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The National Small Mammal Monitoring Scheme; The First Season – Autumn 2009

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Executive Summary

- The National Small Mammal Monitoring Scheme was launched by The Mammal Society (TMS) in autumn 2009. It followed a scoping study and three pilot studies carried out by TMS and collaborators.
- The aims and objectives of the first season's fieldwork were to establish a network of sites throughout the UK, offshore islands and the Republic of Ireland, to enable volunteers to undertake long-term monitoring of small mammal populations.
- The volunteer base comprised individuals who had varying levels of expertise who had either taken part in previous surveys for TMS or who had attended the TMS small mammal training courses.
- Nine ubiquitous species of small mammal were targeted by the scheme, with an additional four species found only on offshore islands.
- The six different field methods were employed, requiring a range of expertise and commitment from volunteers. Two of these involved one-off searches for signs of harvest mice and field voles, two involved live trapping, one utilised barn owl pellet searches and one was a novel method for analysing DNA from faeces.
- A detailed explanation of the NSMMS sampling strategy is provided. This differs from the traditional sampling strategies employed in other national survey and monitoring schemes. A number of characteristics of small mammal field methods and monitoring schemes are presented as the justification for this new sampling strategy. The consequences of applying this sampling strategy are investigated using Monte Carlo simulations and a detailed analysis of the differences between the NSMMS and traditional schemes is given. In conclusion, it is strongly asserted that the NSMMS scheme gives a number of distinct advantages, without violating the statistical requirements of a sampling strategy that can be used to extrapolate findings to the country as a whole.
- A total of 113 transects/barn owl roosts were completed in 38 sites. This represented a completion rate of approximately 23% of selected sites. Sites were well distributed around England and Wales, although there was a paucity of sites in SW and NW England. Only two sites were completed in Scotland and none in Ireland. One site was completed in Jersey.
- 22 harvest mouse nest search transects were completed with 14% revealing the presence of nests. One transect had 22 nests.
- 19 field vole sign search transects were completed with 95% recording at least one type of sign; runs, feeding signs or latrines.
- Although 32 bait tube transects were laid, DNA analysis has not be carried out to date, so no species identities cannot be reported.
- Capture rates in the two trapping transect methods were variable but all transects captured at least one animal. Five species were recorded, dominated by wood mice, followed by bank voles. However, common shrews were captured less frequently than expected which may have been a consequence of insufficiently sensitive trip weights.

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1 Introduction

1.1 Background to the National Small Mammal Monitoring Scheme

A scoping study was initiated in 1996 by the Department of the Environment Transport and Regions (now DEFRA) and the Joint Nature Conservation Committee (JNCC) to determine the best approach for coordinating and running a mammal monitoring network The subsequent reports (Macdonald *et al*, 1998, Toms *et al*, 1999) resulted in the creation of the Tracking Mammals Partnership (TMP) in 2000, comprising a group of organisations tasked with implementing the recommendations of the reports. As members of the TMP, The Mammal Society contributed to the development and launch of an integrated national strategy for mammals (Battersby & Greenwood, 2004). The scheme aims to establish nationwide networks of volunteers to undertake annual surveillance and monitoring of mammals (including small mammals) in order to assess population trends.

To achieve these aims and with funding from JNCC, TMS developed a project proposal for a National Small Mammal Monitoring Scheme (Sibbald *et al*, 2006). Further funding was obtained from JNCC to undertake a two-year pilot study, based on the recommendations of this document, commencing in 2006. This project used 16 expert volunteers recruited through TMS, to trial five different field methods over three field seasons. (winter 2006/7, summer 2007 & winter 2007/8). This provided a large body of data on the efficacy of the different field methods and the time budgets for each. This, in turn, allowed statistical cost-benefit analysis and power analysis which indicated the likely samples sizes required to detect different degrees of change over time (Poulton & Stone, 2008).

Following the designation of the harvest mouse as a BAP species, TMS and the Wildlife Conservation Research Unit (WildCRU) formed a collaboration to investigate the ecology, distribution and abundance of this ellusive species. Funding was obtained from People's Trust for Endangered Speceis (PTES) and Natural England (EN) for Phase I of a three-phase study. In addition to running a stakeholder workshop, this phase included two field trials into methods for monitoring harvest mice; one carried out by WildCRU into intensive methods for experimental studies (Riordan *et al*, 2009) and one by TMS into extensive, volunteer-based methods suitable for large-scale, long-term monitoring (Poulton & Turner, 2009). The results of both these studies emphasised the difficulty of surveying for harvest mice, especially on a large-scale basis. Poulton & Turner (2009) pointed out that low contact rates would make it difficult to ensure volunteer continuity for harvest mice alone and recommended that that they should be incorporated into a national survey for all small mammal species.

1.2 Aims & Objectives

In the spring of 2009, TMS decided to instigate the National Small Mammal Monitoring Scheme (NSMMS). The aim of the scheme was to establish a network of sites throughout the UK, offshore islands and the Republic of Ireland, to enable volunteers to undertake long-term monitoring of small mammal populations.

The specific objectives of the first season were;

- To prepare documentation for the project, including a volunteer handbook, field forms, licence documentation and publicity material.

- To set up systems to ensure efficient and effective administration of the project. This included a volunteer database with automated methods for creating and recording mailshots and *ad hoc* communications.
- To publicise the scheme through the TMS website, Mammal News and targeted invitations to volunteers and organisations.
- To support volunteers in tasks such as communication with others and organisations, site selection and equipment procurement and loan.
- To provide general advice and encouragement to take part and to ensure prompt return of results and samples.
- To develop a questionnaire for volunteers to provide feedback on the strengths and weaknesses of the scheme to help with further recruitment and expansion of the scheme nationally.
- To undertake an exploratory analysis of the first season's data to highlight possible modifications and improvements to the scheme.

1.3 The Volunteers

Two types of volunteers were identified and targeted separately; individuals and organisations. They were generally mutually exclusive, although there were examples of individuals who expressed an interest in taking part in the scheme and were allocated sites, but who also belonged to local mammal groups that had agreed to take part. Individuals were recruited from records of previous volunteers, or attendees at TMS small mammal training courses. Organisations included local mammal groups, county wildlife trusts and other conservation organisations.

1.4 The Species

The NSMMS targeted a specific group of small mammals (Table 1). These comprise species with mean weights generally less than 50g. and who are not largely arboreal. This definition excluded water voles (*Arvicola terrestris*) the two dormice (*Muscardinus avellenarius* and *Glis glis*) and the two rat species (*Rattus norvegicus* and *R. rattus*). However, by including the islands, four additional species have been included in the group.

Table 1. Small mammal species targeted by the NSMMS.

Ubiquitous Species		*Code*	*Britain*	*Ireland*	*Islands**
Wood Mouse	*Apodemus sylvaticus*	AS	✓	✓	✓
Yellow-necked mouse	*Apodemus flavicollis*	AF	✓		
Harvest mouse	*Micromys minutus*	MM	✓		
House mouse	*Mus domesticus*	MD	✓	✓	✓
Bank vole	*Myodes glareolus*	MG	✓	✓	
Field vole	*Microtus agrestis*	MA	✓		
Common Shrew	*Sorex araneus*	SA	✓		
Pygmy shrew	*Sorex minutus*	SM	✓	✓	✓
Water shrew	*Neomys fodiens*	NF	✓		✓
Island Species*					
Orkney & Guernsey voles	*Microtus arvalis*	MV			✓
Millet's shrew	*Sorex coronatus*	SC			✓
Lesser white-toothed shrew	*Crocidura suaveolens*	CS			✓
Greater white-toothed shrew	*Crocidura russula*	CR		✓	✓

* Islands here only include Orkneys, Scillies and Channel Isles

2 Field Methods

Six different field methods were employed in this scheme. Three collected indirect evidence of the presence of small mammals through their field signs (harvest mouse nest transects, field vole sign transects and bait tube transects), two collected direct evidence through live trapping and one collected incidental evidence through barn owl pellet analysis. However, all five transect methods had a number of common features (Figure 1). Firstly, all transects were 100m in length and, secondly, all transects were divided into 10m sections. Field Survey Units (traps, tubes, quadrats, etc.) were placed in each of the 10m sections as described in detail in the sections below. Full instructions on these methods are given in Poulton (2009), along with examples of field forms used to record data.

The five transect-based methods provided a series of techniques offering a range of commitment and experience. The simplest and quickest methods only required a single visit, lasting one to two hours, to search for field signs. Bait tube transects required two visits, but the time spent during each visit was minimal, usually less than half an hour. The level of experience required for these methods was relatively low, although training in the identification of field signs was necessary for beginners. The low-density trapping transects required three visits, over a 36 hour period, although each visit was relatively quick. This method did not require marking or handling of captured animals, so could be carried out by volunteers with less experience when adequately supervised. Finally, the intensive trapping transects required a total of six visits, spending up to eight hours in the field. Four capture sessions were involved, requiring animals to be marked, and so this method was only recommended for volunteers with high levels of experience and expertise.

2.1 Harvest Mouse Nest Transects

Ten 2m x 10m plots were marked out within each transect (Figure 1a) and numbered sequentially from 1 to 10. Each plot was searched systematically for between five and ten minutes, or until a harvest mouse nest was found. Plots were recorded as present or absent for nests, resulting in a frequency count from 0 to 10 for each transect. These transects were visited once only during each season.

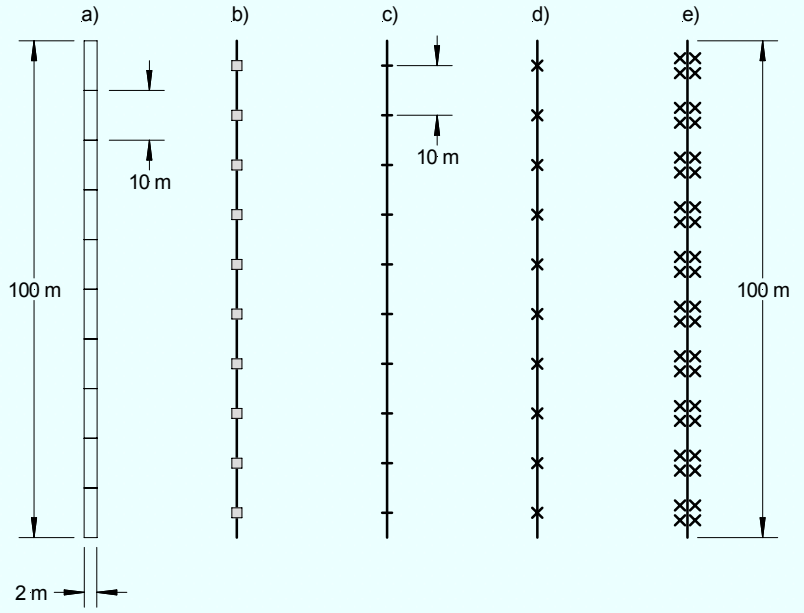

Figure 1. Schematic diagram of the five different types of transect. a) harvest mouse nest transect, b) field vole sign transect, c) bait-tube transect, d) low density live-trapping and e) intensive live-trapping.

2.2 Field Vole Sign Transects

Ten 1m x 1m quadrats spaced at 10m intervals (starting 5m from the beginning of the transect) were searched for the presence of field vole signs (Figure 1b). Field vole signs were classified as runways (worn paths weaving through the grass stems with evidence of chewed-off grass stems), latrines (collections of green/dark green faeces) or feeding signs (clippings of bitten-off grass stems and leaves often left in a criss-cross pattern). Volunteers were asked to search for all three sign types and record the presence of each type separately for each quadrat. This resulted in three frequency counts from 0 to 10 per transect. These transects were visited once only during each season.

2.3 Bait Tube Transects

Bait tubes were made from 4cm diameter plastic waste pipe cut into 20cm lengths with the edges sanded down to reduce the risk of abrasion. One end of each tube was covered with a small piece of muslin or nylon, which was secured in place with an elastic band (Carter & Churchfield, 2006).

Ten bait tubes were used in each transect, each one placed at 10m intervals (5m from the beginning) and numbered sequentially from 1 to 10 (Figure 1c). Tubes were placed with their entrances flush to the ground and hidden out of sight in vegetation. Tubes were baited with 20-30 casters (blowfly pupae *Calliphora* sp.) and small pieces of vegetable or fruit (*e.g.* carrot or apple). Bedding was not placed in the tubes as animals were free to come and go at will. After seven days the transect was revisited and presence of faeces in each tube recorded, giving a count out of ten. Faeces from each tube were collected and stored separately in snap-lock plastic bags, giving a maximum of ten samples per transect. Missing tubes, or those which had been clearly washed out by rain or flooding were marked as "Unused".

