lowest densities of all were found in heather and bog (0.02 main setts/km^2). Very similar results were obtained under Scenario B.

Table 8. Estimated density of main setts for each DHT, based on stratifying by region, together with associated standard errors. Estimates were derived under two different assumptions (A and B) regarding the treatment of excluded squares.

DHT		Number of main setts		Mean number of main setts per 1km^2 square	
		Estimate	*Standard Error*	*Estimate*	*Standard Error*
Acid grassland	A	**384**	197	**0.042**	0.021
	B	**417**	217	**0.045**	0.024
Arable	A	**2739**	360	**0.294**	0.039
	B	**2762**	363	**0.297**	0.039
Coniferous	A	**849**	356	**0.093**	0.039
	B	**867**	366	**0.095**	0.040
Deciduous	A	**265**	74	**0.296**	0.083
	B	**295**	83	**0.330**	0.093
Heather & bog	A	**564**	364	**0.016**	0.010
	B	**807**	490	**0.023**	0.014
Intensive grassland	A	**3598**	486	**0.271**	0.037
	B	**3634**	491	**0.274**	0.037
Natural grassland	A	**207**	96	**0.037**	0.017
	B	**219**	101	**0.040**	0.018
Urban	A	**194**	75	**0.143**	0.055
	B	**207**	79	**0.153**	0.058

Qualitatively similar results were obtained when estimating the percentage of squares that contain main setts, any setts or any form of current badger activity (Table 9).

Table 9. Estimated percentages of 1km^2 squares that include a main sett, any sett or any badger activity for each DHT, based on stratifying by region.

DHT		Percentage of 1km^2 squares containing					
		A main sett		Any sett		Any activity	
		Estimate	*Standard Error*	*Estimate*	*Standard Error*	*Estimate*	*Standard Error*
Acid grassland	A	**4.2**	2.1	**10.3**	3.2	**10.9**	3.2
	B	**4.5**	2.4	**11.3**	3.5	**12.0**	3.6
Arable	A	**25.6**	3.1	**36.8**	3.3	**47.4**	3.2
	B	**25.8**	3.1	**37.1**	3.3	**47.8**	3.3
Coniferous	A	**5.9**	2.0	**11.0**	2.8	**19.2**	3.5
	B	**6.0**	2.1	**11.2**	2.9	**19.6**	3.6
Deciduous	A	**20.3**	5.3	**28.2**	6.2	**32.1**	6.2
	B	**22.8**	6	**31.7**	7.0	**36.0**	7.0
Heather & bog	A	**1.0**	0.6	**2.2**	1.0	**3.9**	1.2
	B	**1.6**	1.0	**3.3**	1.4	**5.9**	1.9
Intensive grassland	A	**20.8**	2.4	**35.8**	2.7	**44.7**	2.7
	B	**21.1**	2.5	**36.1**	2.8	**45.2**	2.7
Natural grassland	A	**3.8**	1.7	**8.6**	2.7	**12.6**	3.2
	B	**4.0**	1.8	**9.3**	2.9	**13.5**	3.4
Urban	A	**14.3**	5.5	**28.2**	7.2	**30.6**	7.3
	B	**15.2**	5.9	**29.9**	7.6	**32.4**	7.7

6.7 Estimates for each region

Table 10 summarises the data for each of the eight regions, whilst Table 11 and Figure 6 provide estimates for the density of main setts within each region. Substantial differences between regions were estimated but again the standard errors were large, relative to the sizes of the estimates themselves, indicating a high degree of uncertainty. Under Scenario A the highest estimated densities were found in Borders (0.38 main setts/km^2) and Lothian (0.37 main setts/km^2), with moderately high densities in Fife (0.21 main setts/km^2), Grampian (0.22 main setts/km^2) and Dumfries and Galloway (0.24 main setts/km^2). Densities in Central (0.03 main setts/km^2), Highland (0.03 main setts/km^2) and Tayside (0.04 main setts/km^2) were much lower, with intermediate densities in Strathclyde (0.09 main setts/km^2). Very similar results were obtained under Scenario B.

Qualitatively similar results were obtained when estimating the percentage of 1km^2 squares that contain main setts, any setts or any form of current badger activity (Table 12 and Figures 7-9).

Table 10. Summary of raw survey results for each region.

Region	All squares	Squares surveyed	Number of main setts	Number of 1km^2 squares containing		
				main setts	any setts	any activity
Borders	4848	84	36	28	38	46
Central	2731	40	2	2	5	8
D+G	6683	110	31	25	44	51
Fife	1447	40	9	9	12	13
Grampian	8938	131	34	26	41	58
Highland	27957	157	13	10	19	28
Lothian	1799	40	15	11	20	25
Strathclyde	15273	165	23	20	38	49
Tayside	7699	110	6	5	7	10

Table 11. Estimated density of main setts for each region, based on stratifying by DHT, together with associated standard errors. Estimates were derived under two different assumptions (A and B) regarding the treatment of excluded squares.

Region		Number of main setts		Mean number of main setts per 1km^2 square	
		Estimate	*Standard Error*	*Estimate*	*Standard Error*
Borders	A	**1838**	350	**0.379**	0.072
	B	**1853**	354	**0.382**	0.073
Central	A	**89**	62	**0.033**	0.023
	B	**90**	63	**0.033**	0.023
Dumfries & Galloway	A	**1588**	333	**0.238**	0.05
	B	**1639**	342	**0.245**	0.051
Fife	A	**303**	83	**0.209**	0.057
	B	**307**	84	**0.212**	0.058
Grampian	A	**1922**	361	**0.215**	0.04
	B	**1932**	363	**0.216**	0.041
Highland	A	**883**	383	**0.032**	0.014
	B	**1018**	444	**0.036**	0.016
Lothian	A	**658**	172	**0.366**	0.096
	B	**673**	176	**0.374**	0.098
Strathclyde	A	**1346**	383	**0.088**	0.025
	B	**1442**	446	**0.094**	0.029
Tayside	A	**328**	152	**0.043**	0.02
	B	**416**	209	**0.054**	0.027

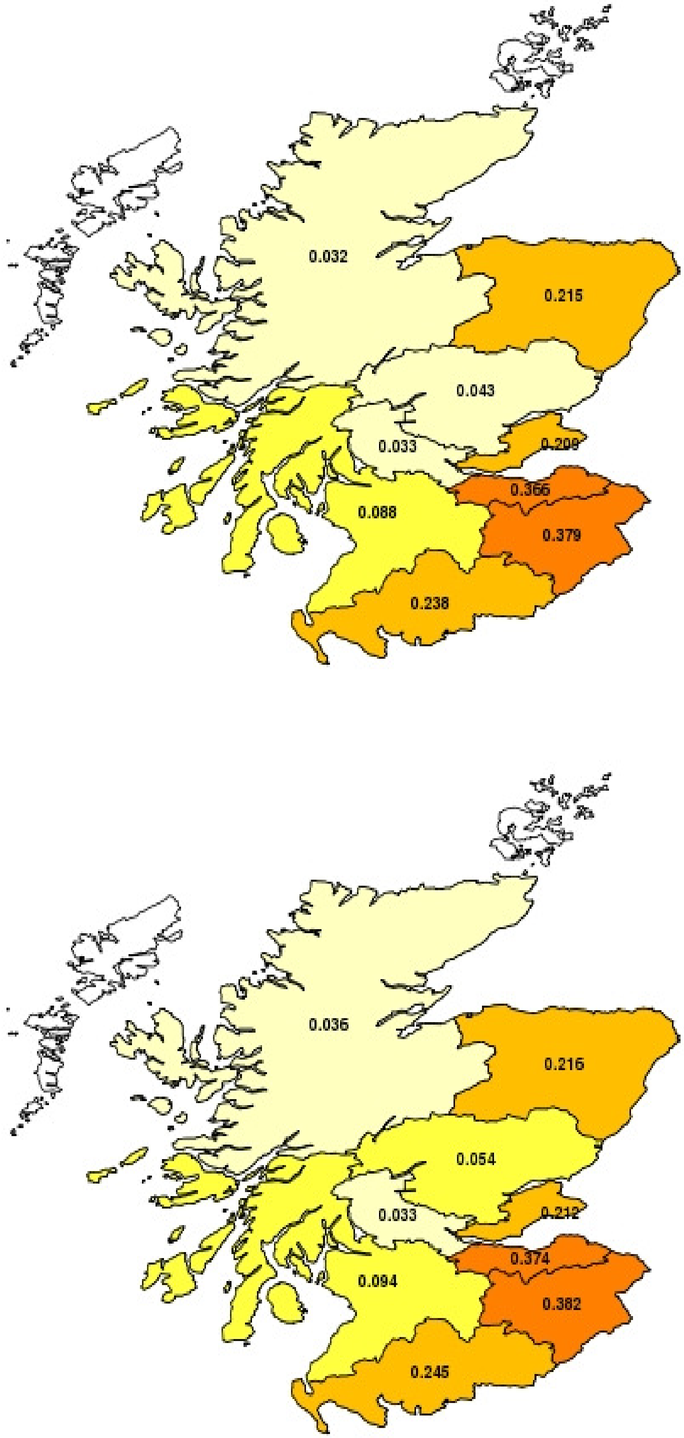

Figure 6. Regional variations in the estimated number of main setts per 1km^2 square, under two different scenarios regarding the treatment of excluded areas (scenario A, top; Scenario B, bottom). Islands were included in the denominator (total number of 1km^2 squares) when calculating the estimates.

Table 12. Estimated percentages of 1km^2 squares that include a main sett, any sett or any badger activity for each region, based on stratifying by DHT.

Region		Percentage of 1km^2 squares containing					
		A main sett		Any sett		Any activity	
		Estimate	*Standard Error*	*Estimate*	*Standard Error*	*Estimate*	*Standard Error*
Borders	A	**29.4**	4.4	**39.9**	4.5	**48.3**	4.5
	B	**29.6**	4.5	**40.3**	4.6	**49.2**	4.7
Central	A	**3.3**	2.3	**7.4**	2.8	**12.6**	3.6
	B	**3.3**	2.3	**7.5**	2.8	**12.9**	3.7
Dumfries & Galloway	A	**19.3**	3.5	**35.1**	4.2	**40.8**	4.2
	B	**20.0**	3.6	**36.2**	4.3	**42.0**	4.4
Fife	A	**20.9**	5.7	**28.8**	6.9	**31.1**	6.9
	B	**21.2**	5.8	**29.3**	7.0	**31.6**	7.1
Grampian	A	**16.2**	2.8	**25.3**	3.1	**36.2**	3.4
	B	**16.3**	2.8	**25.4**	3.1	**37.3**	3.7
Highland	A	**2.4**	1.0	**5.6**	1.5	**8.6**	1.8
	B	**2.8**	1.2	**6.8**	2.0	**10.5**	2.4
Lothian	A	**26.6**	6.4	**48.0**	7.9	**59.4**	7.2
	B	**27.2**	6.5	**49.2**	8.1	**61.0**	7.4
Strathclyde	A	**7.1**	1.5	**14.2**	2.0	**18.7**	2.1
	B	**7.4**	1.6	**14.7**	2.1	**19.3**	2.2
Tayside	A	**3.6**	1.7	**4.5**	1.8	**7.0**	2.2
	B	**4.8**	2.5	**5.6**	2.6	**9.3**	3.4

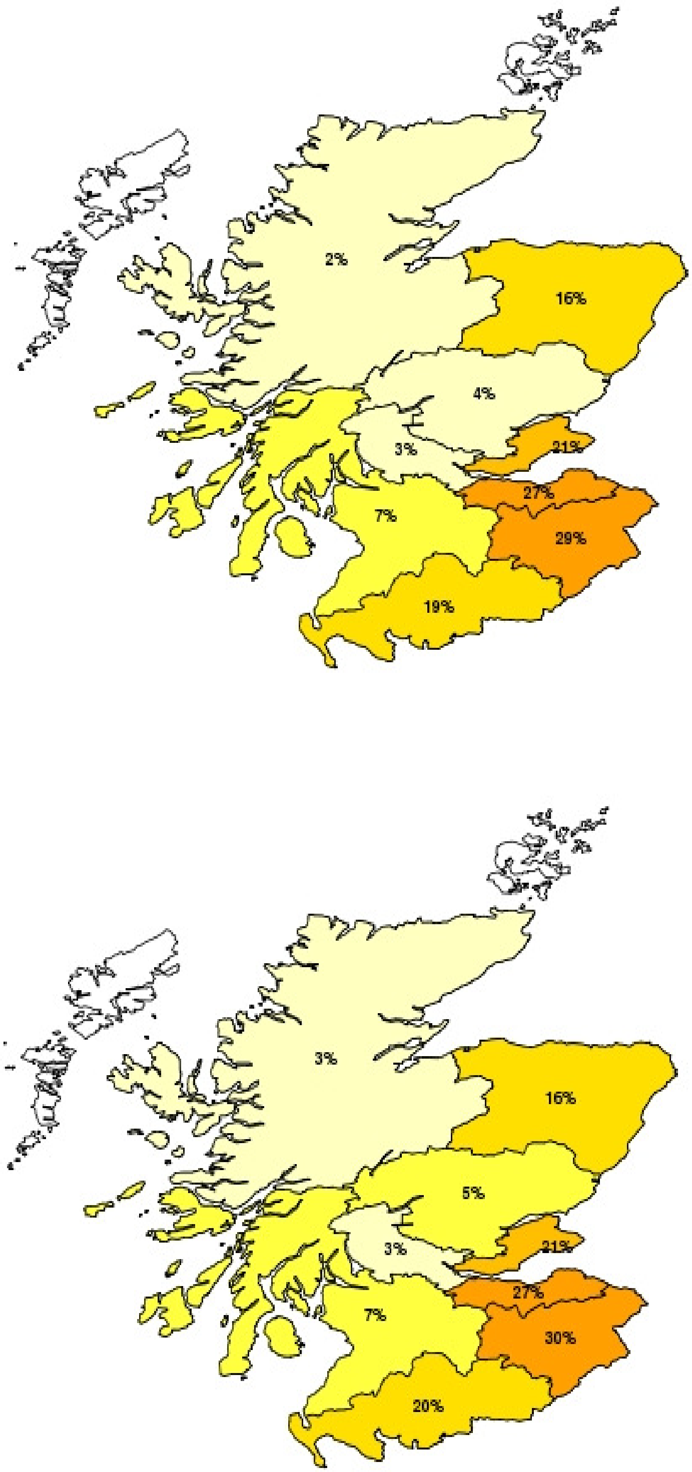

Figure 7. Regional variations in the percentage of $1km^2$ squares that contain a main sett, under two different scenarios regarding the treatment of excluded areas (scenario A, top; Scenario B, bottom). Islands are included in the denominator when calculating the percentage.

