The Mammal Society Research Report No. 8

Pilot Study for a National Monitoring Scheme for Small Mammals in the United Kingdom and the Republic of Ireland

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Executive Summary

- Sixteen expert volunteers trialled five different field methodologies in 26 sites throughout England, Wales and the Republic of Ireland. Fieldwork took place during three seasons, two in the winters of 2006 and 2007 and one in the summer of 2007, resulting in a total of 57 site visits.
- The five field methodologies were undertaken in a total of 149 transects, each 100m in length. Transects were placed in a wide range of habitats, including hedgerows, permanent grassland, arable, deciduous and mixed woodland. A total of 262 visits were made to these transects.
- The field methodologies comprised two single species methods; harvest mouse nest searches and field vole sign searches, bait-tube transects for collecting faeces samples from a range of species and two trapping methods. The extensive trapping method used ten traps placed individually at 10m intervals and were only set for one night's trapping. The intensive trapping transects used ten groups of four traps at 10m intervals, set to trap for two days and two nights.
- Nine small mammal species were targeted, of which eight were recorded during the pilot study. These comprised three shrew species, (common, pygmy and water shrew), two voles (bank and field vole) and three mouse species (field, yellow-necked and harvest mouse). The absent species was the house mouse.
- To compare results from the five different field methods and across the eight species an Index of Information Content (IIC) was derived. This represented the "amount" of information obtained and, therefore, the power of a method to detect change. In general, it showed that the intensive trapping method had the greatest information content and the harvest mouse nest searches had the lowest IIC. There was no significant difference in IIC between sites or volunteers. In contrast, there was a highly significant difference between species, with by far the highest IIC being obtained for wood mice, with the lowest for yellow-necked mice, harvest mice and water shrews.
- Detailed records of the time taken to complete different aspects of the pilot study were kept by volunteers. This enabled an analysis of time budgets to be undertaken, which showed that the intensive trapping method, with multiple visits, did indeed take longer than the other field methods. It also provided data for a cost-benefit analysis by combining the IIC for different methods with the time budgets. Despite the more intensive methods taking longer, the intensive trapping method still gave a significantly greater cost-benefit that the others, although field vole transects also provided a high degree of information for low cost.
- Computer intensive simulation modelling was used to carry out a power analysis by modelling six different degrees of change (5%, 10% & 20% increases and decreases over ten years). The models used empirical data for the mean proportion of transect points with records and the between-year and between-site variances, obtained for each species using each method. This showed that relatively small changes in wood mice and bank voles could be detected with sample sizes of several hundred intensive trapping transects, but that larger sample sizes were required for extensive trapping and for other, less frequently occurring species. Field vole transects could also detect relatively small changes with sample sizes of only one or two hundred transects.
- Two workshops were undertaken, after each of the winter seasons. These provided considerable feedback and anecdotal information from volunteers and proved to be an extremely useful source of qualitative data allowing modifications and improvements to the field methodologies.

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1 Introduction

1.1 Requirement for a small mammal monitoring programme

Small mammals are essential to the ecological functionality of many terrestrial ecosystems both in terms of their intrinsic biodiversity value and their role as prey items for many predatory mammals and birds (King 1985; Fitzgibbon 1997). Small mammals are a key component of UK biodiversity and with species such as the common shrew (*Sorex araneus*) (Love *et al.* 2000) and harvest mouse (*Micromys minutus*) (Sargent 1999) thought to be declining, monitoring of small mammal populations is essential for the development of effective conservation management policies (Battersby & Greenwood 2004).

Changes in small mammal abundance can have significant effects on those predatory species that rely upon them. Extensive dietary studies in Britain have shown that small mammals are particularly important prey items, dominating the diet of the barn owl (*Tyto alba*) (Love *et al.* 2000). The breeding success of tawny owls (*Strix aluco*) is strongly related to small rodent density in woodland (Southern 1970) and that of hen harriers (*Circus cyaneus)* has been shown to be closely correlated to field vole (*Microtus agrestis*) abundance (Redpath, Thirgood & Clarke 2002). Studies have also shown that numbers of short-eared owls (*Asio flammeus*) fluctuate in response to changes in vole density (Village 1987). Small mammals are also important food items for some rarer carnivores such as the pine marten (*Martes martes*) (Birks 2002) and the wildcat (*Felis silvestris*) (Kitchener 1995). Changes in small mammal populations are particularly important for specialist predators that are more vulnerable to changes in a small number of prey species (Harris *et al.* 2000).

Small mammals are also important indicators of changes in agricultural management practices and habitat quality. Bank voles (*Clethrionomys glareolus*) and wood mice (*Apodemus sylvaticus*) have been found to be sensitive to pesticide use (Johnson, Flowerdew & Hare 1992; Macdonald & Tattersall 2001) whereas field voles are sensitive to over-grazing (Battersby 2005; Evans *et al.* 2006) and changes in field margins (Macdonald & Tattersall 2001). A recent study has shown both hedgerow connectivity and local structure to be strong predictors of small mammal density on lowland British farmland, with hedgerow connectivity in particular being a significant predictor for wood mouse (Gelling, Macdonald & Mathews 2007). Therefore, monitoring changes in small mammal populations can provide indications of changes in habitat quality and availability, which can inform management policies.

Monitoring small mammal populations is also important for the effective management of conflict with humans. When they come into contact with humans, small mammals are often considered pests as they can cause damage to property and pose a potential health risk through disease transmission. Species such as wood mice can cause significant economic loss to farmers by feeding on and nesting in stored products, causing contamination with droppings or urine (Macdonald & Tattersall 2001). Field voles have been shown to cause extensive damage to newly planted trees and are potentially damaging in areas of native woodland regeneration (Evans *et al.* 2006) and agri-forestry (Flowerdew & Trout 1995). Small mammals also serve as vectors of disease, representing a serious risk to the health of humans and domestic animals in the UK (Webster & Macdonald 1995) Wood mice are known to carry diseases such as leptospirosis and bTB (NFBG 2004), and yellow-necked mice have been implemented in the spread of Tick Bourne Encephalitis (TBE) in Europe (Battersby 2005).

Despite being an essential component of most terrestrial ecosystems there is a paucity of data on UK small mammal populations. Therefore, many species have not been assessed as part of the UK BAP process as there is insufficient evidence to determine whether populations are increasing, stable or declining (Macdonald & Tattersall 2001). Small mammal monitoring studies to

date have often been short-term, within limited geographical areas (Johnson, Flowerdew & Hare 1992; Rogers & Gorman 1995; Kotzageorgis & Mason 1997), on a single species (Marsh 1999; Carter & Churchfield 2006a), or in a single habitat (Mallorie & Flowerdew 1994; Flowerdew *et al.* 2004). Within the UK there is an urgent need to establish a multi-species monitoring programme that can provide long-term reliable data on small mammal population trends to inform sustainable land management and conservation decisions.

1.2 Background to the Project

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 (Battersby & Greenwood 2004). The subsequent reports (Macdonald, Mace & Rushton 1998; Toms, Siriwardena & Greenwood 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 has contributed to the recent 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, The Mammal Society developed a project proposal for a National Small Mammal Monitoring Scheme in 2006. The Mammal Society proposed a three stage process including:

1. An extensive literature review of UK small mammal ecology and survey techniques,
2. A pilot project to trial and modify survey techniques and sampling strategies and,
3. A national roll out of the small mammal monitoring scheme.

After completion of the literature review (Sibbald, Carter & Poulton 2006) the Small Mammal Pilot Project commenced in the summer of 2006.

1.3 Aims & Objectives

The Small Mammal Pilot Study aims to trial and develop a multi-species UK small mammal monitoring scheme, to survey those species identified in Sibbald, Carter & Poulton 2006. Due to the geographical limitations of the pilot, the island species were nor included, leaving the nine species shown in Table 1 The methods used are to be as cost effective as possible, both in terms of equipment and time, in order to encourage participation of as many volunteers as possible. The overall aim of the National Small Mammal Monitoring Scheme is to quantify long-term species population trends across habitats. The specific objectives of the pilot project were to:

Table 1. The small mammal species targeted in this pilot study.

Latin Name	*Common Name*
Sorex araneus	Common shrew
Sorex minutus	Pygmy shrew
Neomys fodiens	Water shrew
Clethrionomys glareolus	Bank vole
Microtus agrestis	Field vole
Apodemus flavicollis	Yellow-necked mouse
Apodemus sylvaticus	Wood mouse
Micromys minutus	Harvest mouse
Mus domesticus	House mouse

- Assess the effectiveness of the proposed methods for long-term population monitoring
- Gain feedback from expert volunteers regarding the logistical problems and suitability of the survey
- Quantify and compare the survey effort required per field method
- Identify the potential problems of coordinating a national small mammal survey

2 Methodology

2.1 Volunteers

For the purpose of the pilot "expert" volunteers were defined as professional or amateur ecologists who had considerable experience with surveying small mammals, particularly using Longworth traps. Experience was considered important for the purpose of the pilot as volunteers were asked to assist in the evaluation of methods and development of the survey protocol. Each volunteer was provided with a copy of the volunteer handbook, which assumed a level of knowledge with regard to suitable habitats and field survey techniques. It contained copies of field-forms and detailed guidance about project methods and sampling strategies.

2.2 Sampling Strategy

A two-stage sampling strategy was undertaken using Ordnance Survey tetrads (2km x 2km grid squares) as Primary Sampling Units (PSU). Within each PSU varying numbers of Secondary Sampling Units (SSU) were conducted according to availability of suitable habitat. All SSUs comprised a single transect of a fixed length (100m) divided into ten sections or points. Five different SSU types were conducted during the pilot.

Surveys were undertaken during two six-week periods in each year, one in early summer and one in early winter. The aim of this strategy was to enable monitoring of the population peaks and troughs, which are most valuable for the detection of long-term population changes. Using a six week period also gave volunteers some flexibility to complete all the methods required.

2.3 Primary Sampling Units (Sites)

Volunteers supplied a Grid Reference of either their workplace or home, from which a 14km x 14km grid of 49 tetrads was mapped using the Grid Reference as a centre point. Five PSUs were randomly selected from within the 49 tetrads using Microsoft Access. Volunteers were asked to choose a minimum of two tetrads to survey during each season. They were given a degree of discretion in site selection in the event of a site being entirely unsuitable. A PSU field-form was completed for each tetrad. This recorded information on the PSU location, survey times, number of SSUs completed, habitats sampled, travel time and completion times per SSU (Appendix I).

Volunteers were asked to identify relevant landowners and contact them to arrange access. A covering letter was provided confirming volunteer involvement in the survey to facilitate this process. Volunteers used maps or preliminary visits to the PSU site to identify the number of habitats available to plan the number of SSUs to be completed. Habitats were classified into seven broad categories subdivided into 23 specific habitats (Table 2).

2.4 Secondary Sampling Units (Transects)

Five different types of SSU were defined; harvest mouse nest transects, field vole sign transects, bait tube transects, extensive live-trapping transects, and intensive live-trapping transects. All types comprised a 100m long transect divided into ten sections (Figure 1). Depending on the type of SSU, either a single Field Survey Unit (FSU) such as a quadrat, bait tube or Longworth trap, or four Longworth traps were located.

Each volunteer was asked to complete as many SSUs as possible within a minimum of two PSUs during each field season. Volunteers were asked to establish permanent SSUs that would then be

Table 2. General habitat categories, specific habitat belonging to each and examples of microhabitats that may be found in some or all of the specific habitats.

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

re-sampled during the following seasons. SSUs were laid where possible, in a single habitat type. SSUs of the same type were kept at least 250m apart to ensure a large degree of ecological independence. Volunteers were asked to use distinctive starting points for SSUs, such as hedge-row features or trees, to enable re-surveys by a different volunteer if necessary in later seasons. Compass bearings were also recorded from the start and end of each SSU to a prominent object, preferably within 200m to triangulate the transect. Grid-references for the start and end of each transect were also recorded.

2.4.1 Harvest Mouse Transects

Ten sequential 2m x 10m plots were marked out within each transect and systematically searched for harvest mouse nests. Plots were numbered sequentially from 1 to 10. Volunteers were asked to choose between two methods of recording nests to enable comparison of survey effort and effectiveness of each recording technique. Using method one, nests were recorded as present or absent. Using method two, a total count of nests was recorded. Harvest

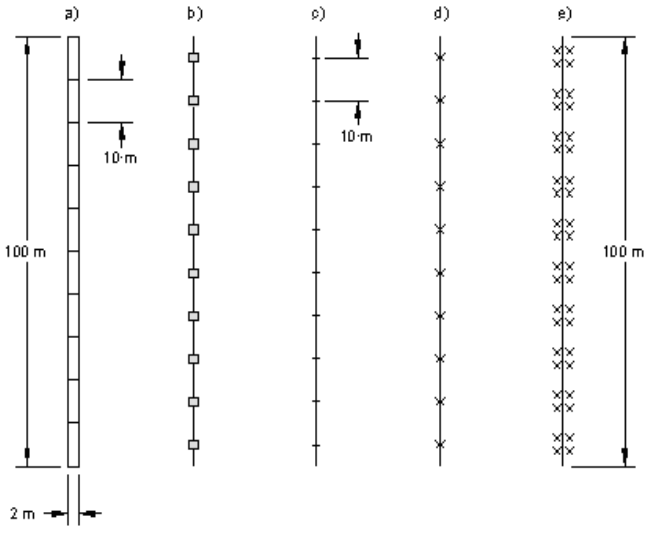

Figure 1. Schematic diagram of the five different types of Secondary Sampling Unit. a) Harvest mouse nest transect, b) field vole sign transect, c) bait tube transect, d) extensive live-trapping transect and e) intensive live-trapping transect.

mouse transects were conducted during a single visit to the PSU.

2.4.2 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. 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 recorded the presence of each type separately for each quadrat. Quadrats were numbered sequentially from 1 to 10. This method was conducted during one site visit.

2.4.3 Bait Tube Transects

Although bait tubes have primarily been used to survey water shrews (*Neomys fodiens*) current developments in DNA techniques mean that this technique is likely to become an effective survey method for other small mammal species. Therefore, tubes were placed in habitats suitable for a variety of small mammal species.

Bait tubes were made from 4cm diameter white plastic waste pipe cut into 20cm lengths with the edges sanded down to reduce the risk of abrasion (Carter & Churchfield 2006b). 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 2006b). A single bait tube was placed at 10m intervals (5m from the beginning and numbered sequentially from 1 to 10) along each transect. Tubes were placed with their entrances flush to the ground and hidden out of sight in vegetation. Tubes were baited with 20-30 pre-frozen casters (blowfly pupae *Calliphora* sp) with no bedding as the animals are free to leave the tube at will. After seven days the transect was revisited and presence of faeces in each tube recorded, giving a count out of ten. All faeces were collected, air dried and stored in containers or vials. Samples were separated per bait tube and labelled with the date, PSU and bait tube number (1-10), giving a maximum of ten samples per SSU. All samples were then posted to Dr Sara Churchfield at Kings College London for species identification.

2.4.4 Extensive Live Trapping Transects

A single Longworth trap was placed at 10m intervals along each transect, using a total of ten traps per SSU. 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 oats and casters to ensure capture of a range of small mammals) and the doors locked open. Traps were then re-visited 24 hours later, food refreshed and the doors set to trap. The next morning the traps were checked, animals identified and released, giving a total of one night-time capture period per SSU. In the summer volunteers were asked to provide a small piece of apple for trapped mammals to reduce the risk of dehydration. At each transect volunteers simply recorded the presence of a species captured against each trap number. Information regarding age, sex or breeding status was not collected. Trap failures were recorded using the following categories: door locked shut, trap knocked over, door locked open, trap stolen and escaped.

2.4.5 Intensive Live Trapping Transects

Intensive trapping transects were similar to extensive transects, except that four Longworth traps were set at each point, at 10m intervals along each transect, so that each transect comprised 40 traps. Traps were numbered sequentially in groups of four, so that the first group was numbered one to four the second five to eight and so on.

Two set-up site visits were required to set the trap line. The traps were laid during the first set up visit, baited and locked open. The next morning the bedding and food was checked and the traps

unlocked. Four "capture" visits were then made to record mammal captures. In the evening the first "capture" visit was made to mark and release the captured animals. The next morning the second "capture" visit was made to record over-night captures and to mark all unmarked animals before release. This process was then repeated for a second 24 hour period, giving two day-time and two night-time capture periods as outlined in Table 3**.**

Table 3. Intensive trapping regime.

Day	*Time*	*Visit Type*	*Activity*
Day 1	AM	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
Day 3	AM	Capture Visit 2	Check traps, record and mark animals
Day 3	PM	Capture Visit 3	Check traps, record and mark animals
Day 4	AM	Capture Visit 4	Check and collect traps, record and don't mark animals

Captured animals were recorded with their species name against their trap number. Unlike the extensive method, individuals were marked with one clip the first time they were trapped (although this was not necessary on the last session). Individuals were only clipped once to indicate that they have previously been trapped. If marked animals were captured they were recorded as a tick against the trap code and the visit when the capture occurred. As with the extensive method, information regarding age, sex or breeding status was not recorded. Capture failures were recorded as before.

2.5 Volunteer feedback workshops

Two volunteer workshops were conducted in order to gain feedback about the project to enable identification of logistical problems and gain recommendations for changes to project methods. During each workshop volunteers provided feedback on the follow topics: time budgets; location, selection and size of tetrads; site access issues; habitat selection; logistics, timing, problems and recommendations for each SSU type.

2.6 Data Storage & Analysis

Data were stored in a custom designed Microsoft Access database. This had a fully relational structure and held spatial and temporal data on PSUs and SSUs, as well as the ecological data collected from FSUs. Data entry forms allowed sophisticated validation on entry and output queries allowed data to be extracted for analysis.

Statistical analysis was undertaken using Statistica v6.1 (2004). Simulations were undertaken using a combination of VBA in Microsoft Access and Statistica Basic.

3 Results

3.1 Volunteers and Primary Sampling Units

A total of 16 volunteers took part in one or more season's fieldwork and between them they established 26 Sites or Primary Sampling Units (PSUs). Eight of the volunteers undertook two PSUs each. Seven completed one PSU, but one volunteer completed three.

The PSUs were well distributed within England, from Yorkshire to Devon and Kent. Two were located in north Wales and two in the Republic of Ireland (Figure 2). There was a small degree of clustering, with five 10km squares containing two PSUs each. Unfortunately, no volunteers were obtained from Scotland.

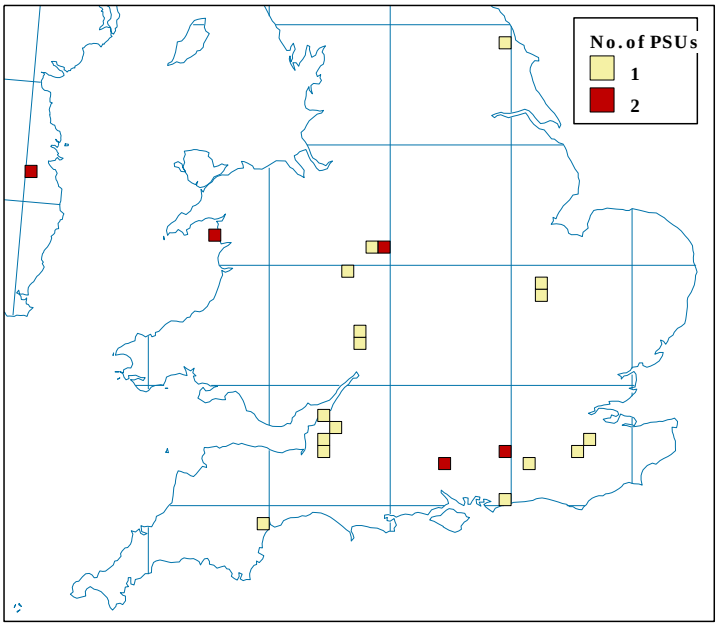

Figure 2. Location of the 26 PSUs plotted within 10km Squares of the British and Irish National Grids.

3.2 Seasons

The pilot comprised three seasons:

- Winter 2006 – 6th December 2006 to 12th February 2007
- Summer 2007 – 28th May 2007 to 13th August 2007
- Winter 2007 – 28th October 2007 to 6th January 2008

The dates above were the first and last visits made to any of the PSUs in each of the three seasons. The seasons were intended to be six-week windows within which the fieldwork had to be completed. However, delays in confirming the contract and, consequently, the volunteers meant that these had to be relaxed to allow an eight to ten week period. Furthermore, the whole of the first season was delayed one month allowing work to continue until February 2007.

The 26 PSUs generated a total of 57 PSU/season combinations. Thirteen were visited during all three seasons, five were visited during two seasons and eight were only visited in one season.

3.3 Secondary Sampling Units

A total of 150 Secondary Sampling Units (SSUs) or transects were established. However, in the event, one of these was not used leaving 149 active SSUs. The location of SSUs within PSUs was highly varied. Volunteers were asked to complete two of each of the five types of SSU in each of their PSUs, ideally giving ten SSUs per PSU. In reality, this ranged from 2 to 15 (Figure 3).

In addition, the types of SSU actually completed varied considerably between PSUs (Figure 4). Harvest mouse and Intensive Trapping transects were the most infrequently used with 19 each. In contrast, more than twice as many Extensive Trapping transects were set. The types of SSU within each PSU are given in Appendix II.

SSUs were placed in sixteen different habitats. The most frequently used habitats were hedgerows with 31 SSUs, followed by permanent grassland with 26 (Table 4). At the other extreme, only one road verge was trapped and two grass leys had field vole transects. However, there were good numbers of deciduous and mixed woodland, arable and other linear habitats such as fences, ditches and streams.

Volunteers were asked to visit all of their SSUs in every season. However, as the number of visits to PSUs indicates, this pattern was not completed. Instead, only 262 visits were made with the pattern shown in Table 5. Only 37 SSUs (25%) were visited in all three seasons. Conversely, 73 SSUs (49%) were only visited once. Ten SSUs were visited only in the two winters, but this at least allows a comparison between-years within-seasons on 32% of SSUs. Similarly, there was a total of 66 SSUs (44%) visited in summer 2007 and then again in winter 2007, allowing between-season comparisons.