Samples were sent to the TMS Surveys Manager and frozen for subsequent DNA analysis. The process of Polymerase Chain Reaction (PCR) allows the DNA from epithelial cells in the gut of the animal producing the faeces to be identified by using species-specific markers.

2.4 Low-density Live Trapping Transects

A single Longworth trap was placed at 10m intervals along each transect, using a total of ten traps per transect (Figure 1d). Traps were set and checked according to the current best practice guidelines(Gurnell & Flowerdew, 2006). Traps were placed on the first evening, filled with bedding, pre-baited (with vegetables, fruit and casters to provide suitable food for a range of small mammals) and the doors locked open. Traps were then re-visited 24 hours later, the food refreshed and the doors set to trap. The next morning the traps were checked, animals identified to species and released. No additional biometric information was collected to reduce the need to handle animals. Trapping failures such as empty traps with closed doors, traps knocked over, doors locked open, traps stolen or animals escaped before identification, were marked as "Unused".

For each trap, the species of animal captured was recorded, giving a possible frequency count out of ten. In a few rare instances, two animals were caught in the same trap. If they were of the same species then, potentially, the count could be greater than ten. All fatalities were recorded.

2.5 Intensive Live Trapping Transects

Intensive trapping transects were similar to low-density transects, in that traps were placed at 10m intervals along the transect. However, in this method, four traps were set at each point, so that each transect comprised 40 traps (Figure 1e). Trap groups were numbered sequentially from 1 to 10 and each trap within the group was coded a to d. This allowed data to be recorded against each individual trap, but also easy aggregation of data at the trap-group level.

Table 2. Intensive trapping regime

Day	*Time*	*Visit Type*	*Activity*
Day 1	PM	Set-up Visit 1	Set, bait and lock open traps
Day 2	AM	Set-up Visit 2	Check food and bedding and unlock traps
Day 2	PM	Capture Visit 1	Check traps, record and mark animals (left flank)
Day 3	AM	Capture Visit 2	Check traps, record and mark animals (left flank)
Day 3	PM	Capture Visit 3	Check traps, record and mark animals (right flank)
Day 4	AM	Capture Visit 4	Check and collect traps, record animals (no mark)

Two visits were required to set the trap line, followed by four capture sessions (Table 2). The traps were laid during the first evening visit, baited and locked open. The next morning the bedding and food was checked and the traps unlocked, giving a twelve hour pre-bait period. Four capture visits were then made at twelve-hourly intervals, starting on the second evening. All animals caught were identified to species, but no other biometric information was recorded.

During the first two sessions, newly-captured animals were marked with a single fur clip on their left flanks; animals previously marked from the first session were not remarked. During the third capture session, all animals were marked on their right flank, regardless of whether they already had left-flank marks. Animals newly captured on the fourth session were not marked, as they would not have a chance of recapture. However, by recording the presence of previous marks on captured animals, it was possible to identify animals caught in either or both of the 24-hour periods. In this way, the data were amenable to Capture-Mark-Recapture estimates. Capture failures and mortality were recorded as in the low-density method.

2.6 Barn Owl Pellet Searches

The barn owl pellet searches were not transect-based, but were based on roosts found anywhere within the tetrads. Each roost was visited twice in the two-month season, about one month apart. On the first visit, all existing pellets on the deposition site beneath the nest were collected (or discarded). Approximately 30 days later, the roost was revisited and any pellets collected and stored in a snap-lock bag. These were sent to the Surveys Manager for subsequent analysis by a TMS expert in small mammal identification. This method allowed a degree of standardisation between roosts, because it ensured that the number of pellets (and numbers of small mammals identified) had been deposited during a known time period.

2.7 Habitats

The relatively small size of transects allowed their location within small, homogenous tracts of land. Volunteers were asked to locate their transects, as far as possible, entirely within uniform habitat types. Twenty-three specific habitat types were identified, belonging to seven broad categories (Table 3). In addition, examples of the microhabitats present within the habitat were also given.

Table 3. General habitat categories, specific habitats belonging to each and examples of microhabitats which may be found in some or all of the specific habitats.

General Category	*Specific Habitats*		*Examples of Microhabitats*
Woodland	1	Deciduous	a) Sparse ground cover within dense woodland
	2	Mixed	b) Bramble / shrub patches
	3	Coniferous	c) Dense grassy clearings / rides
			d) Woodland edges
Open Farmland	4	Permanent grassland	a) Sparse ground cover in leys or arable
	5	Grass Leys	b) No ground cover in ploughed fields
	6	Arable	c) Dense cover in Set-aside fields
	7	Orchards	d) Sparse ground cover
Field Boundaries	8	Hedgerows	a) Sparse ground cover within mature hedgerows
	9	Fence lines	b) Rank grassland alongside fields or roads
	10	Walls	c) Reed / rush beds
	11	Ditches	d)Inundated ground
Riparian	12	Rivers	a) Inundated ground
	13	Streams	b) Bramble / shrub patches
	14	Standing water	c) Reed / rush beds
	15	Canals	d) Rank grassland
Moorland & lowland heath	16	Heather moorland	a) Dense *Calluna* and ericaceous dwarf shrubs
	17	Acid grassland	b) Nardus / Molinia grassland
	18	Lowland Heath	c) Pteridium stands
			d)Semi-improved grassland
Coastal	19	Saltmarsh	a) Dense ground cover (purslane / aster / sea lavender stands)
	20	Sand dunes	b) Dense ground cover (Dune slacks and marram grass stands)
	21	Cliffs / downs	c) Short turf (Araneria grassland)
Urban	22	Road verges	a) Dense rank grassland
	23	Parks & gardens	b) Dense cover in horticulture / flower beds

3 The Sampling Strategy

It became clear in the early stages of the design of the NSMMS that three spatial tranches of sites would be required:

- To provide a representative sample of sites that would allow results to be extrapolated to the country as a whole, the main tranche would be the **National Random Sample**. This is described in more detail below.
- However, it was anticipated that a number of volunteers might come forward in a professional capacity, with a specific requirement to work on sites belonging to, or managed by, their employer organisation. These might include county wildlife trusts with their own reserves, the country agencies with SSSIs or NNRs, National Park Authorities or other landowners such as the National Trust, The Forestry Commission or the MOD. Rather than insist that these volunteers take part in the National Random Sample, and risk losing their interest, it was decided to allow them to select their own **Special Interest Sites**, as long as they conformed to the standard field methods. The results from these sites could not be extrapolated to the country as a whole, but they could be used as case-studies in their own right. Furthermore, as they would usually be sites of high nature conservation value, they could be used as a non-representative tranche of sites that could characterise "optimal" small mammal communities.
- As a number of species and sub-species are only found in the UK on small offshore islands, there was a strong desire to include these in the NSMMS. However, the choice of primary sampling unit and the method of selecting the sample used in the National Random Sample might not be possible on small islands. Consequently, volunteers choosing to work on islands smaller than about 20 km^2 (the area of five tetrads) could treat the whole island as an **Island Site**, as long as they conformed to the standard field methods. This would help to overcome the extreme edge effect found in small, irregularly shaped islands, and allow zones and habitats of interest to be included by choice. As there was no requirement to extrapolate these sites to the country as a whole, the lack of objectivity was less important.

3.1 Temporal Design

From a temporal viewpoint, small mammal monitoring schemes have traditionally trapped in late autumn and late spring to coincide with the peaks and troughs of the annual cycle in productivity (*e.g.* Flowerdew *et al*; 2004, Mallorie & Flowerdew; 1994). Following this approach, the pilot study (Poulton & Stone, 2008) trialled two 2-month windows (April/May and October/November). Volunteers were asked to carry out fieldwork during these periods, with no constraints within the windows. This was the method undertaken in the first season of the NSMMS, running from 1st October 2009 to 30th November 2009.

3.2 Spatial Design of the National Random Sample

There are two main considerations in the design of the spatial dimension of a sampling strategy; a) the choice of the Primary Sampling Unit (PSU, otherwise refered to as a site) and b) the mechanism by which these units will be sampled from the overall population or sampling frame. Other issues such as sample size and stratification are secondary, and are more relevant to questions of power. These have been explored in detail in the Mammal Society's desk study (Sibbald *et al*, 2006) and pilot survey (Poulton & Stone, 2008). Before discussing the details of the spatial sampling strategy it is necessary to explain the specific characteristics of small mammal methods that influence the sampling design.

3.2.1 Specific Characteristics of a Small Mammal Monitoring Scheme

Many long-term monitoring schemes for other taxa, such as birds, bats or butterflies, rely on observational techniques. These usually involve walking a transect or predefined route and recording the presence or counts of individuals. They may also utilise techniques such as distance sampling or constant effort methods to obtain standardised, quantifiable data. Methods used for detection may include visual sightings, identification of calls or songs, or the used of ultra-sonic detectors in the case of bats.

Methods such as these have the huge advantage that volunteers can collect data quickly and unobtrusively, often from public rights-of-way, without the need for access to specific parcels of land. Clearly, there are exceptions to this, such as the monitoring of bat roosts or nest boxes but, in general, observational methods are ephemeral or transient.

Small mammals cannot be monitored in this way. There are a number of factors that characterise the methods described in the previous section;

- All the field methods make use of some form of equipment, either to mark out sections of the transect or to actively obtain data. The equipment may only be used on a single visit, such as quadrats for field vole sign searches, but is usually left unattended for periods of several days.
- They all require access to specific tracts of land. Although it may be possible to establish a field vole transect, say, along a road-side verge or public footpath, most habitats of interest will be in private ownership.
- Furthermore, the methods are all highly localised and habitat specific. For example, to obtain data on populations of small mammals in hedgerows, it would not be feasible to place a trapping transect even five metres away from the hedge. Whilst it might be possible to monitor sedge warblers in a reedbed or ditch from 25 metres away, to monitor harvest mice in such a habitat would require direct access to the habitat.
- Four of the methods described above involve either the permanent removal of biological material (faeces or owl pellets) or the temporary capturing and handling of live animals.

All of the previous points make it essential that landowner permission is obtained for all field methods. This can introduce a substantial overhead in the establishment of a site, and runs the risk that it will not be granted. Two further factors relate to the number and timing of visits.

- The more intensive trapping methods require visits at specific times of day, generally dawn and dusk. The situation regarding licencing is different in all four countries of the UK and the ROI, but currently they set conditions on the length of time that traps can be left between inspections. (In one case this is only three or four hours which would mean more frequent visits than the methodology requires.) This makes the commitment to a full trapping regime essential.
- Furthermore, each PSU may have a number of transects established within it, requiring as many as twelve or fifteen visits in the two month window . The Intensive Trapping transects in particular, involve two visits per day, on sequential days, which can impose a severe time constraint for volunteers.

3.2.2 The Choice of Primary Sampling Unit

These characteristics of the monitoring scheme described above prompted the choice of Ordnance Survey tetrads (2km x 2km square) as the PSUs. They have four times the area of the more commonly used monad (1km x 1km square) and, therefore, a number of advantages.

- On average, they will contain a greater range of habitats, allowing volunteers a better choice of transect location.

- Similarly, they will contain more landowners, so that volunteers are more likely to obtain permission from at least one landowner. In this way, a PSU is less likely to be rejected because of lack of access.
- Tetrads are also less likely to be rejected because they are entirely dominated by unsuitable or inaccessible land.

It is important to emphasise that the field methods do not try to describe the small mammal communities for the PSU as a whole. The PSU is simply the first stage in the sampling strategy that enables the location of transects.

3.2.3 The Choice of Sampling Strategy

The main characteristic of this monitoring scheme that influences sampling strategy is the amount of effort required per site. This means that the distance between the volunteer's home or place of work and their NSMMS site is critical. If ten or fifteen return trips are required, as described above, it would be entirely unreasonable to expect volunteers to cover a site that is more than twenty kilometres distant.

Many national monitoring schemes have adopted a traditional sampling approach based on an objective selection of 1km^2 grid squares (see *e.g.* Walsh *et al*; 2001). The statistical population is defined (*e.g.* all 1km^2 squares in the UK) as the sampling frame. The sample size is then specified in either absolute (*e.g.* 1,000 sampling units) or proportional terms (*e.g.* 1% of the population), depending on the power required. The sampling strategy may also involve stratification based on environmental, habitat or other factors, in order to increase power or to ensure a minimum sample size in small, scarce or important strata. This may allocate equal, proportional or optimal sample sizes to each stratum (Krebs, 1989), depending on the level of *a priori* knowledge of population variances. However, there is a "cost" to stratification, as the subsequent analysis becomes more complex, and statistical models may become much more difficult to construct and interpret.