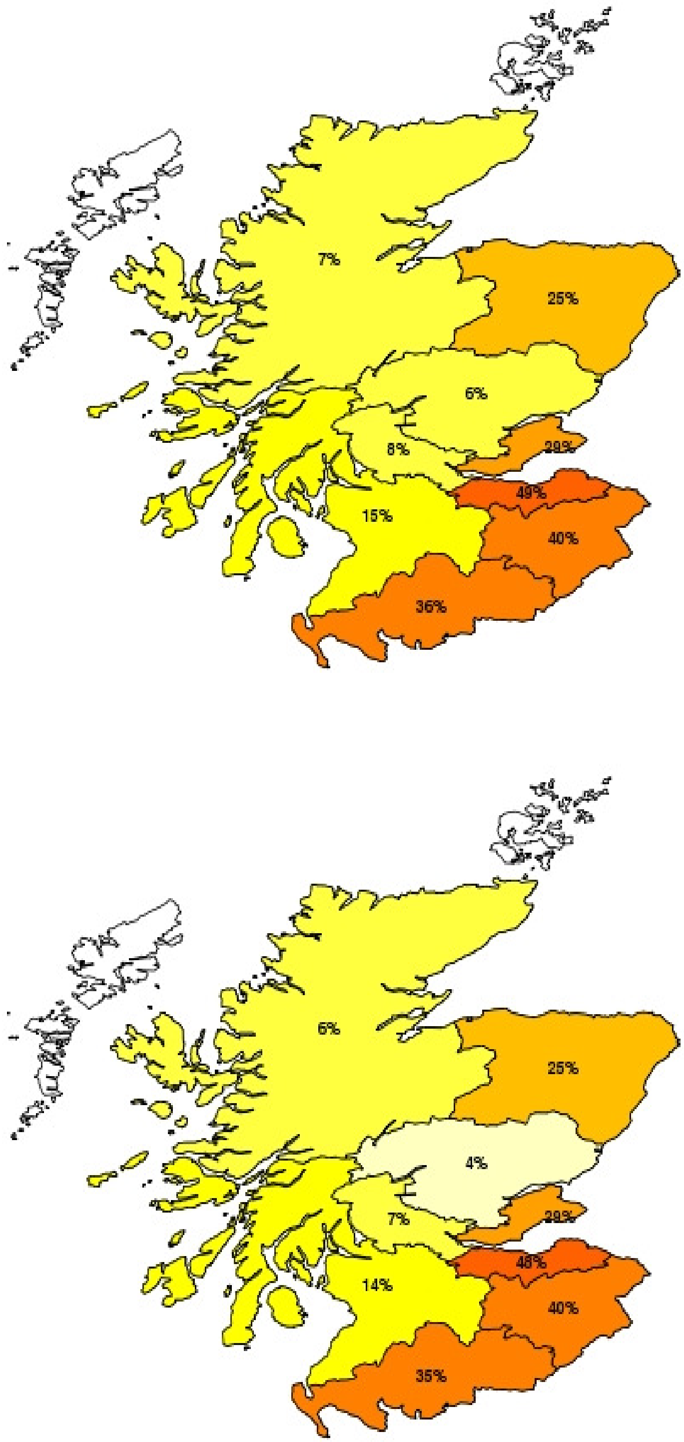

Figure 8. Regional variations in the percentage of 1km^2 squares that contain any sett, under two different scenarios regarding the treatment of excluded areas (scenario A, top; Scenario B, bottom). Islands are included in the denominator when calculating the percentage.

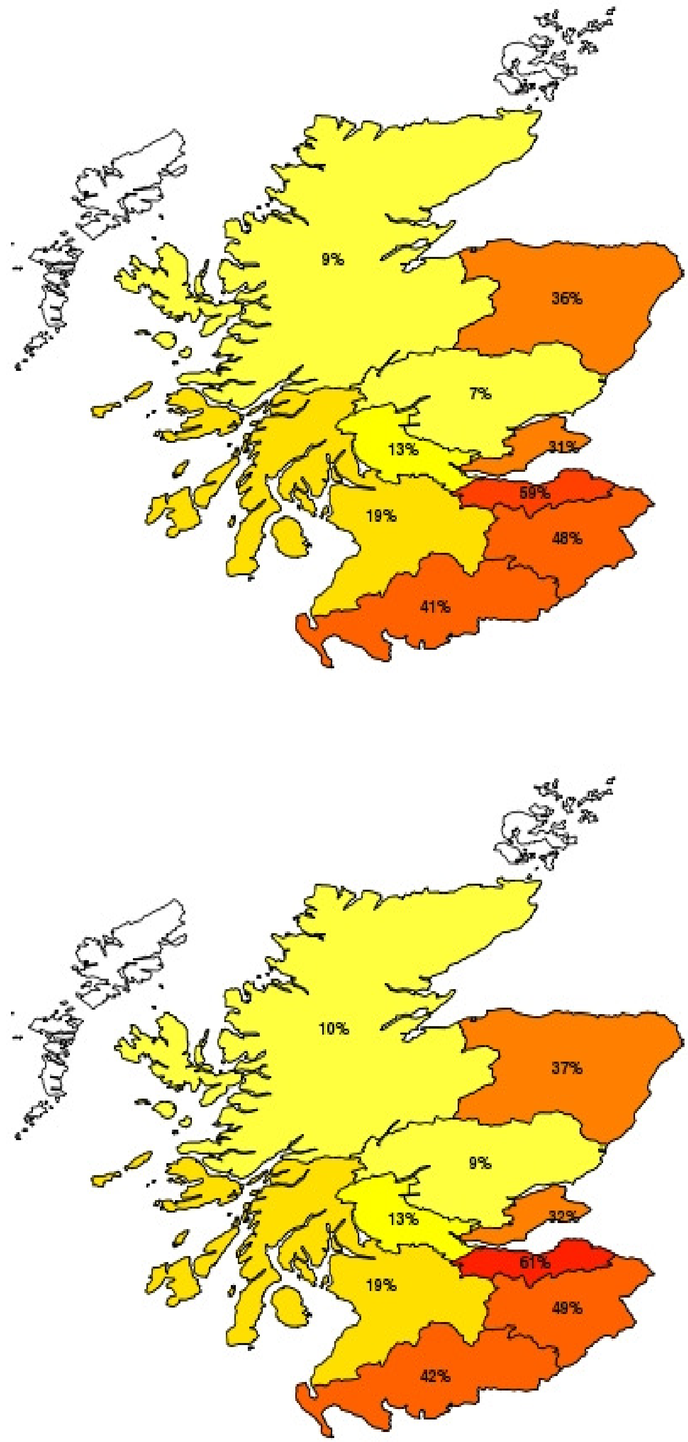

Figure 9. Regional variations in the percentage of $1km^2$ squares that contain badger activity, under two different scenarios regarding the treatment of excluded areas (scenario A, top; Scenario B, bottom). Islands are included in the denominator when calculating the percentage.

6.8 Estimates for finer-scale geographical areas

Corresponding estimates were also produced (Tables 13-15) for seven sub-regions within Strathclyde, Tayside and Grampian. These results provide some evidence that there may have been substantial heterogeneity in badger densities within the larger regions. However, the sample sizes were sufficiently small and the standard errors sufficiently large that these differences could have arisen by chance alone. The results tentatively suggest that densities were lower in Argyll & Bute than in the remainder of Strathclyde, that densities were lower in Perth & Kinross than in the remainder of Tayside and that densities were higher in Moray than in the remainder of Grampian. This corresponds well with sett information contained in the national database of badger records for Scotland, held by Scottish Badgers, especially for the Strathclyde and Grampian regions.

Table 13. Summary of raw survey results for each sub-region.

Sub-region	All squares	Squares surveyed	Number of main setts	Number of 1km^2 squares containing		
				main setts	any setts	any activity
Argyll & Bute	8317	52	3	1	5	6
Ayrshire & Arran	3552	49	11	10	16	21
Clyde Valley	3404	64	9	9	17	22
Aberdeen-shire & City	6647	97	19	15	26	42
Moray	2291	34	15	11	15	16
Angus & Dundee City	2293	34	3	2	2	3
Perth & Kinross	5406	76	3	3	5	7

Table 14. Estimated density of main setts for each sub-region, based on stratifying by DHT, together with associated standard errors. Estimates were derived under two different assumptions (A and B) regarding the treatment of excluded squares.

Sub-region		Number of main setts		Mean number of main setts per 1km^2 square	
		Estimate	*Standard Error*	*Estimate*	*Standard Error*
Argyll & Bute	A	**476**	475	**0.057**	0.057
	B	**574**	572	**0.069**	0.069
Ayrshire & Arran	A	**674**	198	**0.190**	0.056
	B	**688**	202	**0.194**	0.057
Clyde Valley	A	**444**	138	**0.130**	0.041
	B	**447**	139	**0.131**	0.041
Aberdeen-shire & City	A	**1027**	257	**0.155**	0.039
	B	**1031**	259	**0.155**	0.039
Moray	A	**738**	181	**0.322**	0.079
	B	**747**	184	**0.326**	0.08
Angus & Dundee City	A	**166**	143	**0.072**	0.062
	B	**167**	144	**0.073**	0.063
Perth & Kinross	A	**176**	106	**0.033**	0.02
	B	**274**	189	**0.051**	0.035

Table 15. Estimated percentages of 1km^2 squares that include a main sett, any sett or any badger activity for each sub-region, based on stratifying by DHT.

Sub-region		Percentage of 1km^2 squares containing					
		A main sett		Any sett		Any activity	
		Estimate	*Standard Error*	*Estimate*	*Standard Error*	*Estimate*	*Standard Error*
Argyll & Bute	A	**1.9**	1.9	**5.4**	2.6	**6.1**	2.6
	B	**2.3**	2.3	**6.1**	3	**6.8**	3.1
Ayrshire & Arran	A	**17.3**	4.9	**27.4**	5.5	**36.3**	5.7
	B	**17.7**	5	**27.9**	5.6	**37.1**	5.8
Clyde Valley	A	**13.1**	4.1	**25.6**	4.7	**34.3**	5.1
	B	**13.1**	4.1	**25.8**	4.7	**34.5**	5.2
Aberdeen-shire & City	A	**12.3**	2.9	**22.1**	3.6	**35.9**	4.1
	B	**12.3**	2.9	**22.2**	3.7	**37.4**	4.7
Moray	A	**23.3**	5	**32.1**	2.9	**35.2**	4.3
	B	**23.6**	5.1	**32.5**	3	**35.7**	4.3
Angus & Dundee City	A	**4.1**	3.2	**4.1**	3.2	**7.3**	4.5
	B	**4.2**	3.3	**4.2**	3.3	**9.9**	6.6
Perth & Kinross	A	**3.3**	2	**4.2**	2.1	**6**	2.4
	B	**5.1**	3.5	**6.1**	3.6	**7.9**	3.8

6.9 Results for individual local authority areas

Table 16 summarises the raw survey data for the 22 local authority areas that do not directly correspond to regions or sub-regions. Survey sizes were typically very small (with 10 or less surveyed squares for 14 of the local authority areas), so it would be meaningless to attempt to estimate badger densities at this level, but the results may nonetheless suggest apparent heterogeneities that are worthy of further investigation.

Table 16. Summary of raw survey results for smaller local authority areas.

Local authority area	Number of 1km² squares		
	surveyed	with main setts	With any activity
Central			
Clackmannanshire	1	0	0
Falkirk	6	0	4
Stirling	33	2	4
Aberdeen-shire & City			
Aberdeen City	8	4	5
Aberdeenshire	89	11	37
Lothian			
East Lothian	13	6	11
Edinburgh City	8	1	5
Midlothian	10	1	4
West Lothian	9	3	5
Dundee & Angus			
City of Dundee	0	0	0
Angus	35	2	3
Ayrshire & Arran			
East Ayrshire	13	2	8
North Ayrshire	17	2	6
South Ayrshire	19	6	7
Clyde Valley			
City of Glasgow	4	2	2
East Renfrewshire	0	0	0
Renfrewshire	3	0	0
East Dumbartonshire	5	0	1
West Dumbartonshire	3	0	2
South Lanarkshire	36	6	13
North Lanarkshire	8	1	4
Inverclyde	5	0	0

6.10 Results for individual strata

The raw data for each region-by-DHT combination are presented in Tables 17 - 24.

Table 17. Total number of active badger main setts found in each stratum.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	2	16	0	3	0	15	0	-	36
Central	0	1	0	0	0	1	0	0	2
D+G	1	1	4	3	0	19	3	-	31
Fife	-	9	-	0	-	0	0	0	9
Grampian	0	17	4	1	0	11	0	1	34
Highland	1	2	3	5	1	1	0	0	13
Lothian	0	8	-	0	0	7	0	0	15
Strathclyde	0	1	0	1	3	13	1	4	23
Tayside	0	2	1	0	1	1	0	1	6
Total	4	57	12	13	5	68	4	6	169

Table 18. Mean number of active badger main setts per 1km^2 square found within each stratum. Black: strata with no surveyed squares, dark grey: strata with one surveyed square, light grey: strata with 2-19 surveyed squares, yellow: strata with 20 or more surveyed squares.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	0.25	0.57	0	3.00	0	0.62	0		0.43
Central	0	0.20	0	0	0	0.09	0	0	0.05
D+G	0.06	0.33	0.20	1.00	0	0.35	0.3		0.28
Fife		0.33		0		0	0	0	0.22
Grampian	0	0.31	0.20	0.20	0	0.44	0	0.20	0.26
Highland	0.08	0.25	0.12	0.45	0.01	0.04	0	0	0.08
Lothian	0	0.42		0	0	0.88	0	0	0.38
Strathclyde	0	0.25	0	0.17	0.14	0.27	0.04	0.21	0.14
Tayside	0	0.05	0.11	0	0.05	0.06	0	0.50	0.05
Total	0.06	0.3	0.1	0.34	0.03	0.31	0.05	0.15	0.19

Table 19. Number of $1km^2$ squares with badger main setts found in each stratum.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	2	14	0	1	0	11	0	-	28
Central	0	1	0	0	0	1	0	0	2
D+G	1	1	4	2	0	14	3	-	25
Fife	-	9	-	0	-	0	0	0	9
Grampian	0	14	2	1	0	8	0	1	26
Highland	1	2	1	4	1	1	0	0	10
Lothian	0	7	-	0	0	4	0	0	11
Strathclyde	0	1	0	1	1	12	1	4	20
Tayside	0	1	1	0	1	1	0	1	5
Total	4	50	8	9	3	52	4	6	136

Table 20. Percentage of $1km^2$ squares with badger main setts found in each stratum. Black: strata with no surveyed squares, dark grey: strata with one surveyed square, light grey: strata with 2-19 surveyed squares, yellow: strata with 20 or more surveyed squares.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	25	50	0	100	0	46	0		33.3
Central	0	20	0	0	0	9	0	0	5.0
D+G	6	33	20	67	0	26	30		22.7
Fife		33		0		0	0	0	22.5
Grampian	0	26	10	20	0	32	0	20	19.8
Highland	8	25	4	36	1.5	4	0	0	6.4
Lothian	0	37		0	0	50	0	0	27.5
Strathclyde	0	25	0	17	4.8	25	4	21	12.1
Tayside	0	2	11	0	5.3	6	0	50	4.5
Total	6.5	26.5	6.9	23.7	2.1	24.1	5.5	15.0	15.5

Table 21. Number of 1km^2 squares with any badger setts found in each stratum.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	3	19	0	1	0	14	1	-	38
Central	0	3	0	0	0	1	0	1	5
D+G	4	1	5	2	0	29	3	-	44
Fife	-	10	-	0	-	2	0	0	12
Grampian	0	22	3	2	0	12	0	2	41
Highland	2	2	3	5	3	2	2	0	19
Lothian	0	10	-	1	1	5	1	2	20
Strathclyde	1	2	2	1	1	23	2	6	38
Tayside	0	2	1	1	1	1	0	1	7
Total	10	71	14	13	6	89	9	12	224

Table 22. Percentage of 1km^2 squares with any badger setts found in each stratum. Black: strata with no surveyed squares, dark grey: strata with one surveyed square, light grey: strata with 2-19 surveyed squares, yellow: strata with 20 or more surveyed squares.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	38	68	0	100	0	58	14		45.2
Central	0	60	0	0	0	9	0.0	50	12.5
D+G	24	33	25	67	0	54	30		40
Fife		37		0		33	0	0	30
Grampian	0	41	15	40	0.0	48	0	40	31.3
Highland	17	25	12	46	4	9	22	0	12.1
Lothian	0	53		100	33	63	50	33	50
Strathclyde	9	50	7	17	5	48	7	32	23
Tayside	0	5	11	13	5	6	0.0	50	6.4
Total	16.1	37.6	12.1	34.2	4.2	41.2	12.3	30	25.5

Table 23. Number of 1km^2 squares with some level of current badger activity (either signs or active setts) found in each stratum.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	3	22	0	1	1	18	1	-	46
Central	0	4	0	0	0	2	1	1	8
D+G	4	1	7	2	0	34	3	-	51
Fife	-	11	-	0	-	2	0	0	13
Grampian	1	32	5	3	1	14	0	2	58
Highland	2	2	6	6	5	4	3	0	28
Lothian	0	12	-	1	1	6	2	3	25
Strathclyde	1	3	4	1	1	30	3	6	49
Tayside	0	3	2	1	2	1	0	1	10
Total	11	90	24	15	11	111	13	13	288

Table 24. Percentage of 1km^2 squares with some level of current badger activity (either signs or active setts) found in each stratum. Black: strata with no surveyed squares, dark grey: strata with one surveyed square, light grey: strata with 2-19 surveyed squares, yellow: strata with 20 or more surveyed squares.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	38	79	0	100	13	75	14		54.8
Central	0	80	0	0	0	18	17	50	20
D+G	24	33	35	67	0	63	30		46.4
Fife		41		0		33	0	0	32.5
Grampian	50	59	25	60	6	56	0	40	44.3
Highland	17	25	24	55	7	17	33	0	17.8
Lothian	0	63		100	33	75	100	50	62.5
Strathclyde	9	75	14	17	5	63	11	32	29.7
Tayside	0	7	22	13	11	6	0	50	9.1
Total	17.7	47.6	20.7	39.5	7.7	51.4	17.8	32.5	32.8

7. Habitat associations of badgers

7.1 Habitats in the immediate vicinity of main setts

Of the 170 main setts that were found, 152 were attributed to a single habitat, 12 were attributed to multiple habitats, and six had unknown habitat (Table 25). The majority of main setts (96) lay exclusively within woodland, with 62 of these lying exclusively within deciduous woodland and 32 exclusively within coniferous woodland. Moderate numbers of 1km^2 squares were also assigned to boundaries such as hedgerows (14), other grassland (12), improved grassland (11), and dwarf shrub heath (8).