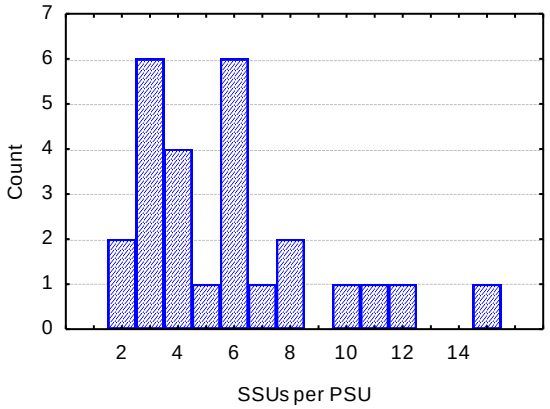

Figure 3. Frequency distribution of number of SSUs per PSU.

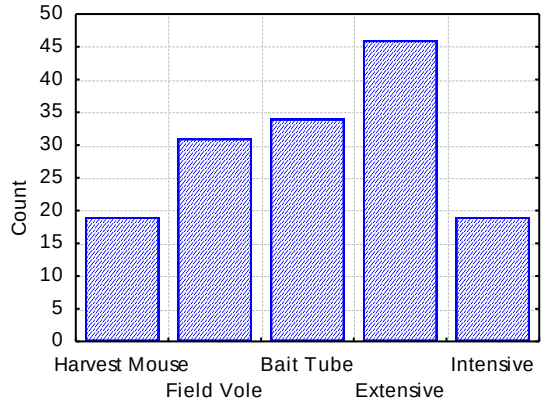

Figure 4. The number of SSUs of each type.

Table 4. Cross-tabulation of Habitat by SSU Type.

Code	*Habitat*	*1: Harvest Mouse*	*2: Field Vole*	*3: Bait-tube*	*4: Extensive Trapping*	*5: Intensive Trapping*	*Total*
1	Deciduous woodland		1	2	11	4	18
2	Mixed woodland		1	4	5	2	12
3	Coniferous woodland				1	1	2
4	Permanent grassland	5	10	3	3	5	26
5	Grass Leys		2				2
6	Arable	7	5	3		1	16
7	Orchards		2				2
8	Hedgerows		3	5	17	6	31
9	Fence lines	2	4	2	4		12
11	Ditches	4	2	2	1		9
12	Rivers			2	1		3
13	Streams			7			7
14	Standing water			1			1
18	Lowland Heath	1	1	1	2		5
20	Sand dunes			2			2
22	Road verges				1		1
	Total	19	31	34	46	19	149

3.4 Time Budgets

3.4.1 PSU Time Elements

Three time elements were recorded at the PSU level for each season (Figure 5).

The average amount of administration time spent on each PSU in each season was slightly less than two hours. In 11 cases, this was recorded as zero, and on one occasion 16 hours was recorded.

Travel time was recorded as the total time spent travelling to and from the PSU (but not within it) during the season. To allow for the different numbers of journeys made to the PSU (dependent on the number and type of SSUs) this was calculated as an average journey time. Across all 57 PSU/Seasons this averaged approximately 35 minutes, although ten cases recorded less than ten minutes and four cases recorded two hours.

On-site time was recorded as the total time spent within the PSU but not actually carrying out the work on an SSU. To account for the different numbers of SSUs undertaken on each PSU, this was recalculated as the mean time spent within the PSU per SSU. On average, only 20 minutes was spent on-site, although this ranged from virtually zero to at least one hour in two cases.

Table 5. The pattern of visits to SSUs by Season. (Visit represents the use of a SSU in a single season, regardless of the number of physical visits required by the field methodology.)

2006 Winter	*2007 Summer*	*2007 Winter*	*SSUs*	*Visits*
X	X	X	37	111
X		X	10	20
X			12	12
	X	X	29	58
	X		47	47
		X	14	14
59	113	90	149	262

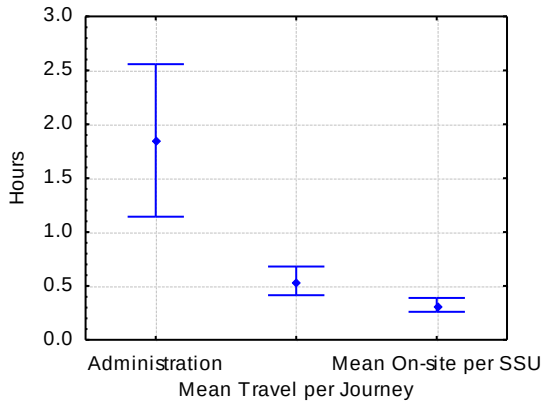

Figure 5. The mean (±95% C.I.) of the three time elements recorded at the PSU level during each season.

3.4.2 SSU Time Elements

The time required to complete an SSU was determined largely by two elements: the nature of the field method and the number of visits required to complete the method (Figure 6).

Harvest mouse and field vole transects only required a single visit each and took approximately the same time to complete; 50 and 40 minutes respectively. The quickest harvest mouse transect took 25 minutes and the longest time was two hours. The equivalent times for field voles were 15 minutes and two hours respectively.

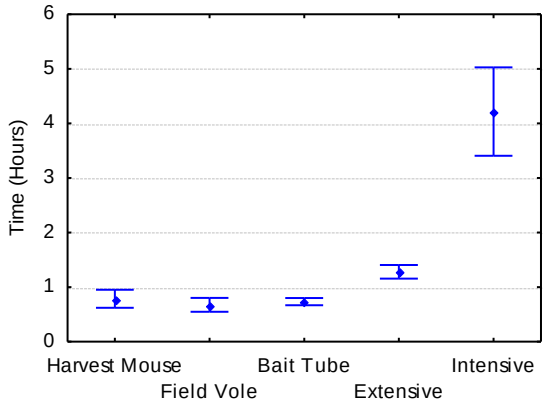

Figure 6. The mean time (±95% C.I.) required to complete each of the five types of SSU.

Bait tube transects required two visits, but each was relatively quick compared to the previous two methods. The average time to complete both visits was approximately 45 minutes, with a minimum recorded time of 22 minutes and a maximum of 1 hour 35 minutes. However, bait tubes were unique in requiring laboratory time for identification of faeces, where possible. This took, on average, 10 minutes per faeces sample. With a mean of 2.5 samples per SSU, we should add 25 minutes to the time required to complete a bait tube SSU.

Extensive trapping transects required three visits to complete. On average these took a total of 1.25 hours, with a minimum of half an hour and a maximum of three hours.

The Intensive trapping transects were the most time consuming as they required six visits to complete. The total time required to complete a transect averaged just under 4.25 hours. However, the times were quite variable with a minimum of 1 hour 20 minutes and a maximum of 8.5 hours.

3.5 SSU Results

3.5.1 Type 1 – Harvest Mouse Transects

A total of 28 seasonal visits were made to these transects and in every case ten Field Survey Units (FSUs) were completed. Harvest mouse nests were recorded in only five SSU/visits (18%). Only one SSU recorded more than one FSU with nests, giving a count of three in summer 2007. For this reason, all subsequent analyses are based on nest presence rather than counts of nests per FSU.

3.5.2 Type 2 – Field Vole Transects

Fifty-two seasonal visits were made to field vole transects. In every case ten 1m square quadrats (FSUs) were completed. Within each quadrat the presence of each of three signs was recorded giving a tally out of ten (Figure 7).

Runs were the most commonly recorded sign, averaging 5.3 FSUs per SSU, only being absent in five visits. The distribution appears to be somewhat bimodal with a peak around three to four FSUs and again around nine or ten. Feeding signs were recorded on average in 3.4 FSUs per SSU. Apart from the 11 visits where no signs were recorded, there was also a peak around two to three FSUs, although only three visits recorded feeding signs in every FSU. Finally, latrines were the least frequently recorded sign, with an average of 1.7 FSUs. They were entirely absent on 22 visits and in only three visits were they recorded in more than five FSUs.

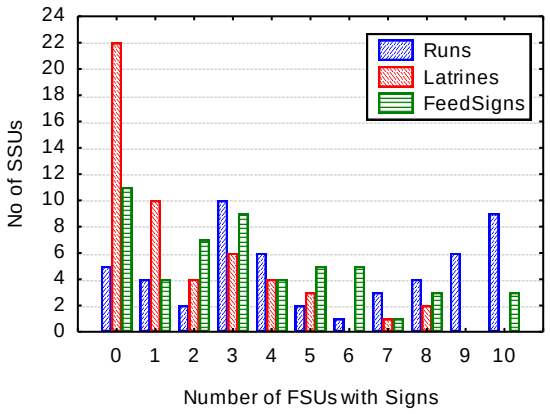

Figure 7. Frequency counts of the numbers of the three different signs recorded in Field Vole Transects.

The combination of signs within SSUs was also important. Only five visits had no signs of any type. Six visits had only a single type of sign recorded – all of them runs – and 11 visits had two different signs. Finally, 30 visits (58%) had all three types of sign recorded.

The overall frequency distribution of signs (Figure 8) showed that on no occasion was the maximum possible count of 30 achieved. However, a fairly good spread of values was obtained, with a minimum tally of two and a maximum of 28.

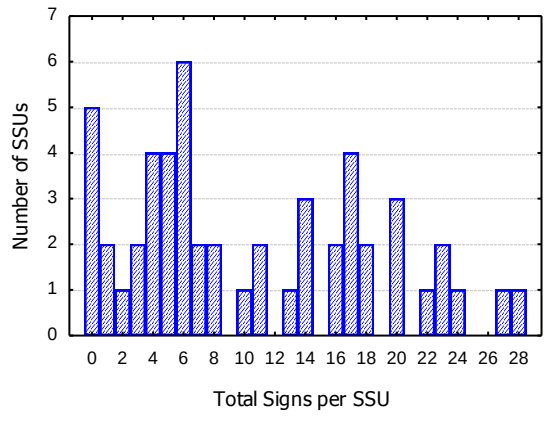

Figure 8. Frequency counts of the total number of signs recorded in Field Vole Transects.

3.5.3 Type 3 – Bait tube Transects

Bait tubes were laid on 70 occasions. In 19 of these one or more tube was lost or otherwise deemed a failure – on two occasions all ten tubes failed (Figure 9).

Ignoring these failures, the absolute number of tubes per SSU/season with faeces present have been plotted in Figure 10. On average, faeces were found in 26% of available tubes within an SSU. Faeces were absent in 27 SSU/seasons (39%) and were present in all available tubes on two occasions. Faeces were identified putatively to genera in 19 of the 45 tubes in which they were found. 15 were identified as *Sorex*, 12 as *Apodemus*, 2 as *Neomys* and 1 *Micromys*.

Figure 9. Frequency count of the numbers of tube failures in Bait Tube Transects.

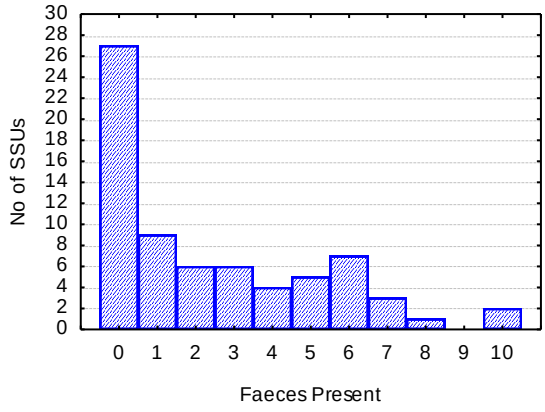

Figure 10. Frequency count of the numbers of tube with faeces in Bait Tube Transects

3.5.4 Type 4 – Extensive Trapping Transects

Extensive trapping transects were laid on 81 occasions. Unfortunately, 37 of these (46%) had one or more trap failures (Figure 11). In the majority of cases (22) there was only one failure but there was one case each of five, six and eight failures per transect. The total number of failures was 74 representing a 9.1% of all trap-visits. In addition there were six escapes from five SSU/Seasons where the animal was unidentified.

Ignoring the failures, the frequency distribution of captures is shown in Figure 12a. This shows that in only five SSU/seasons (6%) were no captures made. In contrast, there were three occasions when all ten traps were occupied. The average rate of capture was 4.83, although the distribution was more uniform than expected. However, by allowing for the number of failures, this pattern changes in one important respect (Figure 12b). Now, 17 SSU/seasons (21%) had all of the available traps occupied.

Eight different species were recorded from the extensive trapping transects (Table 6). *Apodemus sylvaticus* were the most frequently captured, with 240 animals being recorded in 64 (79%) of the SSU/seasons. The next most common species was *Clethrionomys glareolus* with 102 animals found in 43 transects (53%). In contrast, only one each of *Micromys minutus* and *Neomys fodiens* were recorded.

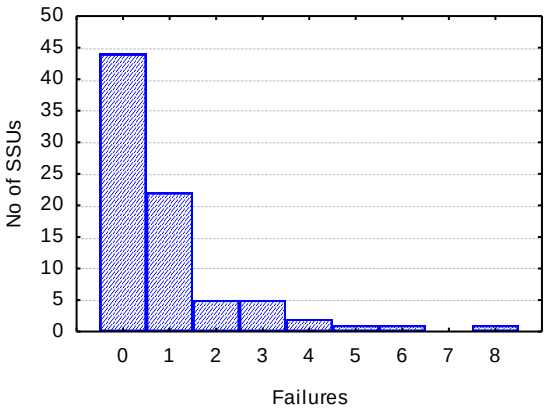

Figure 11. Frequency count of the numbers of trap failures in Extensive Trapping Transects .

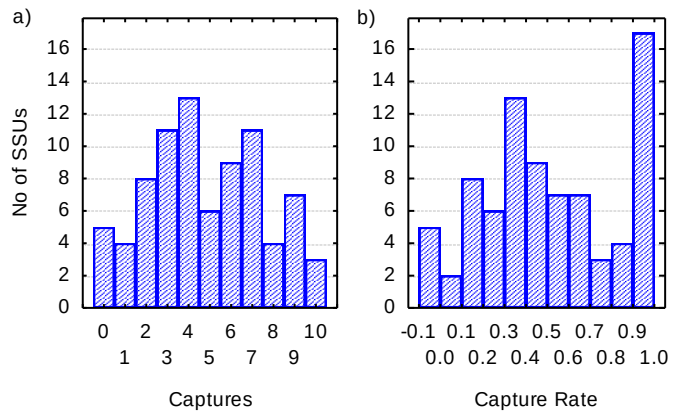

Figure 12. Frequency histograms of a) absolute captures and b) capture rates in Extensive Trapping Transects.

Table 6. Species recorded in Extensive Trapping Transects, with numbers of SSUs, total captures and mean capture rate per SSU.

Species	*Code*	*Common Name*	*SSUs*	*Captures*	*Mean Capture Rate*
Apodemus flavicollis	AF	Yellow-necked mouse	6	7	0.09
Apodemus sylvaticus	AS	Wood mouse	64	239	2.95
Clethrionomys glareolus	CG	Bank vole	43	102	1.26
Micromys minutus	MM	Harvest mouse	1	1	0.01
Microtus agrestis	MA	Field vole	8	9	0.11
Neomys fodiens	NF	Water shrew	1	1	0.01
Sorex araneus	SA	Common shrew	13	24	0.30
Sorex minutus	SM	Pygmy shrew	7	8	0.10

3.5.5 Type 5 – Intensive Trapping Transects

The 19 intensive trapping transects were used on 30 occasions. Each transect comprised 40 traps, which were used over four trapping sessions. This yielded 160 trap-visits per SSU/season or 4,800 in total.

Although 22 SSU/seasons (73%) had one or more failures, only two had more than ten failures with a maximum of 16 (Figure 13). As a proportion of the 160 trap-visits, these were considerably lower than the extensive transects with only 1.9% failure rate. In addition, there were 11 escapes in five SSU/seasons, although in four cases the animals were identified.

Animals were captured in all but one of the 30 SSU/Seasons. A total of 831 captures were made in 4,684 non-failed traps (17.7%). Of these captures, 588 (70.7%) were new captures representing the number of individual animals recorded during the survey. When broken down by SSU/season the captures range from one SSU with no captures to one where 56 new captures and 28 recaptures were made (Figure 14). (Anecdotally this was the same SSU carried out in the winter of 2006 followed by spring 2007.)

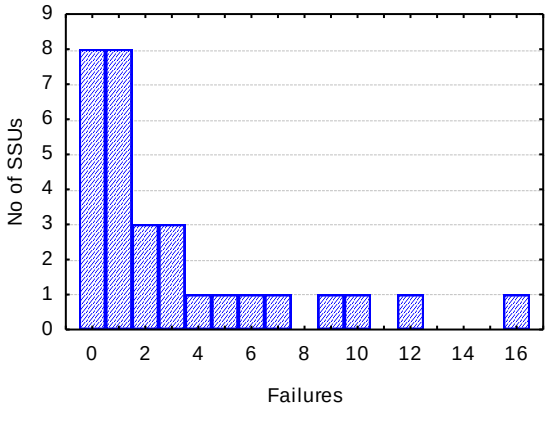

Figure 13. Frequency distribution of the numbers of trap failures in Intensive Trapping Transects

Recaptures were made in all but six of the SSU/seasons.

At the trap group level, 11 SSU/seasons (37%) had all ten groups with captures of new animals(Figure 15). Indeed, 21 (70%) had seven or more groups occupied, reflecting the saturation of groups when summarised to this resolution.

The same eight species were recorded in intensive trapping transects as were found in the extensive SSUs (Table 7). Every SSU/season (except the one which was totally devoid of captures) recorded the presence of *Apodemus sylvaticus*. This was the most frequently captured species with a total of 402 records. The next most widespread species was *Sorex araneus*, which was found in 20 SSU/seasons, although only 110 captures were made. *Clethrionomys* was found in 19 SSU/seasons, but was more frequently captured with a total of 208 records. At the other extreme, only three *Neomys* were recorded in one SSU/season.

Recapture rates for the commoner rodents were remarkably similar at around 44%, although *A. flavicollis* and *Micromys* were recaptured less frequently. Both species of *Sorex* were less commonly recaptured, although the three *Neomys* were all recaptured.

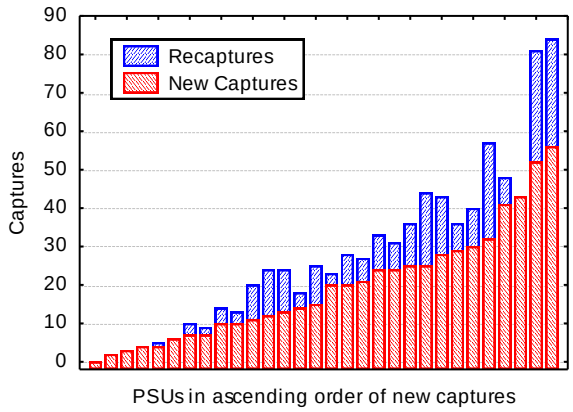

Figure 14. Frequency profile of the numbers of new captures and recaptures in Intensive Trapping Transects.

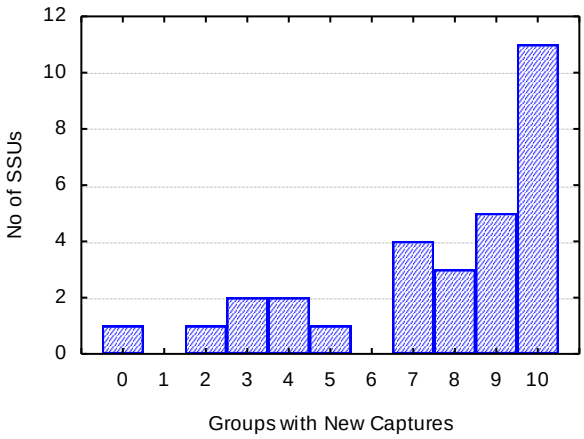

Figure 15. Frequency count of the numbers of trap groups with new captures in Extensive Trapping Transects.

Table 7. Species recorded in Intensive Trapping Transects, with numbers of SSUs, new captures, recaptures and recapture rate.

Species	*Code*	*Common Name*	*SSUs*	*New Captures*	*Re-captures*	*Rate*
Apodemus flavicollis	AF	Yellow-necked mouse	5	12	4	33%
Apodemus sylvaticus	AS	Wood mouse	29	281	121	43%
Clethrionomys glareolus	CG	Bank vole	19	158	70	44%
Micromys minutus	MM	Harvest mouse	2	3	0	0%
Microtus agrestis	MA	Field vole	7	29	13	45%
Neomys Fodiens	NF	Water shrew	1	3	3	100%
Sorex araneus	SA	Common shrew	20	81	29	36%
Sorex minutus	SM	Pygmy shrew	6	13	3	23%

3.6 The Volunteer Workshops

Two volunteer feedback workshops were conducted. The first workshop was conducted on the 9th February 2007 after the first field season and was attended by four project volunteers (one of whom was the author of this report and Chair of the Mammal Society's Survey Committee) and the Project Coordinator. The second workshop was conducted at the end of the project on the

20th February 2008 and was attended by six project volunteers (including the report author and surveys chair), a small mammal expert, the Chief Executive of the Mammal Society and Project Coordinator. A summary of the key outcomes and recommendations of both workshops are provided in Table 8.

Table 8. Workshop outcomes and recommendations.