National small mammal surveys have also used other sampling strategies. Harris (1979) used a "passive" volunteer-based system to request records of harvest mouse nests and other records such as trapping, sightings and cat predation. Marsh *et al* (2001) used a more managed approach for volunteers to carry out a live-trapping regime for yellow-necked mice. In both these examples, the volunteers were allowed to select their own sites, as long as they conformed to certain characteristics. (A good review of other methods, including the use of a regular sampling grid can be found in Macdonald *et al*; 1998).

The final choice of sampling strategy for the NSMMS was informed by these studies, the pilot monitoring scheme (Poulton & Stone, 2008), discussion within TMS Surveys Committee and consultation with organisations such as the Bat Conservation Trust and the British Trust for Ornithology. It was also necessary to estimate the numbers of volunteers likely to take part in the scheme, as well as volunteer turnover and how these figures would translate into numbers of sites.

It was anticipated that the number of volunteers likely to take part at the outset of the scheme would be between 100 and 200, rising to a maximum of 300 to 400 on a sustainable basis. It was considered unlikely that the number of volunteers would ever exceed 500. As some of these would take part through local mammal groups and other organisations, the actual number of sites would probably be lower than this. Furthermore, Noble *et al* (2005) showed that in a pilot winter mammal monitoring scheme with over 1,000 sites, year-on-year turnover was high; exceeding 50% in a number of cases.

The sampling frame comprised all the tetrads in the UK and Republic of Ireland. Great Britain alone has approximately 61,200 tetrads. The standard approach of drawing a sample of this population of tetrads could have been applied, after which the sites would have been allocated to volunteers. The first decision, therefore, was what sampling fraction would be appropriate. A 1% sample would have given 612 tetrads, a 2% would have given 1224, *etc*. This raised the first

problem. If we had realistically estimated that the maximum number of sites we were ever likely to cover using volunteers was 500, then even a 1% sample would be impossible to complete, given that each volunteer covers only one site. Furthermore, The Mammal Society did not have the staff to complete the vacant sites, unlike other, larger organisations or those with external funding.

The problem with incomplete coverage of a sample, is that it immediately becomes biased. If the estimate of 100 to 200 volunteers at the outset was correct, then we would need to have drawn a 0.25% sample of tetrads, which would have yielded just over 150 potential sites which, hopefully, could be matched to volunteers within a few years. However, it would then be necessary to instigate a sequential sampling process, whereby the sample size was increased appropriately as additional volunteers arose.

But this raised the second problem – distance to sites. We have already ascertained that due to the high effort required for small mammal monitoring methods, sites would have to be relatively close to their volunteers. The problem with a small sampling fraction is that the distance between sampling units is high, and the smaller the sampling fraction, the greater the distance. Now, it would be possible to reduce this effect by stratifying the sample, based on *a priori* knowledge of population density or distribution of volunteers. This could increase the sampling fractions in strata with high numbers of volunteers and so reduce the average distance that volunteers had to travel to their nearest site. However, this would leave the few volunteers in the more remote regions with an even worse situation because the sampling density here would be even lower. Other forms of stratification, such as land class or political/administrative regions would provide little or no improvement.

To overcome these problems a different approach to assigning sites to individual volunteers has been developed in the NSMMS. This was based on a location provided by the volunteer; either a home or work grid reference. From this, three zones of tetrads; those within 4km, 7km and 10km were defined (Figure 2). There are 13, 24 and 44 tetrads respectively, in these zones, giving a total of 81 within a straight-line distance of 10km. One tetrad was randomly selected from each zone, providing a list of three, from which the volunteer could choose one as their site. This was marked as a selected site, so that it would not be offered to a subsequent volunteer.

Bearing in mind that straight-line distances do not always equate to real travelling distances, this scheme generally ensured that every volunteer was offered at least one tetrad within about 6km and three tetrads within about 12 or 15km. The main drawback with this system was for volunteers who lived on the coast, where the number of tetrads within the three zones could be severely curtailed. A lesser problem occured for volunteers living near estuaries or large rivers, where the straight-line distance to a tetrad may not have reflected the much longer journey required to reach it by road. However, these problems would still be be faced by a volunteer under a more traditional sampling regime.

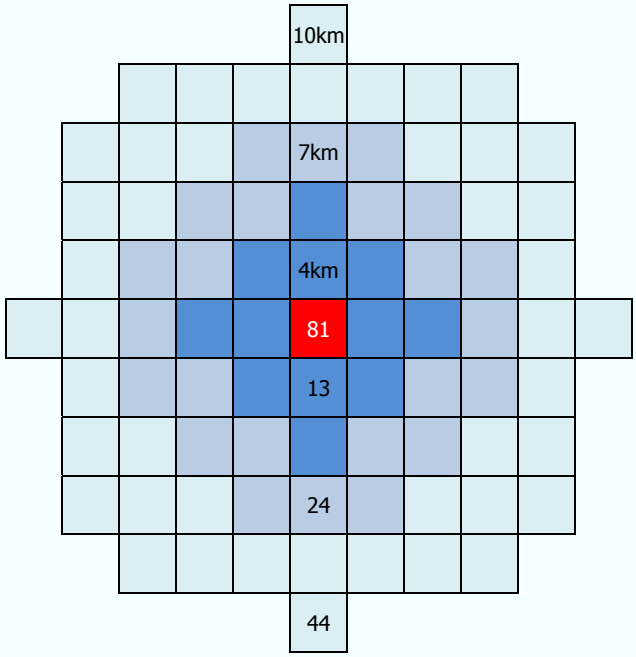

Figure 2. Schematic diagram of the NSMMS sampling strategy. Three sampling zones (10km, 7km and 4km) are shown around the volunteer grid reference, located in the red, central tetrad. The number of tetrads in each zone (81 in total).

The choice of three tetrads was provided to allow for totally unsuitable or unaccessible sites. These might be intensively industrial sites, airports, docks, power stations, MOD sites or inner cities although, as already

mentioned, the size of a tetrad, would usually allow at least part of it to be suitable. In a traditional sampling scheme, these sites would be excluded from the sampling frame.

3.3 Simulation Modelling of Sampling Strategies

To test this sampling strategy against the traditional methods a series of simulations was undertaken using the 61,210 tetrads from Great Britain. The primary purpose was to compare the distributions of sites obtained from the two different approaches. Three main variables were included in the simulations:

- The number of volunteers (100, 200, 500, 1000)
- The number of tetrads in the traditional sampling method (612, 1224, 1836) representing 1%, 2% and 3% sampling fractions.
- Whether the sampling was purely random or stratified by population density.

The last two variables were crossed to give six different traditional sampling strategies, plus the NSMMS strategy, giving seven in total. These were then crossed with all four volunteer numbers to give 28 combinations. To test the differences in outcome between these combinations, four sample statistics were calculated:

- The mean distance between a volunteer's location and their site.
- The number of sites allocated to volunteers.
- The number of volunteers that had sites allocated.
- The mean nearest-neighbour distance between sites.

3.3.1 The Simulation Algorithm

The algorithm for carrying out the simulations proceeded through the following stages. (Note the indented bullets, representing stages that are repeated within the loops.)

- Loop through the four volunteer counts.
    - Generate the relevant number of random locations for the volunteers (100, 200, 500 or 1000).
    - For each volunteer, select a site using the NSMMS scheme described above (Section 3.2.3) and based on the probabilities of 50%, 30% and 20% that the site will be chosen from the 4km, 7km or 10km zones, respectively.
    - Calculate the four sample statistics for the NSMMS sample and store.
    - Loop through the six combinations of sampling parameters (random/stratified and 1%, 2% & 3% samples).
        - Generate the relevant sample of tetrads.
        - Select one site for each volunteer, by finding the nearest unused tetrad in the sample. If no tetrads are available within a 50km straight-line distance, then assign the volunteer to the nearest tetrad, but mark it as "shared". Consequently, the number of volunteers that had sites allocated would be incremented, but the number of sites allocated would not.
        - Calculate the four sample statistics for the sampling parameters and store.
    - Use the next combination of sampling parameters.
- Use the next volunteer count.

This process represented one simulation and generated 112 (4 x 28) sample statistics. The whole process was repeated 5,000 times to give 560,000 values.

To obtain a realistic geographic distribution of volunteers, a weighting from 1 to 100 was assigned to each 100km grid square. This crudely represented the relative densities of volunteers across the country. The weighting was used as the likelihood that a random location would be selected from any particular 100km grid square. Of the 40 100km grid squares used in the simulations (see Appendix), five (NC, ND, NG, NM & NR) were given weightings of 1, whilst only one square (TQ) was assigned a weighting of 100. The weightings did not reflect the proportion of the square that constituted dry land, as this was already accounted for by the number of tetrads within the grid square (between 21 and 2,500). Furthermore, no special case was made for coastal tetrads which fell entirely between the high and low water marks.

To derive a stratification based on population or volunteer densities, we would need exactly this type of weighting system. Consequently, it was also used to derive the three stratified samples and, as such, provided an artificially perfect stratification. In reality, we would either not know the location of all potential volunteers at the outset, or the location of volunteers would not be representative of the population as a whole. Distances between volunteers and their sites were calculated as the Euclidean distance, taking no account of intervening topographical, riverine or coastal features and so gave only a rough estimate of the real travelling distance. The nearest-neighbour distances between sites were calculated in the same way.

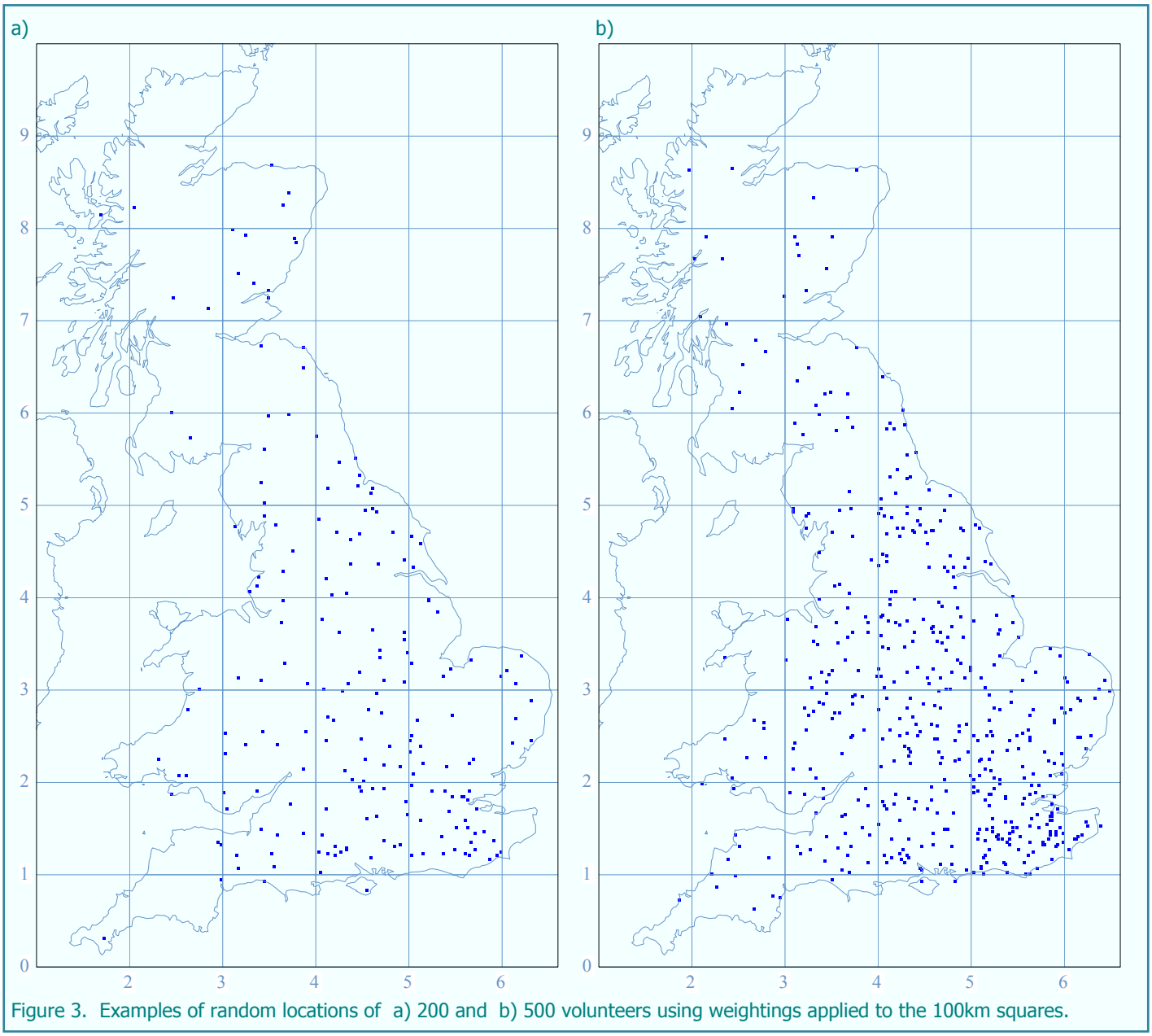

Figure 3. Examples of random locations of a) 200 and b) 500 volunteers using weightings applied to the 100km squares.

