# An analysis of small mammal indirect sampling methodology in hedgerows

**Report for Mammals Trust UK**

**by**

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**Summary**

This study investigated the effectiveness of two indirect sampling methods (bait tubes and hair tubes) at detecting the presence of small mammals in hedgerow habitats. It primarily looked at whether the density of tubes had an effect on species detection rates and estimates of small mammal abundance. The study was carried out on the Woburn Estate in Bedfordshire in four different hedgerow types.

Tubes were placed at high (every 15 m) and low (every 5 m) densities along the hedgerows for two-four week periods. In between tube sampling periods, hedges were live trapped to estimate small mammal numbers. Tube design was modified several times. Nylon mesh (tights) was found to be an inappropriate covering for the tubes due to high destruction rates (presumably by rodents), and blocks of different size and material were trialled to improve hair collection rates. The addition of peanut butter to tubes was found to have no significant effect on either hair or scat collection rates.

Wood mice (*Apodemus sylvaticus*) were the most abundant species present in the hedgerows, followed by bank voles (*Clethrionomys glareolus*). Small numbers of field voles (*Microtus agrestis*), common shrews (*Sorex araneus*), pygmy shrews (*Sorex pygmaeus*), yellow-necked mice (*Apodemus flavicollis*) and house mice (*Mus musculus*) were detected.

The appearance of either scats or hairs in a tube was described as a "hit". There were significantly more hits of hairs than scats in tubes in all hedgerows and at both tube densities. The reason for the poor scat collection rates was unclear. Two days was found to be sufficient time to leave the tubes *in situ* before collecting hairs or scats. Whilst there was no significant difference in the proportion of scats or hairs collected in high and low density tube placements, tubes placed at low density frequently failed to detect the less abundant species. Hair tubes were able to detect several species in hedges where they were not captured by live trapping. However, live trapping detected the presence of house mice in one hedge, whereas the hair tubes did not.

There was a very poor relationship between estimates of numbers produced by indirect and direct sampling methods. On the basis of the results from this study, therefore, it does not seem possible to predict species numbers by indirect sampling. However, this does not exclude the possibility of developing indices of high, moderate and low mammal abundance from such techniques in future studies.

**Acknowledgements**

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## 1. Introduction
### 1.1 Background

Monitoring of small mammal populations in the UK can be useful for many reasons, including; determining the abundance and distribution of species that are rare (e.g. hazel dormouse – *Muscardinus avellanarius*) or have limited distributions (e.g. yellow-necked mouse – *Apodemus flavicollis*) (Flowerdew *et al.* 2004), or as a baseline for studying biodiversity and any long-term changes that may occur (Toms *et al.*, 1999).

Monitoring of small mammal populations can be achieved through direct (trapping) or indirect methods e.g. signs, nest sites, bait tubes, or hair tubes (Dickman 1986; Churchfield *et al.*, 2000). Indirect monitoring methods have several advantages over direct methods. For example, less man-hours may be spent in the field, some methods can be operated by less experienced individuals, the methods pose no risk to the animals and do not interrupt the animal's daily routine, and most use cheap materials (Dickman 1986; Churchfield *et al.*, 2000; Flowerdew *et al.* 2004). However, indirect sampling methods also have disadvantages in that they may only be suitable for detecting the presence/absence of individual species, or, at best, yielding indices of population change. Alternatively the use of live trapping, in combination with mark-recapture techniques can be used to investigate a variety of parameters including population size and density (Gurnell & Flowerdew in press). However, this technique may not be practical for use in large-scale distribution surveys (Flowerdew *et al*. 2004) or in urban areas where there is a risk of vandalism or pilfering (Dickman, 1986), and requires equipment and expertise.

One of the most popular indirect sampling methods for detecting mammals is the use of hair tubes (Suckling 1978; Dickman, 1986; Dickman 1987; Lindenmayer, 1999). These are baited stations with adhesive, which collect the hairs of visitors (Suckling, 1978). Mammalian hair is distinct to species and can be analysed using various laboratory techniques (Teerink, 1991). Faecal analysis has long been used to detect the presence of mammals and recently small bait stations designed for detecting water shrews (*Neomys fodiens)* (Churchfield *et al.*, 2000), have been used for a UK-wide survey of this species.