Topic	*Outcome*	*Recommendations*
Time Budgets	Winter surveys were constrained by limited daylight hours, some volunteers checked traps by torch light and others had to take time off work	• Allow volunteers to survey at any time of year, allowing for volunteer choice.
Tetrads	Some volunteers could not complete the tetrads selected for them due to time or distance	• Use 1km squares as they are in-line with BTO and national habitat surveys. • Selected from a grid of 10 using the BTO model, Regional Coordinators are given 10km^2 grids and complete all the 1km^2 over time using one volunteer per 1km^2 • Maintain some degree of randomisation, but with some flexibility in the choice to keep it attractive to volunteers • Liaise with BTO about using the BTO squares
Habitat Selection	It was not clear which habitats to choose for each SSU, i.e. are we trying to cover all habitats or focus on the most suitable habitats? Often volunteers recorded two habitats when only one was required Changes in habitats were not consistently recorded (i.e. grassland being ploughed up) If the habitat had changed between seasons some volunteers did not conduct the survey	• Be more prescriptive over placement of SSUs types per habitat • Single-species SSUs should be placed in suitable habitats and multi-species SSUs in all habitats • Create a matrix of habitats and SSU types • Record more detailed information about habitats including management practices – record habitats at 2 levels PSU level (land class) and SSU level • Give clear instructions about surveying even when habitats have changed • Give instructions/handbook to students to review to assess clarity • Liaise with BTO to gain information about their habitat surveys
Access Issues	Some volunteers chose tetrads because they knew landowners	• Provide assistance to volunteers to gain landowner permission • Ensure volunteers are given feedback of the results from methods to inform landowners
SSUs	Volunteers often coded the SSUs incorrectly, and failed to re-visit SSUS Volunteers often failed to measure transect lengths	• Revise the handbook to give unambiguous instructions • Recording forms should contain SSU codes once the first survey at a site has been completed, and are then sent out to volunteers each season to avoid mistakes • Remove the requirement to measure transect lengths, start and end points will suffice • Set a limit on the number of SSUs completed per 1km square to reduce clustering and gain better geographical coverage

Table 8 (cont.). Workshop outcomes and recommendations

Harvest mouse transects (HMT)	As very few transects contained nests (18%) it was suggested that perhaps the transects should be longer	• Review this method and possibly conduct trials in the summer of 2008 to test different transect lengths / layouts • Suggested to include this method for two years and obtain a good dataset to review the results and assess the suitability of the methods • Perhaps conduct this method more intensively every five years
Field vole transects (FVT)	Good for attracting volunteers and easy to complete Not necessarily reliable to species as could be bank vole runs	• Record as a combination of three sign types, in order to be positive for Field voles • Review the reliability of the Field vole signs as some may not be Field vole.
Bait tubes (BT)	The majority of tubes were missing or disturbed Many tubes had no faeces Time consuming to analyse samples and not reliable to species	• At present this method is only reliable for water shrews, but it may become worthwhile for other species pending developments in DNA techniques • Perhaps conduct this method on a five year basis until DNA is developed, as there are good baseline data for water shrews
Extensive (ET) and Intensive Trapping (IT)	Attractive to volunteers as they see animals Potential constraint is the number of traps required Volunteers were not sure which trip weights to use Intensive trapping was time consuming and volunteers found it hard to get enough consecutive time to complete the survey	• Give advice on trip weights • Advise volunteers on shrew licenses and handling • Conduct trapping in geographical areas by sending all traps to one area to survey for one year and then move around. This allows most efficient use of traps. • Pre-bait extensive trapping transects on Saturday morning, rather than Friday evening, set traps Saturday night and check traps Sunday morning. This still allows pre-baiting but the SSU can be completed within a weekend so that volunteers do not have to take time off work. • Review the need to pre-bait as if not required volunteer effort could be reduced. • Review evidence for pre-baiting and perhaps conduct a trial over the summer 2008 including an assessment of pre-baiting 12 or 24 hours before trapping • Trapping methods need to be standardised so that times at which traps are checked and set (either am or pm) are the same between extensive and intensive transects
General Recommendations	*Hair Tubes* *Dormice Surveys*	• Potential for using hair tubes for single species Pygmy shrew method. Maintain contact with Michael Pocock who is developing the method over summer 2008. • Potential to conduct dormice surveys as easy to complete and volunteer friendly.

3.7 Missing and Incorrect Data

Numerous errors were identified on both the PSU and SSU fieldforms. These have been summarised to indicate areas where the design of the field forms could be improved or the instructions made less ambiguous.

At the PSU level a total of nine missing or incorrect data recording categories were identified (Figure 16). Transect lengths were the most frequently absent category on PSU forms with 48.2% of all returned forms failing to record this variable. This was followed by missing grid references that were absent on 26.8% of returned forms. Incorrect coding of SSUs and confusing habitat codes occurred on relatively high numbers of PSU forms with 28.6% and 19.6% of returned forms respectively.

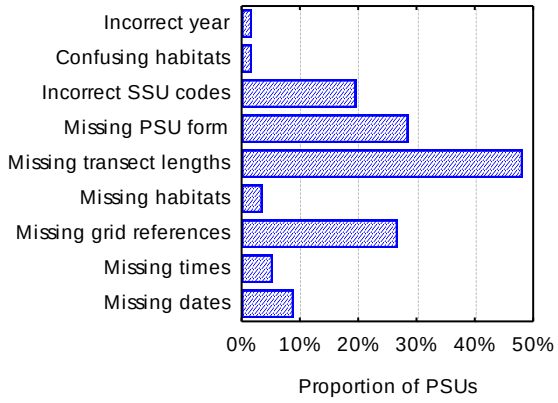

Figure 16. Volunteer errors in completion of PSU fieldforms.

A total of six incorrect data recording categories on SSU fieldforms were identified (Figure 17). As with PSU forms, the overwhelming majority of incorrect data were in the form of incorrect SSU codes representing 15% of SSU forms. Mis-coded trapping failures was the second most frequent category occurring on 5.4% of SSU forms. Overall the percentage of SSU forms with missing or incorrect data ranged from 1.5% to 15%, which was lower than PSU forms which ranged from 1.8% to 48.2%.

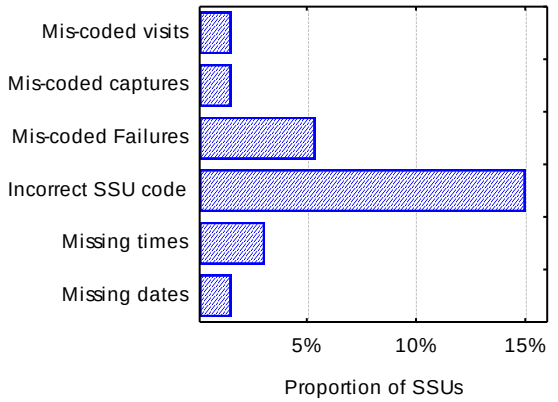

Figure 17. Volunteer errors in completion of SSU fieldforms.

4 Analysis

4.1 Introduction

The analysis of these pilot data has four main aims:

- To investigate the intrinsic information content obtained by the different field methods
- To analyse the time budgets for the different methods
- To combine the information content with the time budgets to provide a cost-benefit analysis
- To use the pilot data to undertake a power analysis of the different field methods.

These form the main sub-sections of this chapter. Within the first three, a number of specific questions have been formulated, which lead directly to testable hypotheses. These are listed at the beginning of each of the sub-sections.

4.1.1 Index of Information Content

The five field methods have been designed to have many common features, such as a standard length of 100m and the use of ten sections or groups within the transect. However, they are still sufficiently different in that they generate ostensibly different and incompatible data.

Firstly, the harvest mouse and field vole transects only obtain data on a single species, whereas the other three are multi-species methods. Secondly, field vole transects record three separate, although probably not independent, variables – runways, latrines and feeding signs. The other methods only record a single variable per species – their presence. Thirdly, harvest mouse and extensive trapping transects can only record a single presence in each FSU (apart from the very rare occurrence of two animals in one trap), which means the data obtained will simply be a count out of ten. However, bait tube and intensive trapping transects can record more than one species per tube or trap-group, so the total counts can sum to more than ten. Finally, extensive trapping transects, have four traps per group and four visits per season, so considerably higher counts are possible. Moreover, by marking animals before release, it is possible to estimate an absolute count of animals present – the Minimum Number Alive (MNA).

The first and, consequently, the third aims described in the introduction require an index of information content that is standard across field methods. This variable should have a number of properties:

- It should reflect the binomial nature of the data, where most information, and ability to detect change, is obtained when proportions are closest to 0.5. In other words, in a count out of 10, the most useful value to detect both an increase and a decrease is 5. Clearly, a count of 1 has very little power to detect a decline whilst a count of 9 has very little power to detect an increase. Indeed, it could be argued that, not only do counts of 0 and 10 have no power to detect decreases and increases respectively, they also have very little power to detect changes in the opposite directions as well. This is because a count of zero might reflect a low population where small sample size is unable to detect a presence. But it might reflect the complete absence of a species, such that a relatively large ingress is required before it can even be detected. Similarly with a count of ten, which might be a "saturated" count from a very high population that would require a catastrophic decline before the frequency count starts to fall below ten.
- It should be able to accommodate missing FSUs. If, for whatever reason, a transect does not contain all ten FSUs (or 40 in the case of intensive trapping), proportionate data will be reduced in power. For example, a count of 5 out of 10 has a greater power to detect change

than 4 out of 8, although both have proportions of 0.5. So when FSUs are missing the index of information content should be reduced.

- It should reflect the absolute magnitude of the data obtained. Firstly, for field vole transects, it is possible to tally the two or three field signs to give counts out of 20 or 30. Secondly, the intensive trapping transects can obtain counts based on 40 traps rather than 10 groups. Frequencies based on these denominators clearly have more power to detect change and contain more information, which should be reflected in a higher index.
- It should exploit the additional information obtained by multi-species methods. Even when the recording of multiple species is exclusive, such as in extensive trapping, so that the tally of records cannot exceed ten, more information is obtained when more than one species is recorded. For example, harvest mouse nests recorded in 5 out of 10 FSUs equates to a proportion of 0.5. However, if an extensive trapping transect records wood mice in three and bank voles in two FSUs, the overall proportion of captures is also 0.5, but clearly more information has been recorded. The index needs to balance the relative importance of multiple species information against the reduced information obtained from each species in this example. In contrast, consider the case where harvest mouse nests are found in all ten FSUs against wood mice and bank voles being captured in five traps each. Here, the latter should obtain a much higher index because not only is there information on two species, but each also provides more useful information than the saturated count of harvest mice.

The concept of information content described above leads naturally to the frequently used indices of diversity derived from information theory, such as the Shannon-Wiener index:

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

Where k is the number of categories and p_i is the proportion of observations found in category i.

In species diversity indices, species are the categories so that, generally, the more species you have the higher the index. Immediately, this introduces a problem with single species, because the proportion will always be 1 so the index will always be log(1) = 0. To overcome this we need to invoke an imaginary species called “missing”, which is found wherever real species are not. In this way, the total number of observations in, say, a harvest mouse transect will always be 10.

$$IIC = -[(p.\log p) + (q.\log q)]$$

$$where:\ p = \frac{n}{N}\ and\ q = \frac{N-n}{n}$$

$$n = Count\ of\ positive\ FSUs$$

$$N = Total\ count\ of\ FSUs$$

If harvest mice are recorded in 5 out of ten FSUs, then missing will also be recorded in 5 out of ten. Both categories generate a p of 0.5 so the index sums to:

$$IIC = -[(0.5 \times \log 0.5) + (0.5 \times \log 0.5)] = 0.301$$

This Index of Information Content (IIC) also has the desirable property of being symmetrical. Thus, a count of 4 out of 10 yields exactly the same index as a count of 6 out of 10. Not only that, but the maximum value is obtained when the proportions approach 0.5, which is the first of the required properties discussed above.

However, a small expedient is required to cope with counts of zero (or ten) in the example given above. These will result in either the recorded species or missing having counts of zero, so that the log cannot be calculated. By adding 1 to the counts of **both** the real and missing species (and so 2 to the denominators of *p* and *q*), a symmetrical index covering all possible outcomes is obtained:

$$Let\ p = \frac{n+1}{N+2}\ and\ q = \frac{N-n+1}{N+2}$$

This index also addresses the second property described above because, if an FSU is missing, it will reduce *N* but not *n*, and so reduce the index. To incorporate the third desirable property, it is necessary to introduce a factor representing the absolute value of the data. By multiplying the previous expression by (*N* + 2) and, finally, subtracting 2, we have a function that gives all the required properties:

$$IIC = -(N+2)\times[(p.\log_2 p)+(q.\log_2 q)]-2$$

For multiple-species methods, the index is calculated for each species and summed. This gives the following generalized expression:

$$IIC = -\sum_{i=1}^{s}[(N+2)\times(p_i \log_2 p_i + q_i \log q_i)-2]$$

Where N = the total number of FSUs,

$$p_i = \frac{(n_i+1)}{(N+2)},$$

$$q_i = \frac{(N-n_i+1)}{(N+2)},$$

n_i = the sum of presence of species (or sign) *i* and

s = the total number of species.

The use of log base 2 gives the final attractive property that for a single species with a proportion of 0.5, the index will equal the number of FSUs. This is best illustrated with an evaluation of all possible values for the index for a number of scenarios.

In the simplest situation where ten FSUs are completed for a single species such as harvest mouse transects, the number of FSUs in which they are present gives values for IIC as shown in Figure 18. This shows the symmetrical nature of the index and the maximum value obtained at a proportion of 0.5. Furthermore, it shows that even counts of 0 or 10 do not represent zero information. With values of 2.97, the index implies that there is approximately one third of the maximum information available.

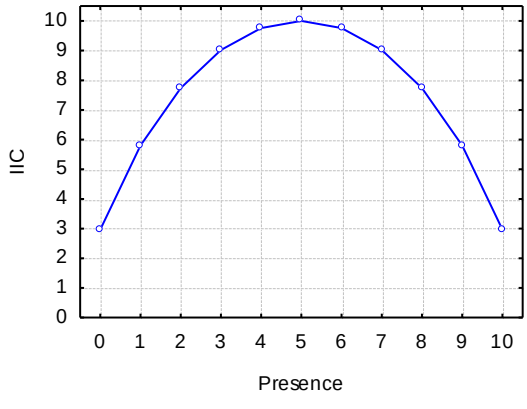

Figure 18. Index of Information Content (IIC) from an SSU with 10 FSUs successfully completed.

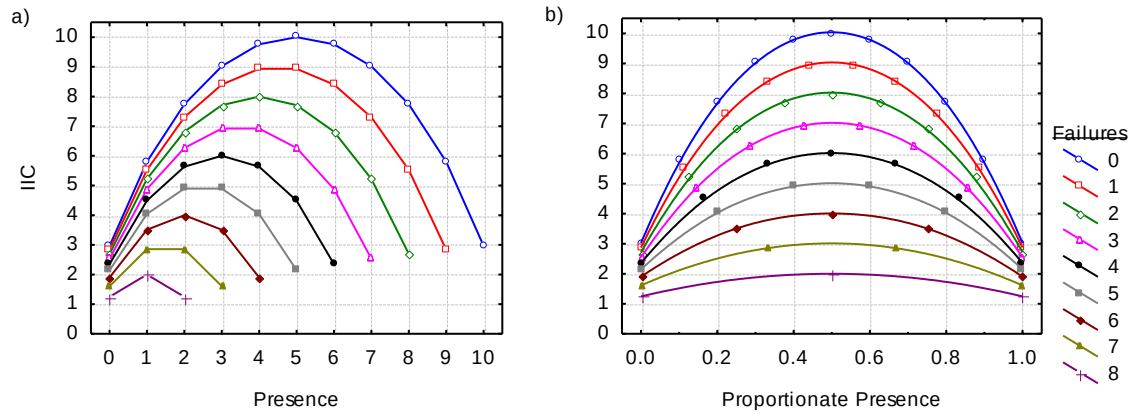

Figure 19. Index of Information Content (IIC) from an SSU with 10 FSUs and varying numbers of failures. Presence is expressed in a) absolute values with straight lines and b) as proportions with smoothed lines.

The effect of FSU failure is to cause the IIC curve to move down the graph (*i.e.* to decline in absolute value; Figure 19a) but also to flatten out (Figure 19b). This is because the maximum possible value decreases more quickly than the minimum values as the number of FSUs declines, so the ratio between them is reduced. The graphs show that although the ratio of maximum to minimum IIC values with no failures is approximately 3.4, with five failures it is only 2.3 and with eight failures it is only 1.6. Note that the smoother lines in Figure 19b indicate that if it were possible to obtain a proportion of 0.5 from nine FSUs, the IIC with one failure would be 9.0.

The third desirable property of the IIC is to reflect the absolute magnitude of the data. In the case of field vole or intensive trapping transects, the counts per FSU could be greater than one, either because more than one field sign is being counted or because multiple traps or sessions allow multiple captures. Taking the latter as an example, we have already shown that if a single capture was recorded in 5 out of 10 FSUs, giving a proportion of 0.5, the IIC would be 10. However, if two captures were made in each of five trap-groups, there would clearly be more information recorded, even though the proportion of FSUs remains at 0.5 (Figure 20). In this case the IIC would be approximately 14, and with three captures in each group it would be 16.6.

Note that the curves become asymmetrical as the counts increase such that the highest IIC from counts of four would be obtained from a proportion of 0.4 rather than 0.5. Furthermore, there are many combinations of counts that can occur which indicate that the IIC can actually take values between the four curves shown. For example if the proportion of traps with captures was 0.4, and the counts were 1, 2, 3 and 4 the IIC would 15.4

The final desirable property doesn't really need illustrating, because it is clear that multiple species records will result in rapidly increasing values for the IIC. As shown in Figure 18 for example, four captures of a single species would give an IIC of 9.76, whereas two captures each of two species would give 2 × 7.75 = 15.5. Indeed, even one capture each of two species gives a greater IIC (11.6) than is possible from only one species. This concurs with the intuitive notion that more species represent more information.

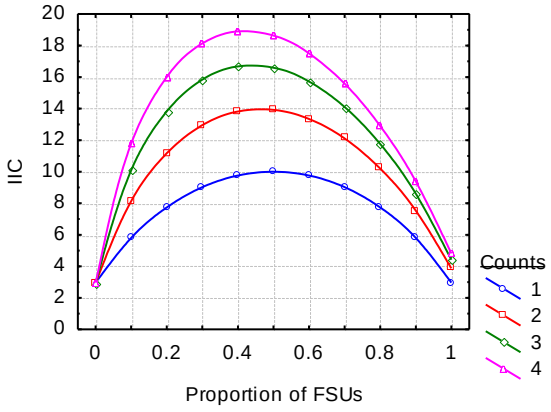

Figure 20. Index of Information Content (IIC) from an Intensive Trapping SSU with different counts in a range of proportions of traps.

4.2 Analysis of Information Content (IIC)

IIC was calculated for every SSU/season. It was used to answer the following questions:

- How does the information content vary between volunteers and sites?
- Is there a difference in the amount of information generated by the five different methods?
- Does the information content differ between years, seasons or habitats?
- How does the amount of information differ between species?
- Do different methods obtain different amounts of information for different species?

In addition, IIC was used to carry out a preliminary investigation of two of the field methods. Firstly, the amount of information derived from the three different signs in the field vole transects was compared, to determine whether it was necessary to record all signs. Secondly, the data from intensive trapping transects can be summarised at three different scales: trap-group, individual trap or individual animal.

4.2.1 Field Vole Signs

The three field vole signs can be used in a number of ways to provide a single value for a site.

- Firstly, the signs could be used individually to give, for example the number of FSUs with runways.
- Two or more signs could be combined using a logical AND operator. So, for each FSU, the presence of, say, runways AND latrines would result in a present (1), but either or neither would result in absent (0).
- Similarly, two or more signs could be combined with a logical OR operator. In this case, the presence of runways OR latrines would result in 1, and only the absence of both would result in 0.
- Finally, signs can be combined with an arithmetic + to give a tally out of 20 or 30.

These give a total of 15 possible response variables as illustrated with data from Site SU 4230 (Table 9). IIC was calculated for all variables in all 52 field vole SSUs and a repeated-measures ANOVA model constructed. This proved to be an extremely robust model with normally distributed residuals, although there was significant heteroscedasticity (Levene's $F_{(14, 765)} = 2.68$, $p < 0.001$).

Table 9. Field vole data from SU4243 showing the three raw field signs plus the twelve ways of combining them into a single value, using logical AND, logical OR and arithmetic +.

	Raw Signs			*AND*				*OR*				*+*			
FSU	*Run-way*	*Latrine*	*Feeding*	*R L*	*R F*	*L F*	*R L F*	*R L*	*R F*	*L F*	*R L F*	*R L*	*R F*	*L F*	*R L F*
1	1	0	0	0	0	0	0	1	1	0	1	1	1	0	1
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	0	1	0	1	0	0	1	1	1	1	1	2	1	2
4	1	0	0	0	0	0	0	1	1	0	1	1	1	0	1
5	1	1	0	1	0	0	0	1	1	1	1	2	1	1	2
6	1	0	1	0	1	0	0	1	1	1	1	1	2	1	2
7	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3
8	1	0	1	0	1	0	0	1	1	1	1	1	2	1	2
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3
Count	8	3	5	3	5	2	2	8	8	6	8	11	13	8	16
Maximum	10	10	10	10	10	10	10	10	10	10	10	20	20	20	30
Proportion	0.8	0.3	0.5	0.3	0.5	0.2	0.2	0.8	0.8	0.6	0.8	0.55	0.65	0.4	0.53
IIC	7.74	9.02	10.00	9.02	10.0	7.74	7.74	7.74	7.74	9.76	7.74	8.83	9.43	11.16	10.20

There was a very highly significant difference between the fifteen methods of calculating IIC ($F_{(14, 714)} = 8.84$, $p = 0$). In general, variables derived using the arithmetic + operator achieved higher IIC than either raw variables or those derived from logical operators (Figure 21). Not surprisingly, the highest IIC was obtained from summing all three field signs, because this resulted in a possible maximum score of 30. This was significantly greater than all raw variables and logical combinations except feeding signs alone and latrines OR feeding signs.

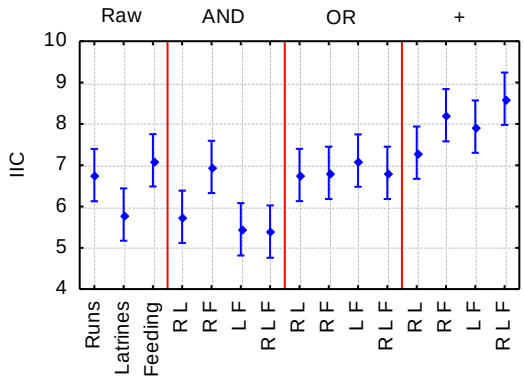

Figure 21. Means and 95% C.I. of IIC for the 15 different methods of summarising field vole signs. The three raw variables are shown on the left, followed by groups of four derived from combining raw variables with logical AND, logical OR or arithmetic + operators.