3.3.2 Examples of the Results of the Simulations

As an example of the distributions of volunteers generated using the 100km square weightings, Figure 3[1] shows the examples of 200 and 500 volunteers. The effect of the weighting of 100 applied to square 51 is clear in Figure 3a, as are the low weightings applied to the five peripheral Scottish squares. Note that in this example, even though square 61 had been assigned a relatively high weighting of 40, it still didn't achieve a single randomly located volunteer.

Figure 4 shows the locations of the 612 tetrads drawn from random and stratified 1% samples. This also clearly shows the effects of the weightings. For example, in the stratified sample, no tetrads were selected in square 28. In contrast, there were 19 tetrads selected in the random sample – roughly in proportion to the area of land within the square (about 2,350 tetrads). At the other extreme, square 51 had 29 in the random sample compared to approximately 100 in the stratified sample.

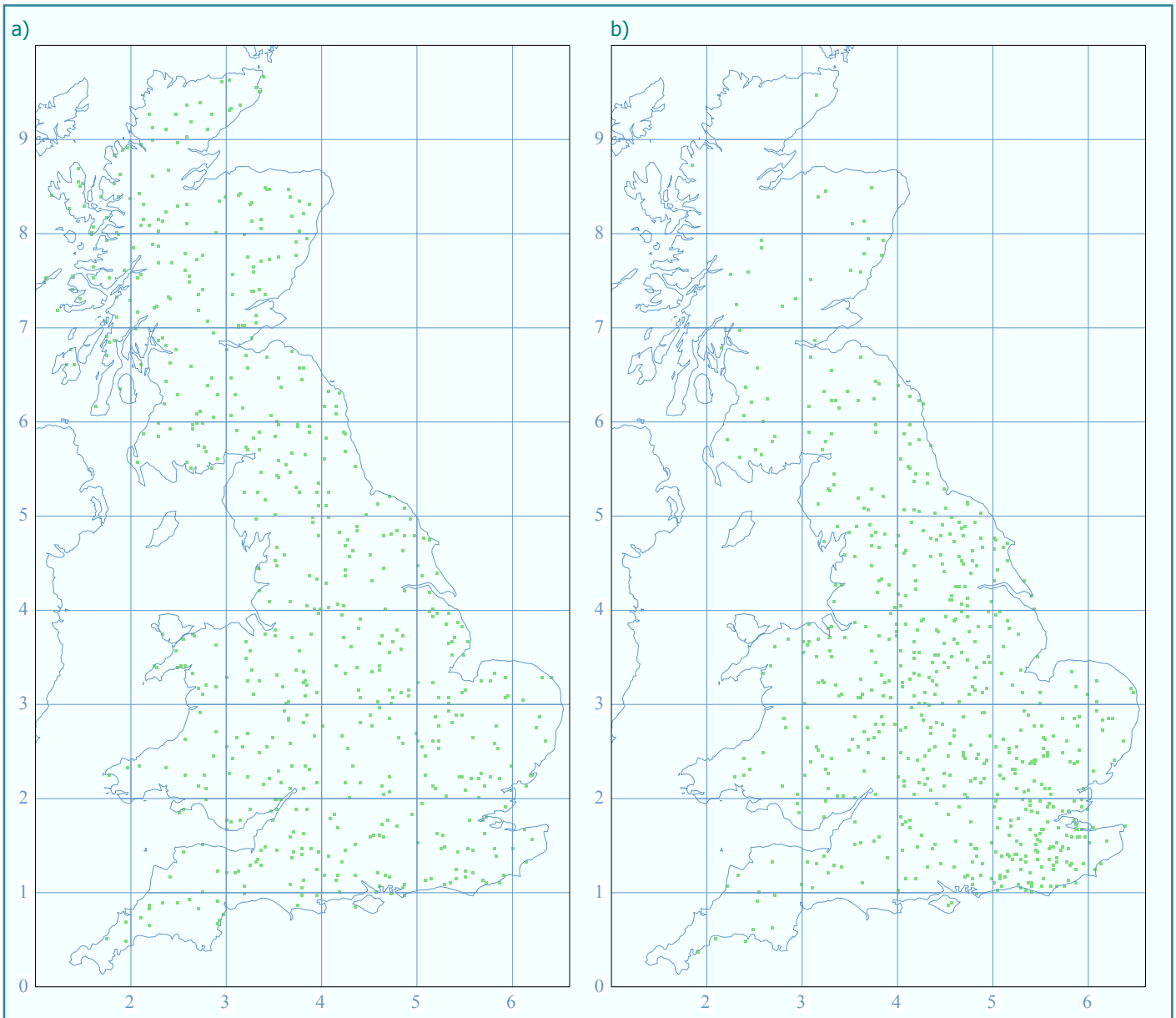

Figure 4. Example of a) 1% fully random and b) 1% stratified random samples of tetrads (n = 612).

[1] All maps comprise embedded bitmap objects. Tetrads are plotted to 2km accuracy, but are shown as 3km squares for easier viewing when displayed on a monitor – zooming in will reveal them in high resolution. Printer resolution is usually higher than screen resolution so should produce useable maps.

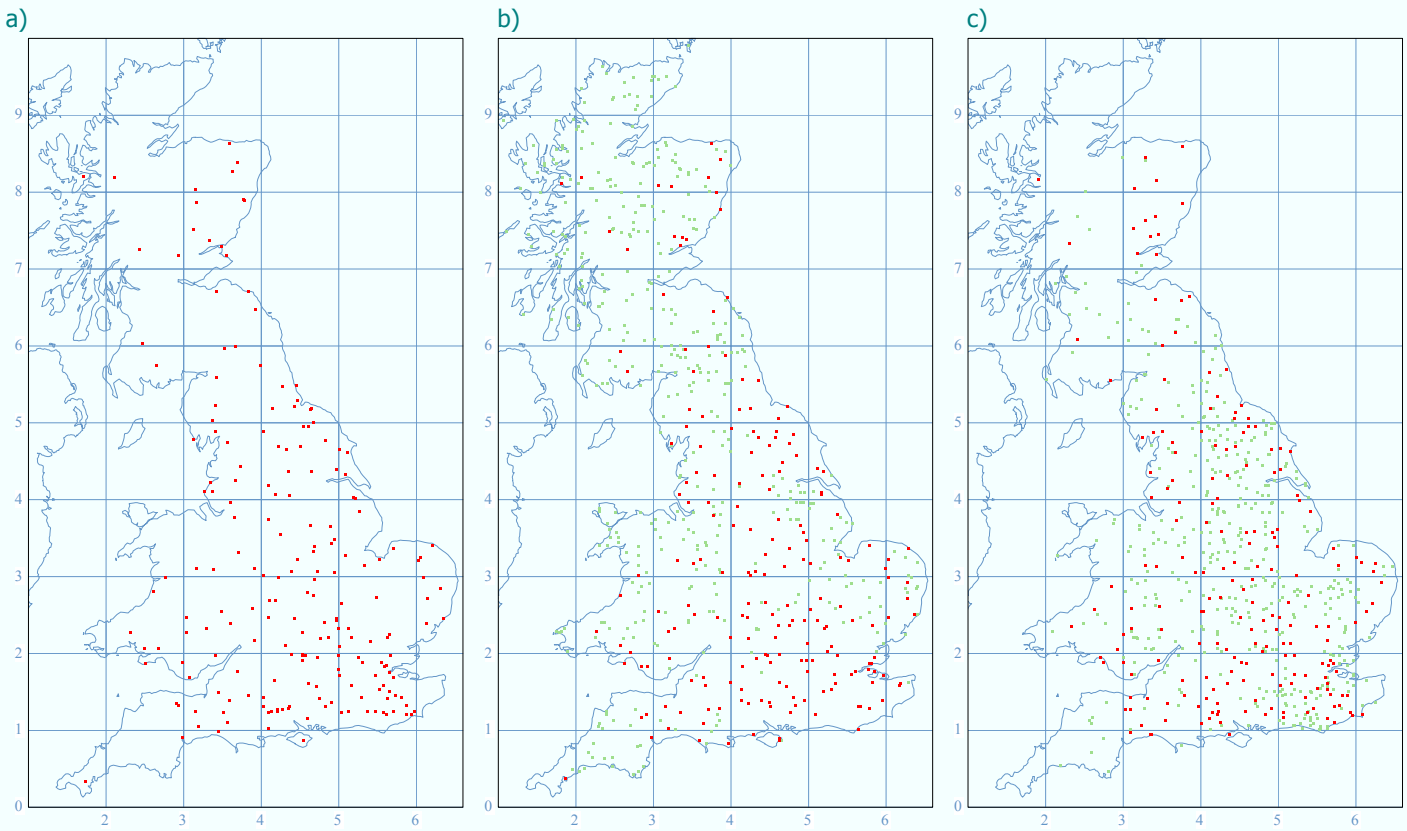

Figure 5. Example of the final distribution of sites (red squares) for the 200 volunteers shown in Figure 3a using a) the NSMMS scheme, b) a random 1% sample of tetrads (n = 612) and c) a stratified 1% samples of tetrads (green squares).

Finally, the results of deriving the sites using the three different sampling strategies are shown in Figure 5. Inevitably, the NSMMS scheme generate a distribution of sites that closely matched the distribution of volunteers – this is what it was designed to do. However, the locations of the sites from the random and stratified sampling strategies were determined primarily by the location of volunteers, but were also influenced by the number and location of nearby tetrads. In particular, the random sampling strategy had the severe drawback that regions of low volunteer density (e.g. square 29 in Figure 5b), resulted in a large number of tetrads not being selected as sites, whereas in areas of high volunteer density (e.g. 51) all available tetrads were assigned as sites. In contrast to this, although the stratified sample was "matched" to the location of volunteers, it had the drawback that in areas of low volunteer density (and hence low tetrad density), the distance that a volunteer had to travel to find a site, may have been unacceptably high. For example, the volunteer towards the SE corner of square 27 in Figure 3a was assigned to the tetrad at the head of the Firth of Tay in square 37 in Figure 5c – a Euclidean distance of about 30kms.

3.3.3 Analysis of Simulation Statistics

The four sample statistics from the simulations were analysed across the different model parameters. Three of them (the mean distance between a volunteer's location and their site, the number of tetrads allocated to volunteers and the number of volunteers that had tetrads allocated) were summarised in their raw form as these measures were of direct interest. However, the mean nearest-neighbour distances between sites were used to calculate an Index of Aggregation.