The distribution and density of monitoring equipment within a field site is likely to affect the results obtained. Bait tubes/hair tubes placed inappropriately or too far apart may fail to detect the presence of species present at low densities. Similarly, surplus indirect monitoring equipment may result in over-inflated abundance estimates, due to 'addicted' individuals repeatedly visiting tubes.

This report concerns, therefore, indirect sampling methodology with particular respect to hedgerow habitats, and examines the effects of tube placement and density on species abundance estimates by validating the results obtained with estimates produced by live trapping. Hedgerows are thought to provide important habitat and dispersal routes for many species of small mammal including harvest mice (*Micromys minutus*), wood mice (*Apodemus sylvaticus*), yellow-necked mice (*Apodemus flavicollis*) and bank voles (*Clethrionomys glareolus*) (Kotzageorgis & Mason, 1997).

### 1.2 Aims

The aims were to study small mammal indirect sampling methodology in hedgerow habitat in order to:

- To assess the effectiveness of bait tubes and hair tubes at detecting the presence of different small mammal species
- To determine whether density of tubes has a significant effect on estimates of small mammal abundance and species detection rates

## 2. Methods

### 2.1 Site Description

The two study sites used in this investigation were located on the Woburn Estate, Bedfordshire. Hedges A and B were located behind the main barn at Dolton's Farm, and Hedges C and D ran along a small steam close to Horsemoore Farm (see Appendix 2). Hedges A and B were 105 m in length whilst hedges C and D were 75 m. All hedges bordered at least one 'set-aside' grassland field. The predominant plant species in Hedge A were common hawthorn (*Cretaegus monogyna*) and blackthorn (*Prunus spinosa*), whilst Hedge B was predominantly composed of common hawthorn. The main plant species in Hedge C were blackthorn, elder (*Sambuca nigra*) and hazel (*Corylus avellana*). Hedge D was slightly different to the other hedges because it was formed from fully-grown trees as well as shrubbery. The main species in this hedge were oak (*Quercus robur*), hazel and elder.

### 2.2 Survey methods

For this investigation, Churchfield *et al*.'s (2000) bait tube design and Dickman's (1986) hair tube design were adapted to produce a dual-purpose tube. Tubes of 20 cm by 4 cm were covered at one end and baited with whole oats and blowfly pupae (*Calliphora vomitoria*) to encourage small mammals to enter the tube and to defecate. Double-sided sticky tape was placed at the top of the front entrance of the tube in order to collect guard hairs from the backs of animals entering the tube.

Tube design was modified throughout the experiment in an attempt to improve the numbers of hairs and scats collected. The first designs used thick, woolly tights to cover the back end of the tube but square plastic seedling trays were used as a replacement after the first week. During the first week of the experiment, double-sided sticky tape was attached to 1 x 1 x 3 cm polystyrene blocks to collect hairs. These were swapped for 1 x 1 x cm wooden blocks cut into 5 cm sections during week two, and subsequently, 16 mm quadrants cut into 5 cm sections were used for the remainder of the study (Figure 4.1). In week six, Sellotape Sticky-Fixers® were trialled instead of double-sided tape but were deemed unsuccessful, thus the sticky-tape design prevailed. For a four week period, peanut butter was added to the pupae and oat mix in alternate tubes (odd numbers) to determine whether this encouraged animals to spend more time in the tubes, and thus whether scat collection improved.

Hedges were worked on a rotational basis[1] (see Appendix 1). Tubes were either placed at low density (every 15 m along the hedgerow) or at high density (every 5 m) and were left *in situ* for two days. In between tube sampling periods, hedges were live-trapped using Longworth traps. Two traps were placed every 5 m along the hedgerows and were checked twice a day for four days. Animals were marked with individual fur clips, weighed, sexed and released.