Taking individual contrasts, there was no significant difference between the three raw variables from this model, although a subsidiary analysis of these three alone did show a marginally significant difference between latrines and feeding signs ($F_{(2, 102)} = 3.67$, $p = 0.028$). Combining signs with AND was generally worse than raw variables with all runs AND latrines AND feeding being significantly worse than feeding alone. Combining signs with OR generally resulted in higher IIC, especially latrines OR feeding, although these were not significantly better than raw variables.

4.2.2 Intensive Trapping

The purpose of this preliminary analysis was to quantify the difference in summarising the trapping results at three different scales:

- Firstly, new captures can be aggregated by trap-group to give the presence of a species in a trap-group. This results in counts out of ten FSUs for each species and makes the data directly comparable with the other four field methods.
- New captures can be aggregated across sessions to give the presence of species in individual traps. This results in counts out of 40 FSUs for each species and, from the discussion in the pervious section, should contain considerably more information.
- Finally, new captures can be counted within each trap. The sum of these counts represents the MNA and, theoretically provides the maximum amount of information from these data.

IIC was calculated for all three summaries to compare their properties. This was done for all species aggregated together to give an overall comparison and for *Apodemus sylvaticus*, *Clethrionomys glareolus* and *Sorex araneus* individually.

A repeated-measures ANOVA model was constructed from the 30 SSU/seasons, including an interaction term between the PSU and Period (year/season). Unfortunately, this term was incomplete resulting in an unbalanced model, so the Period factor itself could not be tested. The square-root of IIC was used as the response variable in this model to reduce heteroscedasticity (which remained significant) and normalise residuals.

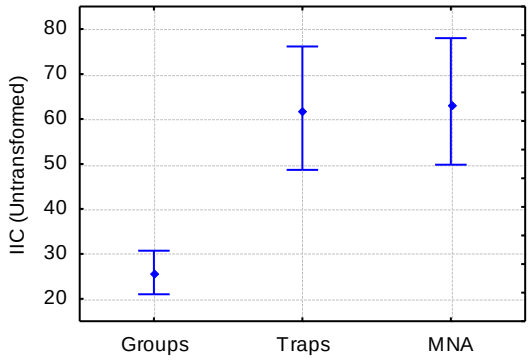

Figure 22. Untransformed means and 95% C.I. of sqrt(IIC) for the three different methods of summarising intensive trapping transects.

Not surprisingly, there was a very highly significant difference between the three different vari-

ables ($F_{(2, 65)}$ = 78.78, p = 0, Figure 22). Clearly summarising the results to ten trap-groups resulted in significantly less information than 40 individual traps or by utilising MNA. Approximately 2.5 times more information was obtained from using the latter compared with summarising to trap-groups.

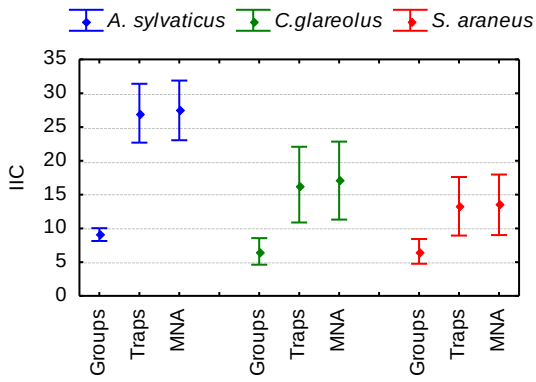

Figure 23. Means and 95% C.I. of IIC for the three different methods of summarising intensive trapping transects, for each of the three main species.

Each of the three main species also showed a significant difference between the three IIC values (Figure 23), although *Sorex araneus* was only marginally significant ($F_{(2, 83)}$ = 3.14, p = 0.048). However, the same pattern was evident with significantly lower IIC for groups than traps or MNA. For the purposes of the subsequent analyses, both the group and trap-based IIC will be used, because the former are compatible with the other four field methods, whilst the latter clearly provide more power, but might behave differently for different species.

4.2.3 How does the information content vary between volunteers and sites?

To account for the various factors that might influence IIC, a six-way partially crossed and nested ANOVA model was constructed with the following terms:

- Method – 5 levels
- Volunteer – 16 levels
- PSU nested with Volunteer – 26 levels
- Year – 2 levels
- Season – 2 levels
- Habitat category – 6 levels
- Method × Year – 10 levels
- Method × Season – 10 levels

All 261 SSU/seasons were included in the model. However, due to the severely unbalanced nature of this model, it was not possible to include other interaction terms between Method, Volunteer and PSU, nor the interaction between Year and Season. The response variable was transformed using $\log_e$ to normalise the residuals and reduce the heteroscedasticity.

The PSU factor nested within volunteers was unbalanced, with seven volunteers only completing one PSU, eight completing two and one completing three. However, after accounting for the other factors and interactions, there was no significant difference between sites within volunteers ($F_{(10, 214)}$, = 0.87, $p \approx 0.60$, Figure 24). Nor was there any difference between sites themselves ($F_{(15, 214)}$, = 0.86, $p \approx 0.57$). Moreover, the ratio of Volunteer to PSU variances was not significant ($F_{(15, 10)}$, = 1.01, $p \approx 0.51$).

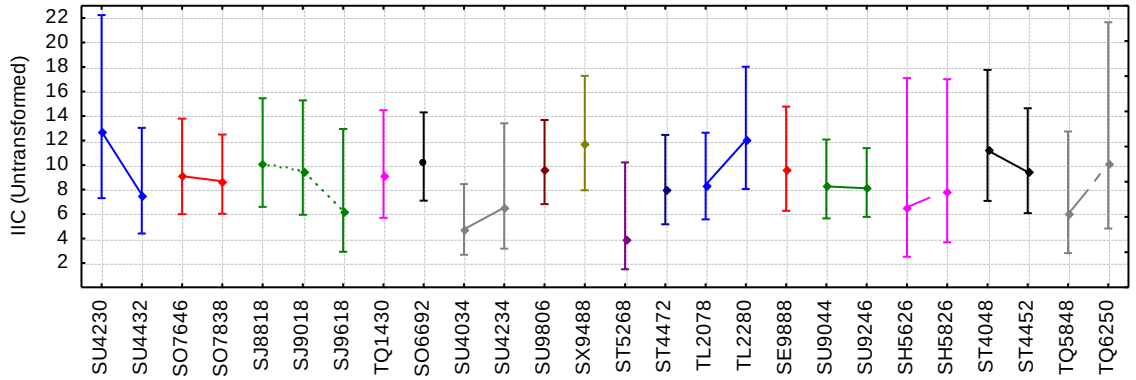

Figure 24. Untransformed least-squares means and 95% C.I. of IIC for the 26 PSUs nested within volunteers (colour-coded) derived from a six-way ANOVA.

4.2.4 Is there a difference in the amount of information generated by the five different methods?

Due to the unbalanced nesting in the model described above, it was not possible to compute all the marginal means for the other terms of interest. Given that the volunteer factor was not significant, a slightly reduced model was built, excluding this factor, but retaining the PSU factor (Table 10).

Table 10. Results of a five-way unbalanced crossed ANOVA of $\log_e$ IIC. (Highly significant results highlighted in red.)

	SS	DF	MS	F	p
Intercept	293.52	1	293.52		
PSU	8.29	25	0.33	0.866	0.652
Method	51.89	4	12.97	33.877	0.000
Year	0.92	1	0.92	2.397	0.123
Season	0.60	1	0.60	1.578	0.210
HabCode	0.74	5	0.15	0.386	0.858
Method × Year	2.05	4	0.51	1.338	0.257
Method × Season	1.56	4	0.39	1.016	0.400
Error	81.94	214	0.38		

This model revealed that there was a highly significant difference between the five methods (Figure 25). Firstly, the intensive trapping IICs were summarised to individual traps, and provided significantly more information than all the others with an untransformed mean of 39.4. However, the very high variation is shown by the individual IIC values, ranging from 4.78 (the single SSU with zero captures) to over 140. The high values represent the combination of multiple species being recorded in intermediate numbers of traps (between 15 and 25).

Secondly, harvest mouse transects were significantly less informative than the other four methods. This was simply due to the fact that nests were only recorded on 5 of the 28 SSU/seasons. Field vole, bait tube and extensive trapping transects formed a somewhat ambiguous group of intermediate IIC scores. All had significantly greater mean IIC than harvest mouse and significantly lower mean IIC than intensive transects. Furthermore, Extensive transects had signifi-

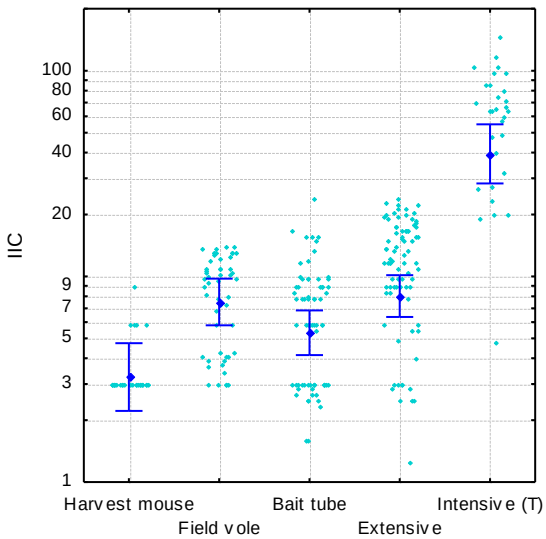

Figure 25. Untransformed least-squares means and 95% C.I. of IIC (on log scale) for the five field methods derived from a six-way ANOVA. Points are the individual IIC records, horizontally jittered for clarity.

cantly greater mean IIC (8.03) than bait tube transects (5.32). However, depending on the conservativeness of the post hoc tests, there were marginally significant differences between extensive and field vole transects (Newman-Keuls, $p \approx 0.015$), and between field vole and bait tubes (Newman-Keuls, $p \approx 0.025$).

The scores for extensive trapping were augmented by multiple species records – 52 of the 81 SSU/seasons (64%) recorded two or more species. In contrast, the relatively high scores in field vole transects, despite being single-species, were augmented by using tallies of all three signs – of the 47 SSU/seasons with signs 30 recorded all three signs in one or more FSU. The unexpectedly low scores for bait tubes, however, were more difficult to explain, especially as it is a multi-species method. Firstly, there was an unexpectedly high number of zero records (36%) of SSU/seasons. This was compounded by the number of failures, which reduced the IIC of even those SSUs where faeces were recorded. The final reason is probably methodological, in that identification of faeces to species or even genera was difficult, which means that they were often lumped into a single unidentified category which did not exploit to potential multi-species information. Indeed, in those cases where more than one species was identified, the IICs were in the same range as extensive trapping IICs.

4.2.5 Does the information content differ between years, seasons or habitats?

None of these three main factors were significant. Furthermore, the two interaction terms that were fitted to the model (method × year and method × season) were also non-significant. This implies that the methods work equally well across years, seasons and habitats and supplies consistent amounts of information after the very large differences between methods have been accounted for.

4.2.6 How does the amount of information differ between species?

To undertake the analysis of species effects a repeated-measures ANOVA model was constructed using log transformed IIC from the extensive and intensive trapping transects alone. The model used Method, Year & Season as the main factors of interest, with the interactions method x year and method x season. PSU was also added to account for site differences. The repeated-measures variable was species, which had eight levels, and was crossed with all six between-effects terms. The model was highly significant overall with well-distributed residuals (Table 11).

Table 11. Repeated-measures ANOVA for species. (Highly significant effects are highlighted in red, and marginally significant highlighted in magenta.)

	SS	*DF*	*MS*	*F*	*p*
Intercept	673.961	1	673.961		
PSU	8.776	21	0.418	1.448	0.120
Method	62.128	1	62.128	215.213	0.000
Year	1.821	1	1.821	6.308	0.014
Season	0.517	1	0.517	1.789	0.185
Year × Method	0.000	1	0.000	0.001	0.974
Season x Method	0.017	1	0.017	0.059	0.809
Error	24.249	84	0.289		
Species	29.357	7	4.194	39.241	0.000
Species × PSU	33.245	147	0.226	2.116	0.000
Species × Method	6.020	7	0.860	8.046	0.000
Species × Year	1.156	7	0.165	1.545	0.149
Species × Season	2.295	7	0.328	3.068	0.004
Species × Year × Method	0.258	7	0.037	0.344	0.933
Species × Season × Method	0.341	7	0.049	0.455	0.867
Error	62.843	588	0.107		

The between-effects factors all show the same pattern as in the full ANOVA model described in 4.2.3. However, in this model the year effect was marginally significant, emphasising the fact that overall, SSU/seasons in 2007 gave higher IIC values than those in 2006.

There was a very highly significant overall species effect in this model (Figure 26). Post hoc testing showed that significantly more information was obtained for *Apodemus sylvaticus* than any other species. The untransformed mean IIC

for this species was 8.3, which was significantly greater than the mean of 5.9 for *Clethrionomys*. This in turn, was significantly higher than the mean for *Sorex araneus* (4.5). Finally, there was a single homogeneous group comprising the other five species.

These results are explained generally by the frequencies at which the different species were encountered, and in this sense IIC is a surrogate for captures. However, this is mitigated by the fact that *A. sylvaticus* and sometimes *Clethrionomys* caused the transects to be "saturated" and so would have reduce their IIC values.

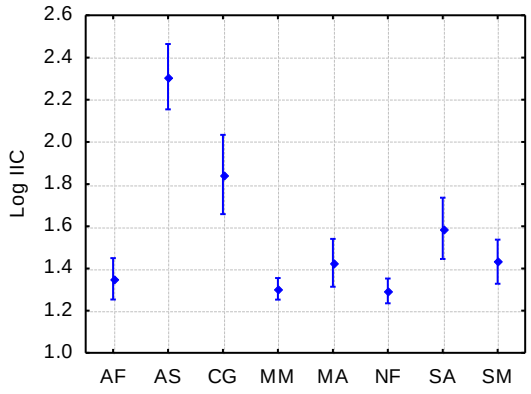

Figure 26. Least-squared means and 95% C.I. of Log IIC for the eight species recorded in extensive and intensive transects, derived from a repeated-measures ANOVA. (Species codes as in Table 7.)

4.2.7 Do different methods obtain different amounts of information for different species?

This far more interesting question can be answered from the repeated-measures ANOVA with the interaction between species and method. This was highly significant, indicating that not only are species inherently different, but their relative differences depend on the method (Figure 27).

Firstly, it is important to note that the difference between methods shown in section 4.2.3 holds for all species. For each species independently, there was a highly significant difference between the two methods. Secondly, within each method, there were three entirely distinct homogenous groups. In the intensive method, these comprised a) *Apodemus sylvaticus* alone, b) *Clethrionomys* and *Sorex araneus* and c) all the others. However, for extensive trapping transects *Sorex araneus* belonged to the "other group", leaving *Clethrionomys* in a distinct group of its own. The implication of this is that extensive trapping does not provide as much information, relatively speaking, about common shrews as does intensive trapping.

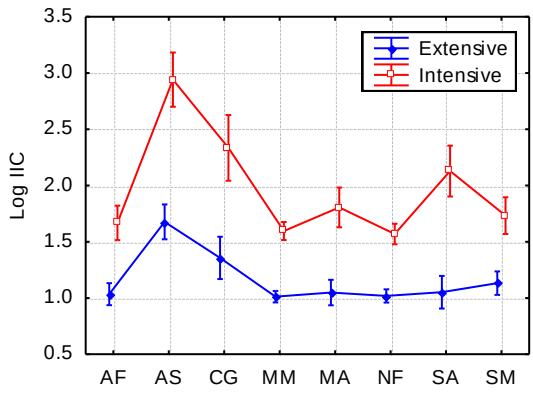

Figure 27. Least-squared means and 95% C.I. of Log IIC for the interaction between species and method recorded in extensive and intensive transects. (Species codes as in Table 7.)

Given that there are two methods specifically designed to record individual species, it is important to analyse their ability to provide information compared to the more general trapping methods. Firstly, harvest mouse transects were set in all habitat categories apart from woodland. A simple two-way ANOVA model was constructed using data from harvest mouse, extensive and intensive transects (excluding woodland SSUs). The main factors were PSU and method, with no interaction term. This showed a highly significant difference between all three methods ($F_{(2, 78)} = 42.5$, $p \approx 0$). Not surprisingly, intensive trapping gave significantly more information (mean untransformed IIC of 4.94), but this was entirely due to the higher IIC values for zero captures.. More interestingly, there was a significant difference between extensive trapping and harvest mouse transects with means of 2.88 and 3.34 respectively (Newman-Keuls $p \approx 0.01$). The lower mean for extensive trapping is almost entirely due to the number of trap failures, because every harvest mouse transect completed 10 FSUs.

Secondly, a similar restricted model was constructed for field voles. As these types of transects were set in all habitat categories, all extensive and intensive trapping SSUs were included. The model showed a highly significant difference between the three methods ($F_{(2, 137)} = 76.1$, $p \approx 0$), with significantly lower mean IIC from extensive transects (3.00) than either field vole (7.30) or extensive trapping transects (6.46).

4.3 Analysis of Time Budgets

The following questions were asked specifically of the time data recorded at the PSU and SSU level:

- Do volunteers take different amounts of time to complete SSUs?
- Does the time taken vary between methods?
- How does the time taken vary between year, season and habitat?
- Is there more variation in time between volunteer than method?

A simple breakdown of the times required for the five different methods is given in Figure 6. However, this deals only with the actual time spent on the SSU itself. Clearly, the time spent should also include travel time and at least a proportion of preparation and within-PSU time.

The simplest way to combine these elements is to calculate the average time required to complete an SSU/season when only a single SSU is undertaken. However, this ignores the possibility that the quicker methods could be carried out in parallel. For example, the time spent on an extensive SSU visit was considerably less than that spent on an intensive SSU visit. It would be possible, therefore, to undertake several extensive SSUs at the same time. This would incur additional on-site time (moving between SSUs), but would reduce the travel time to and from the PSU.

To accommodate this, times per SSU were also calculated based on four SSUs being run concurrently in a single PSU, for all except intensive trapping transects. This seemed to be an intuitive comparison because the intensive method used four times as many FSUs than the other methods. Admin time was not included in these calculations. On average, this resulted in roughly half the time required when four SSUs were undertaken, compared to a single SSU (Figure 28), although this was largely influenced by the bait tube and, to a lesser extent, the extensive transects. This variable was used in all subsequent calculations, using a $\log_e$ transformation as the response variable.

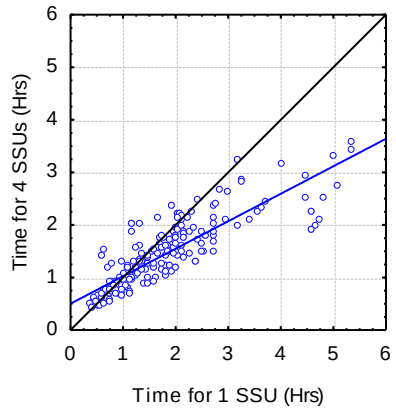

Figure 28. Comparison between times required per SSU for one and four SSUs per PSU. Best-fit straight-line relationship plotted ($T_4 = 0.5 + 0.53T_1$).

4.3.1 Do volunteers take different amounts of time to complete SSUs?

A similar approach was taken to model construction for the analysis of time budgets as was used for modelling IIC. Firstly, a six-way partially crossed and nested ANOVA was constructed to test for volunteer and site effects. This showed a very highly significant difference between volunteers ($F_{(15, 216)}$, =16.08, $p = 0$) but no significance between PSUs within volunteers ($F_{(10, 2164)}$, = 1.43, $p \approx 0.171$, Figure 29).

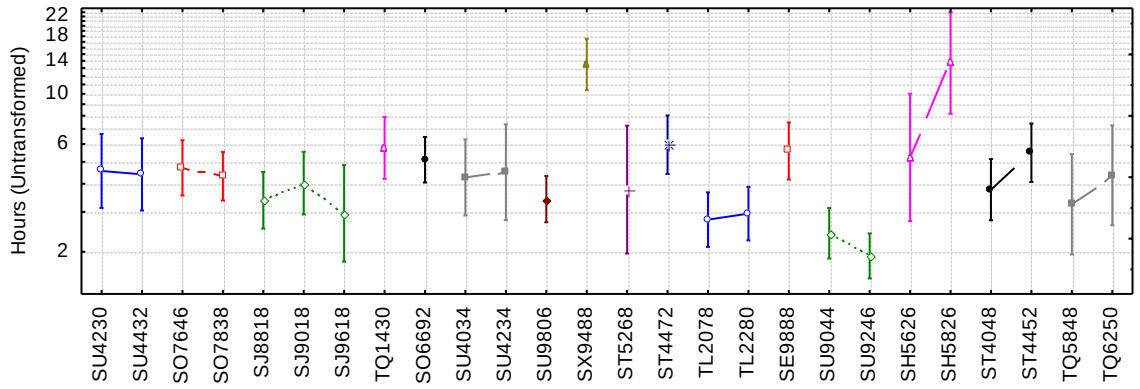

Figure 29. Untransformed least-squares means and 95% C.I. of time required to complete one SSU from the 26 PSUs nested within volunteers (colour-coded) derived from a six-way ANOVA.

The reduced model excludes the volunteer factor, but retains the PSU factor, on the basis that this really represents a volunteer effect. This five-way ANOVA with two interactions is full-rank, so all terms can be evaluated.

4.3.2 Does the time taken vary between methods?

The other terms of interest within the model could not be calculated because of its unbalanced nature. Consequently a reduced model was constructed that excluded the volunteer term, but retained the PSU term, on the basis that the very large difference between them was actually a volunteer effect rather than a true site effect.