Table 25. Actual habitats in which badger main setts were found.

Habitats	Frequency	Percentage
Single habitats		
Deciduous woodland	62	36.5
Coniferous woodland	32	18.8
Boundaries	14	8.2
Other grassland	12	7.1
Improved grassland	11	6.5
Dwarf shrub heath	8	4.7
Bracken	4	2.4
Arable & horticultural	3	1.8
Rivers & streams	2	1.2
Standing open water	1	0.6
Inland rock	1	0.6
Built-up areas	1	0.6
Coastal habitats	1	0.6
Mixed habitats		
Deciduous / improved grassland	4	2.4
Deciduous / coniferous woodland	2	1.2
Deciduous / bracken / bog	1	0.6
Coniferous / improved grassland	1	0.6
Coniferous / rivers & streams	1	0.6
Coniferous / other grassland	1	0.6
Boundaries / improved grassland	1	0.6
Dwarf shrub heath / inland rock	1	0.6
Unknown habitat	6	3.5

7.2 Comparison of fine-scale and broad-scale habitat associations

The habitat characteristics of the area immediately surrounding the sett were compared with the DHT of the 1km^2 square within which it lay (Table 26). Little association between the broad-scale (DHT taken from LCM2000) and fine-scale (recorded by surveyor) classifications of habitat was apparent: 126 setts (74%) lay in a square with a DHT that was either arable or intensive grassland and only 25 setts (15%) lay in squares with deciduous or coniferous woodland as the DHT. In contrast, 96 of the 164 setts (59%) with known local habitat characteristics were either wholly within deciduous or coniferous woodland, and only 14 squares (9%) were located wholly within arable farmland or improved grassland. 47 main setts were found within deciduous woodland but lay within squares for which the DHT was either arable or intensive grassland (corresponding to 29% of all setts with known habitat characteristics and to 76% of setts that lay within deciduous woodland).

Table 26. Frequency table comparing actual habitats in which setts were found (rows) against DHTs of the squares that contain them (columns).

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Deciduous	1	24		9	2	23		3	62
Coniferous		12	9	1		9	1		32
Boundaries		5		1	1	7			14
Other grassland	2	4			1	3	1	1	12
Improved grassland		2		1		7	1		11
Dwarf shrub heath		1	1			6			8
Bracken		2			1		1		4
Arable & horticultural			1	1		1			3
Rivers & streams		1				1			2
Standing open water								1	1
Inland rock						1			1
Built-up areas								1	1
Coastal habitats						1			1
Unknown / mixed	1	6	1			10			18
Total	4	57	12	13	5	69	4	6	170

The habitat characteristics of setts are also compared between regions (Table 27). This highlights more subtle variations in the habitat characteristics of setts.

Table 27. Frequency table comparing actual habitats in which setts were found (rows) against the regions that contain them (columns).

	Borders	Central	D+G	Fife	Grampian	Highland	Lothian	Strathclyde	Tayside
Deciduous	15		4	5	10	9	8	8	3
Coniferous	8		7	2	9	2	1	1	2
Boundaries	1		7		2	1	2	1	
Other grassland	1	1	2	1	1		1	4	1
Improved grassland	4	1	3		1			2	
Dwarf shrub heath			1		2		3	2	
Bracken	2		1					1	
Arable & horticultural	1				2				
Rivers & streams	1				1				
Standing open water								1	
Inland rock			1						
Built-up areas								1	
Coastal habitats			1						
Unknown / mixed	3		5	1	6	1		2	
Total	36	2	32	9	34	13	15	23	6

7.3 Exploring broad-scale habitat associations

At the broader spatial scale, statistical models were used to investigate the relationship between the badger population within a 1km^2 square and the environmental characteristics of that 1km^2 square. It should be noted that, as identified in Section 7.2, the habitats in which main setts were actually found did not necessarily reflect the overall habitat characteristics of the 1km^2 squares that contained these setts and there is consequently value in considering habitat associations at the broad scale as well as the local scale. The results presented are exploratory and more detailed modeling would be required before conclusive inferences could be drawn.

Logistic regression models (e.g. McCullagh & Nelder, 1989) were used to analyse the relationship between habitat and the presence or absence of main setts within each 1km^2 square. Similar models were also used to describe the relationship between habitat and the presence/absence of any sett, and the presence/absence of any badger activity.

The effects of various potential explanatory variables were considered:

(a) the DHT within the square (a categorical variable);(b) the mean altitude of the square;

(c) the standard deviation of altitude within the square, which provides a crude measure of how steep or undulating the ground is;

(d) the percentage cover of each of the 16 individual LCM 2000 Target Level 1 land classes;

(e) the presence or absence of each land class.

The decision regarding which of these variables to include in the model, and which to exclude, was determined based on the data (see Appendix P). The detailed results are relatively complicated, but consistently suggested that the proportional land cover of deciduous woodland, arable farmland and improved grassland were important factors in explaining the presence/absence of (a) main setts, (b) any setts and (c) any badger activity. Higher proportions of these three land uses were associated with higher probabilities that a $1km^2$ square contained some form of badger activity, setts of any kind, or at least one main sett. The effect of a 1% change in the amount of deciduous woodland is larger than that of a 1% change in improved grassland which is, in turn, greater than the effect of a 1% change in the amount of arable farmland. Factors other than these three variables (most notably the presence/absence of coniferous woodland within the square) may also be important but the evidence is more ambiguous in these cases (Appendix P).

8. Discussion

8.1 Key findings

Using survey data collected from a sample of 877 1km^2 squares across Scotland, the total number of main setts in Scotland was estimated at between 7300 and 11200 main setts and it was estimated that between 7.1% and 10.4% of 1km^2 grid squares in Scotland contain a badger main sett. These ranges mainly reflect sampling uncertainty (which results from the fact that only about 1% of squares within Scotland were surveyed), but also reflect uncertainty about the way in which squares that have been excluded on the grounds of health and safety should be treated.

The regions containing the highest estimated densities of badger main setts were the Scottish Borders and the Lothians, whilst the regions containing the lowest estimated densities were Tayside, Central and Highland. There was generally a high degree of uncertainty associated with estimates at the regional level, because relatively small numbers of squares were surveyed within each region, but the regional differences that have been identified were consistent with information in the current national database of badger records held by Scottish Badgers. Differences in badger densities between regions may be explained by factors such as land use, climate, habitat availability (for both sett location and foraging) and levels of past persecution.

Further analysis provided tentative evidence to suggest that there may have been substantial heterogeneities in badger main sett densities within some of the larger regions. For example, the results for the Strathclyde region indicated marked differences in badger main sett densities between Ayrshire and Argyll (with estimated densities considerably higher in the former than the latter). These results must be interpreted with great caution because the design of the survey did not allow us to estimate densities at fine spatial scales in an unbiased way, but the differences between Ayrshire and Argyll do correspond with data already held by Scottish Badgers.

The highest densities of main setts occurred within 1km^2 squares for which the dominant habitat type was arable farmland, deciduous woodland or intensive grassland with the lowest densities occurring in squares dominated by heather and bog. The density estimates for squares dominated by arable farmland were consistent with other recent research (Campbell & Hartley, 2007).

The dominant habitat types of the 1km^2 squares that contained badger main setts often differed from the local habitats within the immediate vicinity of main setts. 96 of the 164 main setts with known local habitat characteristics (60%) were located wholly within deciduous or coniferous woodland, with only 14 main setts (9%) located wholly within arable farmland or improved grassland. Around 40% of all main setts (64) were located in woodland areas but lay within squares for which the dominant habitat type was arable farmland or improved grassland. This apparent discrepancy may be explained by considering the differences in the habitat requirements for the two main activities of the badger: sett building and foraging. Factors affecting sett site selection often, but not always, include the availability of sloping terrain (to reduce digging effort and aid drainage) and cover (for protection against the elements and to minimise general disturbance). Woodland sites therefore often have favourable conditions for the establishment of setts and this may explain why the majority of main setts were recorded within woodland habitats (also reported in Harris & Yalden, 2008). A $1km^2$ square with only a small area of woodland - and thus with woodland not being the dominant habitat type - could potentially be suitable for badgers, however, because a larger area is required for foraging than for sett building. Agricultural land often provides a rich foraging resource for badgers (Kruuk & Parish, 1982; Kruuk & Parish 1985), with the high numbers of earthworms present in the fields being easily accessed by the badgers, and this may explain why the majority of $1km^2$ squares that contain main setts were dominated by agricultural land.

Estimated densities of badger main setts were also relatively high within $1km^2$ squares dominated by urban habitats. This is an interesting result, but should be interpreted with caution because of the relatively small number of squares of this kind that were surveyed. Urban areas have not been included in previous national surveys, so comparisons with previous density estimates were not possible for this habitat type.

8.2 Comparison against previous surveys

The focus in this report has been upon providing a snapshot of the current badger population within Scotland. It is intended that this survey also will also provide a baseline against which future changes can be evaluated.

It has not been possible to make direct comparisons between the raw results of this survey and those of the previous national (UK) surveys in the 1980s and 1990s (Wilson *et al.*, 1997) because (a) different sets of $1km^2$ squares were surveyed in those surveys and (b) the SBDS was specifically designed to over-sample areas with high badger densities and to under-sample those with low densities, whereas the previous two surveys were not. Estimates that accounted for stratification would be comparable, in principle, between the different surveys, but Wilson *et al.* (2007) did not produce such estimates for individual nations (e.g. Scotland) or regions (e.g. Southern Scotland). In fact, the nature of the design used in the earlier surveys meant that it would not have been valid to produce estimates for individual regions or nations, because the designs of these surveys did not involve stratifying by either nation or region.

However, Wilson *et al.* (1997) do present the crude overall numbers of main setts that were recorded in Southern Scotland (Dumfries & Galloway, Borders, Strathclyde and Lothian) and Northern Scotland (Fife, Central, Tayside, Grampian and Highland) and a very crude indication of change can therefore be obtained by comparing these numbers against those obtained within the current survey. The results of this comparison are shown in Table 28, and suggest that the density of main setts is higher in the current survey than in the previous two surveys.

Table 28. Comparison of raw results obtained in the current survey against those obtained by Wilson *et al.* (1997).

	Number of surveyed squares	Number of main setts	Number of 1km^2 squares with main setts	Number of 1km^2 squares with any setts
1980s (Wilson *et al.*, 1997)				
Southern Scotland	208	15 (7.2%)	15 (7.2%)	31 (14.9%)
Northern Scotland	366	8 (2.2%)	6 (1.6%)	24 (6.6%)
1990s (Wilson *et al.*, 1997)				
Southern Scotland	208	15 (7.2%)	14 (6.7%)	25 (12.0%)
Northern Scotland	366	12 (3.3%)	10 (2.7%)	20 (5.5%)
2007/8 (SBDS)				
Southern Scotland	399	105 (26.3%)	84 (21.1%)	140 (35.1%)
Northern Scotland	478	64 (13.4%)	52 (10.9%)	84 (17.6%)

The raw figures were consistent with the hypothesis that there has been a substantial increase in the number of main setts between the 1990s and 2007/8 but, for the reasons outlined above, it was not possible to be certain that there has actually been an increase at all or, if an increase has occurred, to be confident about the rate at which numbers have increased. Increases in badger numbers since the 1990s have been reported from other sources (Macdonald & Baker, 2005), but it was not clear how closely these reported increases in badger numbers relate to an increase in the number of badger main setts.

8.3 Limitations and further work

No attempt has been made in this report to estimate the total number of individual badgers within Scotland. This was because the survey was not designed to quantify the sizes of badger social groups found or the number of individual badgers. There are inherent problems in estimating overall badger numbers from main sett estimates, due to the limited amount of appropriate and up-to-date information available on mean social group sizes for the different regions and habitats in Scotland. Much of the work on mean social group sizes has been carried out some time ago, a summary of which has been compiled by Feore (1994 cited Reid *et al.,* 2008), and it has been shown that there can be considerable changes in mean social group size over time (Rogers *et al.*, 1997).

Although much research has been conducted on how habitat affects the distribution and density of badgers in Britain (Cresswell *et al.*, 1990; Feore & Montgomery, 1999), the use of the survey data to study the habitat preferences of badgers within Scotland was very much preliminary and further research in this area would be worthwhile.

The survey data also contained information on badger activity levels for all survey squares and this was not analysed in detail in this report. There is therefore potential for future studies to analyse the data collected on the location and abundance of badger field signs, such as badger paths, badger dung pits and latrines, badger hairs and badger prints. Research suggests that field signs could provide a useful tool in monitoring change between successive surveys (Sadlier, 2003). Activity levels have also been used to estimate badger numbers but variations in environmental conditions and badger behaviour appear to complicate the relationship between the abundance of field signs and badger numbers (Wilson *et al.*, 2003).

Estimates for the number of badger main setts within individual geographical regions and dominant habitat types were produced alongside the national estimates, but were in most cases highly uncertain (and therefore not particularly meaningful). This is an inevitable result of the fact that sample sizes for individual regions or habitat types were relatively small. More precise estimates could only be obtained through the collection of data at additional sites.

Interesting data has emerged from this survey regarding the presence of badgers in urban areas. Only a small number of urban sites were included in this survey (40), thus estimates have a high degree of uncertainty. Further research would be beneficial to provide more detailed information on the extent to which badgers are present in urban areas in Scotland. Recent research in this area could prove helpful for repeat surveys (Huck *et al.*, 2008; Davidson *et al.*, 2008; Davidson *et al.*, 2009).

In this survey, volunteers were involved in locating and identifying badger hair but surveyors were not required to retain and return any badger hair found. It is recommended that any future surveys consider retaining hair samples as they could provide a valuable resource for DNA analysis (Frantz *et al.*, 2004; Scheppers *et al.*, 2007).