3.3.3.1 The Distance Between Volunteers and Sites

For each of the 5,000 simulations the mean distance between the volunteer and the site which was allocated to them was calculated for all volunteers. To compare these distances between different

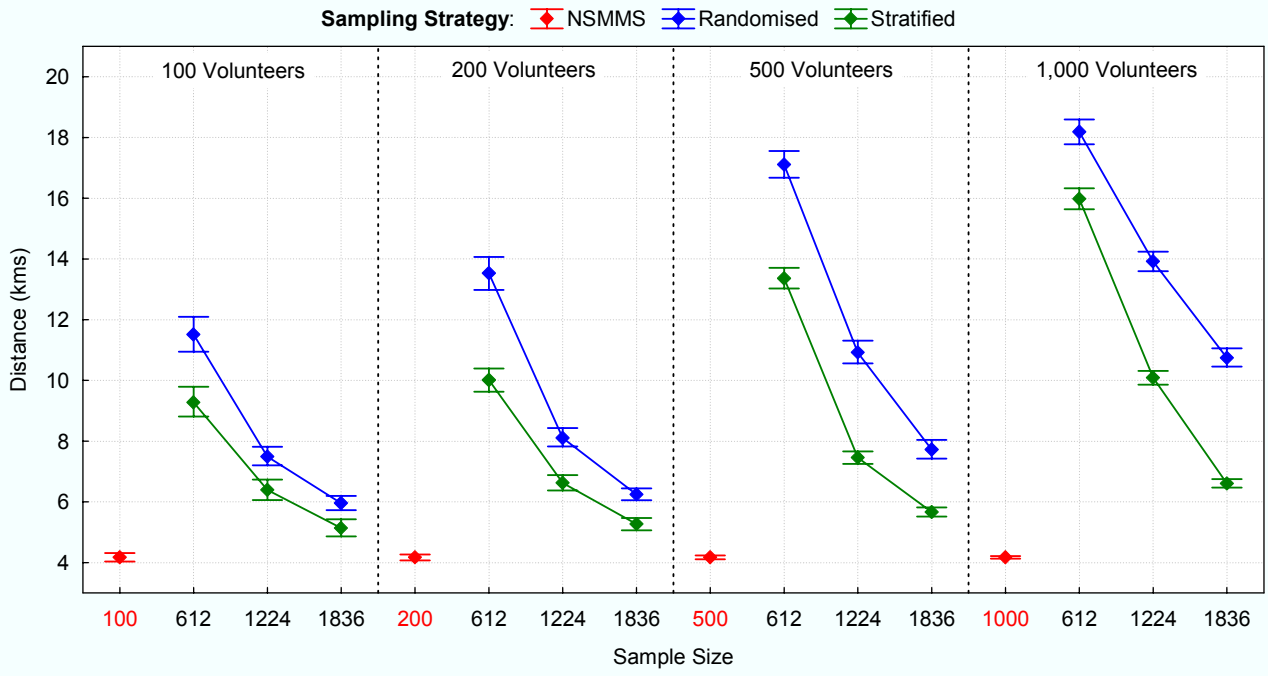

Figure 6. The medians and quartiles of mean euclidean distances between volunteers and sites from 5,000 simulations. The graph shows all combinations of four different numbers of volunteers, three different sampling strategies and three different sample sizes.

numbers of volunteers, the sampling strategies and the three sample sizes, the median and upper and lower quartiles across all 5,000 simulations were calculated (Figure 6).

Firstly, the median distances generated from the NSMMS strategy was always 4.17km, and was entirely independent of the number of volunteers. This was simply a function of the algorithm used to generate the three random tetrads and then select one as the site. In contrast, not only were the distances from the randomised and stratified samples different, but they were both highly influenced by number of volunteers and sample size. The three factors worked in contrasting ways:

- The mean distances were always significantly higher in the randomised samples than the equivalent stratified. This has already been alluded to in the previous section (Figure 5b & c), but it can be seen here as a general feature across all volunteer numbers and sample sizes. The reason for this was the better spatial matching of the stratified sample to the distribution of volunteers.
- The distances declined with increasing sample size. The reason for this is clear; with an absolutely larger sample, there is a greater likelihood of having a site near to any volunteer location.
- The distances increased with increasing volunteer numbers. The reason for this is that as the number of volunteers increases, so too does the likelihood that the nearest tetrad has already been allocated. This means that the next nearest tetrad has to be allocated, and so on, resulting in an increase in the mean distances for the sample as a whole.

These last two factors have a strong interaction, such that when the number of volunteers is a small proportion of the sample size (*i.e.* the number of tetrads available for allocation) then all volunteers will be allocated their nearest tetrad. This is clearly advantageous, but is counteracted by the other variables

Most importantly, all of the traditional sampling strategies resulted in mean distances between volunteer and site that were greater than those using the NSMMS method. The lowest distances were derived from a small number of volunteers combined with a large, stratified sample. For example, with only 100 volunteers, the median distances were approximately 11km when sites were allocated from a 1% stratified sample (612 tetrads), but declined to about 7.5km using a 2% sample and 6km using a 3% sample.

3.3.3.2 The Proportion of the Sample allocated as Sites

For each of the 5,000 simulations, and for all combinations of numbers of volunteers, sampling strategy and sample size, the number of tetrads that were allocated as sites was recorded. Clearly, in the case of the NSMMS sampling strategy, this was always 100%, in as much as the "sample" was drawn sequentially for each volunteer.

However, the traditional strategies had two constraints to site allocation; that each volunteer only undertook one site, and no tetrads further than 50km could be assigned. Consequently, the smaller the number of volunteers and the larger the sample size, the higher the proportion of tetrads that were **not** allocated (Figure 7).

The three factors had a strong interaction so that when the ratio between the number of volunteers and the sample size was small (*i.e.* less than 1:10) there was no difference between the randomised and stratified sampling strategies. But when the number of volunteers approached the sample size, or even exceeded it, the differences between the two sampling strategies increased. This was because, even with an overall excess of volunteers, the randomised sample had many more tetrads in the regions that were sparse in volunteers. The corollary of this, is that in those regions where many volunteers were concentrated, there would be a high number of sites with more than one volunteer. In other words, the problem with a randomised sampling regime is that tetrads were underused where volunteers were sparse and overused where they were common.

Unfortunately, the stratified sampling strategy, although better, did not solve this problem entirely. As previously pointed out, when the ratio of volunteers to sample size was small, then a high proportion of tetrads would not be allocated. (In fact, the proportion not allocated was simply the reciprocal of this ratio. However, even when there was an excess of volunteers, there remained a small probability that some tetrads would be further than 50km and so not be allocated. The only example of this in the simulations was 1,000 volunteers and a stratified sample of 612 tetrads. Even though this ratio was now much greater than unity, the median number of tetrads not allocated across simulations was seven, with a maximum in one simulation of 31.

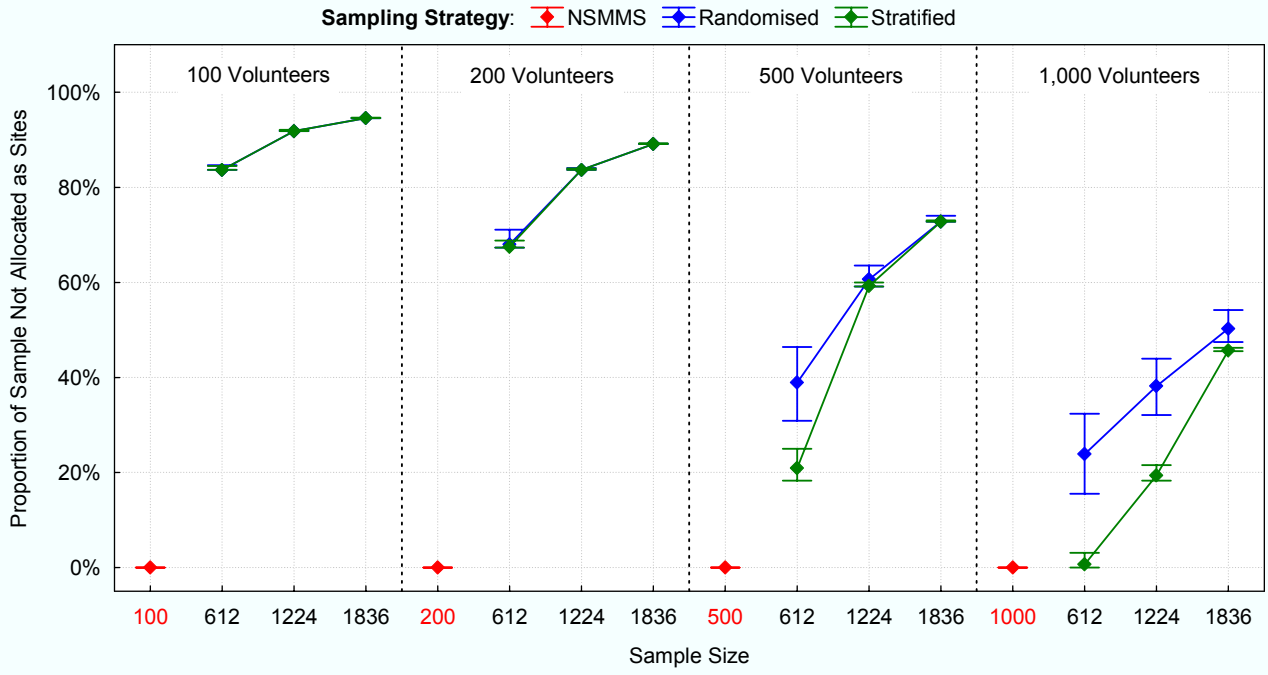

Figure 7. The median, minimum and maximum proportions of the sample allocated as sites from 5,000 simulations. The graph shows all combinations of four different numbers of volunteers, three different sampling strategies and three different sample sizes

3.3.3.3 The Number of Volunteers with No Sites

The third statistic that was recorded during the simulations was the number of volunteers who were not allocated any sites. This could only happen when there were no tetrads within 50km, regardless of whether they were already allocated.

Firstly, the NSMMS strategy never failed to allocate a site, as this was a primary characteristic of the strategy. However, in most of the combinations of traditional sampling strategies there were some simulations when volunteers were not allocated sites (Figure 8). The most striking feature of this graph is that the problem was worse for the stratified sample than the randomised. Although **on average** volunteers were nearer tetrads when they were drawn as a stratified sample, in remote regions the stratification caused the density of tetrads to be low, so the few volunteers in these regions had a greater chance of no tetrad within 50km. In contrast, the randomised sample was evenly spread across Great Britain so that, for a given sample size, there was less chance of there being no tetrad within 50km. Clearly this effect reduced as the sample size increased.

3.3.3.4 The Index of Aggregation

The most obvious criticism of the NSMMS sampling strategy is that it will result in an aggregated distribution of sites, because their location is driven almost entirely by the location of volunteers. In order to test this, the nearest-neighbour distances from each of the simulations were used to calculate an Index of Aggregation [*R* following Clarke & Evans (1954); cited in Krebs (1989)]. This statistic is simply the ratio between the observed mean nearest-neighbour distance and the expected distance, based on the overall density of sites within the study area. A ratio of 1 represents a random distribution, with values approaching zero when aggregation is high and an upper limit of approximately 2.15 for regular patterns.

It should be pointed out that this index is biased if a boundary strip is not included and if the shape of the study area is irregular. Both of these conditions apply here. Furthermore, although it is possible to test for the significance of a departure from randomness using the standard error of the expected nearest-neighbour distance, no tests of the absolute levels of aggregation have been made. Instead, the index has only been used in a comparative way, so any biases were considered to be the

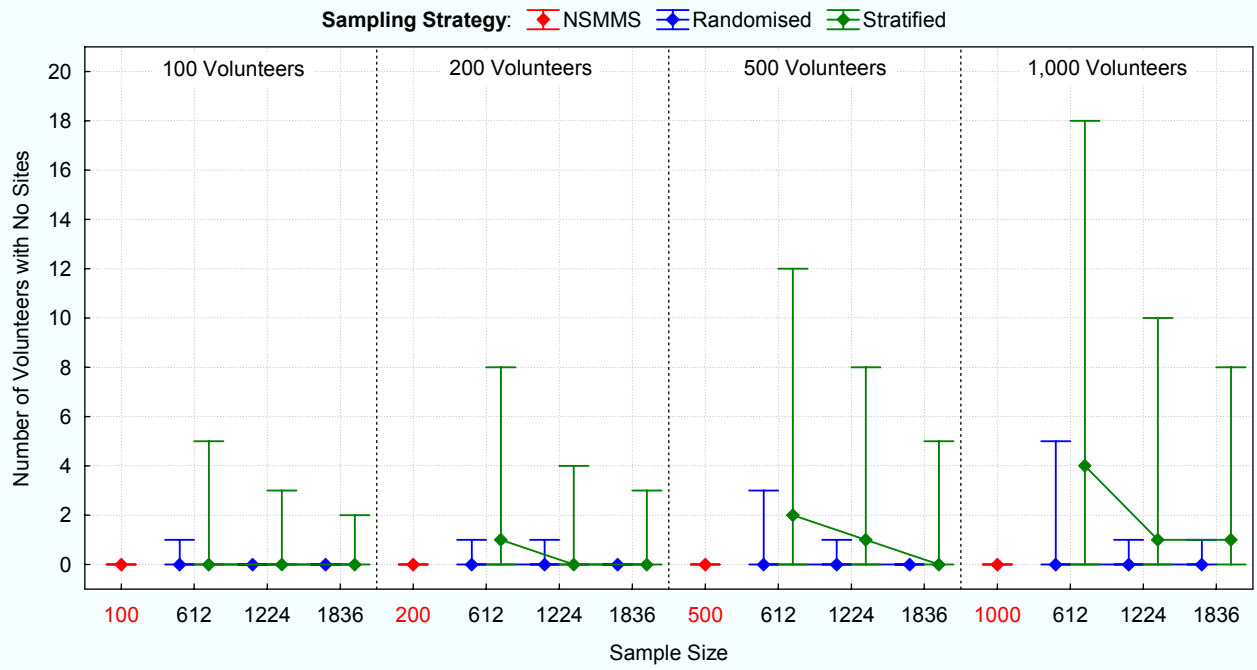

Figure 8. The median, minimum and maximum number of volunteers with no sites allocated from 5,000 simulations. The graph shows all combinations of four different numbers of volunteers, three different sampling strategies and three different sample sizes. The randomised and stratified plots have been offset horizontally for clarity.

same across all simulations and could be ignored.