Table 12. The results of a five-way ANOVA of time taken to complete one SSU. (Highly significant effects are highlighted in red, and marginally significant highlighted in magenta.)

Term	*SS*	*DF*	*MS*	*F*	*p*
Intercept	140.98	1	140.98		
PSU	47.04	25	1.88	10.720	0.000
Method	9.08	4	2.27	12.932	0.000
Year	12.00	1	12.00	68.359	0.000
Season	8.02	1	8.02	45.716	0.000
Habitat Category	0.82	5	0.16	0.933	0.460
Method x Year	2.53	4	0.63	3.610	0.007
Method x Season	3.08	4	0.77	4.388	0.002
Error	37.91	216	0.18		

This model showed a highly significant difference in the time taken to complete different methods (Table 12). Post hoc tests showed that there were significant differences between all five methods, except between harvest mouse and field vole transects and harvest mouse and bait tube transects (Figure 30).

4.3.3 How does time taken vary between year, season and habitat?

These three main effects were also fitted to the ANOVA model, plus the method interactions with year and season. Firstly, habitat category had no effect whatsoever. However, the year and season main effects were both highly significant. In 2006 the mean time to complete an SSU was 3.8 hours, whereas in 2007 it was only 2.8 hours. Similarly in the summer the mean time taken was 3.5 hours, but in winter it was only 2.7 hours.

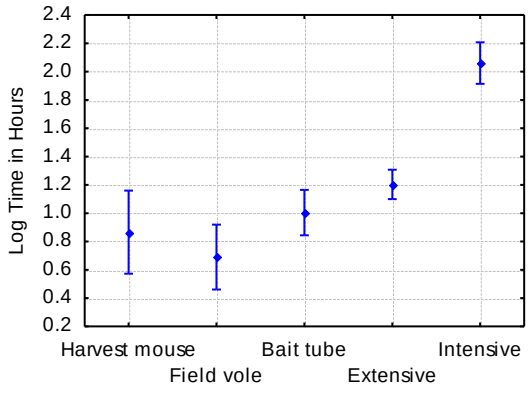

Figure 30. Weighted means and 95% C.I. of Log Time to complete the different methods, derived from a five-way ANOVA.

Furthermore, both interactions with method were significant, although the method × year interaction was only marginally and was difficult to interpret. The method × season interaction was highly significant (Figure 31). Post hoc tests showed two main interaction effects. Firstly, there was a significant difference between season for harvest mouse ($p < 0.001$) and field vole ($p \approx 0.001$) but not for the other three methods. The former took longer to complete in the summer (untransformed means of 3.1 and 2.6 hours respectively) than in the winter when they only took 1.8 and 1.6 hours respectively. Secondly, in the summer there was no significant difference between harvest mouse, field vole, bait tubes and intensive trapping transects, but they were all significantly quicker than intensive trapping transects. However, in the winter, they formed three distinct groups; harvest mouse and field vole being significantly quicker than bait tube and extensive transects, which were, in turn, significantly quicker than intensive transects.

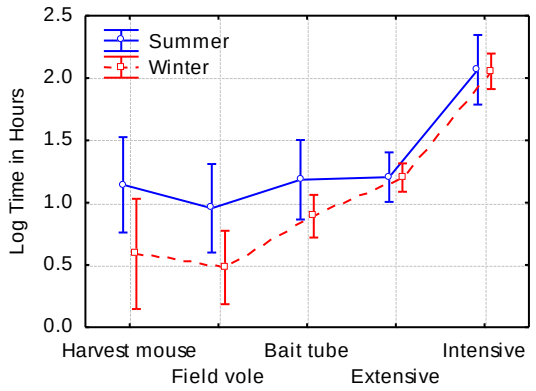

Figure 31. Weighted means and 95% C.I. of the interaction of time to complete the different methods and season, derived from a five-way ANOVA.

4.3.4 Is there more variation in time between volunteer than method?

This question is difficult to answer because not every volunteer did every method. However, a reduced, but unbalanced model indicated that there was significantly less variance between volunteers than between methods ($F_{(15, 4)}$, = 0.121, $p \approx 0.999$).

4.4 Cost-benefit Analysis

The following questions were posed for the cost-benefit analysis:

- Does the amount of time spent on the "searching" methods determine the amount of information obtained?
- What is the overall cost-benefit between the five different methods?
- Does the cost-benefit vary between years, seasons or habitats?
- Does the cost-benefit differ between species?

The concept of cost-benefit combines the amount of information obtained by completing an SSU (the benefit) with the time taken to complete it (the cost). The easiest way to express this, using the units already analysed in sections 4.2 and 4.3, would be as IIC/hr. Indeed, being a ratio-scale variable, this was extremely well distributed and is used for all the subsequent analyses.

4.4.1 Does the amount of time spent on the "searching" methods determine the amount of information obtained?

This preliminary analysis makes the distinction between the two methods that utilise searches – harvest mouse and field vole transects – from the others that utilise equipment such as tubes or traps. In the latter cases the time taken to complete the transect is dependent to a large degree on the amount of information (faeces or captures) that are obtained. But, in contrast, the time spent for the two search methods is, to some degree, independent of the amount of information gathered. Clearly when a nest or field sign is found in an FSU, the volunteer can move on to the next unit, so an abundance of signs will allow the SSU to be complete relatively quickly. However,

when signs are scarce, the point at which the volunteer abandons an "empty" FSU and moves on, might determine the amount of information obtained.

A simple one-way ANCOVA model was constructed, using log IIC as the response variable, Method as the categorical predictor variable with two levels and log Time as a continuous predictor. This showed no significant predictive relationship between Time and IIC ($F_{(1, 249)} = 0.686$, $p \approx 0.408$). Furthermore, there was no interaction so this independence held true for both Methods.

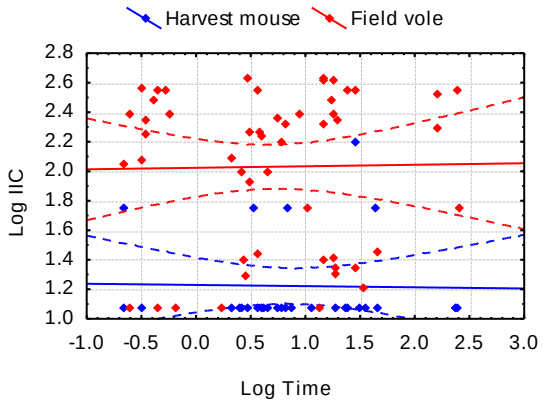

Figure 32. The relationship between information content and time spent searching in harvest mouse and field vole transects, derived from a one-way ANCOVA. (Best-fit straight lines with 95% C.I. shown.)

4.4.2 What is the overall cost-benefit between the five different methods?

As the previous analysis of IIC has shown, there were no significant volunteer or habitat effects. Consequently, to simplify this analysis a four-way partially-crossed ANOVA model was constructed, using the $\log_e$ of IIC / Hour as the response variable and PSU, method, year and season as categorical predictor variables. The method × year and method × season interactions were also included to give a full-rank model.

There was a very highly significant difference between the cost-benefit of the five different methods ($F_{(4, 219)} = 11.89$, $p = 0$, Figure 33). Firstly, despite requiring considerably more time to complete, Intensive trapping transects still provided the highest cost-benefit with a mean rate of 6.6 IIC / Hour. This was significantly greater than any other method.

The next most beneficial methods were field vole and extensive trapping transects, which formed a homogeneous group. Their means were not significantly different from each other at 3.8 and 3.2 IIC / Hour respectively.

However, both of these methods had significantly greater cost-benefit than bait-tubes with a mean of 2.1 IIC / Hour. Finally, the least beneficial method appeared to be harvest mouse transects, with a mean IIC / Hour of only 1.4. This was marginally significantly less than bait tube transects, but clearly much lower than the other three methods.

This pattern largely follows that uncovered during the analysis of IIC itself, although the greater time required for the more powerful methods tends to weight them down. For this reason, the maximum rates for all five methods were between 10 and 20 IIC / Hour, with only two SSUs exceeding this rate. The main differences occur with field vole and bait tube transects, where the former have relatively high IIC and the latter are

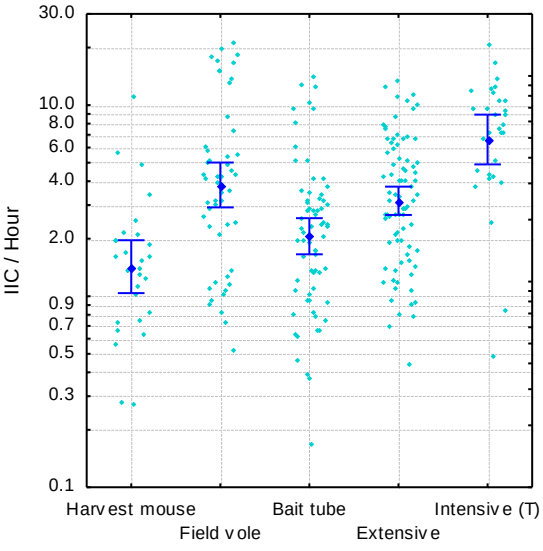

Figure 33. Untransformed weighted means and 95% C.I. of IIC / Hour (on log scale) for the five field methods derived from a four-way ANOVA. Points are the individual IIC / Hour ratios, horizontally jittered for clarity.

relatively time consuming. So the marginal difference in their raw IIC became a much more significant difference when rates were compared (Newman-Keuls $p < 0.001$).

4.4.3 Does the cost-benefit vary between years or seasons?

The four-way ANCOVA model was also used to assess the effects of year and season. Both of these main factors were very highly significant ($F_{(1, 219)} = 37.37$, $p = 0$ and $F_{(1, 219)} = 25.27$, $p = 0$, respectively). Furthermore, their interactions with method were both non-significant, indicating that the differences between year and season were constant across method.

The cost-benefit in 2007 was much greater than 2006 with a mean IIC / Hour of 3.2 compared to only 2.2. A similar pattern was evident between seasons, with means of 3.3 in winter compared to 2.5 in summer. Both of these effects were due to the shorter times spent in 2007 and winter, rather than higher intrinsic IIC values.

4.4.4 Does the cost-benefit differ between species?

A similar five-way repeated-measures ANOVA was constructed as used in section 4.2.6 but using the log of IIC / Hour calculated for each of the eight species. This was applied to extensive and intensive trapping transects only. Because the repeated-measures response variable was divided by a constant value within SSU/seasons (*i.e.* the time taken to complete the SSU was the same for all species) the results of this model were only partially different from the analysis of raw IIC.

Firstly, the F-ratios and significance levels for all species terms in the model were identical, but the effect on method was to remove any significance at all. This is shown most clearly in the interaction plot between species and method (Figure 34). The shape of the traces are identical to Figure 27, but the values of the means and the widths of the error bars has changed. Most importantly, the IIC rates for the intensive transects have "dropped" towards those for the extensive transects, so that now only AS had significantly different rates between the two methods (Newman-Keuls $p \approx 0.03$) with untransformed means of 2.2 and 1.2 respectively.

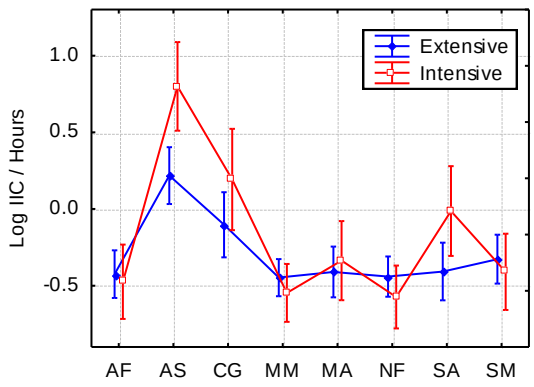

Figure 34. Least-squared means and 95% C.I. of Log IIC / Hours for the interaction between species and method recorded in extensive and intensive transects. (Species codes as in Table 7.)

The analysis of IIC for harvest mouse and field vole transects carried out in section 4.2.7 have been repeated here using log IIC / Hour as the response variable. Firstly, for harvest mice, the greater time costs for extensive, and especially intensive trapping transects, penalised them compared to harvest mouse transects. The highly significant difference between all three ($F_{(2, 78)} = 10.10$, $p < 0.001$), meant that the latter became the most efficient method for this species, with an untransformed mean rate of 1.38 IIC / Hour. This was followed by extensive trapping (0.82 IIC / Hour) and, finally, intensive trapping with a mean of 0.63 IIC / Hour.

The analysis of field voles provided similar results. In this case the greater time taken by intensive trapping meant that the IIC rate was identical to extensive trapping (0.84 IIC / Hour for both). However, field vole transects had a significantly greater cost-benefit ($F_{(2, 78)} = 57.63$, $p \approx 0$) with a mean of 3.33 IIC / Hour.

4.5 Power Analysis

The purpose of the power analysis was to utilise the pilot data to estimate the sample sizes required from a full small mammal monitoring programme. A power analysis of this type requires three main parameters:

- The degree of change it is desired to detect
- The starting mean for the population parameter
- The variance of the population parameter

The first of these can be set arbitrarily by the experimenter to represent any degree of change. The other two can be approximated from the sample statistics obtained from the pilot study. So, for each combination of method and species, we can derive a mean and variance, which we can assume are unbiased estimators of the population parameters.

All the data acquired in the pilot analysis were the proportions of FSUs with records or field signs. These have been expressed as Presence-Absence Ratios (*sensu* Sibbald, Carter & Poulton; 2006) as they allow the correct calculation of the rate of decrease – unlike proportions. So, the mean for each combination of method and species is the mean PA-Ratio across SSU/seasons. Similarly, the variance is calculated from the PA-Ratios from each SSU/season, expressed as the Co-efficient of Variation (V = SD/Mean)

4.5.1 Preliminary Correlation Analysis

Before undertaking the simulation modelling, it was necessary to check the two trapping methods to ensure that there were no negative correlations between species. This was especially important for the extensive trapping transects because, with only ten traps, as they became filled they were then unavailable to other species.

Two separate cross-correlation analyses were carried out on each method separately (Table 13). There were no significant negative correlations in either matrix. This strongly suggests that "trap saturation" was not a problem. Interestingly, there were fewer significant positive correlations in the extensive than the intensive transects, with *Sorex araneus* being positively correlated with *Micromys* and *Neomys*. The larger number of significant positive correlations in the intensive transects indicates that sites which had high captures of *S. araneus*, for example, also had high captures of *Clethrionomys*, and that there was a surplus of traps available for their capture.

Table 13. The cross-correlations between species for Extensive (upper right) and Intensive (lower left) trapping transects. Data are the correlation co-efficient (*r*) colour-coded magenta for marginally significant and red for highly significant.

		Extensive (n = 81)							
	Species	*AF*	*AS*	*CG*	*MA*	*MM*	*NF*	*SA*	*SM*
	AF		-0.061	0.198	-0.006	-0.024	-0.024	-0.092	-0.076
	AS	-0.021		-0.080	-0.073	-0.021	-0.021	-0.083	-0.069
	CG	0.381	0.252		-0.087	-0.039	-0.039	-0.056	0.072
Intensive (n = 30)	*MA*	-0.136	0.523	-0.039		-0.040	-0.040	0.082	-0.001
	MM	-0.099	0.372	-0.034	0.670		-0.014	0.359	-0.036
	NF	-0.072	-0.152	0.046	-0.065	-0.047		0.359	-0.036
	SA	0.159	-0.037	0.558	-0.031	-0.081	0.050		-0.062
	SM	0.586	0.053	0.502	-0.144	-0.104	-0.076	0.494	

4.5.2 Simulation Modelling

The power analysis has been carried out using a simulation procedure similar to, but more complex than that described in Sibbald, Carter and Poulton (2006). Firstly, the declines were modelled as exponential rather than linear. Six different degrees of change have been modelled, three decreases and three increases:

- -0.512% p.a. = 5% decrease over 10 years
- -1.053% p.a. = 10% decrease over 10 years
- -2.231% p.a. = 20% decrease over 10 years
- +0.488% p.a. = 5% increase over 10 years
- +0.954% p.a. = 10% increase over 10 years
- +1.824% p.a. = 20% increase over 10 years

Secondly, the simulation procedure actually requires two components of variance; the Between-site V and the Between-year V. The former was based on the variance between site means and, consequently, was calculated from the number of SSU/seasons that the method used (from 30 to 81). However, the Between-Year V was based on the mean of within-site variances, which was only calculated from two or three seasons. In all cases where only one visit was made, the Between-year V was zero.

Finally, as the raw data were binomial, the number of trials from which the frequency counts were obtained was required as another parameter in the simulation models. These were derived from the pilot data to take account of the number of failures. For example, the mean number of successful traps in the extensive trapping transects was 9.09. So to reflect the fact that nearly 10% of traps fail using this method, the number of trials for these simulations was set at 9 rather than 10.

One compromise was required for the bait tube transects. Because it was not possible to identify faeces to species it was decided only to distinguish them as rodent, shrew or all faeces. These three categories were used as "pseudo-species" in the power analysis, based on the fact that they at least indicated the degree of sample size that might be required.

This gave a final list of 21 method/species combinations (Table 14). Note the reduced number of trials in bait tubes and the two trapping transect methods as discussed above. PA-Ratios were notably high for faeces in bait tubes and *A. sylvaticus* in extensive trapping transects. Between-year V was always considerably smaller than between-site V, probably for the reasons indicated above.

Table 14. The four parameters obtained from the pilot data used in the 21 combinations of method and species simulations.

Method	*Species*	*Trials*	*PA-Ratio*	*SiteV*	*YearV*
Harvest mouse	MM	10	0.041	1.931	0.063
Field vole	MA	30	1.196	1.764	0.401
Bait tubes	Faeces	9	3.578	3.729	0.646
	Rodent	9	0.147	1.016	0.703
	Shrew	9	0.247	1.893	0.598
Extensive trapping	AF	9	0.028	1.532	0.184
	AS	9	4.366	3.135	0.478
	CG	9	0.337	2.925	0.375
	MA	9	0.028	1.284	0.225
	MM	9	0.017	0.888	0.140
	NF	9	0.017	1.161	0.114
	SA	9	0.056	1.961	0.254
	SM	9	0.027	1.321	0.174
Intensive trapping	AF	39	0.012	2.144	0.199
	AS	39	0.347	0.903	0.321
	CG	39	0.161	1.377	0.318
	MA	39	0.028	2.389	0.198
	MM	39	0.003	3.343	0.031
	NF	39	0.003	3.354	0.085
	SA	39	0.081	1.339	0.255
	SM	39	0.011	2.112	0.171

The simulations used the following process:

- For each method/species combination randomly select a sample size from a uniform distribution between values 10 and 1000.
- Create a vector (length sample size) of site means, by drawing random values from a zero-truncated normal distribution with mean of PA-Ratio and standard deviation of PA-Ratio × SiteV.
- Create a matrix (sample size × years) of site/year means. Draw these randomly from a zero-truncated normal distribution with a mean of the site mean and SD of the PA-Ratio × YearV.
- Apply the annual rates of change to all site/year means. Year 0 has no change, year 10 has ten years worth of annual changes.
- Create a matrix (sample size × years) of counts. Draw these randomly from a binomial distribution with a mean *p* of the site/year mean back-converted to probabilities and a *t* of the number of trials.
- Carry out a logistic regression analysis of these counts against sample size, using a Generalized Linear Modelling process. Store the sample size, the *b* co-efficient and standard error of the co-efficient.
- Repeat this process 1,000 times.

This resulted in a total of 6 degrees of change × 21 method/species combinations × 1,000 simulations = 126,000 logistic regressions.

For each method/species combination this process generated 1,000 simulated populations all with the same average starting mean, variances and change over ten years, but with differing sample sizes (*n*). Each simulation generated a single absolute *t* statistic for the significance of the change, derived from the *b* co-efficient and the SE of the co-efficient.

By plotting *t* against *n* it is possible to define a straight-line relationship passing through the origin using least-squares regression (Figure 35a). Furthermore, it is also possible to plot on these axes a function representing the significance of *t* at any α-level for any sample size. The point at which the best-fit line crosses the significance function determines the average sample size that would yield a significant result from a logistic regression using the relevant parameters. In this example (*A. sylvaticus* from intensive trapping transects with a simulated decline of 20%) the sample size required to test to an α-level of 0.05 is approximately 77 – for an α-level of 0.01 it is considerably higher at around 110.

Now, there are two obvious problems with this graph. Firstly, there is a line of simulations yielding a *t*-value of zero. These are the logistic regressions that failed due to inadequacies in the GLZ modelling approach. Although they only numbered about 3.3% of simulations, they have leverage on the slope of the best-fit line, especially when they occur at large sample sizes.

Secondly, this example clearly shows the non-linear relationship between *t* and sample size. As sample size increases, the rate of decrease in *t* levels off. This implies that, had we simulated extremely large samples, *t* would eventually have stabilised at the very small value. This shape has the effect of making the straight-line fit a very conservative estimate at small sample sizes and optimistic at large sample sizes. So, our example estimate for an α-level of 0.05 appears to fall above the main cluster of points rather than the centre.

To overcome this it is tempting to fit a power function, such as t^2. In fact, by iterative trial-and-error, the function $t = -0.15 \times \text{SampleSize}^{1.7}$ gives a much better fit (Figure 35a). Using this curve, the estimated sample size now required for an α-level of 0.05 falls dramatically to 22. Clearly, the sample size is very sensitive to the shape of the best-fit line, especially at smaller sample sizes.