Weather conditions were recorded for each tubing and trapping session, and maximum and minimum temperatures were also noted. Vegetation surveys were carried out on the hedgerows and surrounding fields. Presence or absence of species in the canopy layer, and percentage cover of ground vegetation were noted at each trap point.

Scats were dried and then identified as either rodent or shrew according to the protocol listed in Churchfield *et al.* (2000). Hairs were soaked in detergent for 24 hours to remove them from the sticky-tape, washed and then preserved in 70% ethanol. Hairs were identified using keys and methods detailed in Teerink (1991). Cuticle scale imprints were achieved using the gelatine method, whilst cross sections were attempted using balsa wood supports.

## 3. Results

### 3.1 Small mammal assemblage

Overall, seven species of small mammal were trapped within the four hedgerow sites. Out of 202 individuals captured, over 62% were wood mice (*Apodemus sylvaticus*) and 29% were bank voles (*Clethrionomys glareolus*), whereas field voles (*Microtus agrestis*), common shrews (*Sorex araneus*), pygmy shrews (*Sorex minutus*), house mice (*Mus musculus*) and yellow-necked mice (*Apodemus flavicollis*) were captured much less frequently.

Figure 3.1 shows the minimum number of animals alive (MNA) during each trapping period, for individual hedges. Hedge A was found to contain the largest number of animals as well as a wide variety of small mammal species. Common shrews, pygmy shrews, field voles and house mice were only captured in Hedge A, whilst Hedge D was the only site inhabited by yellow-necked mice.

The numbers of animals captured in each hedgerow fluctuated between trapping periods. Wood mice captures tended to decrease throughout the summer, whereas bank vole captures increased.

Overall, the number of captures was greater during morning trap rounds than during evening rounds (Figure 3.2). This is because significantly more mice were captured overnight than during the day ($X^2_1$= 132.6, P<0.001). However, there was no significant difference between morning and evening captures of bank voles ($X^2_1$= 1.78, P = 0.182)

[1] Studies of hedges C ands D were abandoned during weeks 12-14, to allow for more time to analyse the enormous number of hair and scat samples. However, the surrounding fields were mowed during Week 16 and thus it was decided to discontinue the experiment in these hedges due to the likelihood that very few animals remained.

### 3.2 Trap success and weather conditions

The number of captures of bank voles during morning trap rounds was significantly positively correlated with the minimum overnight temperature ($r = 0.45$, $P = 0.046$). However, this was not the case for wood mice ($r = -0.29$, $P=0.211$), nor for the total number of morning captures[2] ($r = 0.05$, $P = 0.801$). Similarly, the number of bank vole captures during evening rounds was significantly positively correlated with the maximum daytime temperature ($r = 0.72$, $P = 0.001$), and so was the total number of evening captures[2] ($r = 0.64$, $P = 0.003$), but number of captures of wood mice was not ($r = -0.38$, $P=0.108$).

For the purpose of analysing the effects of weather on capture success, weather conditions were categorised into; Type 1 – clear, Type 2 – slightly cloudy, Type 3 – overcast, Type 4 – rainy. Weather was found to have a significant effect on the number of captures ($X^2=12.296$, $P<0.05$) but this was mainly due to fewer animals being captured during rainy periods.

### 3.3 Efficiency of indirect sampling methods

During the first few weeks of the study, a few complications arose with the tube design. The first sets of tubes were chewed extensively (presumably by mice) and thus results were very poor. For this reason, the data from these 'trial and error' periods have been omitted from the majority of the following analyses.

A total of 656 tubes were set during this study. Less than 5% of tubes were left untouched (i.e. the bait was intact and there was no evidence that any small mammal had entered the tube). Whilst small mammal hairs were found to be present in over 60% of tubes laid, only 40% contained small mammal scats. Nevertheless, hair collection rates improved greatly as the tube design was modified and during the latter half of the study it was not uncommon for over 80% of tubes laid to contain hair samples. However, 22% of the total number of hairs collected were deemed unidentifiable. Many of the hairs collected were already damaged, or became damaged during the attempt to remove them from the adhesive tape. This was particularly a problem when tubes only contained a single hair.