The index has been used to test the one-tailed hypothesis that aggregation resulting from the NSMMS strategy was greater than that resulting from the traditional sampling methods. Within each simulation the mean nearest-neighbour distance from the NSMMS sites was compared with each of the mean nearest-neighbour distances derived from all six combinations of sampling strategy and sample size, for each of the four numbers of volunteers. To acquire significance levels for these 24 tests, the 5,000 simulations were used as a series of Monte Carlo tests. The number of occasions that R from the NSMMS strategy was $<$ R from the traditional method was tallied and if this exceeded 4,750 the test was considered significant at the $\alpha = 0{\cdot}05$ level (Table 4).

Table 4. Significance levels derived from 5,000 Monte Carlo simulations testing the one-tailed hypothesis that the degree of aggregation resulting from the NSMMS strategy was greater than traditional strategies. (Results significant at $\alpha = 0.05$ are shown in red.)

Volunteers	*Strategy*	*Sample Size*		
		612	*1224*	*1836*
100	Random	0.3358	0.3888	0.4258
	Stratified	0.5538	0.5502	0.5618
200	Random	0.2550	0.2892	0.3274
	Stratified	0.4886	0.4892	0.5174
500	Random	0.0570	0.1440	0.1686
	Stratified	0.5894	0.3578	0.3444
1000	Random	0.0040	0.0154	0.0528
	Stratified	0.6048	0.4542	0.2252

Most importantly, there was no evidence that for any numbers of volunteers or sample sizes, the NSMMS strategy was more aggregated than **stratified** samples. For small numbers of volunteers there was no evidence that the NSMMS strategy was more aggregated than the **randomised** strategy. However, as the ratio of volunteers to sample size increased, the levels of site aggregation declined (*i.e.* R increased) to a degree that resulted in the NSMMS sites being significantly more clustered. In the simulations, only two combinations (1,000 volunteers and 612 or 1,224 tetrads) reached this level of significance, although two others were marginal (Table 4).

The reason for this can be seen from the spatial distributions of these samples. The NSMMS sampling strategy clearly results in a sample of sites that is clustered towards the SE of England (Figure 9a). This reflects the distribution of volunteers and all 1,000 volunteers had sites allocated to them. Using the 1% random sample of 612 tetrads (Figure 9b), all but one of these (in square 27) was allocated to volunteers. This pattern of sites had the same degree of aggregation as the NSMMS sample because the same assumptions were made in the algorithm for generating the volunteer and tetrad locations. However, the pattern of sites resulting from the randomised sample (Figure 9c) was clearly less aggregated, with only 470 tetrads being allocated. This was due to the surplus of volunteers in the SE compared to tetrads, meaning that many volunteers had to share sites, and the surplus of tetrads in the remote parts of Scotland compared to volunteers, meaning that a relatively large number of tetrads could not be allocated to volunteers.

3.3.4 Conclusions

Ultimately, with the constraints imposed by the characteristics of a small mammal monitoring scheme (Section 3.2.1), the location of sites using any sampling strategy is almost entirely determined by the location of volunteers. Although a stratified sampling strategy with a sample size matching the expected number of volunteers can give an adequate sample of sites, this stratification is dependent on *a priori* knowledge of the distribution of volunteers, which is likely to change with volunteer turn-over. Stratified samples also have the tendency to leave some volunteers without sites, unless the sample size is very large compared to the number of volunteers. In this situation, though, the distances between volunteers and sites becomes unacceptably high, which would almost certainly result in loss of volunteers, and the proportion of sampling units actually used is unacceptably low. In summary it seems impossible to "square the circle" of these conflicting factors.

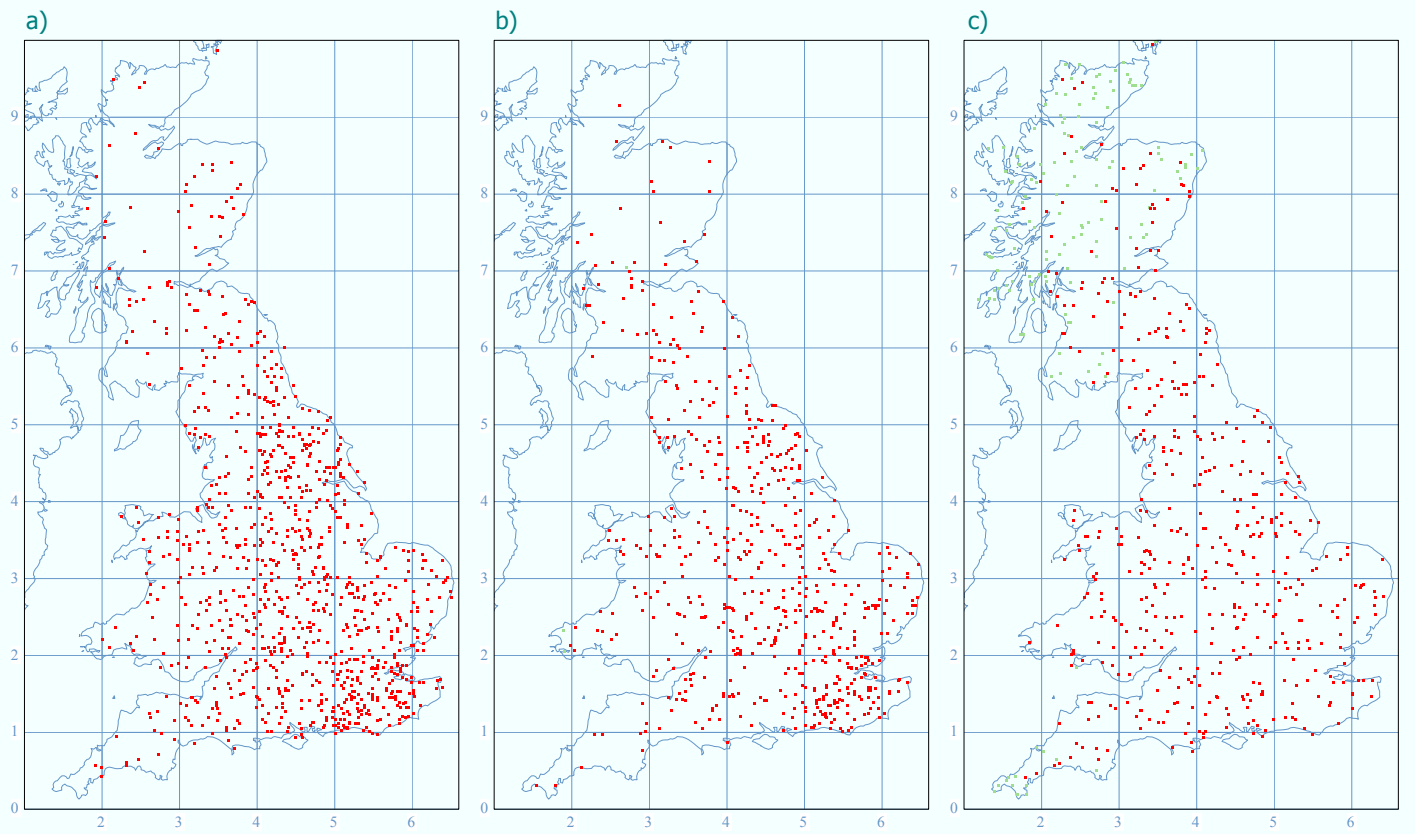

Figure 9. Location of sites allocated to 1000 volunteers using a) the NSMMS sampling strategy, b) a 1% stratified sample and c) a 1% randomised sample of tetrads. Red squares are sites, whilst green squares in maps b & c represent tetrads in the sample not allocated as sites.

The NSMMS strategy does not violate the basic requirements of a sampling scheme;

- That the sample is representative (as far as the distribution of volunteers allows),
- That the sampling units are independent of one another, so that the selection of one unit does not influence the selection of any others, and
- That the selection of sampling units is objective.

It must be conceded that the final point here is not strictly true, as volunteers were given a list of three tetrads from which to choose their site. It would be more objective if the three tetrads selected for the volunteer were presented in a random order, which should be followed when choosing a site. In other words, the first site in the list should be selected unless it was a) entirely unsuitable or b) unacceptably far away. This might be an improvement to the NSMMS sampling strategy that could be implemented in the future.

The two main conclusions from this simulation exercise are;

- The final samples of sites generated using the NSMMS strategy proposed here have a spatial distribution that is generally indistinguishable from sites generated using traditional sampling strategies .
- The NSMMS is superior to traditional methods in three main ways;
  - considerably lower volunteer-to-site distances,
  - a guarantee of individual site allocation to volunteers, if required, and
  - no redundancy of sampling units.

4 Results from Autumn 2009

4.1 Publicity and Volunteers

The publicity for the autumn 2009 season was carried out in through three different media. Primarily, the scheme management software enabled individual, personalised emails to be sent to known groups and individuals, introducing the scheme and inviting them to return an electronic Expression-of-Interest (EOI) form. This included space to supply one (or more for groups) grid reference from which a list of tetrads could be generated. When this was received by the Surveys Manager, electronic copies of the handbook (Poulton, 2009), fieldforms, other documents and the tetrad list were sent to the volunteer. Volunteers were asked to inform the Surveys Manager which site(s) they had chosen, although in a number of cases this only became evident when fieldforms and samples were returned. In addition to this active method, two passive methods were used; an article in Mammal News and the TMS website. These generated *ad hoc* expressions-of-interest, which were then incorporated into the process described above.

It was decided in September 2009 that the first season should constitute a "soft launch" for the scheme by restricting the number of personalised emails that were sent out. In the first tranche, emails or letters were sent to 37 Local Mammal Groups, 45 County Wildlife Trusts and 78 individuals who had recently volunteered for surveys or pilot studies. One week later a further 150 emails were sent to individuals who had been on TMS Small Mammal training courses over the previous three years. Of these, one of the emails to groups and 36 to individuals "bounced back" giving a total of 273 successful communications (Table 5).

The numbers of EOIs returned from groups and individuals was significantly different ($\chi^2_{(1)} = 12.9$, $p < 0.001$) with a lower return rate from groups (Table 5b). This was influenced by the number of *ad hoc* EOIs from individuals in response to the Mammal News article and from the website. In contrast, the number of sites selected from each EOI was significantly higher for groups which was inevitable as groups were encouraged to undertake a number of sites, whereas most individuals only undertook one site each. However, these figures also reflected the more active response rate from groups in the selection of sites. The actual rates of completion of sites and the number of transects per site were very similar for groups and volunteers.

Table 5. Details of publicity, volunteers, sites and transects completed during the first season (autumn 2009). The breakdown is by Groups and Individuals, and by National Random Sample (NRS), Special Interest Sites (SIS) and Island Sites.

	Groups				*Individuals*				*Overall*
a)	*NRS*	*SIS*	*Island*	*Total*	*NRS*	*SIS*	*Island*	*Total*	
Successful Mailshots				81				192	273
Expressions of Interest	19	8	2	29	101	15	0	116	145
Sites Selected	79	9	2	90	58	16	0	74	164
Sites Completed	11	8	1	20	14	4	0	18	38
Transects Completed	29	23	2	54	50	9	0	59	113
b)									
EOI Return Rate				36%				60%	53%
Sites Selected / EoI				3.1				0.6	1.1
Sites Completion Rate				22%				24%	23%
Transects / Site				2.7				3.3	3.0

4.2 Sites

In total 38 sites were completed in the autumn 2009 season (Table 5). The completion rate was almost identical for groups and individuals at around 23%.

Table 5a shows that there was also a greater tendency for groups to undertake SIS sites. Although this was not significant, it was to be expected as a number of the groups were County Trusts with sites of their own. Nevertheless, it was encouraging that over 70% of the sites undertaken by groups belonged to the NRS.