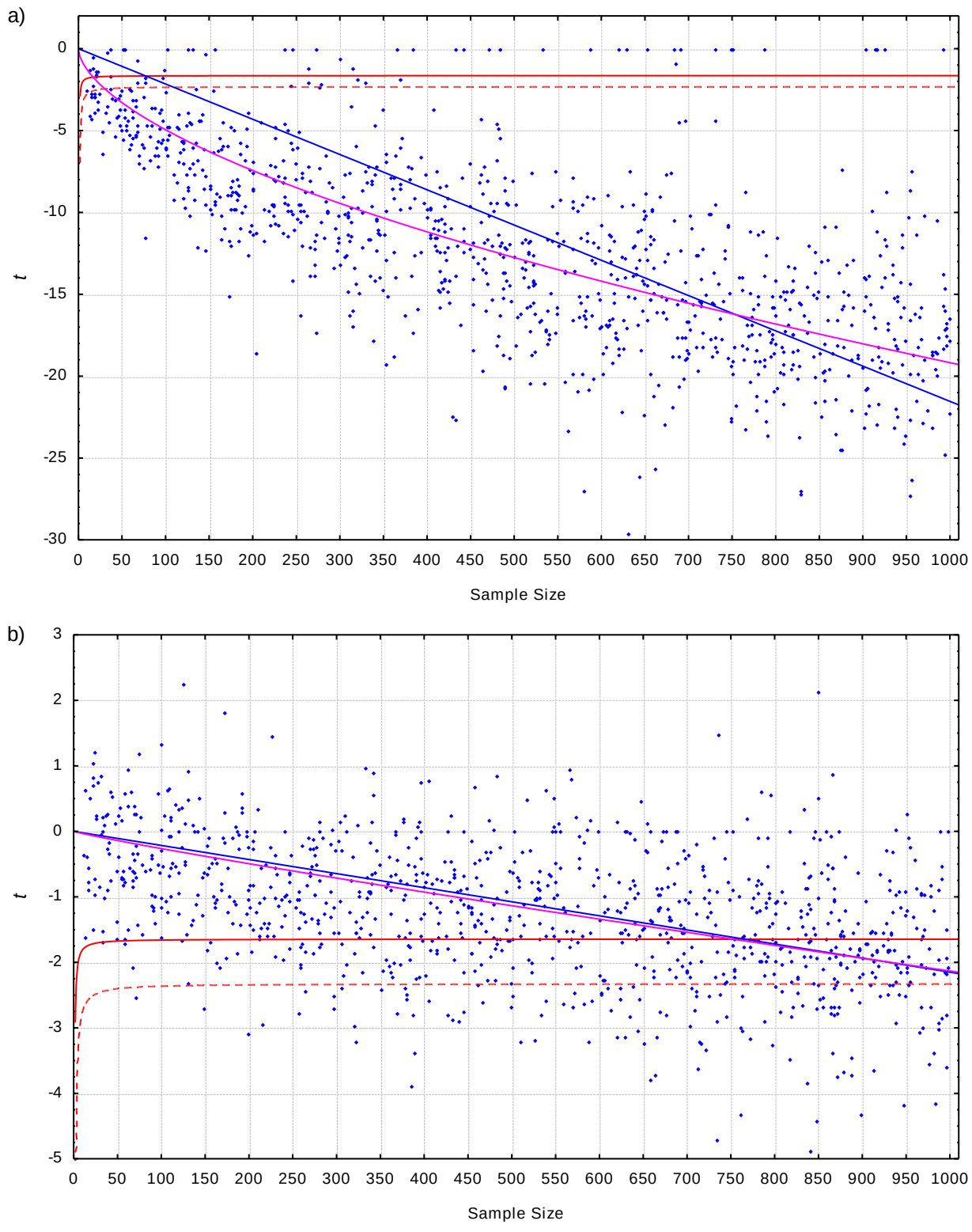

Figure 35. Plot of *t* from 1,000 simulated logistic regression analyses against sample size for a) *Apodemus sylvaticus* in intensive trapping transects at a decline of 20% and b) *A. flavicollis* in extensive trapping transects at a decline of 10% over ten years. The solid blue line is the best-fit straight line (passing through the origin) of *t* against *n*, whilst the solid magenta line is the best-fit function in (a) of $n^{0.59}$ and in (b) of $n^{0.91}$.

The solid red line represents the one-tailed significance function for $t_{(\alpha= 0.05,\, n)}$, whilst the dotted red line is the significance function for $t_{(\alpha= 0.01,\, n)}$

This problem is confounded by the fact that when the overall relationship is less extreme, the curvi-linear nature of the best-fit disappears (Figure 35b). In this example for *A. flavicollis* with a decline of 10% over ten years using extensive trapping, the sample size required for significance at $\alpha = 0.05$ is approximately 760 for both curves. For $\alpha = 0.01$, both lines reach the right-hand end of the graph before crossing the function line, indicating that a sample size larger than 1000 would be required.

To solve these problems we can take a non-parametric approach to using the relationship between *t* and sample size. Firstly, group the simulations into blocks based on their sample size. With 1,000 simulations, setting the bounds at intervals of 50 would give an average of 50 simulations in each of the 20 blocks, which correspond to the x-axis intervals shown in Figure 35. Now, count the proportion of simulations within each block that have *t*-values exceeding the desired α-level. For *A. sylvaticus* in the first block (representing sample sizes from 10 to 50) 32 of the 40 simulations (80%) were significant at $\alpha = 0.05$ (Figure 36a). Even at $\alpha = 0.01$, 29 of the 40 simulations (72.5%) were significant, suggesting the this sample size is adequate to achieve significance at both levels.

For *A. flavicollis*, the pattern is quite different (Figure 36b). For an α-level of 0.05, the proportions climb steadily, with some fluctuations until 50% is reached in the sample group 700 – 750. The confidence intervals show that the 52% of simulations achieving significance is marginal, and the fact that the next group is well below 50%, suggests that a more conservative estimate would be 800 – 850. In other words it would be sensible to set a higher threshold than 50% – say 55% – for the proportion of significant simulations. In contrast, the plot for $\alpha = 0.01$ shows that even the largest sample size group does not achieve anywhere near 55% significant simulations, which concurs with the parametric result described above.

This non-parametric approach has two further advantages to the fitting of linear or curvi-linear relationships between *t* and sample size. Firstly, by categorising the sample sizes it avoids spurious accuracy. Rather than agonising over the shape of the curve and whether this moves the critical point by a factor of three or more, it ensures that the results of the simulations are treated with caution. We are now simply stating that to test for a 10% decline over ten years at $\alpha = 0.05$ in *A. flavicollis* using the extensive sampling transects, we should conservatively use a sample size of between 800 and 850 SSUs.

Secondly, it emphasises that we should not extrapolate beyond the range of sample sizes used in the simulations. As illustrated in Figure 36b, we should limit our conclusions for *A. flavicollis* in

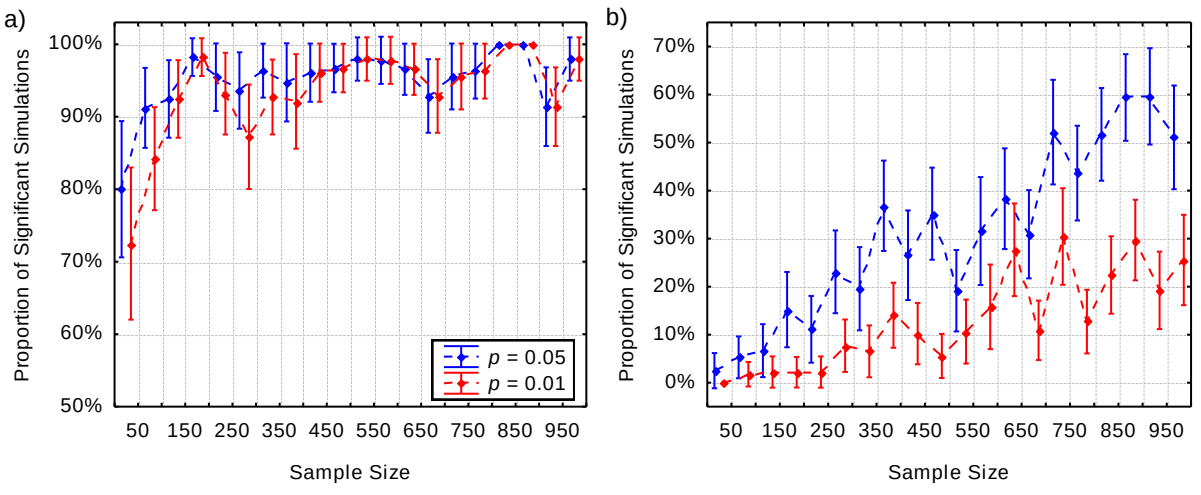

Figure 36. Mean proportions (with 90% C.I.) of significant simulations in each of 20 sample size categories for a) *A. sylvaticus* from intensive trapping transects and b) *A. flavicollis* from extensive trapping transects.

the same situation to need a sample size of at least 1000.

This approach has been used for all method/species combinations at the four different levels of change described at the beginning of this section. Furthermore, once the simulations had been created, any number of α-levels could be tested. Here we have just used the standard levels of $\alpha = 0.05$ and $\alpha = 0.01$. The 20 sample size categories described above have been used, with three additional categories.

- > 1,000 – for those simulations where the non-parametric method failed to reach a value of 55%, and the straight-line relationship indicated a sample size of over a thousand.
- > 2,000 – for those simulations where the straight-line relationship indicated a sample size of over two thousand.
- ∞ – for more extreme simulations that failed to resolve entirely.

The six charts on the following pages (Figure 37– Figure 39) show the results of the simulation modelling of the three different degrees of change. They have been arranged in pairs of increases and decreases in ascending order of magnitude of change. A number of clear trends emerge from this sequence of simulations.

Firstly, the major factor influencing sample size is the PA-Ratio at the start of the simulations (Table 14). For example, with a 5% decrease, the species requiring the smallest sample size were those with a PA-Ratio around 1, ranging from *Clethrionomys* in intensive trapping transects (0.161) to *A. Sylvaticus* in extensive transects (4.266). All those species with very small PA-ratios, especially *Micromys* and *Neomys* usually required the greatest sample sizes. The two measures of variation had a secondary influence on sample size.

Secondly, the degree of change that is detectable, also determines sample size to a great degree. For example to detect 5%, 10% and 20% declines of *S. araneus* with $\alpha = 0.05$ requires sample sizes of >1,000, 551 – 600 and 101 – 150 respectively.

Thirdly, it is clear that the sample sizes required at an α-level of 0.01 are always equal to or greater than for an α-level of 0.05, which conforms with sampling theory. In some cases, the differences can be quite great. For example, to detect a 5% decrease in *A. sylvaticus* at $\alpha = 0.05$ (Figure 37) requires a sample size of only 201 – 250, where as to detect the same change at $\alpha = 0.01$ requires a sample size of 651 – 700.

Finally, the sample sizes required for an increase are broadly similar to those required for a decrease. However, these two types of change are not symmetrical, especially where the starting PA-Ratios are greater than unity. So, with 20% changes (Figure 39), *A. sylvaticus* in extensive transects and all faeces recorded in bait-tube transects still require large sample sizes because they have relatively high "occupancy" with PA-Ratios of 4.4 and 3.6 respectively.

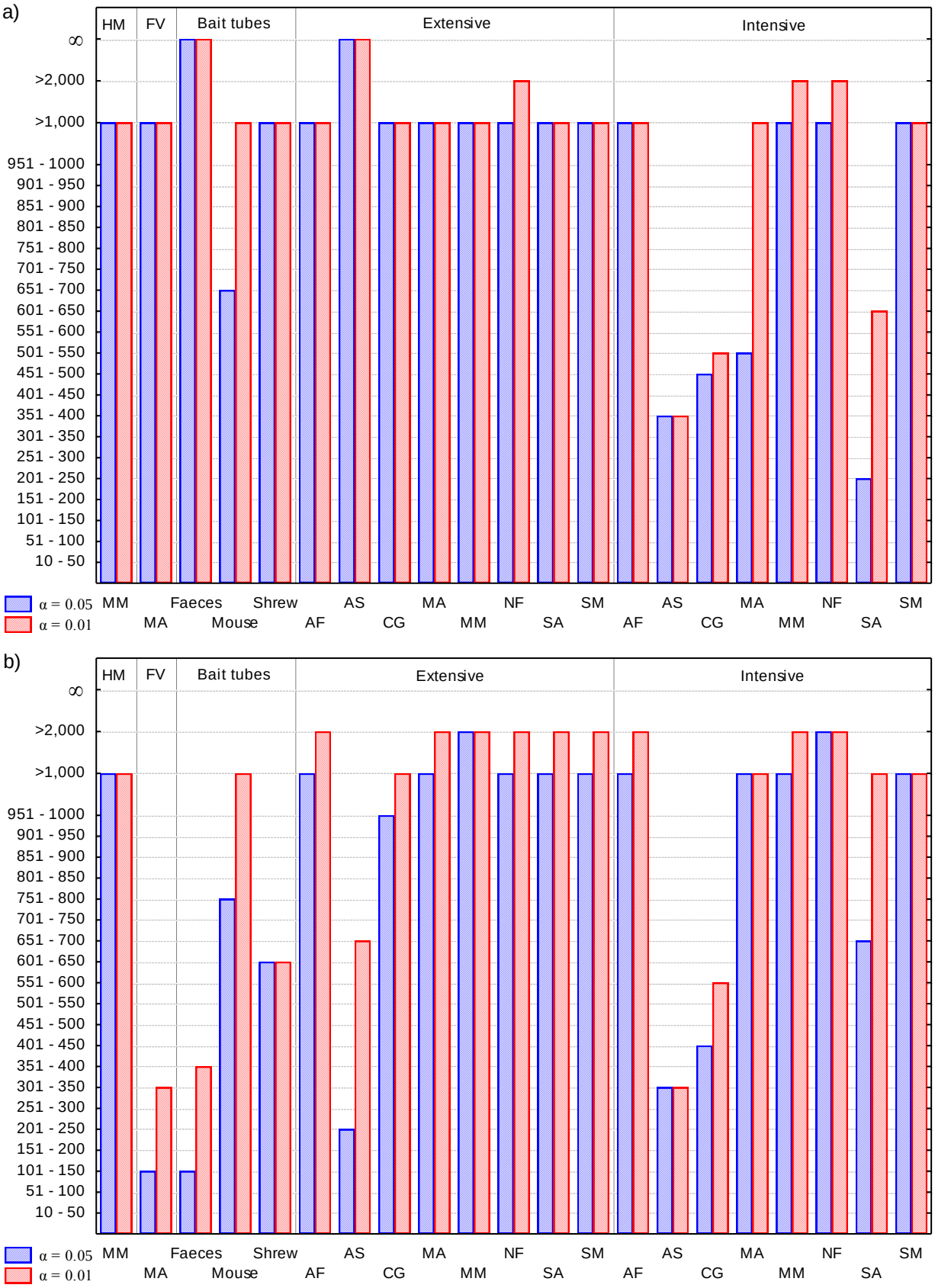

Figure 37. Sample size categories required to detect a) a 5% increase and b) a 5% decrease over ten years at two different α-levels. The five different methods are indicated at the top of the chart and the species (& pseudo-species) are as in Table 7.

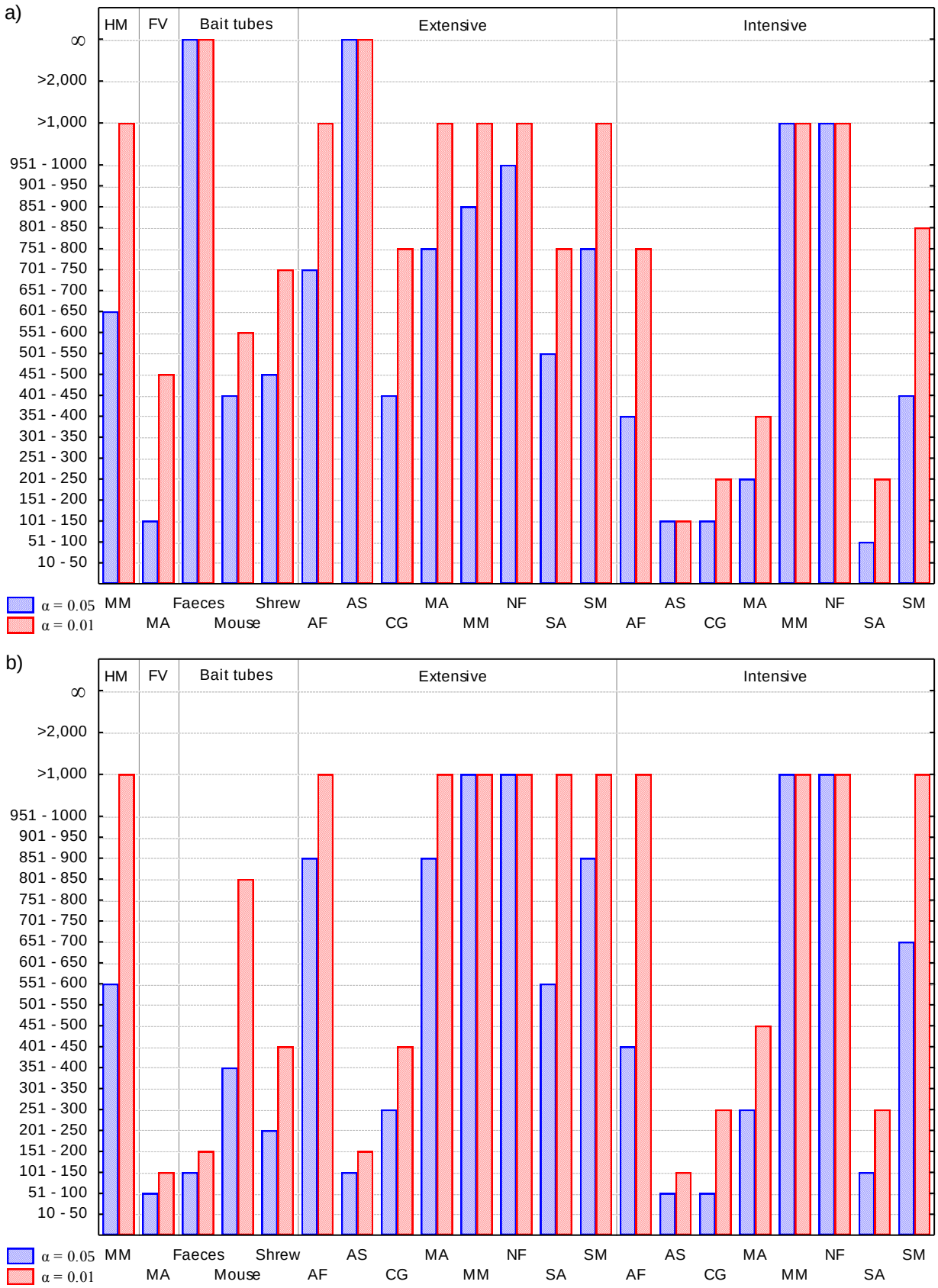

Figure 38. Sample size categories required to detect a) a 10% increase and b) a 10% decrease over ten years at two different α-levels. The five different methods are indicated at the top of the chart and the species (& pseudo-species) are as in Table 7.

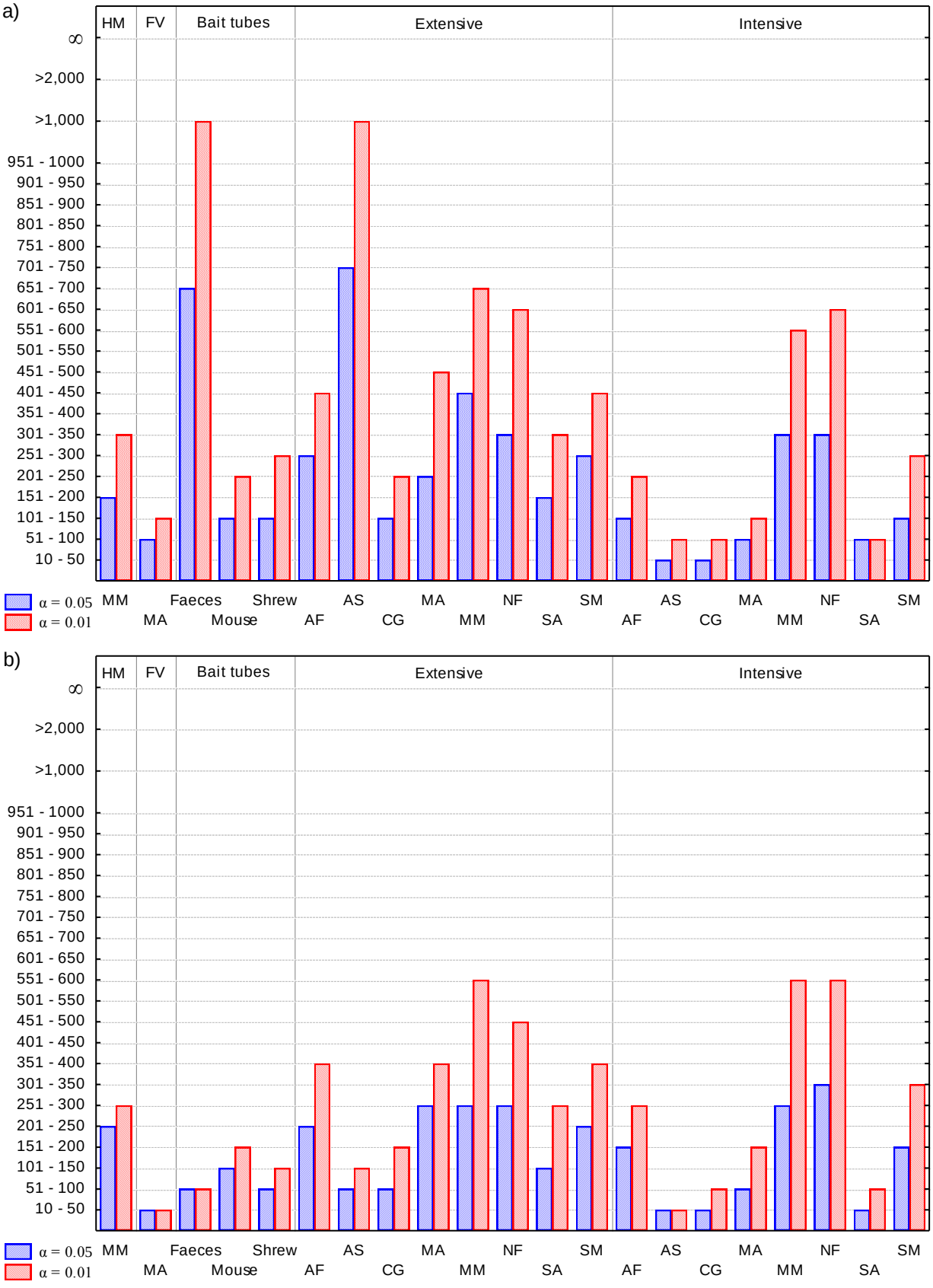

Figure 39. Sample size categories required to detect a) a 20% increase and b) a 20% decrease over ten years at two different α-levels. The five different methods are indicated at the top of the chart and the species (& pseudo-species) are as in Table 7.