8.4 Key achievements of the survey

This was the first systematic national survey of the number of badger social groups within Scotland since the mid 1990s. A total of 877 $1km^2$ squares were surveyed, with these squares selected via stratified random sampling and distributed throughout a wide range of different habitat types and geographical areas. Notably, survey data were collected by trained volunteers, with the use of a volunteer network yielding considerable cost savings and making a survey of this scale viable. Data quality checks (including expert resurveys of 37 squares) suggested that the data were generally accurate and reliable (with the resurvey work detecting only one error).

The results of the survey have provided a robust basis for estimating the total number of active badger main setts currently within Scotland with a reasonable level of precision, and for estimating the number of $1km^2$ squares that contain a badger main sett, any sett, or any form of badger activity. The results have also, just as importantly, provided a baseline against which the results of future surveys can be compared.

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List of Appendices

Appendix A. Number of $1km^2$ squares assigned to each stratum within the survey design

The most substantial way in which we deviated from proportionality was in reducing the number of $1km^2$ squares assigned to "upland habitat", on the grounds that badger sett densities might be expected to be several times lower in upland habitat than in other habitat types[2]. We reduced the number of $1km^2$ squares in upland habitat to 60% of the level that would be adopted if the numbers of $1km^2$ squares were strictly proportional to the area occupied. This meant that the number of $1km^2$ squares in the Upland habitat was reduced from 407 to 244, with the spare 163 squares then re-allocated to other habitats (in direct proportion to the area occupied by those habitats).

Direct proportionality allocated 231 of the upland squares to Highland region, and 176 to other regions. We decided that it was undesirable for the majority of upland squares to be located in Highland region, because and (a) this would make it difficult to separate out the effects of geographical location (Highland region) and habitat (upland) on badger densities and (b) it would be difficult to recruit sufficient volunteers to survey a large number of upland squares within this region. When reducing the overall number of upland squares, we therefore fixed the number of upland squares in Highland region to be 100. The reduction in the overall number of upland squares therefore came primarily from reducing the number of $1km^2$ squares in Highland region by 131, with just 32 upland squares being removed from all other regions.

We also ensured that a total of at least 40 squares were allocated to each region and to each habitat type; this required us to make very slight increases to the number of $1km^2$ squares allocated to Lothian, Fife, and to urban habitats.

For the final stage of the stratification, the four dominant broad habitat types were sub-divided into eight dominant habitat types so that the number of strata rose from 36 to 72. Within dominant broad habitat types, numbers of $1km^2$ squares were assigned in direct proportion to the areas occupied by each dominant habitat type, but with a slight adjustment in order to increase the number of $1km^2$ squares assigned to deciduous woodland.

[2] Wilson *et al.*, 1997, for example, reported - Table 3.1, page 37 - that their national survey of badger populations in the UK had encountered 0.017 main setts per $1km^2$ square in 'Upland VII' habitat, as opposed to 0.09 main setts per $1km^2$ square in Arable III habitat and 0.25 main setts per $1km^2$ square in Pastoral habitat; the definition of "Upland VII habitat" in Wilson *et al.*, 1997, is quite similar to that of "upland habitat" within our study.

Appendix B. Adjustments to survey design to deal with errors in the land cover maps

Manual checks revealed that there were some discrepancies between the dominant habitat types derived from the Land Cover Map 2000 (LCM2000) and the land cover shown in the corresponding Ordnance Survey maps. Such discrepancies are probably due to errors in the LCM2000 data, which were derived from an automated classification of satellite images. A few squares that were classified by LCM2000 as “urban”, but appeared not to contain any buildings on the corresponding OS map; such squares were exchanged for other urban squares within the same region and 100km x 100km grid square. We did not attempt to correct for more subtle errors that may be present in the LCM2000 data.

Appendix C. Substitution of 1km^2 squares: detailed comparison of substituted and non-substituted squares

C1. Number of substitutions

153 of the 1009 squares that were included in the original were found to be unsuitable, and were substituted (replaced) by another square (Table C1).

C2. Reasons for substitutions

Six of these squares were on the Isle of Bute, which was incorrectly included in the original design, and one related to an error in transcribing the grid reference of the original square. Three of the substitutions involved replacing squares from strata with relatively high coverage by squares from strata with relatively poor coverage, in order to ensure that at least 40 squares were surveyed within each region and habitat type.

The remaining 143 substitutions were made on the grounds that they were unsuitable for survey. In these cases, care was taken to try and ensure that the decision to make a substitution was not influenced by the likelihood - or perceived likelihood - of badger setts occurring within either the square that was proposed to be replaced or the square that was to be used as a substitute. The detailed reasons for substitution are only recorded for 30 of the 143 squares, but suggest that difficulties in safely accessing the site - as a result of either extreme remoteness, denial of access by the landowner, or the presence of dangerous activities on the site – are likely to be the key factor (representing 26 of the reasons given). The remaining four squares were substituted on the grounds that the original square was a long distance from the surveyor's home, and that it would therefore have been impractical for them to survey the site.

C3. Selection of substitute squares

Substitute squares were selected by the Survey Coordinator from a reserve set of 1km^2 squares provided by BioSS, which was also generated by stratified random sampling. The locations of these substitute squares are shown in Figure C1. Ideally, substitute squares were meant to be from the same region, dominant habitat type and 100x100km National Grid square as the square that they were intended to replace, in order to ensure that the process of substitution did not distort the overall coverage of the survey. All of the 153 substitute squares came from the same region as the squares that they were intended to replace, but the other two criteria were relaxed in a small number of cases in order to ensure that it was practical for surveyor to survey the substitute square: six of the substitute squares had a different dominant habitat type than the square that they replaced, and 22 of the substitute squares lay within a different 100x100km grid square.

C4. Comparison of substitute squares against the squares they replaced

In Figure C3 we plot the mean altitudes of 1km^2 squares that have been substituted for against the altitudes of the squares that they have been replaced with. We find that that the mean altitudes of the replacement squares tend to be lower than those of the squares that they replaced (193m as opposed to 282m), and this difference is highly statistically significant ($p < 0.001$ using a paired t-test). The standard deviations of the altitudes within square – which provide an overall measure of how undulating or steep the ground is – are also lower for the replacement squares than for the squares that they replaced (22.1m as against 36.2m, with a p-value of 0.016 from applying a paired t-test to the log standard deviations). These results suggest that there tend to more difficulties in surveying squares with high altitudes or more undulating or steep ground.

Landscape heterogeneity, as measured by the number of land types that occupy at least 1% cover with a particular square, is higher in the replacement squares than in the squares that they have substituted for (an average of 4.84, as against 3.67, which is highly statistical significant). Percentage cover values for deciduous, improved grassland, natural grassland, arable and built-up areas tend to be higher in the replacement squares than in the squares they replace (Table C2), whilst percentage cover values for dwarf shrub heath, coniferous and acid grassland all tend to be lower.

C5. Final design

The number of 1km^2 squares per stratum in the final design – after substitutions and the inclusion of the nine extra squares – is shown in Table C3, and a more detailed geographical breakdown is given in Table C4.

Table C1. Number of substitutions within each stratum.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	3	0	3	0	4	0	1	0	11
Central	1	0	0	0	3	0	0	0	4
D+G	8	0	6	0	2	7	4	0	27
Fife	0	0	0	0	0	0	0	0	0
Grampian	1	0	3	1	6	0	0	0	11
Highland	4	0	5	0	27	2	2	0	40
Lothian	0	1	0	0	1	1	0	1	4
Strathclyde	10	0	16	1	11	5	4	0	47
Tayside	1	0	2	1	3	1	1	0	9
Total	28	1	35	3	57	16	12	1	153

Table C2. Comparison of land cover in the squares that were substituted for ("old"), and the squares they were replaced with ("new").

	Mean percentage cover		Squares with at least 1% cover	
	Old	**New**	**Old**	**New**
Sea/estuary	2.02	2.26	9	9
Inland water	1.55	1.37	19	20
Littoral	0.12	0.34	5	7
Supra-littoral	0	0	0	0
Bog	1.82	1.43	22	16
Dwarf shrub heath	34.67	28.90	117	123
Montane habitats	0.37	0.09	8	1
Deciduous	2.14	5.10	45	87
Coniferous	20.83	18.01	84	98
Arable & horticulture	1.47	2.71	19	40
Improved grassland	7.23	12.70	43	96
Natural grassland	7.27	9.26	45	78
Acid grassland	19.33	15.54	110	114
Fen, marsh & swamp	0	0	0	27
Built-up areas	0.76	1.55	17	18
Inland bare ground	0.37	0.61	18	25

Table C3. Number of 1km^2 squares allocated to each stratum within the final study design, after allowing for substitutions.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	9	28	11	1	8	25	7	0	89
Central	5	5	6	2	6	12	7	2	45
D+G	17	4	25	3	3	59	10	0	121
Fife	0	27	0	1	0	6	1	5	40
Grampian	2	68	23	5	17	32	5	5	157
Highland	13	10	30	11	85	25	9	3	186
Lothian	1	19	0	1	3	8	2	6	40
Strathclyde	16	5	40	9	29	62	38	20	219
Tayside	7	41	10	8	19	17	8	2	112
Total	70	207	145	41	170	246	87	43	1009

Table C4. Number of 1km^2 squares allocated to each stratum, based on a more detailed breakdown of geographical regions.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Aberdeen & -shire	2	61	13	1	11	19	4	4	115
Moray	0	7	10	4	6	13	1	1	42
Argyll & Bute	13	0	30	6	16	5	12	2	84
Ayshire & Arran	2	1	7	1	7	34	10	2	64
Clyde Valley	1	4	3	2	6	23	16	16	71
Dundee & Angus	3	15	0	0	6	6	3	1	34
Perth & Kinross	4	26	10	8	13	11	5	1	78

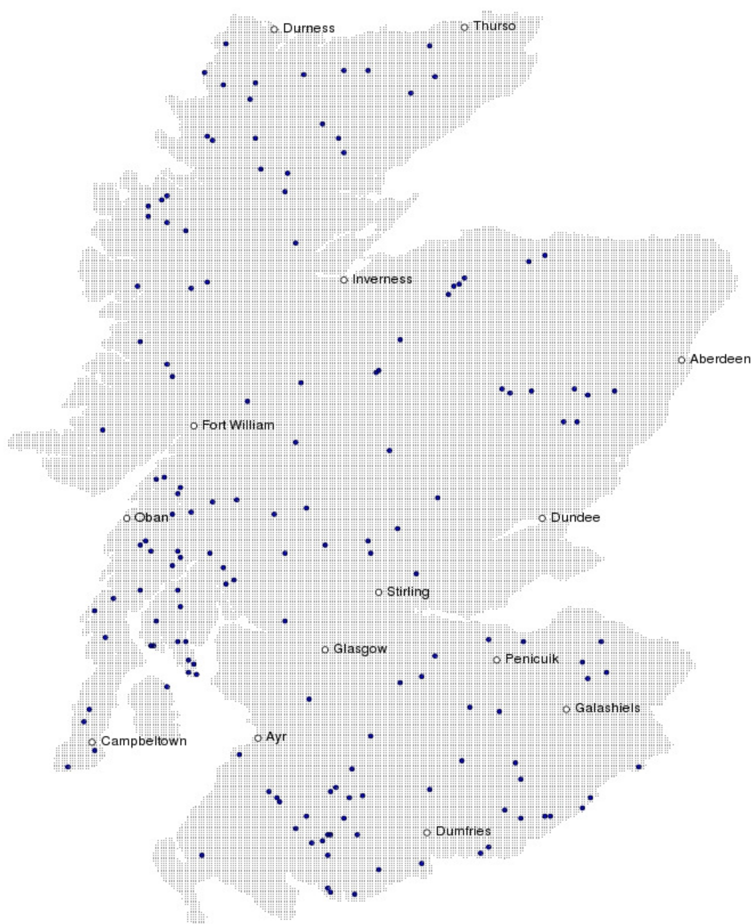


Figure C1. Locations of substituted squares.

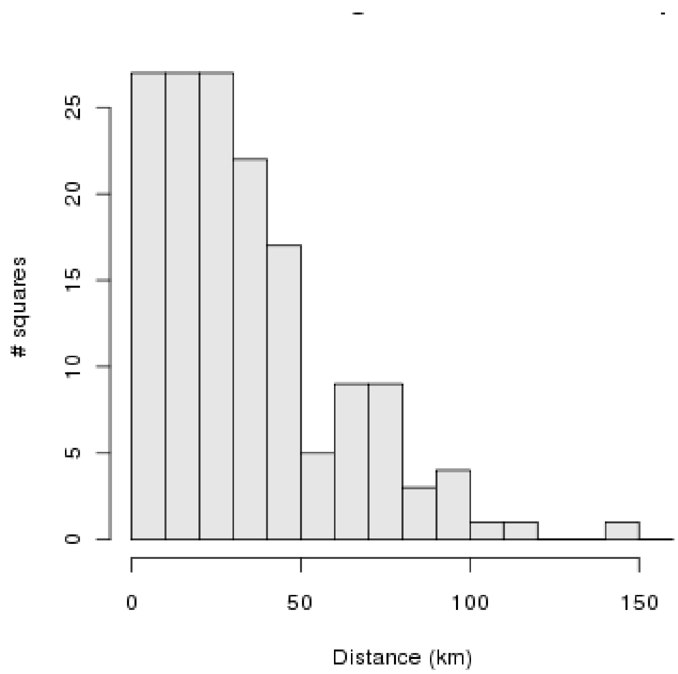


Figure C2. Distribution of distances between squares that have been substituted for and the squares

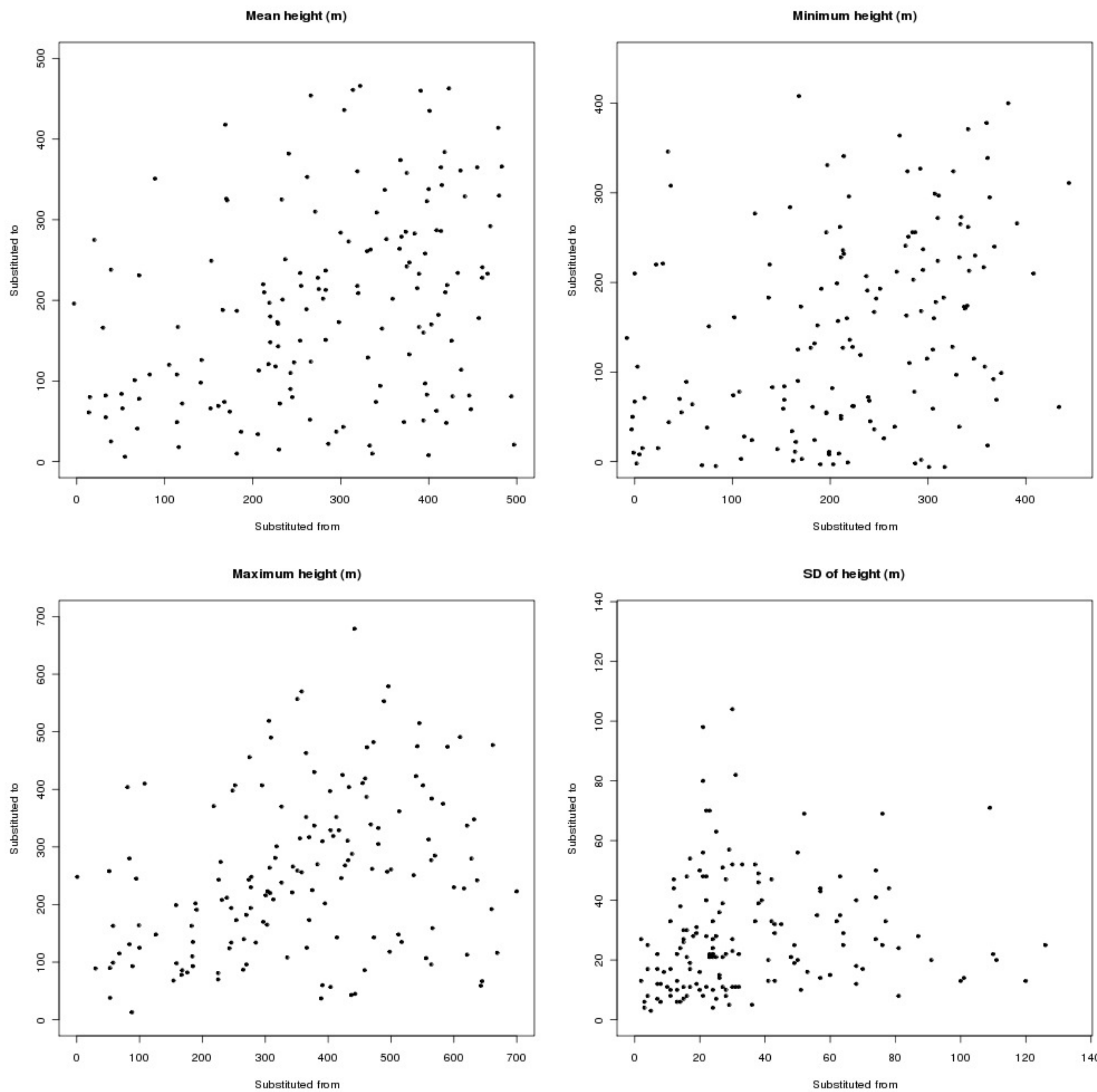


Figure C3. Comparison of the mean, minimum, maximum altitude of 1km^2 squares that have been substituted for and the squares that have replaced them.