Very few shrew scats or hairs were collected during the study. However, shrews were not commonly caught during trapping sessions either, indicating that only low numbers of these animals reside in the hedgerows.

[2] The single captures of a pygmy shrew and a house mouse have been excluded from these data sets.

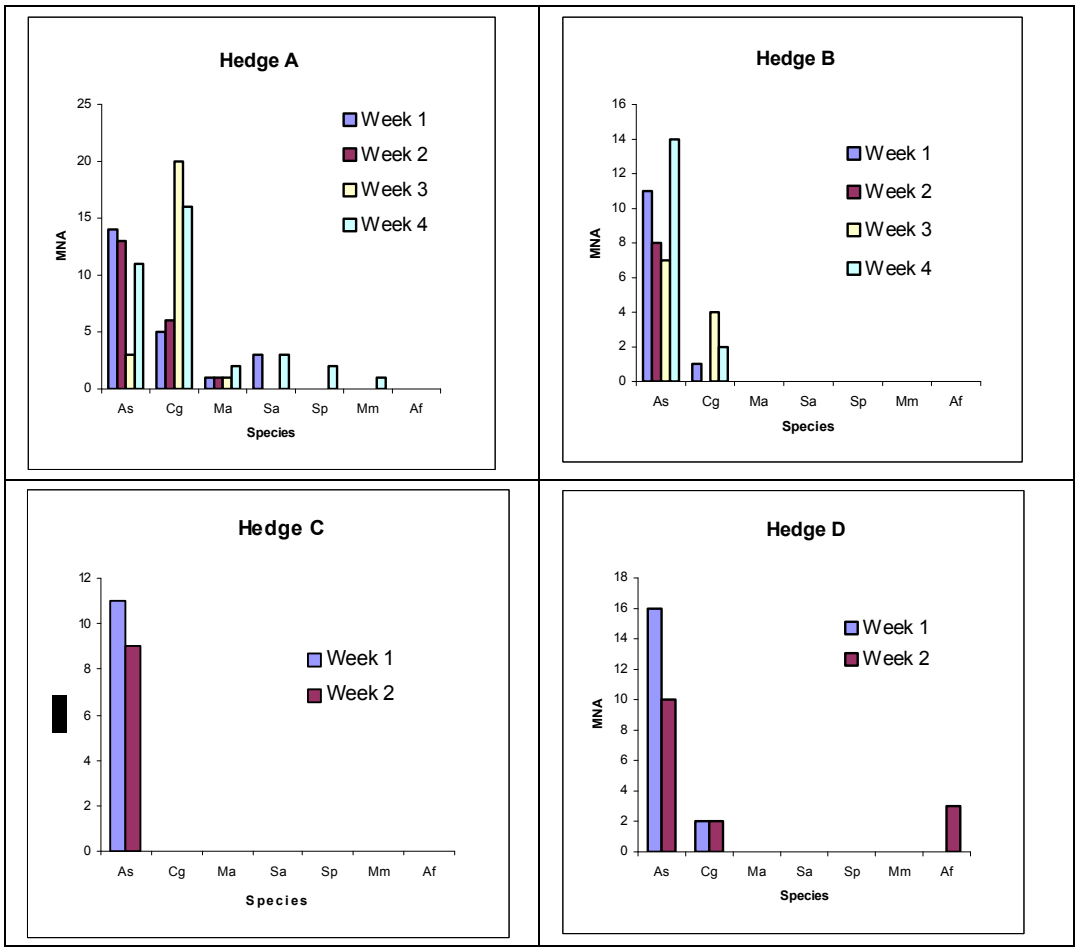


**Figure 3.1 Minimum number of animals alive (MNA) in four hedgerow habitats, as revealed by live trapping. *Apodemus sylvaticus* (As), *Clethrionomys glareolus* (Cg), *Microtus agrestis* (Ma), *Sorex araneus* (Sa), *Sorex Pygmaeus* (Sp), *Mus musculus (*Mm) and *Apodemus flavicollis* (Af). Week numbers refer to the first, second, third and fourth time hedges were trapped (see Appendix 1 for dates).**