5 Discussion & Recommendations

The results and analyses of this pilot study provide a great deal of information to guide the development of a National Small Mammal Monitoring Scheme (SMMS). In the discussion below, the primary aim is to indicate which factors should be considered in the design of the scheme and to integrate the statistical analyses with the qualitative results and feedback from the workshops.

5.1 Sampling Strategy & General Survey Design

5.1.1 Primary Sampling Units

One of the themes that evolved from the workshops was whether the PSUs needed to be as large as O.S. tetrads or whether 1km^2 squares would be large enough. The selection of tetrads was made primarily to increase the likelihood that a wide range of habitats was available within PSUs and, therefore, represented within the pilot study. Given that they were asked to work on a maximum of two PSUs, the limited number of volunteers might have constrained the number of habitats, especially those specific types required for harvest mouse and field vole transects. In the event, this did not appear to be the case, although only 19 harvest mouse transects were established (Figure 4). Overall, 16 different habitats were selected out of the 23 prescribed (Table 4). The only major types missing from the pilot were upland heather moorland and acid grassland, saltmarsh, cliffs and downs, and parks and gardens.

A simple spatial summary of the location of SSUs within PSUs also suggested that 1km^2 squares might have been sufficient. Of the 22 PSUs that had grid references for each of their SSUs, ten had all their SSUs within one of the four 1km^2 squares. A further eight had all their SSUs within two squares, leaving only four PSUs with their SSUs distributed in all four 1km^2 squares. The analysis of time budgets (Section 3.4.1) showed that administration time – the time required to survey the PSU and obtain permission from landowners – was the largest element. If this could be reduced by only needing to survey one quarter of the area, the startup time for a PSU could be reduced. Furthermore, several other national schemes, such as the BTO's Breeding Bird Survey, are based around 1km^2 squares, so there would be considerable advantage in standardising on this size.

5.1.2 Temporal Organisation

The analysis of IIC showed that this variable did not differ significantly between year or season (Table 10). Given that IIC was determined ultimately by the numbers of signs or captures, this was a somewhat ambiguous result. The lack of a difference between years was not unexpected, given the short time period and the relatively small sample size. However, we know from previous work (Mallorie & Flowerdew 1994; Flowerdew *et al.* 2004) that the seasonal fluctuation in capture rates can be very pronounced, so achieving no distinction between seasons **within methods** was not to be expected.

The selection of the six-week windows in November/December and May/June were made to coincide with the peaks and troughs of captures experienced in these periods. However, the first two seasons in this pilot were delayed by four to six weeks (Section 3.2) which had the effect of shifting both past the extremes of the cycle. Anecdotal reports from the volunteers showed that juvenile animals were regularly caught during the summer period, which was intended just to sample the over-wintering adult population. Similarly, a considerable decline in late-born young of the previous year had occurred by the middle of February. Both these effects would have tended to equilibrate capture-rates in the two seasons.

A second theme that developed from the workshops was whether alternative survey periods should be used. Arguably, the most important period is that which samples the adult populations at the beginning of the breeding season. However, given that it is not always certain when this occurs and, moreover, that weather factors and climate change may cause this to alter over time, it was proposed that the fixed survey periods be extended or even abolished altogether. Instead, as long as volunteers undertook their fieldwork within the same short windows each year, they could undertake fieldwork at any time of year, or at least within a greatly extended period. With such a regime, though, it would be necessary to distinguish adult from juvenile animals in the spring/early summer. This might not be possible without handling animals which could reduce the benefits of the extensive trapping method.

This could have a number of advantages. Firstly, the workshops highlighted a problem with mid-winter trapping; the shortage of daylight. This was a major factor in causing the delays to the end of the winter periods. By allowing at least some of the volunteers the opportunity to work in late-autumn or early-spring, this may be avoided. Secondly, it is anticipated that trap availability will be a limiting factor in the SMMS. By staggering the requirements for traps, many more trapping SSUs could be completed by more volunteers. Finally, if the winter peaks and summer troughs do vary in timing between years, with an adequate sample size it might be possible to pinpoint them, which would not be possible within a constrained time-window. This would allow the added benefit of detecting long-term changes in these population parameters, which might be a result of global warming.

The pilot survey period was too short to test the effect of not surveying SSUs in every year. One suggestion from the workshops was that the "expensive" methods, primarily intensive trapping, could be undertaken on a rolling schedule, for example, in five different regions of the country with a five-year interval in each. This would also allow the limited number of traps to be circulated around the country, utilising them more intensively. The scope of this study did not allow the power analysis to test the effect of longer than annual intervals. However, anecdotal evidence from other power analyses carried out for TMS, suggest that power declines quite quickly as the interval increases, but probably not as much as the saving in time. In other words, for a given number of sites, surveying in alternate years, halves the amount of effort required. But, if the reduction in power is less than 50%, the overall cost-effectiveness may be higher.

5.1.3 Volunteer Issues

Overall, volunteer recruitment was high enough to provide sufficient data to meet the aims and objectives of the pilot study. However, during the project there was a turnover of volunteers, with some agreeing to take part but then failing to complete any SSUs. We anticipate that there will be a similar problem in the national roll out of the SMMS. This was a major factor in the BTO/TMS Winter Mammal Monitoring study (Noble *et al.* 2005). However, it is likely that the levels of turnover during the pilot were higher due to its deliberate complexity and the level of involvement required from the volunteers. Furthermore, in line with the recommendations from Macdonald *et al* (1998) the SMMS would aim to minimise volunteer drop-out through investment in training, feedback and professional supervision, all of which was not considered necessary for the expert volunteers.

The mechanism for the random generation of the list of PSUs for each volunteer appeared to be successful with the majority of volunteers selecting one or more from the list. However, some volunteers chose known, local sites, either because they were convenient from a travel point-of-view or because the landowners were known to them. The mean return travel time to PSU of 35 minutes suggested that the choice of a 14km ×14km square containing 49 tetrads did not impose excessive travelling time. Indeed, this average was strongly influenced by two volunteers who apparently took between one and two hours for each return journey – without their times, the av-

erage return journey was only 20 minutes. This scheme balanced the needs of the volunteers with the requirement for an objective element in site section at the PSU level.

Overall time elements at the PSU level were low with a mean of 2 hours administration and only 20 minutes spent on-site not completing SSUs (Section 3.4.1). It is likely, however, that the administration times were an underestimate because, at the workshops, some volunteers highlighted the fact that time spent cleaning, preparing and maintaining traps was not recorded. This perhaps explains the high variation in administration times recorded. In the SMMS it is likely that administration time will be reduced with support from The Mammal Society office through the provision of a network of Regional Representatives, who will assist with site access and liaison with landowners. Furthermore, once the SMMS is up and running we anticipate that administration times will be reduced as PSUs become established. Indeed, ignoring one outlier (16 hours) the administration time during the first season was a significantly greater (2.5 hours) than subsequent seasons (50 minutes).

The mean time taken to conduct an SSU also varied between years, taking less time in 2007 as compared to 2006 (Section 4.3.3), with a corresponding higher cost benefit per SSU (Section 4.4.3). It is likely that this was a result of volunteer familiarisation with both project methods and field sites. As volunteers become accustomed to the methods and familiar with sites it takes less time to complete surveys; the location of the start and end points of the SSU are already mapped and easy to find, transects are already measured and searching techniques are practised. It is reasonable to assume, therefore, that once up and running the cost-benefit of SSUs within the SMMS would more closely resemble those recorded in 2007.

5.1.4 Secondary Sampling Units

The number of SSUs per PSU is an important statistic. As shown in the majority of these analyses, the SSU was treated as the main unit for analysis, having accounted for the fact the SSUs were clustered within PSUs. In the SMMS, the main unit for the analysis of change will be the SSU.

The question arises then, whether it is better to have a large number of PSUs, each with only a few SSUs, or to concentrate more SSUs within a smaller number of PSUs. Given that the SSUs are not attempting to describe the whole PSU, and that we can account for the clustering statistically, the issue becomes one of scale. We can consider the PSUs to sample at a landscape scale, so that increasing their number ensures a representative coverage of geographical location and major land cover types. On the other hand, increasing the number of SSUs within the PSU allows for increased coverage of specific habitats. For example, it might be more valuable ecologically, for a large number of SSUs to be set in a PSU that is located in a rare landscape type such as lowland heath or upland hay meadows, than to use only a few there and spread the rest amongst a number of PSUs in common farmland habitats.

The final decision should also be based on the balance between the time budgets for PSUs and SSUs. Given that the time to complete an SSU is independent of the number of SSUs in the PSU, this reduces to the ratio between the three time elements shown in Figure 5; administration, travel and on-site times. As discussed in the previous section, administration time is the greatest single element, although in subsequent seasons, this was less than one hour on average. Taking 30 minutes per return journey and 20 minutes on-site time, it is easy to calculate the total time required to undertake *x* SSUs of one type within *y* PSUs. For example, four single-visit SSUs in one PSU would take approximately 2.8 hours. In contrast one Such SSU in each of four PSUs would take 7.3 hours, a ratio of 2.6:1. Clearly, adding an additional SSU to an existing PSU (within the limits of what can be achieved in one visit) would be far more cost-effective than establishing a new PSU. This strongly suggests that volunteers should be encouraged to focus their efforts on a single PSU, with which they can become familiar, and set the number (and type) of SSUs to reflect the amount of time they want to contribute to the scheme.

5.2 Field Methods

Firstly, it is important to emphasise that none of the field methods (with the exception of intensive trapping) provide estimates of actual population sizes. Instead, each field method provides an index of activity which can be used as a surrogate for abundance. It may be that the relationships between absolute abundance and the indices obtained from different methods are not linear, or even the same. For example, the effectiveness of individual sign types as predictors of field vole density is not consistent between studies. Lambin, Petty & MacKinnon (2000) found a significant linear correlation between live trapped field vole densities and sign indices in the Kielder Forest in Northumberland. In this study, signs based on the presence of fresh grass clippings explained more of the variability in vole trapping indices. This was confirmed by Wheeler (2002) who found grass clippings to be a reliable index of density in upland habitats. However, sign survey studies in lowland habitats (Wilkinson, Craze & Harris 2004), found runways gave the best correlations with field vole abundance when compared to latrines or grass clippings.

However, as long as the "effort" employed in a given method is constant, we can use changes in the frequency counts per SSU to infer changes in the underlying populations. It may prove worthwhile to undertake calibration exercises between intensive trapping transects and the other four methods to obtain calibration equations that could be used to estimate population. This procedure is likely to have a low level of confidence, but with large enough sample sizes of the less intensive methods, might provide a better estimate of absolute population than could be provided by intensive trapping alone.

Each of the five field methods has a different balance of advantages and disadvantages. Many of these are specific to individual species and will be discussed in detail in the next section (5.3), especially the two single-species methods. However, bait tubes and the two trapping methods have certain general properties that are discussed here.

5.2.1 Bait tube transects

Overall, bait tube transects had comparatively low IIC values, which was mainly due to the relatively high levels of tube failure. Furthermore, on average, only 26% of available tubes contained faeces, in contrast to Greenwood, Churchfield & Hickey (2002), who found that 81% of their tubes contained faeces. The number of failures during this survey may have been exacerbated by the heavy rain experienced during the summer 2007 season, resulting in many tubes being completely washed out. D. Scott (*pers. comm.*) found that during surveys with over 1500 tubes, failure rates were much lower than found during this study. Anecdotal evidence from this survey showed that when a bait tube transect that had many failures was followed immediately by an extensive trapping transect, most of the traps recorded captures. It may be that the failure rate of tubes was a consequence of the seven-day period between placing and retrieving them. If the tubes were found, the bait consumed and faeces deposited within a few days, then leaving the tubes for seven days would only allow evidence to be lost.

The main advantage of this field method, especially compared to trapping, is that it is easy to employ and does not require a high level of volunteer expertise. Animals do not need to be handled to ascertain their presence. Furthermore, the equipment is very cheap, amounting to only a few pounds for ten tubes. They are relatively durable and can be reused a number of times.

The main drawback with bait tubes as employed in the current pilot study, is that identification of species other than water shrews from faecal samples is not reliable (Greenwood, Churchfield & Hickey 2002). Moreover, the time required to identify faecal remains to species or even genus adds considerably to the cost side of the cost-benefit equation and further reduces the potential of this method for the SMMS.

Bait tubes have been shown to be valuable for monitoring water shrews (Carter & Churchfield (2006a). However, this was only possible because careful placement near riparian habitats simplified the identification of faeces. To be used as a multi-species method, a quick and powerful technique must be found to allow batch identifications of hundreds of faecal samples. Progress is being made at the Waterford Institute of Technology with real-time polymerase chain reaction (PCR) techniques to identify DNA in faeces, at a reasonable cost (C. O'Reilly, *pers. comm.*). Such laboratory techniques may change this into a highly reliable and cheap field method which could be employed by non-expert volunteers on a widespread basis. However, until these techniques are available, bait tubes are probably only suitable as a single-species method, targeted at water shrews.

5.2.2 Extensive trapping transects

This method has been very successful during the pilot study. Volunteers appeared to be very happy to use the method, being relatively quick and simple. The absences of a requirement to handle animals meant that it could be employed by less expert volunteers such as schools, colleges or local mammal groups. The main reservation expressed at the workshops was the requirement to pre-bait for 24 hours before setting the traps, which meant that the whole field period was 36-40 hours. In the winter, this was difficult to achieve over a weekend, due to short day-length, without taking time off work. If pre-baiting were delayed until the following morning (reducing the pre-bait period to 8 – 12 hours), then the whole SSU could be completed in 24 hours and easily accommodated within a weekend. It is known, however, that captures of certain species, especially field voles can be reduced with less pre-baiting (J. Flowerdew; *pers. comm.*).

Overall this method gave surprisingly useful results. All eight species were recorded, although a number were infrequently caught. The cost-benefit of extensive trapping was shown to be lower than intensive trapping, but the fact that it only required one quarter of the number of traps made it a highly attractive method. The cost of Longworth traps can be prohibitive and, even with a trap-loan scheme, being able to acquire useful data on a number of species from only ten traps was a very unexpected result. Given that the visit time per SSU was so low (approximately 25 minutes), it was quite possible to run several SSUs concurrently, if traps were available. Over a long weekend, for example, it was perfectly feasible to complete eight extensive transects with 40 traps, when it might only have been possible to complete one intensive SSU.

The main drawback from a data point-of-view was that trap saturation may have occurred when animal numbers were high. However, there was no evidence of negative correlation between species, which would have indicated that a dominant species was reducing captures of others. Furthermore, there was no evidence that more diurnally active species were under-recorded compared to intensive trapping.

5.2.3 Intensive trapping transects

Intensive trapping was undoubtedly the most sophisticated field method and provided more information than any other technique. Its main advantages were twofold. Firstly, it was the only method that obtained useful data on the rarer species, especially pygmy shrews and yellow-necked mice (see Section 5.3). Secondly, by marking animals, it was the only method that allowed absolute numbers of animals to be estimated. With single marks it was possible to tally the number of individual animals captured, but with a slight modification it would be possible to use capture-mark-recapture (CMR) techniques to provide a more accurate estimate of local population size. Anecdotally, in one SSU in the final season, animals were marked with two clips, one on the left-hand side for either of the first day's captures and one on the right-hand side for either of the fifth or sixth sessions. Using these with a standard Peterson Index gave population estimates for bank voles that were 60% greater than MNA. These two factors made it

a very useful complement to the extensive trapping method, but also to the other methods that only obtained relative indices of abundance.

However, this method was the most time-consuming and required the highest level of expertise. In addition, 40 traps were required for a period of four days. Furthermore, it appears that the time taken to clean, prepare and maintain traps was not always accurately recorded, so the cost-benefit analysis might have been slightly favourable to this and the extensive methods. The cost of bedding and casters also needs to be considered. The most important cost, though, is the price of the traps themselves. Sibbald *et al* (2006) reviewed the range of available traps and found that Longworth traps were the standard type used in the UK but, at over £40 each, may be prohibitively expensive. Cheaper traps are available but mixing different traps may not be advisable.

5.3 Species Accounts

Eight of the nine targeted species listed in Table 1 were recorded during the pilot. The absent species was the house mouse (*Mus domesticus*). Given the wide range of habitats in which SSUs were set, this emphasises the commensal nature of this species, which may only be recorded in the SMMS if urban areas or other man-made habitats are included.

Each of the species showed different patterns of records across the individual field methods. This section of the discussion compares and contrasts the methods, using the three main analytical procedures, for each species in turn.

5.3.1 *Sorex araneus* (common shrew)

Common shrews were recorded in both trapping transects; 16% of extensive and 66% of intensive SSU / Seasons. Furthermore, 21% of the bait-tube transects had faeces identified to *Sorex*, and it would be reasonable to assume that most of these were *S. araneus*. This is similar to studies such as Churchfield, Barber & Carter (2000) who recorded a majority of *Sorex* in tubes at two of four sites sampled, and Carter & Churchfield (2006a) who also found a majority of terrestrial shrews across sites during a National Survey.

In terms of overall IIC, this species had the third highest average, significantly less than wood mice and bank voles but significantly greater than all other species. The differences between the two trapping methods was also highly significant, largely due to the much greater frequency of occurrence in intensive transects. This could have been a consequence of the ranging behaviour of common shrews, indicated by the fact that new animals were being still caught at a higher rate on the second day (55%) than was found in the other main species (<40%). It may be that the single session in the extensive method did not give them enough time to find the traps. The outcome of this is that common shrews had very low mean IIC in extensive transects. However, the cost-benefit analysis showed a comparative reduction in the IIC rate for intensive trapping which was, therefore, not significantly greater than extensive transects.

This pattern was highlighted with the power analysis. A 5% decline over ten years could be detected at $\alpha = 0.05$ with a sample of 651 – 700 intensive transects. However, for extensive transects a sample size of over 1000 sites would be required. The sample size falls dramatically for a decline of 10% to only 101 – 150 for intensive transects, but remained at 551 – 600 for extensive transects. It should be pointed out that, given the assumption made above, bait-tube transects appeared to have similar power to the intensive trapping transects.

5.3.2 *Sorex minutus* (pygmy shrew)

Pygmy shrews were recorded in 8% of extensive trapping transects and 20% of intensive transects. As with common shrews their mean IIC was significantly greater in the latter, although the cost-benefit analysis showed no such difference. The power analysis showed that neither

method was able to detect a 5% decline with less than 1,000 sites. It would require a 20% decline over ten years for either method to be able to detect it with 95% confidence. In this case between 201 and 250 extensive transects would be required, with only 151 – 200 intensive transects being required. The lower cost of the former indicates that it would be the preferable method for this species.

5.3.3 *Neomys fodiens* (water shrew)

This species was the most infrequently recorded with one capture in extensive transects and one SSU / season in intensive transects, although three individuals were identified. Furthermore, the partial analysis of faeces from the bait-tube transects indicated two SSUs containing water shrew droppings. Not surprisingly, these very low rates of occurrence resulted in very low IIC and cost-benefit values. This was reflected in the power analysis which indicated that both trapping methods were unable to detect less than a 20% decline without sample sizes of >1,000 SSUs.

It is unlikely that trapping will be able to detect a realistic rate of decline with pragmatic sample sizes. However, this species is unusual in that it does have characteristic, species-specific remains in its faeces, in those habitats where they have access to aquatic prey (Churchfield, Barber & Quinn 2000). This would enable bait tubes to be used for this species, although it would require a greater time element for identification of remains. In the pilot, the samples from a single SSU took approximately half and hour to analyse, and even then it was not always possible to identify remains to species. Inclusion of these times would have further reduced the cost-benefit for this method.

5.3.4 *Clethrionomys glareolus* (bank vole)

This was the second most frequently encountered species, with only wood mice being more common. It was, however, only recorded reliably in the two trapping transects; 53% of extensive and 63% of intensive SSU / Seasons. IIC was significantly higher in the latter method, but even in intensive transects it had a significantly higher mean IIC than all other species except wood mice. However, the cost-benefit analysis showed no significant difference in the two methods. The power analysis implied that although both methods could detect a 5% decline at 95% confidence with less than 1,000 SSUs, it was only with a decline of 10% over ten years that small sample sizes could be used. The difference between the two methods was pronounced, with 251 – 300 extensive transects being required, but with less than a third of this number of intensive transects.

5.3.5 *Microtus agrestis* (field vole)

Field voles were recorded by three of the field methods They were found in 80% of field vole transects, 10% of extensive trapping and 23% of intensive trapping SSU/Seasons. The IIC for field vole transects was calculated using the arithmetic sum of the three field signs, which did have the effect of augmenting the mean IIC. However, the direct comparison of these three methods (Section 4.2.6) showed significantly greater IIC for field vole transects than extensive trapping, although similar to intensive trapping. The high IIC for field vole transects was largely due to the frequency of recording, and was only partially influenced by the intrinsic values of the IIC. Had a different method for their calculation been used, say the sum of latrines and feeding signs only , this would have decreased the mean IIC values by only 9% and would not have altered the results of this analysis. The IIC for the field vole transect method was also increased relative to the trapping methods by its complete lack of failures.

The power analysis supported the analysis of IIC. Even a 5% decrease over ten years could be detected with 95% confidence using a sample of between 101 and 150 field vole transects. In contrast, both the trapping methods would require sample sizes of >1000 to detect this degree of change. Only when the rate of decline was 10% over ten years did the sample size for the inten-

sive trapping method fall to 251 – 300 SSUs. And to make use of the extensive trapping method with this sample size, the decline would have to have been 20%. These results are broadly in line with those of Wilkinson (2004), who proposed that sign surveys could detect a 25 – 50% change in field voles with a sample of 100 sites.