Appendix D. Standardised recording sheets used for the Scottish Badger Distribution Survey

SCOTTISH BADGERS

Scottish Badger Distribution Survey 2006 - 2009

Recording Sheet

Grid reference for 1km square: (e.g. AB 12 34)

Recorder name:

Date(s) visited: (DD/MM/YY)

Square fully surveyed: (Y/N)
(Note: If you have been unable to survey the full square, please give details in the 'Other information' section of this form e.g. inaccessible due to steep slopes, abandoned due to bad weather, lack of time etc. Please also mark clearly on your map any land that has not been surveyed).

Signs of presence of badgers

The 1-km survey square is broken up into nine sub-squares as follows:

7	8	9
4	5	6
1	2	3

This nine square grid is marked on the overlay sheet, which is included in your survey pack. To use the overlay sheet, ensure that the bottom left corner of the overlay grid is lined up with the bottom left corner of the 1-km survey square on the 1:10,000 map.

For each sub-square, please record presence/ absence of paths, prints, dung pits/latrines, badger hairs and badger setts. Refer to the information in the survey pack to help confirm your findings.

✓ - Present
X - Absent

	Badger paths	Badger prints	Dung pits/ latrines	Badger hairs	Badger setts
Square 1					
Square 2					
Square 3					
Square 4					
Square 5					
Square 6					
Square 7					
Square 8					
Square 9					

Badger setts

Please record all badger setts found within the 1-km survey square in the table below. Use the guidance provided in the survey pack to:

- confirm your findings as a badger sett
- decide on the status of each entrance
- decide on the category of each sett
- decide on the habitat type on which the sett is found
- establish the grid reference of the sett
- identify evidence of human disturbance (if necessary)

	Confirmation of badger sett				Number of entrances			Category of sett			Broad habitat code	Sett grid reference (AB 1234 5678)	Evidence of human disturbance
	Spoil heap	Hair	Print	Bedding	Well-used	Part-used	Disused	Main (M)	Other (O)	Unsure (U)			
Sett e.g.	✓	✓	x	✓	4	3	3	M			3	NT 3879 3423	x
Sett A													
Sett B													
Sett C													
Sett D													
Sett E													

If human disturbance is suspected, please contact Ian Hutchison (ian@scottishbadgers.org.uk, Tel: 01356 624 851). Please also provide further details in the 'Other information' section below.

Habitat data

On the 1:10,000 scale OS map, mark out the main habitat types found on the 1-km square, and their approximate boundaries. Please code each accordingly, using the habitat codes included in the survey pack.

Other information

Please use this space to add any further information e.g. details of human disturbance, access issues, health and safety issues, areas of square not surveyed, identification of setts adjacent to 1-km survey square etc. Continue over if necessary.

If you have any queries regarding the recording form, please contact the Survey Coordinator (elaine@scottishbadgers.org.uk, Tel: 01896 830 092). Please return recording form and maps to: Survey Coordinator, Scottish Badger Distribution Survey, 43 Montgomery Street, Innerleithen, EH44 6JP. Please return forms as soon as possible after completing your survey, but no later than 28.02.09.

Appendix E. Classification used in determining the degree of usage of each badger entrance

1. Well Used

Entrance is clear of debris and vegetation, with sides worn smooth. A well used entrance does not necessarily have evidence of recent excavation. Leaf litter and cobwebs can appear within a few hours and thus should not be used to determine degree of usage.

2. Partially Used

Entrance is not in regular use and has debris e.g. twigs in the entrance. Entrance could be used after only a minimal amount of clearance.

3. Disused

Entrance has not been in use for some time, is partially blocked and could not be used without considerable effort. Possibly only an overgrown spoil heap and a depression in the ground may remain where the entrance used to be. Rabbits and foxes may take over part of a sett and keep disused entrances open.

Appendix F. Sett classification system used to determine the category of the badger sett located

A **Main Sett** will show signs of almost constant occupation (recent excavation, discarded bedding etc.), with obvious paths to and from the sett, and between sett entrances. Main setts usually have several holes with large spoil heaps, but in exceptional circumstances they may only have one or two entrances. It is normal to find a main sett with some dormant/ disused entrances.

Other setts are those within an occupied territory. They are generally not in use all of the time and may or may not be connected to the main sett by paths. There may be little spoil outside the holes and there may just be a single hole. When not in use by badgers, these setts may be taken over by foxes or even rabbits. However, the tunnel itself, as opposed to the entrance hole, can still be identified as that of a badger by its shape, which is at least 25 centimetres in diameter and normally a flattened oval shape.

Appendix G. Habitat types and codes used for badger sett recording and habitat mapping (adapted from Haines-Young, R.H. et al., 2000)

1. Broad-leaved, mixed and yew woodland
Broadleaved woodland is dominated by trees which are more than 5m high when mature, which form a distinct, although sometimes open, canopy. It includes native broadleaved trees (such as oak, ash and beech), non-native broadleaved trees (such as sycamore and horse chestnut), and yew trees. Mixed woodland is included if broadleaved trees in conifers cover more than 20% of the total stand.

2. Coniferous woodland
This form of woodland is dominated by trees which are more than 5m high when mature, which form a distinct, although sometimes open, canopy. It includes stands of native conifers (Scots pine but not Yew) and non-native conifers (such as Larch and Sitka spruce). Recently felled woodland is also included in this category.

3. Boundaries and other linear features
Hedgerows, fences, lines of trees, walls, stones, earth banks, grass strips, dry ditches, roads, tracks, railways and narrow strips of semi-natural vegetation along verges or cuttings.

4. Arable and horticulture
All arable crops (cereal and vegetable), orchards, market gardening, commercial flower growing, freshly ploughed land, fallow areas, short-term set-aside and annual grass leys.

5. Improved grassland
Characterised by the dominance of a few fast growing species e.g. rye grass and white clover. Typically used for grazing and silage, but can also be managed for recreational purposes. They are often intensively managed using fertiliser and weed control treatments, and may also be ploughed as part of the normal rotation of arable crops.

6. Other grassland
Includes neutral, calcareous and acid grassland. These types of grassland can be distinguished from improved grassland in that they are less fertile and contain a wider range of herb and grass species. These grasslands may be unimproved or semi-improved.

7. Bracken
Stands of vegetation dominated by a continuous canopy cover of bracken at the height of the growing season.

8. Dwarf Shrub Heath
Generally occurs on well drained, nutrient poor, acid soils. Vegetation predominantly heathers or dwarf gorse species.

9. Fen, marsh and swamp
Ground that is permanently, seasonally or periodically waterlogged as a result of ground water or surface run-off. Fens, flushes, marshy grasslands, rush-pastures, swamps and reedbeds.

10. Bog

Wetlands that support vegetation that is usually peat forming and which receives nutrients principally from precipitation rather than ground water. Where bogs have not been modified by surface drying and aeration or heavy grazing the vegetation is dominated by plants tolerant of acid conditions, such as bog mosses and cotton-grass.

11. Standing open water and canals

Lakes, pools, reservoirs, canals, ponds, gravel pits and water-filled ditches.

12. Rivers and streams

Rivers and streams from bank top to bank top.

13. Montane habitats

Habitat types occurring exclusively above the former natural tree line on mountains. Includes prostrate dwarf shrub heath, snow-bed communities, sedge and rush heaths, and moss heaths. Contains species characteristic of alpine and arctic regions and the vegetation is often 'wind-clipped' or prostrate.

14. Inland rock

Both natural and artificial exposed rock surfaces, such as inland cliffs, caves, screes, as well as various excavations such as quarries and quarry waste.

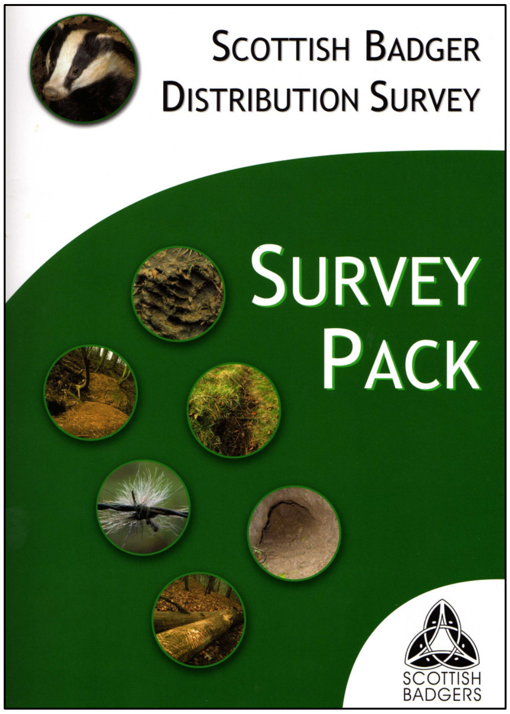
15. Built-up areas and gardens

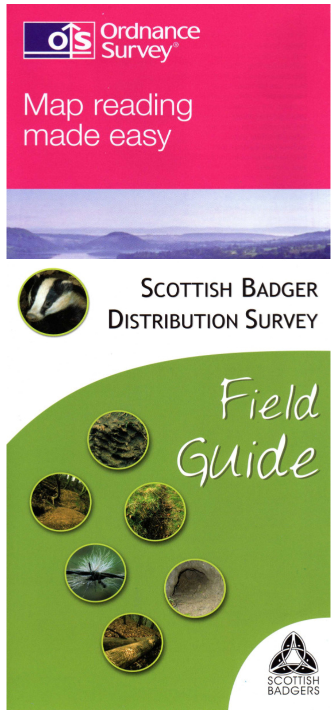
Rural and urban settlements, farm buildings, caravan parks and other man-made built structures such as industrial estates, retail parks, waste and derelict ground, urban parkland and urban transport infrastructure, domestic gardens and allotments.

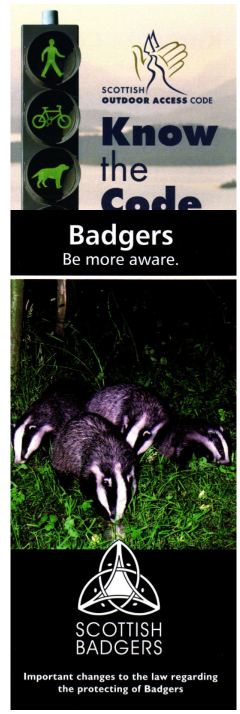
16. Coastal Habitats

Includes sea cliffs, sand dunes, saltmarshes, rocks etc.

Appendix H. Survey packs issued to surveyors for the Scottish Badger Distribution Survey







Appendix I. Missing data: detailed comparison of surveyed squares and those for which data were missing

I1. Overall level of missing data

Data were received for 877 of the 1009 squares within the modified design, with no data available for the remaining 132 squares. The overall level of coverage relative to the original objective of surveying one thousand squares is therefore 87.7%.

I2. Comparison of surveyed and unsurveyed squares

The Survey Coordinator prioritised the allocation of survey work in such a way as to ensure that there was at least 67% coverage within each individual stratum. This target was achieved (Table I1), with coverage being 100% or higher for 35 of the 66 strata, and less than 80% for only ten of the strata. The lowest levels of coverage were generally in Strathclyde (Table I2): a more detailed breakdown of these results (Table I3) shows that this generally reflects relatively low levels of coverage in Argyll and Bute and reasonable levels of coverage throughout the remainder of that region.

The Survey Coordinator also attempted to ensure that there were no unsurveyed squares that lay more than 10km from the nearest surveyed square. In reality, there were 4 squares that violated this rule, but all of these were in highly inaccessible areas and three of them actually lay within 11km of a surveyed square. The average distance from a square with missing data to the nearest square with non-missing data was 4.92km; a graph showing the distribution of distances is given in Figure I1.

The locations of the 132 unsurveyed squares are shown in Figure I2; note that 24 of these squares are themselves substitutions for squares in the original design. It can be seen that the squares are spread throughout Scotland, but that there are relatively few missing squares in lowland and central Scotland and relatively large numbers in the more isolated parts of north and west Scotland. The locations of the 877 surveyed squares are shown in Figure 5.

The average altitude of 1km^2 squares that were missed is significantly higher than that of 1km^2 squares that were surveyed (193m as against 160m; p-value of 0.003 using a t-test), and the standard deviation of altitudes within each 1km^2 square is also slightly higher (p-value of 0.017 using a t-test). There is weak evidence that landscape diversity, as measured by the average number of habitat types with at least 1% land cover, may also be slightly higher for surveyed 1km^2 squares than for missing 1km^2 squares (p-value of 0.095 from fitting a logistic regression model with number of habitat types as the response variable and the presence variable missing/non-missing as the explanatory variable). The percentage cover values for deciduous, arable, improved grassland and built-up areas are generally higher in surveyed than in missed squares (Table I4), whilst the percentage cover values for dwarf shrub heath, coniferous, acid grassland and natural grassland are generally lower.

Table I1. Percentage of 1km^2 squares surveyed in each stratum, relative to the original design shown in Table 3. Note that all squares have at least 67% coverage.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	88.9	100	72.7	100	100	96	100	-	94.4
Central	80	100	83.3	100	83.3	91.7	85.7	100	88.9
D+G	100	75	80	100	100	91.5	100	-	90.9
Fife	-	100	-	100	-	100	100	100	100
Grampian	100	79.4	83.3	125	94.1	78.1	80	100	83.4
Highland	92.3	114.3	80.6	100	81	109.5	100	100	88.7
Lothian	100	100	-	100	100	100	100	100	100
Strathclyde	68.8	80	70.7	75	72.4	76.2	73	95	75.3
Tayside	100	100	90	114.3	95	100	87.5	100	98.2
Total	88.6	92.6	78.4	100	84.1	88.9	84.9	97.6	87.7

Table I2. Difference between the number of 1km^2 squares that were actually surveyed in each stratum and the number of squares in the final, modified, design shown in Table 5.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Borders	-1	0	-3	0	0	-1	0	0	-5
Central	-1	0	-1	0	-1	-1	-1	0	-5
D+G	0	-1	-5	0	0	-5	0	0	-11
Fife	0	0	0	0	0	0	0	0	0
Grampian	0	-14	-4	1	-1	-7	-1	0	-26
Highland	-1	1	-6	0	-16	2	0	0	-20
Lothian	0	0	0	0	0	0	0	0	0
Strathclyde	-5	-1	-12	-2	-8	-15	-10	-1	-54
Tayside	0	0	-1	1	-1	0	-1	0	-2
Total	-8	-15	-32	0	-27	-27	-13	-1	-123

Table I3. Proportion of 1km^2 squares surveyed in each stratum, relative to the original design, based on a more detailed breakdown of geographical regions. Squares with less than 67% coverage are shown in yellow, and those with less than 50% coverage in red.