The geographical location of selected and completed sites is shown in Figure 10. Firstly, apart from the one site completed in Jersey, there were no sites outside the mainland of Great Britain, most notably from Ireland. Scotland was poorly represented with only 10 sites selected, of which only two were completed. In contrast, Wales had 23 sites selected, although only three were completed.

The bulk of the remaining sites were in central and southern England. There was a notable absence of sites selected in the south-west peninsula and north-west England, with a dearth of completed sites in East Anglia and the north-east. Indeed, there were only four sites completed north of the Mersey/Humber line, including the whole of Scotland.

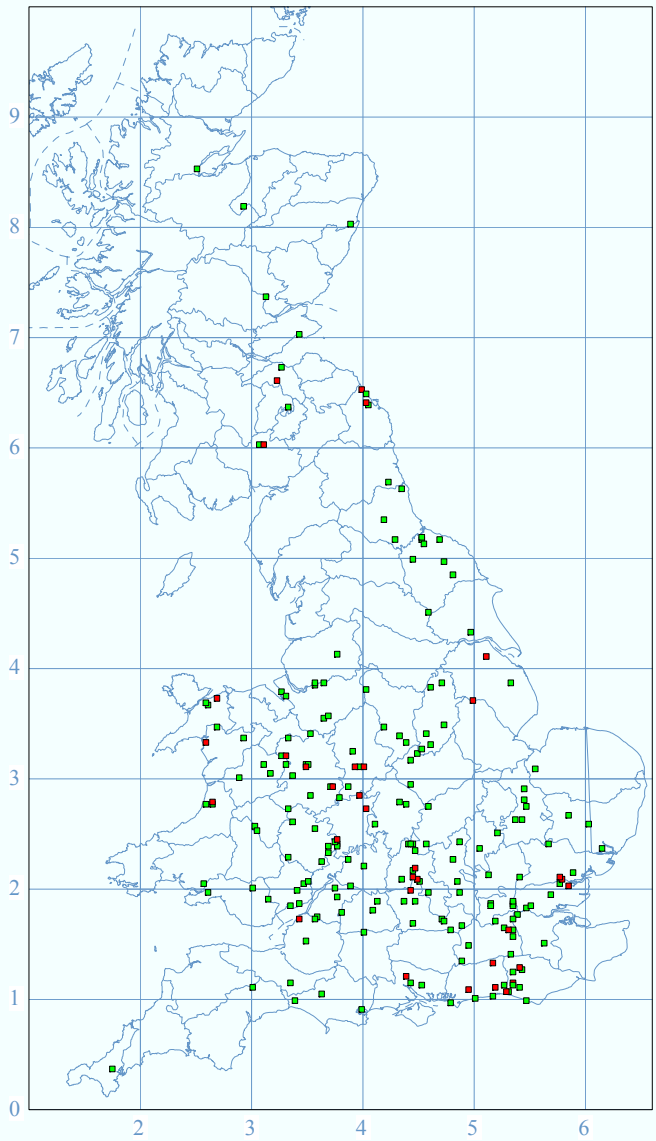

Figure 10. Distribution of selected sites (green) and sites that were completed (red), although one site in Jersey is not shown. (NB: sites are plotted to 2km resolution, but symbols are shown as 5km squares for clarity.)

4.3 Transects

A total of 113 transects and barn owl roosts were completed (Table 5). This equated to a rate of 3.0 transects per site, with no significant difference between groups and individuals. Not surprisingly, of the five different types of transect, Intensive Trapping was undertaken least frequently due to the greater time commitment and experience required (Table 6). However, Low Density Trapping was popular, with 32 transects completed, equal to Bait Tube transects. There was no significant difference in the popularity of the transect types between the National Random Sample and Special Interest Sites ($\chi^2_{(5)} = 8.11$, $p \cong 0.15$), nor between groups and individuals ($\chi^2_{(5)} = 10.4$, $p \cong 0.07$).

Table 6. Numbers of transects and barn owl roosts completed in the three different types of site.

Site Type	*HM*	*FV*	*BT*	*LDT*	*IT*	*BO*	*Total*
NRS	16	14	24	22	2	1	79
SIS	6	5	7	10	2	2	32
Island	0	0	1	0	1	0	2
Total	22	19	32	32	5	3	113

4.3.1 Harvest Mouse Transects

22 harvest mouse transects were completed, of which only three (13.6%) contained nests. All transects had ten successfully competed sections making 220 in total. The three positive transects had 2, 4 & 8 sections with harvest mouse nests, giving a mean presence of 6.4%. However, the transect with eight positive sections actually had a count of 22 nests, an extremely high count in a 100m transect.

4.3.2 Field Vole Transects

A total of 19 field vole transects were completed, all with ten successfully completed quadrats. The most frequently recorded field sign was runs (Figure 11a) – only one transect did not record any runs. The mean number of quadrats with runs was 6.7, with a modal value of 10. Latrines showed the opposite picture, with a modal value of 0, also with six transects (Figure 11b). The mean number of quadrats with latrines was 2.9 and the maximum number of quadrats per transect was 9. Finally, the number of quadrats with feeding signs showed a more uniform distribution (Figure 11c) with a mean occurrence of 4.6 quadrats per transect.

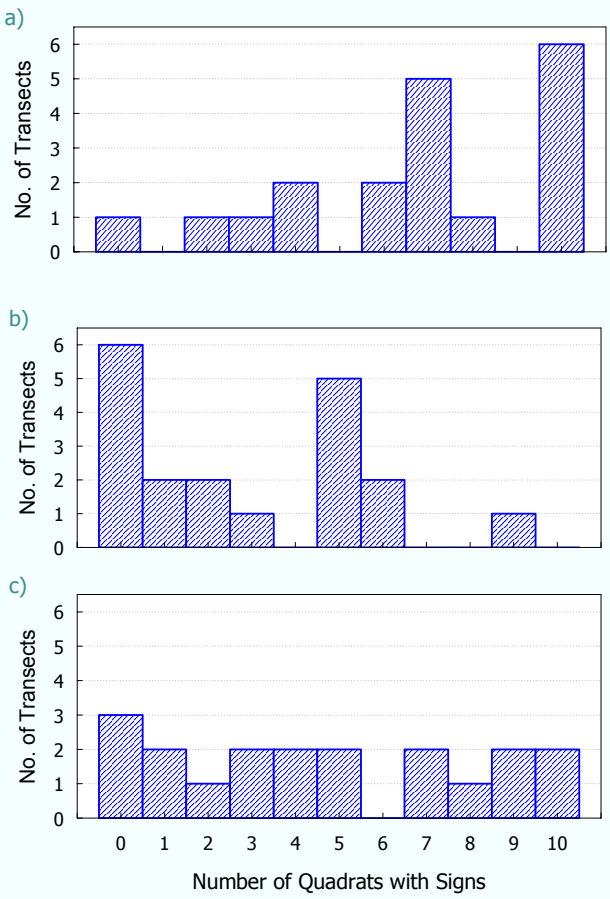

Figure 11. Frequency histograms of the number of quadrats per field vole transect with a) runs, b) latrines and c) feeding signs ($n = 19$)

Combining the three types of field sign within each transect, showed a very wide range of total field sign tallies (Figure 12). Only one transect had a zero count and, at the other extreme, one had 28 – representing 93% of the maximum possible count. The sequence of increasing tallies for runs, feeding signs and latrines described above is generally replicated within transects. With only one exception, runs were always the most frequently recorded sign, followed by feeding signs and then latrines. Latrines were usually only recorded when the combined tallies of the other two signs reached about ten. However, there were only two out of 15 transects with total tallies of ten or more, that didn't have all three signs recorded. This pattern suggests that the three different signs can be used in a sequential way, with runs more easily picking up the presence of field voles when relatively scarce, but the other signs becoming more important as vole abundance increases.

4.3.3 Bait Tube Transects

A total of 32 bait tube transects were laid, although four of these had lost all ten tubes or they were entirely washed out, leaving 28 "active" transects. Of these, the majority (18) had all ten tubes successfully collected, nine transects has a single "lost" tube and one transect only collected seven tubes. Overall the average success-rate, in terms of tube collection, was 84%.

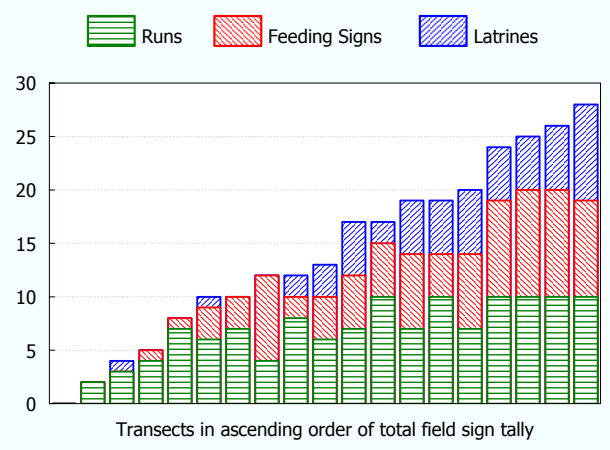

Figure 12. Combined tallies of the three field vole signs.

Overall 161 putative samples were collected which represents just over 60% of usable tubes. The number of samples per transect ranged from zero to ten, with a full range of values (Figure 13). Only two transects did not yield any faeces samples, meaning that nearly 93% of transects provided at least one sample. Bearing in mind that ten of these 28 transects had fewer than ten tubes, a histogram of proportions of tubes with faeces would skew slightly more to the right. For example, of the nine transects with only nine tubes collected, two had faeces samples from all the tubes – it would not be unreasonable to expect the tenth tube to have yielded a faeces sample. Similarly, the transect with only seven tubes yielded six samples – a rate quite likely to have yielded eight or nine samples from ten tubes.

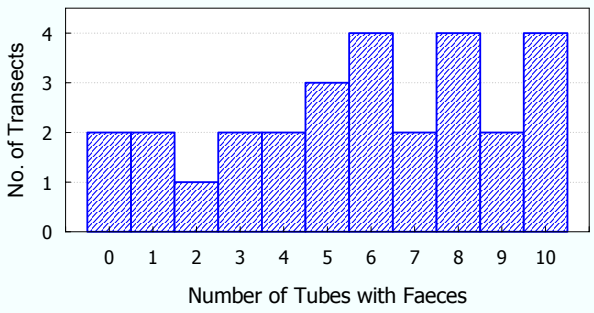

Figure 13. Frequency histograms of the number of bait tubes per transect with faeces (n = 28).

Unfortunately, at the time of writing, the DNA analysis of the faeces collected from the tubes has not been carried out. It may be that some of the samples did not actually contain faeces, or the DNA has become degraded over time, preventing a successful amplification. Consequently, this method has been unable to provide any data on species identity for this report.

4.3.4 Low Density Trapping Transects

32 low density trapping transects were set. Of these 17 (53%) had a complete set of ten functioning traps. A further 8 transects (25%) had one trap which failed to function or from which an animal had escaped. The remaining seven transects had two, three or five trap failures, resulting in a total of 292 (91%) functioning traps.

A total of 170 animals were caught in these traps giving an overall capture rate of 58%. Every one of the 32 transects was successful in capturing at least one animal (Figure 14). The spread of capture rates was very even, with three transects with one capture each and three with ten. (Indeed, in of of these latter transects, the ten animals were caught in only nine traps, as one trap caught two live wood mice.) Furthermore, by taking account of the number of available traps, the frequency histogram was skewed further to the right, with six transects achieving a capture in every available trap (Figure 14b).

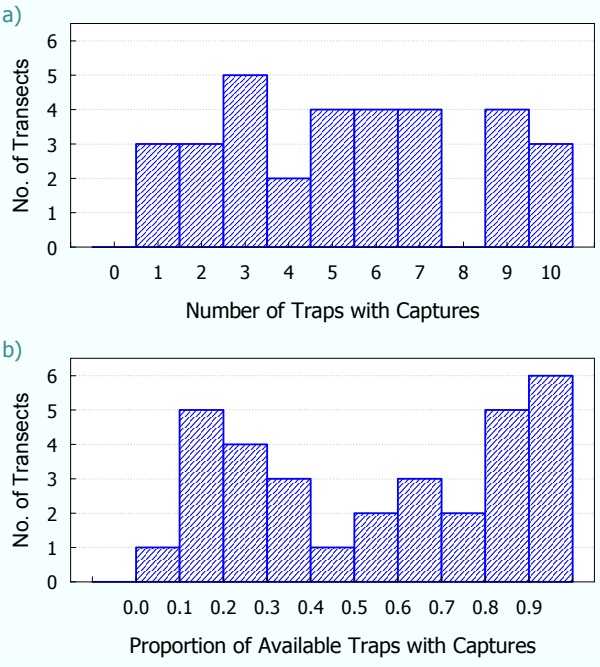

Figure 14. Frequency histograms of a) absolute and b) relative numbers of traps with captures on Low Density Trapping transects (n = 32).