The cost-benefit analysis further supported the use of field vole transects. The much greater time required by intensive trapping brought their cost-benefit down to exactly the same rate as extensive. However, the much shorter time required for field vole transects, largely due to being a single-visit method, meant that their cost-benefit ratio increased to nearly four times that of the two trapping methods.

However, there are still issues that need to be considered with the use of field vole transects. Firstly, (Redpath, Thirgood & Redpath 1995) indicated that it can be difficult to distinguish between new an old signs. In particular, runways may be quite long-term features and can be kept open by species other than field voles (J. Flowerdew, *pers. comm.*) The more ephemeral latrines and feeding signs would be more likely to change from year to year. As indicated above, the sum of these two would still provide a high degree of information, and even if "latrines OR feeding signs" were used to give a frequency count out of ten for the SSU, the IIC would still only be reduced by a further 9%. At the workshops, it was suggested that runs could be used as a general indicator of the presence of field voles in a quadrat, which would prompt a more careful search for the other two signs.

Secondly, there was a significant difference between the time taken on field vole transects in the two seasons. In the summer the average time was 2.6 hours, whereas in the winter only 1.6 hours was spent. This difference may have been caused by differences in vegetation cover, but could equally well have been a volunteer effect, with less time being spent during the colder weather. It may be relevant that the only two methods which showed this seasonal effect were the two sedentary search methods. There was, however, no relationship between the time spent on field vole transects and the IIC, so this effect did not appear to be biasing the results.

5.3.6 *Apodemus flavicollis* (yellow-necked mouse)

Yellow-necked mice were only recorded in the two trapping transects, and then on relatively few occasions; 7% of extensive and 17% of intensive transects, with 7 and 12 animals captured respectively. Although more significant information was detected with the latter method, the cost-benefit analysis showed no difference. Furthermore, the power analysis was able to show that small levels of change would not be detectable with pragmatic sample sizes. Only when the decline reached 20% over ten years would either method be likely to detect it – extensive transects requiring a sample size of 201 – 250 and intensive, slightly lower at 151 – 200. Given the considerably shorter time requirement of the former method, this is likely to be most successful in detecting change.

5.3.7 *Apodemus sylvaticus* (wood mouse)

This species was the most frequently encountered throughout the pilot study. A total of 239 animals were caught in 79% of the extensive trapping transects and 281 individuals caught in 29 out of 30 intensive trapping SSU / Seasons. Given this huge difference with its congeneric, all 12 records of faeces identified to *Apodemus* in bait tubes probably belonged to this species.

Both the high frequency of occurrence in SSUs and the large number of animals captured contributed to the high IIC for this species. The overall mean IIC was 8.3 which was significantly greater than any other species, as were the separate mean IICs for extensive (5.4) and intensive (18.9). Furthermore, the cost-benefit analysis showed that, even allowing for the greater time required for intensive trapping, this method still provided more information than extensive trapping.

This was the only species to show this distinction, probably because it was the only species that achieved a degree of saturation in some SSUs. In one of the 81 extensive SSU / Seasons, all ten FSUs had wood mice captures. On four other occasions, all non-failed traps were occupied, and a further five SSU / Seasons had all but one of the available traps occupied by wood mice. The effect of this was to reduce the mean IIC because a capture rate of ten out of ten generated the same IIC as a rate of zero out of ten. In contrast, the abundance of traps in the intensive trapping transects allowed even large numbers of wood mice to be captured without saturation occurring.

The power analysis reflected this pattern, although with some ambiguity. To detect a decline of only 5% both methods would need a sample size of around 250 – 300 at an α-level of 0.05, and probably twice this with 99% confidence. The differences between these two α-levels for each method are difficult to explain but were probably due to stochastic effects in the simulations and the non-parametric method used for selected the sample size categories. The pattern was clearer for 10% declines where sample sizes of 101 – 150 and 51 – 100 respectively were required.

Possibly more important than the declines, though, are the increases. This was the only species where increases were difficult to detect, but only with extensive trapping. Even a 10% increase could not be detected with a sample size of many thousand SSUs and a 20% increase would still require a sample of over 700 SSUs. This is almost certainly a result of the trap saturation and means that extensive trapping may be less use in situations where detecting population increases is important. In contrast, intensive trapping has equal power to detect increases or decreases.

5.3.8 *Micromys minutus* (harvest mouse)

Harvest mice were recorded by three field methods, but all in very low numbers; 18% of harvest mouse transects, only one extensive trapping SSU / Season and 7% of intensive SSU / Seasons. Not surprisingly, this resulted in the lowest mean IIC, especially for the harvest mouse transects themselves.

As with field voles, there was a significant seasonal difference in the time taken to complete these SSUs; over three hours in summer but less than two hours in winter. The same arguments probably apply, with less vegetation making winter searching easier, but the cold weather also encouraging volunteers to move on quickly. The lack of any relationship between search effort and the recording of nests means that the seasonal effect may not be important.

Despite being a single-visit method, harvest mouse transects were still quite time consuming so their cost-benefit was still lower overall than other methods. However, the direct comparison with captures of harvest mice only (Section 4.4.4) showed that harvest mouse transects were significantly more efficient than the two trapping methods. It should be pointed out that in the first winter season, harvest mouse transects were set at 10m wide, but the time taken to search this area was prohibitive, so transects were reduced to 2m width in subsequent seasons.

This is confirmed by the power analysis which, although small declines were not detectable with any method, a 10% decline might be detectable with a sample of 551 – 600 harvest mouse transects, whereas over 1000 trapping transects would be required. However, 20% declines showed less difference with all three methods requiring between 200 and 300 sites. These results are similar to Nobel *et al* (2005) who showed that field signs data could detect a change of ±25% for all signs except harvest mouse nests, with a sample size of 600 or less.

Harvest mice appear to be less trappable than other rodents when traps are placed on the ground, for most of the year except late autumn and early winter (J. Flowerdew, *pers. comm.*). This would mitigate against the two ground-based trapping transects. However, given that the trapping transects were not placed specifically for harvest mice, their cost-benefit may increase if harvest mouse habitats were targeted. Furthermore, it might be worth considering above ground transects. These could be based on the extensive method, with traps attached to branches in

hedgerows adjacent to cereal fields or attached to raised platforms in reedbeds and other suitable habitat.

5.4 Summary

The species accounts presented in the previous section indicate that different methods are suited to different species (Table 15). Certain conclusions are clear:

Table 15. Matrix of recommended methods for each of the eight species recorded in the pilot study. Single ticks are useful methods, double ticks are highly recommended methods and queries indicate possible methods after further development.

	Species							
Method	*SA*	*SM*	*NF*	*CG*	*MA*	*AF*	*AS*	*MM*
Harvest mouse nests								?
Field vole signs					✓✓			
Bait tubes	?		?				?	
Extensive trapping	?	✓		✓		✓	✓	?
Intensive trapping	✓	✓		✓✓	✓	✓	✓✓	?

- Field vole signs are well suited to monitor field voles. These are relatively quick and easy to complete and, if habitats are well chosen, produce a high encounter rate.
- Extensive trapping can be used to monitor four species although, maybe unexpectedly, not common shrews, due to the low capture rates in a single session. They may also have only limited value for detecting increases in wood mice due to trap saturation. It may be possible to use targeted or modified extensive transects to monitor harvest mice.
- Intensive trapping transects are the recommended method for monitoring bank voles and wood mice. This is because they can exploit the high abundance of these species to detect relatively small degrees of change with practical sample sizes. Intensive transects may also be able to monitor changes in common and pygmy shrews, field voles and yellow-necked mice.

Other issues besides the quantitative factors used for this analysis are also important in deciding which methods might be useful for the SMMS.

Harvest mouse nest and field vole sign transects have the enormous advantages that a) they can be carried out on a single visit, b) they do not require expensive equipment and c) they can be carried out by non-expert volunteers. These factors alone make them extremely valuable in a national volunteer-based programme. They provide a route into the scheme for less experience volunteers and, given the very large number that could be completed, may provide extensive coverage, both from a geographic and habitat point-of-view.

Bait tubes also do not require a high level of expertise or expensive equipment and so provide another route into the scheme. As discussed above, their drawback is that they can only be used as a single-species method targeted at water shrews until DNA-based species identification is developed. Hair tubes are another method that might provide a useful technique. Work is currently underway at the University of Bristol to develop a multiple-tube method for monitoring shrews, which may enable the identification of pygmy shrews without the need to identify hair samples (M. Pocock, *pers. comm.*). It might also be possible to use hair tube samples as a source of DNA, if identification techniques are developed further.

Extensive and intensive trapping transects both provide the huge incentive that volunteers actually see and record live animals. The extensive method does not require handling or marking, although it could be employed for training purposes where experts are introducing new volunteers to the SMMS. When sufficient expertise has been developed intensive trapping generally provides the most rewarding experience by allowing close inspection of animals and records of recaptures. It should also be pointed out that The Mammal Society has been carrying out train-

ing workshops for over ten years. In particular, it has organised more than 20 "Small Mammal Ecology & Survey Techniques" workshops, resulting in several hundred accredited volunteers. With adequate publicity, it may well be possible to raise a large number of volunteers with sufficient skills to carry out extensive, or even intensive trapping transects.

5.5 Recommendations

These recommendations follow naturally from the findings of the Pilot Study and the discussion presented in the previous sections. At this stage, they are only recommendations for further methodological development and do not include suggestions for the national roll-out of the SMMS.

- Primary Sampling Units. Undertake a consultation with British Trust for Ornithology (BTO), Centre for Ecology and Hydrology (CEH) and others on the merits of using $1km^2$ squares as the PSUs. Consider the advantages of co-locating PSUs on existing sample squares from schemes such as Breeding Bird Census (BBS) or the Countryside Survey (CS) versus the problems of "landowner fatigue".
- Multi-year Sampling Strategy. Undertake a power analysis to investigate the effects of non-annual sampling on ability to detect change versus the saving in volunteer time and equipment costs.
- DNA identification from faeces and hair samples. Undertake consultation and/or trials with Waterford Institute of Technology and others into the feasibility of this method.
- Hair tubes. Consult with M. Pocock at Bristol University to establish the design of hair tubes for shrew (especially pygmy shrew) identification.
- Extensive trapping specifically for harvest mice. Undertake comparison of existing harvest mouse transects followed by extensive trapping transects. In suitable habitats, attempt above-ground trap placement.
- Calibrate non-intensive field methods. Carry out direct comparisons of the four non-intensive field methods with intensive trapping transects to calibrate the indices in terms of absolute population estimates.

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7 References

Battersby, J. (2005) *UK Mammals: species Status and Population Trends, First Report*. JNCC / Tracking Mammals Partnership, Peterborough.

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

Birks, J. (2002) *The Pine Marten*. The Mammal Society, London.

Carter, P. & Churchfield, S. (2006a) *Distribution and habitat occurrence of water shrews in Great Britain, The Mammal Society Research Report No 7*. The Mammal Society, London.

Carter, P. & Churchfield, S. (2006b) *The water shrew handbook.* The Mammal Society, London.

Churchfield, S., Barber, J. & Quinn, C. (2000) A new survey method for Water Shrews (*Neomys fodiens*) using baited tubes. *Mammal Review*, **30**, 249-254.

Evans, D.M., Redpath, S.M., Elston, D.A., Evans, S.A., Mitchell, R.J. & Dennis, P. (2006) To graze or not to graze? Sheep, voles, forestry and nature conservation in the British uplands. *Journal of Applied Ecology*, **43**, 499-505.

Fitzgibbon, C.D. (1997) Small mammals in farm woodlands: the effects of habitat, isolation and surrounding land-use patterns. *Journal of Applied Ecology*, **34**, 530-539.

Flowerdew, J.R., Shore, R.F., Poulton, S.M.C. & Sparks, T.H. (2004) Live trapping to monitor small mammals in Britain. *Mammal Review*, **34**, 31-50.

Flowerdew, J.R. & Trout, R.C. (1995). Population dynamics of small mammals in new woodlands. In *The Ecology of Woodland Creation* (ed R. Ferris-Kaan), pp. 183-199. Wiley, Chichester.

Gelling, M., Macdonald, D.W. & Mathews, F. (2007) Are hedgerows the route to increased farmland small mammal density ? Use of hedgerows in British pastoral habitats. *Landscape Ecology*, **22**, 1019-1032.

Greenwood, A., Churchfield, S. & Hickey, C. (2002) Geographical distribution and habitat occurrence of the Water Shrew (*Neomys fodiens*) in the Weald of South-East England. *Mammal Review*, **32**, 40-50.

Gurnell, J. & Flowerdew, J.R. (2006) *Live Trapping Small Mammals: A Practical Guide* The Mammal Society, London.

Harris, S., McLaren, G., Morris, M., Morris, P., Yalden, D. & University Press, C. (2000). Abundance/mass relationships as a quantified basis for establishing mammal conservation priorities. In *Priorities for the Conservation of Mammalian Diversity: Has the Panda Had its Day?* (eds A. Entwhistle & N. Dunstone), pp. 101–117. University Press, Cambridge.

Johnson, I.P., Flowerdew, J.R. & Hare, R. (1992). Populations and diet of small rodents and shrews in relation to pesticide usage. In *Pesticides and the Environment: the Boxworth Project* (ed P. Grieg-Smith, Frampton, G., & Hardy, T). HMSO, London.

King, C.M. (1985) Interactions between woodland rodents and their predators. *Symposia of the Zoological Society of London*, **55**, 19-247.

Kitchener, A. (1995) *The Wildcat*. The Mammal Society, London.

Kotzageorgis, G.C. & Mason, C.F. (1997) Small mammal populations in relation to hedgerow structure in an arable landscape. *Journal of Zoology*, **242**, 425-434.

Lambin, X., Petty, S.J. & MacKinnon, J.L. (2000) Cyclic dynamics in field vole populations and generalist predation. *The Journal of Animal Ecology*, **69**, 106-118.

Love, R.A., Webbon, C., Glue, D.E. & Harris, S. (2000) Changes in the food of British Barn Owls (*Tyto alba*) between 1974 and 1997. *Mammal Review*, **30**, 107-129.

Macdonald, D.W., Mace, G. & Rushton, S. (1998) *Proposals for the future monitoring of British mammals*. Department of the Environment Transport and Regions with Joint Nature Conservation Committee, London and Peterborough.

Macdonald, D.W. & Tattersall, F. (2001) *Britain's Mammals: The Challenge for Conservation.* People's Trust for Endangered Species, London.

Mallorie, H. & Flowerdew, J.R. (1994) Woodland small mammal population ecology in Britain. A preliminary review of The Mammal Society survey of wood mice (*Apodemus sylvaticus*) and bank voles (*Clethrionomys glareolus*). *Mammal Review*, **24**, 1-15.

Marsh, A. (1999) *The National Yellow Necked Mouse Survey, The Mammal Society Research Report No. 2.* The Mammal Society, London.

NFBG. (2004) *Bovine TB in Cattle, NFBG briefing paper*. National Federation of Badger Groups, London.

Noble, D., Carter, P., Harris, S., Leech, D., Poulton, S. & Shearer, G. (2005) *Winter Mammal Monitoring – a pilot study.* BTO Research Report No. 410, The Mammal Society Research Report No. 5. British Trust for Ornithology, Thetford and The Mammal Society, London.

Redpath, C.J., Thirgood, S.J. & Redpath, S.M. (1995) Evaluation of methods to estimate field vole abundance in the uplands. *Journal of Zoology*, **237**, 49-57.

Redpath, S.M., Thirgood, S.J. & Clarke, R. (2002) Field vole *Microtus agrestis* abundance and hen harrier *Circus cyaneus* diet and breeding in Scotland. *Ibis*, **144**.

Rogers, L.M. & Gorman, M.L. (1995) The population dynamics of small mammals living in set-aside and surrounding semi-natural and crop land. *Journal of Zoology*, **236**, 451-464.

Sargent, G. (1999). Harvest Muse in Trouble. In *Mammal News*, Vol. 111, p 1.

Sibbald, S., Carter, P. & Poulton, S. (2006) *Proposal for a National Monitoring Scheme for Small Mammals in the United Kingdom and the Republic of Eire, The Mammal Society Research Report No. 6*. The Mammal Society, London.

Southern, H.N. (1970) The natural control of a population of tawny owls (*Strix aluco*). *Journal of Zoology*, **162**, 197-285.

StatSoft, Inc. (2004) *STATISTICA*, version 6. www.statsoft.com.

Toms, M.P., Siriwardena, G.M. & Greenwood, J.J.D. (1999) *Developing a mammal monitoring programme for the UK: BTO Research Report No.223*. BTO, Thetford.

Village, A. (1987) Numbers, territory-size and turnover of short-eared owls *Asio flammeus* in relation to vole abundance. *Ornis Scandinavica*, **18**, 198-204.

Webster, J.P. & Macdonald, D.W. (1995) Parasites of wild brown rats (*Rattus norvegicus*) on UK farms. *Parasitology*, **111**, 247-255.

Wheeler, P. (2002) *The distribution of mammals across the upland landscape*. PhD, University of Manchester, Manchester.

Wilkinson, S.A.J., Craze, P.G. & Harris, S. (2004) *Monitoring field vole (Microtus agrestis) numbers in lowland Britain: The Mammal Society Research Report No.4* pp 23. The Mammal Society, London.

8 Appendices

Appendix I. Example of PSU & SSU Fieldforms

The Mammal Society Small Mammal Pilot Monitoring Project	
P S U Field form	
Tetrad Grid Reference:	Volunteer:
Year:	Season:
Start Date:	End Date:
Total time spent assessing PSU, arranging access, etc. (hrs):	
Total time spent travelling to and from PSU (hrs):	
Total time spent travelling within PSU (but not doing fieldwork in SSUs - hrs):	
Total number of visits to PSU:	

SSUs						
Code	Transect Type	Habitat	Transect Length		Grid References	
			1	2	Start	End
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

The Mammal Society
Small Mammal Pilot Monitoring Project

Harvest Mouse Nest S S U Field form

Date:	**PSU:**	SSU Code:	Time spent on SSU:

Field Survey Units (2m x 10m Plots)

Plot	Present OR Count		Notes
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Location Diagram of SSU

Please draw a sketch of the SSU, orientating the SSU in relation to key features such as trees, pylons houses etc. Please include triangulation bearings for the start and end point of the SSU, from key objects less then 200m from the point

The Mammal Society
Small Mammal Pilot Monitoring Project

Field Vole Sign S S U Field form

Date:	**PSU:**	SSU Code:	Time spent on SSU:

Field Survey Units (1m x 1m Quadrats)

Quadrat	Runways	Latrines	Feeding Signs	Notes
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Location Diagram of SSU

Please draw a sketch of the SSU, orientating the SSU in relation to key features such as trees, pylons houses etc. Please include triangulation bearings for the start and end point of the SSU, from key objects less then 200m from the point

The Mammal Society
Small Mammal Pilot Monitoring Project

Bait-Tube S S U Field form

PSU:		SSU Code:
Visit	Date:	Time spent on SSU (excluding time within PSU):
1		
2		

Field Survey Units (Single Bait-Tubes)

Tube	**Faeces Present**	**Notes**	**Species/Group** (for lab use only)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Location Diagram of SSU

Please draw a sketch of the SSU, orientating the SSU in relation to key features such as trees, pylons houses etc. Please include triangulation bearings for the start and end point of the SSU, from key objects less then 200m from the point

The Mammal Society
Small Mammal Pilot Monitoring Project

Extensive Live-Trapping S S U Field form

PSU:		SSU Code:
Visit	Date:	Time spent on SSU (excluding time within PSU):
1: Traps laid (pm)		
2: Traps set (pm)		
3: Traps checked (am)		

Location Diagram of SSU

Field Survey Units (Single Longworth Traps)

Trap	**Species**	**Failure** (S = door locked shut, O = door locked open, M = trap missing, E = escaped)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

The Mammal Society
Small Mammal Pilot Monitoring Project

Intensive Live-Trapping S S U Field form

PSU:		**SSU Code:**
Visit	Date:	Time spent on SSU (excluding time within PSU):
Set-up 1: (Day 1 am)		
Set-up 2: (Day 2 am)		
Capture 1: (Day 2 pm)		
Capture 2: (Day 3 am)		
Capture 3: (Day 3 pm)		
Capture 4: (Day 4 am)		

Location Diagram of SSU

Please draw a sketch of the SSU, orientating the SSU in relation to key features such as trees, pylons houses etc. Please include triangulation bearings for the start and end point of the SSU, from key objects less then 200m from the point

Field Survey Units (single Longworth Traps)

For failures, record these codes in the Sp column:
(S = door locked shut, O = door locked open, M = trap missing, E = escaped)

Trap	C. Visit 1	Capture Visit 2		Capture Visit 3		Capture Visit 4	
	Sp.	Sp.	Marked?	Sp.	Marked?	Sp.	Marked?
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							
34							
35							
36							
37							
38							
39							
40							

Appendix II. SSU Types by PSU

PSU GridRef	1: Harvest Mouse	2: Field Vole	3: Bait-tube	4: Extensive Trapping	5: Intensive Trapping
SE9888	2	2	2	2	2
SH5626	1	1			
SH5826	1	1		1	
SJ8818	1	1	1	1	
SJ9018	1	1		1	
SJ9618	1	1	1	1	
SO6692			2	4	2
SO7646		1	2	2	1
SO7838	1		2	2	1
ST4048		1	1	1	1
ST4452		1	1	1	1
ST4472	1	1	1	3	1
ST5268				2	
SU4034			3		
SU4230		2		2	2
SU4234			3		
SU4432		2		2	2
SU9044		2	2	2	
SU9246		2	2	2	
SU9806	3	3	2	4	
SX9488	2	2	2	2	
TL2078		2	1	5	3
TL2280	3	2	3	4	3
TQ1430		2	3		
TQ5848	1	1		1	
TQ6250	1	1		1	