	Acidic Grassland	Arable and Horticultural	Coniferous	Deciduous	Heather and Bog	Intensive Grassland	Natural Grassland	Urban	Total
Aberdeen & -shire	200	82	92.3	100	90.9	78.9	75	100	85.1
Moray	0	57.1	72.7	133.3	100	76.9	100	100	79.1
Argyll & Bute	57.1		63.6	60	52.9	62.5	28.6	100	55.9
Ayshire & Arran	100	100	83.3	100	100	75.8	100	50	83.1
Clyde Valley	-	75	150	100	100	81.8	100	100	95.5
Dundee & Angus	100	100			85.7	100	100	100	95.5
Perth & Kinross	100	100	90	114.3	100	100	80	100	98.7

Table I4. Comparison of land cover in the 1km^2 squares that were missed and those that were actually surveyed.

	Mean percentage cover		1km^2 squares with at least 1% cover	
	Surveyed	Missed	Surveyed	Missed
Sea/estuary	1.84	0.95	51	6
Inland water	1.23	1.52	91	17
Littoral	0.21	0.29	37	7
Supra-littoral				
Bog	0.88	1.27	53	14
Dwarf shrub heath	14.43	22.68	557	103
Montane habitats	0.03	0.00	4	0
Deciduous	6.82	5.00	576	82
Coniferous	12.85	15.76	548	77
Arable & horticulture	17.58	8.92	487	42
Improved grassland	20.70	18.50	684	85
Natural grassland	9.93	12.95	564	86
Acid grassland	8.72	9.47	521	84
Fen, marsh & swamp				
Built-up areas	4.08	2.21	290	25
Inland bare ground	0.59	0.46	132	25

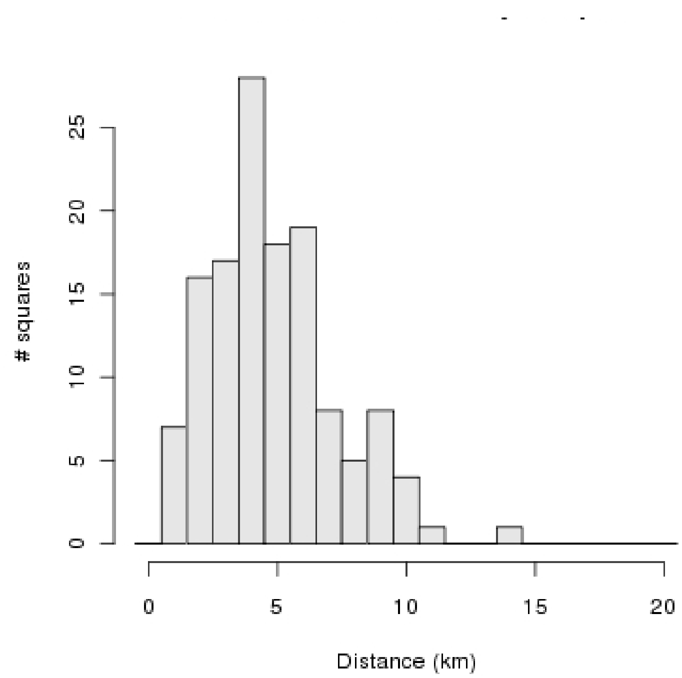


Figure I1. Distribution of distances (in km) from each survey square with missing data to the nearest survey square with non-missing data.

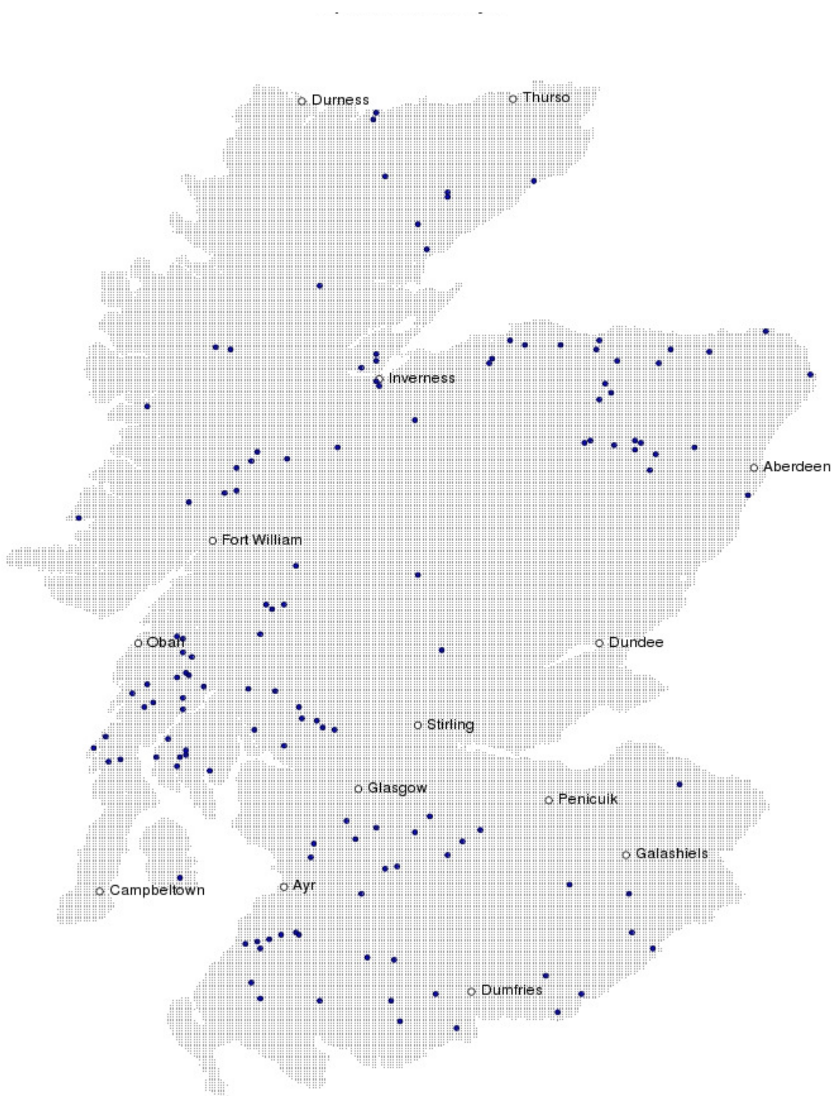
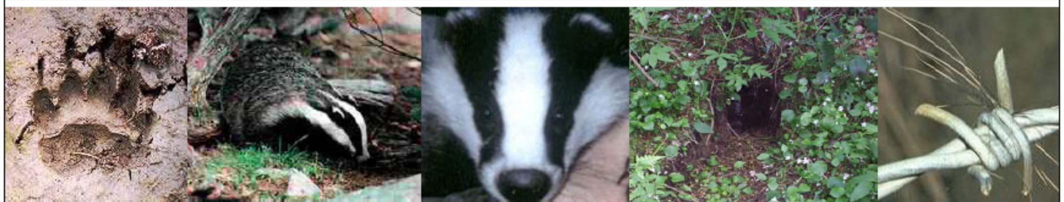


Figure I2. Location of 1km^2 squares for which data were missing.

Appendix J. The fact-sheet on the Scottish Badger Distribution Survey produced for prospective volunteers (front page only)

SCOTTISH BADGER DISTRIBUTION SURVEY



FACTSHEET

The Scottish Badger Distribution Survey is a three year project to determine badger distribution and density in Scotland. The Heritage Lottery Fund and the Scottish Executive are funding the project. The survey will be conducted by volunteers from across Scotland and will provide a baseline from which future changes can be measured.

AIMS AND OBJECTIVES

- To find density and distribution of badger main setts, and the types of habitat in which they are most often found.
- To involve local communities in survey work, raising awareness of badgers amongst the general public.

SCOPE OF THE STUDY

- We aim to survey at least one thousand 1x1km squares selected at random across Scotland, approximately 1% of the land mass.
- We will not be including land above 500 metres or boggy areas.
- We will only be surveying mainland Scotland, with the exception of Arran, where badgers are known to be present.

WHAT ARE WE LOOKING FOR?

- We are surveying for the presence or absence of badger setts and signs, and evidence of human disturbance to setts.

WHAT IS THE ROLE OF THE VOLUNTEER SURVEYOR?

Volunteer Badger Surveyors will be allocated one or more of the randomly selected survey squares, depending on their individual time commitment. They will be given a square(s) in their local area, so they should not have to travel far. They will check the square(s) for badger setts, signs and disturbance, and then record their findings on the Recording Sheet. They will also record the type of habitat that they find in their square(s) e.g. deciduous woodland, pasture etc. They will then send their Recording Sheet back to us, to be added to our central database.

WHAT SKILLS WILL VOLUNTEER SURVEYORS REQUIRE?

As we will provide a free briefing session to all volunteers, the survey is suitable for beginners. You should be enthusiastic and fit and healthy enough to work out in the field. As we are surveying for badger setts and signs, not the badgers themselves, all survey work can be carried out during daylight hours.

WHAT IS THE TIMESCALE OF THE PROJECT?

- Briefing sessions will take place in the Winter of 2006/2007. The survey will commence Winter 2007/2008.

Appendix K. The volunteer sign-up sheet used for the Scottish Badger Distribution Survey

SCOTTISH BADGER DISTRIBUTION SURVEY

VOLUNTEER SURVEYORS REQUIRED!

- Do you want to get involved in nature conservation?
- Would you like to learn how to carry out a badger survey?
- Can you spare a few hours of your time?

If so, then why not join us on this exciting new project to discover badger distribution in Scotland. The survey requires volunteers to make just a few visits, each lasting less than half a day, to your very own 1 x 1 km local survey square, selected by us. In return for your time, we will provide a free one-day training session on badger surveying, and bring you out into the field to look for badger setts yourself!

As we are only surveying for evidence of active badger setts, not the badgers themselves, all survey work can be carried out during daylight hours. You will not be required to survey on high ground and you do not need any previous survey experience as full training will be given. Training events will be held Winter 2006/2007. Surveying will commence Winter 2007/2008.

If you are interested in becoming a Volunteer Badger Surveyor, simply fill out the form below and send it to us at: Scottish Badger Distribution Survey, 48 Adelphi Place, Portobello, EH15 1BE. Alternatively, you can email us at elaine@scottishbadgers.org.uk or contact us via our website at www.scottishbadgers.org.uk

Name ....

Address ....

....

.... **Post Code** ....

Tel. No. (s) ....

Email ....

Interests/ Experience **(Note: experience is not essential as full training will be given)** ....

....

....

Scottish Charity SC034297

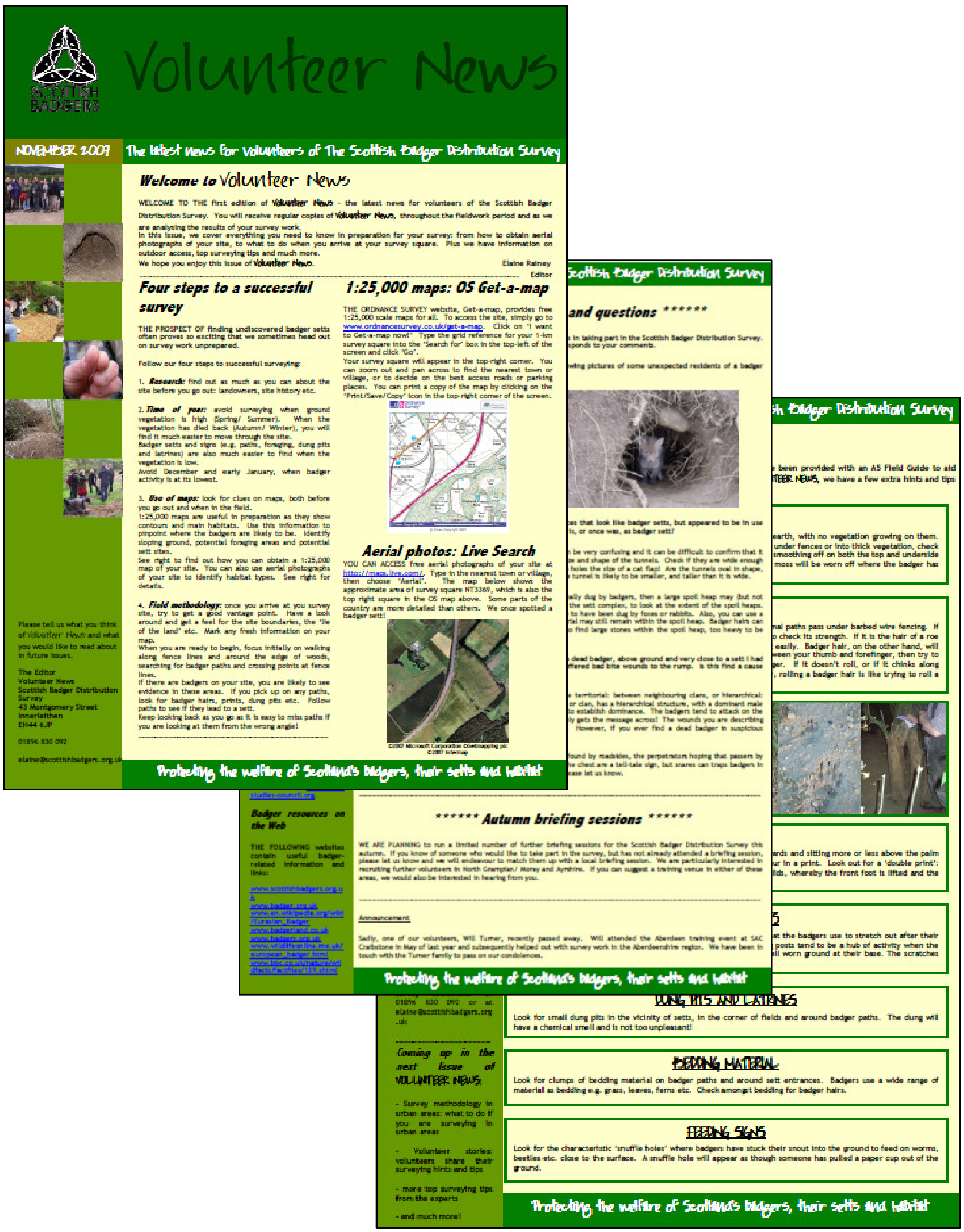
Supported by the Heritage Lottery Fund

SCOTTISH BADGERS

Scottish Badgers
Working together with
Scottish Natural Heritage
To protect Scotland's Badgers

SCOTTISH NATURAL HERITAGE

Appendix L. Sample copy of the volunteer newsletter for the Scottish Badger Distribution Survey



Volunteer News

NOVEMBER 2007 The latest news for volunteers of The Scottish Badger Distribution Survey

Welcome to Volunteer News

WELCOME TO THE first edition of Volunteer News - the latest news for volunteers of the Scottish Badger Distribution Survey. You will receive regular copies of Volunteer News, throughout the fieldwork period and as we are analysing the results of your survey work.
In this issue, we cover everything you need to know in preparation for your survey: from how to obtain aerial photographs of your site, to what to do when you arrive at your survey square. Plus we have information on outdoor access, top surveying tips and much more.
We hope you enjoy this issue of Volunteer News.