Four species were recorded in these transects. Captures were dominated by wood mice with 109 animals (64% of all captures). This species was caught in every transect except one (Figure 15a) giving an average capture rate of 37%. However, only four transects had more than five wood mouse captures, so the concern that high populations of wood mice would saturate the relatively small number of traps appeared to be unfounded.

Bank voles were next most frequently captured species, with 54 animals (32% of all captures). However, nearly half the transects did not capture this species (Figure 15b). In the other 17 transects captures were either of a small number of animals or a surprisingly large number. In-

deed, five transects had more than five captures, compared to only four for wood mice.

The other two species recorded were common shrew (four captures in four transects) and field voles (three captures in two transects). The two transects with field voles were the only ones to catch three different species. Finally, mortality rates were satisfactorily low, with only two dead wood mice in one transect.

4.3.5 Intensive Trapping Transects

Only five Intensive Trapping transects were completed in the first season. One of these was an island site (Jersey), two were Special Interest Sites and two belonged to the National Random Sample (Table 7). Each of the 40 traps was set for four trapping sessions, give a total 160 possible trap-sessions per transect. Trap-failure rates were very low, with 0, 1, 3, 4 & 5 per transect, giving an overall failure rate of 1.6%.

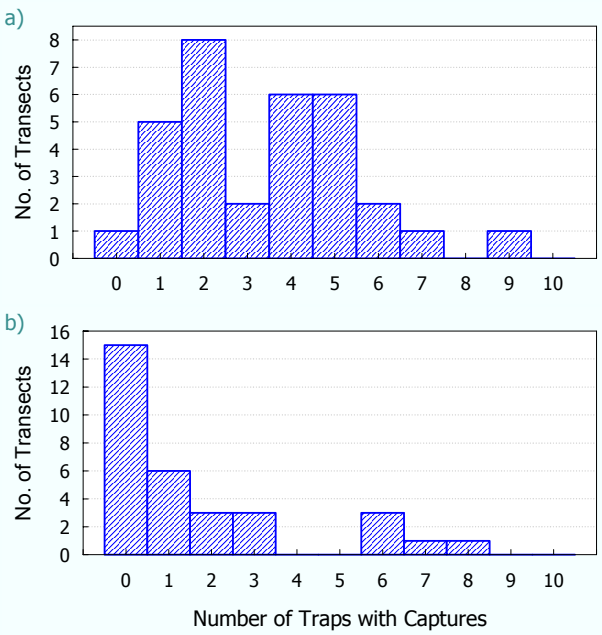

Figure 15. Frequency histograms of a) wood mouse and b) bank vole captures on Low Density Trapping transects (n = 32).

A total of 72 individual animals were recorded on these five transects, although nearly half of them were recorded on one transect. Although many of these animals were marked and recaptured a number of times, no attempt has been made here to derive CMR estimates of population size. There was no mortality in any of the five transects.

Five small mammal species were recorded, again dominated by wood mice and bank voles with 56% and 24% of the animals respectively. (It is worth pointing out that the four bank voles caught in Jersey would have been the indigenous sub-species *Myodes glareolus caesarius*.) Field voles were caught in three transects and constituted a greater proportion of records (14%) than from the Low Density transects. Three common shrews were caught in two of the transects and, unlike the LDT transects, two pygmy shrews were recorded in two separate transects. Finally, a weasel *(Mustela nivalis*) was caught on the third inspection in one of the transects. It was released unmarked, but because no replacement trap was available for the final session, the trap it occupied was treated as one of the four trap failures from this transect.

Table 7. Total number of animals and the number of individual animals by species from the five Intensive Trapping transects.

Sample	*Wood mouse*	*Bank vole*	*Field vole*	*Common shrew*	*Pygmy shrew*	*Total*	*(Weasel)*
Jersey	2	4				6	
SIS	3		6	1		10	
SIS	10	1				11	
NRS	17		1		1	19	
NRS	10	16	3	2	1	32	(1)
Total	**40**	**17**	**10**	**3**	**2**	**72**	**(1)**

4.3.6 Barn Owl Roosts

Only three Barn Owl roosts were completed. Pellets from two of them were returned to the Surveys Manager with 17 and 10 per sample. The third roost was an existing National Barn Owl Survey site located within the volunteer's tetrad, so the sample of five pellets was sent directly to the co-ordinator of the national survey. The other two samples have yet to be analysed.

4.4 Habitat Analysis

The range of habitats covered by the 102 transects with habitat types recorded was very wide (Table 8). A total of 17 different habitats (out of the 23 specified in the handbook) belonging to seven categories was included. Deciduous woodland and, somewhat surprisingly, permanent grassland were the most frequently used habitats with 19 each, followed by hedgerows with 11 transects. Of the remaining 14 habitats, only three were used just once.

Excluding the small number of Intensive Trapping transects a contingency chi-sqared analysis showed that there was no significant difference between field methods in their habitat placement ($\chi^2_{(18)} = 26.7$, $p \cong 0.85$). The two species-specific methods were well distributed amongst the main habitat categories with the only exception being riparian habitats. Most interestingly, volunteers spread their Bait Tube and Low Density Trapping transects through all the main habitat categories and most of the individual habitat types (12 and 10 respectively). Although numbers of transects in this first season were low, the good spread of habitat types indicates that habitat analysis should be possible in the future.

Table 8. Breakdown of habitat types by transect type.

Category	*Habitat*	*HM*	*FV*	*BT*	*LDT*	*IT*	*Totals*
Woodland	Deciduous	0	1	7	10	1	19
	Mixed	2	2	3	0	1	8
	Coniferous	0	1	1	0	0	2
Open Farmland	Permanent grassland	7	6	3	3	0	19
	Grass Leys	1	1	0	1	0	3
	Arable	1	1	0	0	0	2
Field Boundaries	Hedgerows	0	0	6	4	1	11
	Fence lines	1	1	2	3	1	8
	Walls	2	1	0	0	0	3
	Ditches	0	0	0	1	0	1
Riparian	Rivers	0	0	1	2	0	3
	Streams	0	0	2	0	1	3
	Standing water	0	0	1	0	0	1
Moorland	Acid grassland	3	1	3	1	0	8
Coastal	Sand dunes	1	1	1	2	0	5
	Cliffs / downs	0	0	1	0	0	1
Urban	Road verges	3	0	0	2	0	5
	All Habitats	21	16	31	29	5	102

4.5 Discussion and Conclusions

The "soft roll-out" undertaken in this first season inevitably meant that the number of volunteers was low. However, the basic rate of return of expressions-of-interest were satisfactorily high, especially for individuals. But this did not manifest itself in completion of the selected sites. The reasons for this are probably two-fold. Firstly, a number of individuals returned their expressions-of-interest, but had already decided not to take part until the following spring. Due to the short timescale between the email invitations and publicity being produced, and the start of the autumn field season, many volunteers did not sign up until well into the field season. The second reason, was probably due to a perceived complexity in the field methods. This is supported by the higher relative completion rate (compared to EOI return rate) from groups as opposed to individuals, where collective expertise might have encouraged volunteers to try out the methods. In future seasons, it will be very important to encourage new volunteers either to join local mammal groups, or to take part using the simpler field methods to start with.

The development of the three tranches in the sampling strategy was highly successful. Although, at the outset, no indication was given in the publicity that Special Interest Sites would be accommodated, these proved to be very popular, especially with groups. Eight of the nine SIS sites selected by groups were completed; a much higher proportion than the 14% of NRS sites completed. This is

not surprising, because groups had a vested interest in carrying out the survey on their own reserves or managed sites. In the future, the survey administrator should encourage local mammal groups to undertake NRS sites in addition to their SIS sites to increase coverage and allow country-wide and national extrapolation. However, it should not be forgotten that many groups such as County Wildlife Trusts and some individuals would not take part unless they were allowed to work on their own sites, so a two-pronged approach is likely to be the best strategy.

The geographical distribution of sites, both selected and completed, was distinctly non-random, although this wasn't tested statistically. The complete absence of sites in Northern Ireland and the Republic probably reflected the relatively small number of TMS members and the lower rate of involvement in previous surveys and training courses. The latter probably also applies in Scotland, although TMS has historically had a strong presence in Scottish universities. More surprising is the complete absence of completed sites in parts of England, especially the SW, Kent and East Anglia, where well-organised mammal groups have been active for some time. These must be targeted in future seasons.

Harvest mouse nests were only found in 14% of the 22 transects. This is lower than the 24% of transects with nests reported by Poulton & Stone (2008) and the 40% found by Riordan *et al* (2009). However, in both of these recent studies, half and all of the transects, respectively, were 200m in length, which may account for the higher detection rate. The highest count in the present study was 22 nests in a single 100m transect, although the next highest count was six nests. A similar pattern was found by Riordan et al (2009) who recorded an outlier of 18 nests in one 200m transect, with all other transects revealing fewer than eight nests. These results suggest that, although the harvest mouse nest search transect is a useful method for introducing volunteers to the NSMMS, it is likely to provide binary (presence/absence) data at best. (This may be a characteristic of the population dynamics of this species, with short periods of relatively high numbers followed by localised extinction.) However, its speed and relative ease means that a large number of transects could be completed, and until data from repeat-visits are available, it will be difficult to judge the efficacy of this method. It is worth pointing out here that neither of the two trapping methods returned harvest mouse captures.

The field vole sign transects returned useful data, with only one of the 19 transects failing to record signs of any sort. The sequential accumulation of signs shown in Figure 12, could be developed to provide a more sensitive index of field vole abundance than a simple count out of ten transect sections. A calibration of field vole sign searches against intensive trapping might be a worthwhile exercise in the future.

In the absence of DNA identifications at this stage, no useful conclusions can be drawn about the bait tube method.

The overall capture rate in Low Density Trapping transects of 58% compared favourably with the rate achieved for this method (48%) by Poulton & Stone (2008), although one of their three seasons was a spring session when capture rates are generally lower. However, their pilot study made us of a small group of expert volunteers, whereas these transects were carried out by self-selecting volunteers – either they had correctly assessed their own levels of expertise and experience, or these factors are unimportant in determining success-rates for Low Density Trapping. The number of individual animals captured using the Intensive Trapping method was highly variable (six to 32) and the species lists from both methods was more restricted (four and five respectively) than the eight species recorded by Poulton & Stone (2008). In particular, shrew captures appeared to be lower than other studies would predict. This might have been a result of trip-weights not being set low enough to capture lighter animals which, in turn, might have been a consequence of traps having to be borrowed and/or being stored for long periods of time. Finally, mortality was low with only two dead woodmice, from one transect, recorded in 1079 trap-sessions. This is lower than similar studies and should encourage the use of trapping methods by volunteers in the future.

The final recommendation from the first season of the NSMMS is that the study should continue for at least a further three seasons, preferably five. In this way, at least two autumn seasons, when young of the year cause capture rates to be inflated, and two spring seasons, which primarily record the over-wintering, breeding populations, will have been completed. This would be the minimum requirement for a robust base-line, which cannot be achieved with a single season or year for species known to fluctuate widely over time, both stochastically and cyclically (Flowerdew *et al*, 2004). It will also give a realistic indication of site-turnover and the likely maximum number of sites acheivable, which will allow a better indication of power of the NSMMS to detect change.

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7 Appendices

Weightings applied to 100km Grid Squares in the Simulations

Eastings	Northings	Label	Weighting
1	0	SW	5
1	2	SM	2
1	6	NR	1
1	7	NM	1
1	8	NG	1
2	0	SX	10
2	1	SS	12
2	2	SN	10
2	3	SH	10
2	5	NX	4
2	6	NS	10
2	7	NN	4
2	8	NH	2
2	9	NC	1
3	0	SY	15
3	1	ST	25
3	2	SO	25
3	3	SJ	30
3	4	SD	25
3	5	NY	12
3	6	NT	15
3	7	NO	12
3	8	NJ	8
3	9	ND	1
4	0	SZ	15
4	1	SU	40
4	2	SP	50
4	3	SK	50
4	4	SE	50
4	5	NZ	35
4	6	NU	20
4	8	NK	10
5	0	TV	20
5	1	TQ	100
5	2	TL	50
5	3	TF	20
5	4	TA	25
6	1	TR	40
6	2	TM	30
6	3	TG	30