Elaine Rainey
Editor

Four steps to a successful survey

THE PROSPECT OF finding undiscovered badger setts often proves so exciting that we sometimes head out on survey work unprepared.

Follow our four steps to successful surveying:

1. ***Research:*** find out as much as you can about the site before you go out: landowners, site history etc.

2. ***Time of year:*** avoid surveying when ground vegetation is high (Spring/ Summer). When the vegetation has died back (Autumn/ Winter), you will find it much easier to move through the site.
Badger setts and signs (e.g. paths, foraging, dung pits and latrines) are also much easier to find when the vegetation is low.
Avoid December and early January, when badger activity is at its lowest.

3. ***Use of maps:*** look for clues on maps, both before you go out and when in the field.
1:25,000 maps are useful in preparation as they show contours and main habitats. Use this information to pinpoint where the badgers are likely to be. Identify sloping ground, potential foraging areas and potential sett sites.
See right to find out how you can obtain a 1:25,000 map of your site. You can also use aerial photographs of your site to identify habitat types. See right for details.

4. ***Field methodology:*** once you arrive at you survey site, try to get a good vantage point. Have a look around and get a feel for the site boundaries, the 'lie of the land' etc. Mark any fresh information on your map.
When you are ready to begin, focus initially on walking along fence lines and around the edge of woods, searching for badger paths and crossing points at fence lines.
If there are badgers on your site, you are likely to see evidence in these areas. If you pick up on any paths, look for badger hairs, prints, dung pits etc. Follow paths to see if they lead to a sett.
Keep looking back as you go as it is easy to miss paths if you are looking at them from the wrong angle!

1:25,000 maps: OS Get-a-map

THE ORDNANCE SURVEY website, Get-a-map, provides free 1:25,000 scale maps for all. To access the site, simply go to www.ordnancesurvey.co.uk/get-a-map. Click on 'I want to Get-a-map now!' Type the grid reference for your 1-km survey square into the 'Search for' box in the top-left of the screen and click 'Go'.
Your survey square will appear in the top-right corner. You can zoom out and pan across to find the nearest town or village, or to decide on the best access roads or parking places. You can print a copy of the map by clicking on the 'Print/Save/Copy' icon in the top-right corner of the screen.

Aerial photos: Live Search

YOU CAN ACCESS free aerial photographs of your site at http://maps.live.com/. Type in the nearest town or village, then choose 'Aerial'. The map below shows the approximate area of survey square NT3369, which is also the top right square in the OS map above. Some parts of the country are more detailed than others. We once spotted a badger sett!

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Please tell us what you think of Volunteer News and what you would like to read about in future issues.

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Protecting the welfare of Scotland's badgers, their setts and habitat

Badger resources on the Web

THE FOLLOWING websites contain useful badger-related information and links:

www.scottishbadgers.org.uk
www.badger.org.uk
www.en.wikipedia.org/wiki/Eurasian_Badger
www.badgerland.co.uk
www.badgers.org.uk
www.wildlifeonline.me.uk/european_badger.html
www.bbc.co.uk/nature/wildfacts/factfiles/189.shtml

******** Autumn briefing sessions ********

WE ARE PLANNING to run a limited number of further briefing sessions for the Scottish Badger Distribution Survey this autumn. If you know of someone who would like to take part in the survey, but has not already attended a briefing session, please let us know and we will endeavour to match them up with a local briefing session. We are particularly interested in recruiting further volunteers in North Grampian/ Moray and Ayrshire. If you can suggest a training venue in either of these areas, we would also be interested in hearing from you.

Announcement

Sadly, one of our volunteers, Will Turner, recently passed away. Will attended the Aberdeen training event at SAC Craibstone in May of last year and subsequently helped out with survey work in the Aberdeenshire region. We have been in touch with the Turner family to pass on our condolences.

Protecting the welfare of Scotland's badgers, their setts and habitat

01896 830 092 or at elaine@scottishbadgers.org.uk

Coming up in the next issue of VOLUNTEER NEWS:

- Survey methodology in urban areas: what to do if you are surveying in urban areas
- Volunteer stories: volunteers share their surveying hints and tips
- more top surveying tips from the experts
- and much more!

DUNG PITS AND LATRINES

Look for small dung pits in the vicinity of setts, in the corner of fields and around badger paths. The dung will have a chemical smell and is not too unpleasant!

BEDDING MATERIAL

Look for clumps of bedding material on badger paths and around sett entrances. Badgers use a wide range of material as bedding e.g. grass, leaves, ferns etc. Check amongst bedding for badger hairs.

FEEDING SIGNS

Look for the characteristic 'snuffle holes' where badgers have stuck their snout into the ground to feed on worms, beetles etc. close to the surface. A snuffle hole will appear as though someone has pulled a paper cup out of the ground.

Protecting the welfare of Scotland's badgers, their setts and habitat

Appendix M. Technical details of procedures used to provide an estimate of total number of badger main setts

M1. Total number of main setts

Assume that we are interested in estimating the total number of badger main setts *Y* within a particular region. We know the total number of 1km^2 squares within that region (*N*), the number of 1km^2 squares that have been surveyed (*n*), and the number of main setts that have actually been found (*y*).

M1.1. Ignoring stratification

The simplest way to estimate *Y* is to ignore the stratification involved in the design, by assuming that the observed squares constitute a simple random sample from the population of all squares within the region. An estimate for the total number of main setts is then given by

$$\hat{Y}_{\text{simple}} = \frac{Ny}{n}. \qquad (1)$$

This formula simply involves dividing the number of main setts (*y*) by the proportion of 1km^2 squares that have been surveyed *n / N*. The standard error associated with the estimator in Equation 1 is equal to

$$\text{SE}(\hat{Y}_{\text{simple}}) = N\sqrt{\left(1 - \frac{n}{N}\right)\frac{s^2}{n}}, \qquad (2)$$

where s^2 is the sample variance in the number of main setts per 1km^2 square (as derived from the survey data). This can be used to calculate an approximate 95% confidence interval

$$\hat{Y}_{\text{simple}} \pm 1.96 \times \text{SE}\left(\hat{Y}_{\text{simple}}\right). \qquad (3)$$

M1.2. Accounting for stratification

Equations 1-3 ignore the fact that we adopted a stratified random design when selecting the squares to survey, and, more importantly, that we deliberately chose to over-sample certain strata and to under-sample others. These estimators are therefore likely to be both biased and inefficient: in particular, they are likely to over-estimate the total number of main setts, because we have deliberately under-surveyed areas with relatively low badger densities. We can obtain a more appropriate estimator by taking account of the number of 1km^2 squares that were surveyed within each stratum. If there are a total of *S* strata then an estimate of *Y* is given by

$$\hat{Y}_{\text{strat,upper}} = \sum_{k=1}^{S} \frac{N_k y_k}{n_k} \qquad (4)$$

where N_k denotes the total number of 1km^2 squares within stratum k, n_k denotes the number of 1km^2 squares that have been surveyed within stratum k, and y_k denotes the number of main setts that have actually been found within stratum k. The corresponding standard error is equal to

$$\mathrm{SE}\left(\hat{Y}_{\mathrm{strat,upper}}\right)=\sqrt{\sum_{k=1}^{S} N_k^2\left(1-\frac{n_k}{N_k}\right)\frac{s_k^2}{n_k}}=\sqrt{\sum_{k=1}^{s} g_k s_k^2}\ , \quad (5)$$

where s_k^2 denotes the sample variance for the number of main setts per 1km^2 squares within stratum k and

$$g_k=\frac{N_k(N_k-n_k)}{n_k}\ . \quad (6)$$

An approximate 95% confidence interval can be constructed via

$$\hat{Y}_{\mathrm{strat,upper}} \pm t_d \times \mathrm{SE}\left(\hat{Y}_{\mathrm{strat,upper}}\right), \quad (7)$$

where t_d is the 97.5% quantile of a t-distribution with d degrees of freedom. The value of d can be based on the Satterthwaite approximation

$$d=\left(\sum_{k=1}^{S} g_k s_k^2\right)^2 \Bigg/ \sum_{k=1}^{S}\left(\frac{g_k^2 s_k^4}{n_k-1}\right). \quad (8)$$

M2. Number of 1km^2 squares that contain a main sett / any sett / badger activity

Another key objective of the analysis is to estimate the total number of 1km^2 squares Y that contain (a) a badger main sett, (b) any active badger sett (main or other), and (c) any form of badger activity (either signs or an active sett), based on the observed number of 1km^2 squares y in which these types of activity have actually been recorded.

The statistical methods are almost identical to those used for calculating the total number of main setts. The only substantive difference is that, because the data are presence, the sample variance now follows immediately from the values of n and y via the equation

$$s^2=\frac{y(n-y)}{n(n-1)}$$

(with equivalent formulae for the sample variances of the individual strata, s_k^2).

Appendix N. Exploring the impact of various different strategies for merging strata

N1. Selection of strata

Which strata should be used for estimation? The obvious choices would be to use combinations of geographical regions with either dominant habitat types (leading to 72 strata) or dominant broad habitat types (leading to 36 strata), since these were the stratifications that were used in constructing the design.

Difficulties arise if, as here, there are strata which contain a single surveyed square or contain no surveyed squares at all. In the latter case, neither the estimator nor the variance can be calculated. In the former case, the estimator can be calculated but the variance cannot (as we need at least two observations in order to calculate the within-stratum variance). These problems can be avoided by merging strata so as to ensure that each stratum contains at least two squares which have actually been surveyed, but care needs to be taken to ensure that strata are merged in an appropriate way.

We investigate four procedures for merging strata:

"<u>sparse</u>": merge all strata containing less than two surveyed squares into a single new stratum

<u>"area"</u>: if a stratum contains less than two surveyed squares then merge it with an equivalent stratum for the same habitat type in a nearby geographical area that contains two or more surveyed squares. For example, "Urban in Highland" contains only one surveyed square and so would be merged into "Urban in Grampian". Regions are merged as follows, when required: Dumfries and Galloway is merged into Strathclyde; Lothian is merged into either Borders or Central; Highland is merged into Grampian; Borders is merged into either Lothian or Dumfries & Galloway; Fife is merged into either Lothian or Central. Sub-regions are combined in the same way, and additionally by merging Ayrshire into Clyde Valley (and vice-versa), Aberdeen & Aberdeenshire into Moray (and vice-versa), merging Perth & Kinross into Central, merging Argyll & Bute into Highland, and merging Dundee & Angus into either Perth & Kinross or Aberdeen & Aberdeenshire.

<u>"habitat":</u> if a stratum contains less than two surveyed squares then merge it with an equivalent stratum for a similar habitat type and the same geographical area. DBHTs are always merged into "agricultural". DHTs are combined by merging "deciduous" into "coniferous" (and vice-versa), "acid grassland" into "heather & bog" and "urban" into "arable", whilst "arable", "natural grassland" and "heather & bog" are all merged into "improved grassland."

<u>"super-regions":</u> use geographical areas that are sufficiently large that each area-by-DHT combination contains at least two surveyed squares. We achieve this through the use of five "super-regions" (Table N1), which are based on aggregations of neighbouring local authority areas.

Spatial heterogeneities in the occurrence of missing data within the larger regions – especially Strathclyde - also lead us to also consider an alternative stratification in which Strathclyde, Tayside and Grampian are divided into sub-regions, leading to a total of 13*4 = 52 or 13*8 = 104 strata.

N2. Impact on estimates and standard errors

We estimate the overall number of badger main setts within Scotland (Table N2), the number of $1km^2$ squares that contain at least one main sett (Table N3), the number of $1km^2$ squares that contain at least one sett of any kind (Table N4) and the number of $1km^2$ squares that contain any form of current badger activity (Table N5) using twenty different forms of stratification (including “no stratification”, which corresponds to treating the data as if they arise from a Simple Random Sample). The estimates are derived under two different assumptions about the treatment of areas that were excluded from the design but which could contain badgers.

For all four measures, the estimates obtained without stratification are substantially higher than those obtained using any form of stratification. This reflects the fact that the design was deliberately designed to under-represent habitat types and geographical areas with low badger densities, so the unstratified estimates, which ignore this under-representation, will systematically over-estimate the overall size of the national population.

The three stratification schemes that are based solely on geographical areas (super-region, region or sub-region) also produce substantially higher estimates than those which also include information on habitat, presumably for the same reason. Stratification schemes that include dominant broad habitat type (DBHT) also lead to slightly higher estimates than those which use the finer classification scheme provided by dominant habitat type (DHT). The stratification schemes that include DHT all lead to virtually identical estimates and standard errors, even though, for example, the scheme that stratifies by DHT-by-sub-region combinations contains almost ten times more strata than that which stratifies by DHT alone.

Scenarios A and B represent different assumptions about the treatment of excluded areas. The differences between the estimates obtained under these two scenarios are very large if the estimates assume no stratification, since the badger density within excluded areas is assumed to be equal to the national average. The differences are much smaller once stratification is used, reflecting the fact that the excluded squares tend to lie within strata that have low badger densities, but are still not negligible.

Table N1. Definitions of "super-regions".

Local authority area	Super-region
Aberdeen City Aberdeenshire Moray Dundee City Angus	NE
Perth & Kinross Stirling Falkirk Clackmannanshire	Mid
Borders Fife City of Edinburgh East Lothian West Lothian Midlothian	SE
Highland Argyll & Bute	NW
East Ayrshire South Ayrshire North Ayrshire Glasgow City Inverclyde Renfrewshire East Renfrewshire South Lanarkshire North Lanarkshire East Dumbartonshire West Dumbartonshire Dumfries & Galloway	SW

Table N2. Estimated number of badger main setts within Scotland, together with standard errors and 95% confidence intervals, as obtained using various different forms of stratification and under two different assumptions regarding the treatment of excluded areas. Strata that contain less than two surveyed squares are merged according to one of three possible rules.

Table N3. Estimated number of $1km^2$ squares within Scotland that contain a badger main sett, together with standard errors and 95% confidence intervals, as obtained using various different forms of stratification and under two different assumptions regarding the treatment of excluded areas.

Table N4. Estimated number of $1km^2$ squares within Scotland that contain any active badger sett, together with standard errors and 95% confidence intervals, as obtained using various different forms of stratification and under two different assumptions regarding the treatment of excluded areas.

Table N5. Estimated number of $1km^2$ squares within Scotland that contain any current badger activity, together with standard errors and 95% confidence intervals, as obtained using various different forms of stratification and under two different assumptions regarding the treatment of excluded areas.

Number of main setts							
Treatment of excluded areas	Stratification	Rule for merging strata	Number of strata	Estimate	Standard error	95% CI lower limit	95% CI upper limit
A	No stratification	-	1	11447	1008	9472	13423
	Super-region	-	5	9901	934	8067	11736
	Region	-	9	10178	941	8331	12025
	Sub-region	-	13	10095	945	8239	11950
	DBHT	-	4	9417	874	7700	11133
	DHT	-	8	8940	856	7259	10621
	DBHT x Super-region	-	20	9331	926	7512	11150
	DHT x Super-region	-	40	8927	915	7129	10725
	DBHT x Region	sparse	31	9245	853	7568	10922
		habitat	30	9254	854	7576	10933
		area	30	9279	856	7597	10960
	DBHT x Sub-region	sparse	42	9304	872	7586	11023
		habitat	41	9295	871	7579	11011
		area	41	9307	875	7584	11030
	DHT x Region	sparse	61	8900	842	7244	10556
		habitat	60	8800	827	7173	10426
		area	**60**	**8955**	**849**	**7284**	**10625**
	DHT x Sub-region	sparse	80	9100	911	7290	10910
		habitat	79	8871	887	7107	10636
		area	79	9059	914	7245	10874
B	No stratification	-	1	13650	1203	11292	16009
	Super-region	-	5	11154	1104	8986	13322
	Region	-	9	11507	1110	9327	13687
	Sub-region	-	13	11384	1114	9196	13572
	DBHT	-	4	10072	1004	8101	12043
	DHT	-	8	9482	1001	7516	11448
	DBHT x Super-region	-	20	9907	1090	7764	12051
	DHT x Super-region	-	40	9491	1104	7317	11665
	DBHT x Region	sparse	31	9713	937	7872	11554
		habitat	30	9728	938	7884	11571
		area	30	9755	939	7908	11601
	DBHT x Sub-region	sparse	42	9786	966	7881	11691
		habitat	41	9777	966	7874	11680
		area	41	9797	969	7887	11707
	DHT x Region	sparse	61	9319	920	7508	11130
		habitat	60	9209	904	7430	10987
		area	**60**	**9370**	**925**	**7549**	**11191**
	DHT x Sub-region	sparse	80	9564	1014	7543	11586
		habitat	79	9308	988	7336	11280
		area	79	9508	1013	7488	11528

Number of 1km² squares containing a main sett								
Treatment of excluded areas	Stratification	Rule for merging strata	Number of strata	Estimate	Standard error	95% CI lower limit	95% CI upper limit
A	No stratification	-	1	9202	720	7790	10613
	Super-region	-	5	7856	636	6608	9104
	Region	-	9	8137	662	6837	9437
	Sub-region	-	13	8013	650	6737	9289
	DBHT	-	4	7497	607	6306	8689
	DHT	-	8	7109	579	5972	8247
	DBHT x Super-region	-	20	7338	601	6158	8518
	DHT x Super-region	-	40	7022	581	5881	8163
	DBHT x Region	sparse	31	7345	594	6179	8511
		habitat	30	7354	594	6187	8520
		area	30	7372	595	6204	8541
	DBHT x Sub-region	sparse	42	7367	593	6202	8532
		habitat	41	7357	591	6196	8518
		area	41	7366	594	6199	8533
	DHT x Region	sparse	61	7039	571	5917	8161
		habitat	60	7006	568	5889	8122
		area	**60**	**7069**	**574**	**5942**	**8196**
	DHT x Sub-region	sparse	80	7125	578	5987	8262
		habitat	79	6995	570	5874	8116
		area	79	7097	582	5951	8242
B	No stratification	-	1	10972	860	9287	12658
	Super-region	-	5	8809	741	7354	10265
	Region	-	9	9187	781	7654	10721
	Sub-region	-	13	9020	766	7515	10525
	DBHT	-	4	8010	694	6648	9373
	DHT	-	8	7482	648	6211	8754
	DBHT x Super-region	-	20	7753	686	6405	9101
	DHT x Super-region	-	40	7401	664	6096	8705
	DBHT x Region	sparse	31	7743	672	6424	9062
		habitat	30	7755	672	6434	9076
		area	30	7776	673	6454	9099
	DBHT x Sub-region	sparse	42	7772	676	6443	9101
		habitat	41	7761	674	6436	9086
		area	41	7777	677	6447	9108
	DHT x Region	sparse	61	7377	637	6124	8629
		habitat	60	7340	634	6094	8586
		area	**60**	**7409**	**640**	**6152**	**8666**
	DHT x Sub-region	sparse	80	7488	652	6204	8771
		habitat	79	7341	643	6076	8606
		area	79	7451	655	6162	8740

Number of 1km² squares containing any active sett

Treatment of excluded areas	Stratification	Rule for merging strata	Number of strata	Estimate	Standard error	95% CI lower limit	95% CI upper limit
A	No stratification	-	1	15156	868	13455	16857
	Super-region	-	5	13344	800	11774	14914
	Region	-	9	13668	816	12066	15270
	Sub-region	-	13	13493	806	11911	15075
	DBHT	-	4	12592	760	11100	14084
	DHT	-	8	12024	721	10608	13439
	DBHT x Super-region	-	20	12430	760	10936	13923
	DHT x Super-region	-	40	12034	735	10591	13477
	DBHT x Region	sparse	31	12427	747	10960	13894
		habitat	30	12439	746	10973	13905
		area	30	12441	745	10977	13904
	DBHT x Sub-region	sparse	42	12495	750	11021	13969
		habitat	41	12455	748	10986	13925
		area	41	12464	748	10995	13933
	DHT x Region	sparse	61	12059	723	10638	13479
		habitat	60	11998	720	10582	13414
		area	**60**	**12092**	**724**	**10669**	**13514**
	DHT x Sub-region	sparse	80	12178	725	10753	13603
		habitat	79	11991	716	10583	13399
		area	79	12143	726	10717	13569
B	No stratification	-	1	18072	1036	16042	20103
	Super-region	-	5	15105	950	13240	16969
	Region	-	9	15499	974	13586	17411
	Sub-region	-	13	15272	963	13381	17163
	DBHT	-	4	13663	902	11891	15435
	DHT	-	8	12758	826	11135	14380
	DBHT x Super-region	-	20	13268	894	11511	15025
	DHT x Super-region	-	40	12736	853	11059	14413
	DBHT x Region	sparse	31	13230	873	11513	14947
		habitat	30	13239	873	11524	14954
		area	30	13245	871	11532	14958
	DBHT x Sub-region	sparse	42	13307	881	11574	15040
		habitat	41	13257	878	11530	14984
		area	41	13274	879	11547	15002
	DHT x Region	sparse	61	12715	832	11079	14350
		habitat	60	12652	829	11021	14282
		area	**60**	**12748**	**832**	**11111**	**14385**
	DHT x Sub-region	sparse	80	12861	840	11209	14514
		habitat	79	12653	831	11018	14287
		area	79	12813	839	11162	14464

Number of 1km² squares containing any form of current badger activity							
Treatment of excluded areas	Stratification	Rule for merging strata	Number of strata	Estimate	Standard error	95% CI lower limit	95% CI upper limit
A	No stratification	-	1	19486	935	17654	21318
	Super-region	-	5	17382	881	15653	19111
	Region	-	9	17872	899	16107	19637
	Sub-region	-	13	17637	887	15895	19380
	DBHT	-	4	16375	833	14739	18010
	DHT	-	8	15872	809	14284	17460
	DBHT x Super-region	-	20	16124	829	14496	17752
	DHT x Super-region	-	40	15798	814	14200	17396
	DBHT x Region	sparse	31	16236	815	14634	17837
		habitat	30	16250	815	14650	17851
		area	30	16256	813	14658	17853
	DBHT x Sub-region	sparse	42	16281	821	14669	17893
		habitat	41	16249	819	14641	17857
		area	41	16261	818	14653	17868
	DHT x Region	sparse	61	15913	798	14345	17480
		habitat	60	15855	797	14289	17420
		area	**60**	**15950**	**798**	**14381**	**17519**
	DHT x Sub-region	sparse	80	16032	807	14446	17618
		habitat	79	15842	801	14267	17417
		area	79	15976	804	14396	17556
B	No stratification	-	1	23236	1116	21049	25423
	Super-region	-	5	19812	1057	17736	21887
	Region	-	9	20424	1086	18291	22557
	Sub-region	-	13	20120	1074	18010	22230
	DBHT	-	4	17826	1003	15856	19796
	DHT	-	8	17023	959	15139	18907
	DBHT x Super-region	-	20	17343	994	15390	19297
	DHT x Super-region	-	40	16881	972	14970	18793
	DBHT x Region	sparse	31	17466	984	15531	19400
		habitat	30	17478	983	15545	19411
		area	30	17488	982	15558	19419
	DBHT x Sub-region	sparse	42	17510	991	15561	19459
		habitat	41	17467	988	15524	19411
		area	41	17491	988	15547	19435
	DHT x Region	sparse	61	16986	956	15105	18867
		habitat	60	16925	955	15046	18804
		area	**60**	**17024**	**957**	**15142**	**18906**
	DHT x Sub-region	sparse	80	17120	969	15214	19026
		habitat	79	16906	963	15011	18801
		Area	79	17048	965	15149	18946

Appendix O. Treatment of 1km^2 squares with a dominant habitat of littoral

Under Scenario B, “excluded” squares within mainland Scotland are assigned to a stratum based on region and dominant habitat type. This is not possible for the relatively small number of 1km^2 squares in which “littoral” is the dominant habitat type, since these squares do not belong to any existing stratum. This issue can be avoided by recalculating the dominant habitat type with “littoral” excluded from the calculations. This is a sensible strategy for those squares in which the “littoral” areas correspond to tidal mud-flats or other areas below the high water mark - these are unlikely to be badger habitats, so sett densities should be no higher than those associated with the dominant land use after littoral areas have been excluded. It is not necessarily sensible for squares in which the “littoral” areas correspond to extensive sand dune systems (which may provide relatively good habitat for badgers).

We therefore deal separately with the very small number of 1km^2 squares (92 in mainland Scotland) for which the dominant habitat type is “littoral”, and the “supra-littoral” land use class is the dominant land use within these littoral areas. These squares are excluded from all of our calculations, corresponding, in effect, to an assumption that badger densities within these squares are zero. The result is that our estimates for the number of 1km^2 squares containing setts or activity could be under-estimated by up to 92. This is a negligible quantity, relative to the standard error associated with the national estimates, so we do not consider this issue further.

Appendix P. Detailed results from broad-scale habitat modelling using logistic regression

Broad-scale habitat models were identified using a stepwise selection algorithm in which model performance was quantified using either the Akaike Information Criterion (AIC; Akaike, 1974) or the Bayesian Information Criterion (BIC; Schwarz, 1978). Manual checks were used to verify that the stepwise procedure has indeed generated a model with lower AIC (or BIC) than a range of plausible alternatives.

This is called the “non-spatial” approach; a “spatial” variant is also considered in which sub-region is included as an additional explanatory variable that cannot be removed during the process of stepwise selection, in order to see if the effects of habitat and altitude were similar after accounting for differences in the overall badger densities of different geographical areas.

The results are shown in Tables P1-P3. They highlight the fact that the proportional cover of deciduous woodland, arable and horticulture and improved grassland all seem to be consistently important variables in determining the presence/absence of badger main setts, any badger setts, and any badger activity. Models selected using AIC (but not BIC) always also contain the presence/absence of coniferous woodland.

The effects of dwarf shrub heath, built-up land, inland water and natural grassland are ambiguous, in the sense that the direction of these effects is not consistent across different models. Finally, the proportional land covers for bog, montane habitats, supra-littoral areas and fen, marsh and swamp do not feature in the models for any of the three measures of badger activity. This is probably due to the fact that these habitats are all relatively rare, and so occur within relatively few of the surveyed squares; the survey data therefore provides an inadequate basis for determining whether or not these particular habitats are associated with badger activity.

The models and estimates obtained using the spatial and non-spatial versions of the models were always broadly similar, suggesting that the effects of land cover upon badger activity were likely to be similar even after accounting for the large differences between regions in overall badger densities. The models obtained using BIC always contain less explanatory variables than the equivalent versions obtained using AIC (3-4 variables for BIC as against 6-10 variables for AIC), and this is an inevitable result of the fact that BIC imposes a stronger penalty against model complexity than AIC. The variables identified using BIC are almost always subsets of those selected using AIC.

Table P1. Habitat characteristics associated with the presence/absence of main setts: results of fitting logistic regression models. For each column estimates are shown for those terms that were included in the final model, as determined by stepwise selection using either AIC or BIC, and colours denote whether the estimates are positive (yellow) or negative (green). Blank entries represent terms that were dropped from the model during stepwise selection, and grey entries denote the intercept term. Sub-region was also included as an additional explanatory variable in the model: results of this "spatial" analysis are shown in the 2^{nd} and 4^{th} columns, but note that the estimates of the "sub-region" effect itself are not actually shown. Land use categories either enter the model as continuous variables (% cover occupied) or binary variables (presence/absence of the land cover type).

		Using AIC		Using BIC	
		Non-spatial	Spatial	Non-spatial	Spatial
Intercept		-3.10	-3.27	-3.05	-3.24
Mean altitude			-0.299		
Unevenness (SD of altitude)					
Sea/estuary	**% cover**				
	presence				
Inland water	**% cover**	-4.49			
	presence				
Littoral	**% cover**				
	presence	-168.81	-176.52		
Supra-littoral	**% cover**				
	presence				
Bog	**% cover**				
	presence				
Dwarf shrub heath	**% cover**	-2.35			
	presence	37.07	41.07		
Montane habitats	**% cover**				
	presence				
Deciduous	**% cover**	2.81	3.31	3.67	4.17
	presence				
Coniferous	**% cover**				
	presence	44.63	53.40		
Arable & horticulture	**% cover**	1.99	2.09	2.19	2.24
	presence				
Improved grassland	**% cover**	2.00	1.73	2.35	1.75
	presence				
Natural grassland	**% cover**				
	presence				
Acid grassland	**% cover**				
	presence				
Fen, marsh & swamp	**% cover**				
	presence				
Built-up areas	**% cover**				
	presence				
Inland bare ground	**% cover**				
	presence				

Table P2. Habitat characteristics associated with the presence/absence of any active sett. All other details are as for Table P1.

		Using AIC		Using BIC	
		Non-spatial	Spatial	Non-spatial	Spatial
Intercept		-3.13	-3.38	-2.38	-2.63
Mean altitude					
Unevenness (SD of altitude)			0.012		
Sea/estuary	**% cover**				
	presence				
Inland water	**% cover**		-11.4		
	presence		1.45		
Littoral	**% cover**				
	presence				
Supra-littoral	**% cover**				
	presence				
Bog	**% cover**				
	presence				
Dwarf shrub heath	**% cover**				
	presence		0.35		
Montane habitats	**% cover**				
	presence				
Deciduous	**% cover**	3.12	3.06	3.55	4.48
	presence				
Coniferous	**% cover**				
	presence	0.40	0.37		
Arable & horticulture	**% cover**	2.02	2.11	1.94	2.27
	presence				
Improved grassland	**% cover**	2.71	1.93	2.68	2.17
	presence	0.50	0.59		
Natural grassland	**% cover**				
	presence		0.33		
Acid grassland	**% cover**				
	presence				
Fen, marsh & swamp	**% cover**				
	presence				
Built-up areas	**% cover**	1.65			
	presence				
Inland bare ground	**% cover**				
	presence				

Table P3. Habitat characteristics associated with the presence/absence of any badger activity. All other details are as for Table P1.

		Using AIC		Using BIC	
		Non-spatial	Spatial	Non-spatial	Spatial
Intercept		-2.56	-2.03	-1.94	-1.88
Mean altitude			-0.0018		
Unevenness (SD of altitude)					
Sea/estuary	**% cover**				
	presence				
Inland water	**% cover**				
	presence				
Littoral	**% cover**				
	presence				
Supra-littoral	**% cover**				
	presence				
Bog	**% cover**				
	presence				
Dwarf shrub heath	**% cover**				
	presence		0.34		
Montane habitats	**% cover**				
	presence				
Deciduous	**% cover**	2.57	2.89	3.07	4.46
	presence		0.35		
Coniferous	**% cover**				
	presence	0.40	0.40		
Arable & horticulture	**% cover**	2.02	2.14	1.98	2.32
	presence				
Improved grassland	**% cover**	2.64	2.11	2.66	2.24
	presence	0.41			
Natural grassland	**% cover**				
	presence				
Acid grassland	**% cover**		-1.20		
	presence				
Fen, marsh & swamp	**% cover**				
	presence				
Built-up areas	**% cover**	1.17			
	presence				
Inland bare ground	**% cover**				
	presence		0.62		0.68