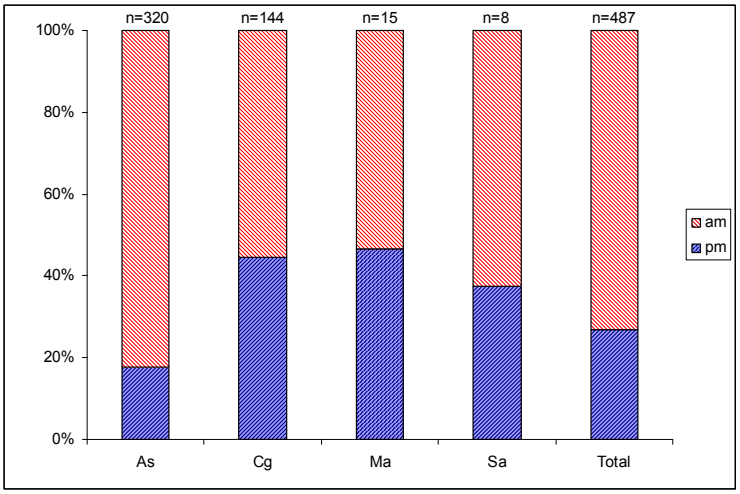


**Figure 3.2 Total number of captures of small mammals during morning and evening trap rounds (combined for all hedgerows).**

Whilst there was a significant positive correlation between the number of rodent hairs and the number of rodent scats collected at both high density ($r_s$=0.59 P<0.001) and low density tube distribution ($r_s$ =0.56, P<0.002), and between the total number of rodent hairs and scats collected ($r_s$= 0.73, P<0.001), scats were much less reliable as an indicator of rodent presence.

Tubes were left in place for two days and collected midweek (1st inspection) and at the end of each week (2nd inspection). Whilst bait was removed entirely from the majority of tubes, it was impossible to confirm that small mammals had taken the bait (rather than slugs, snails, insects or birds). Thus, the total number of small mammal 'hits' in tubes was derived from the number of tubes where hairs or scats had been deposited.

There was no significant difference in the number of 'hits' between the 1st and 2nd inspection for hairs or scats at either high or low density tube placement[3] (all $X^2$, P>0.05). This indicates that two days was a sufficient sampling period, and that animals were not more likely to enter the tubes during the latter half of the week than during the first two days. There were significantly more hits of hairs in the tubes than scats, irrespective of inspection time and tube density (Figure 3.3).

| Tube | Tube Density and Collection | | | |
|---|---|---|---|---|
| Type | LD1 | LD2 | HD2 | HD2 |
| Hairs | 49 | 51 | 136 | 140 |
| Scats | 28 | 34 | 76 | 88 |
| $X^2_1$ | 5.727 | 3.400 | 16.981 | 11.860 |
| P | 0.017 | 0.065 | <0.001 | 0.001 |

**Figure 3.3 Number of hits of scats and hairs in tubes, irrespective of species[3]. 1 = 1st inspection, 2 = 2nd inspection, LD = low density tube placement, HD = high density tube placement. $X^2$ values show that significantly more hairs were deposited in the tubes than scats.**

When the efficiency of high density and low density tubes were compared[3] (taking into account the number of tubes and thus, the expected number of hits), there was no significant difference in the number of hairs or scats collected ($X^2$ = 0.0139, P>0.05; $X^2$ = 0.0371, P>0.05 respectively), i.e. the number of hits achieved was in proportion to the number of tubes laid out. This demonstrates that placement of tubes at a high density was not more efficient than at low density. Nevertheless, tubes placed at low density frequently failed to detect the presence of less abundant species, whereas these species were sometimes detected by the high density placement of tubes.

Results from the hair tubes revealed that common shrews, field voles and bank voles were present in Hedge C. These species were not trapped in this hedge. Conversely, a house mouse was trapped in Hedge A, but was not detected by the hair tubes.

There was a significant correlation between the number of midweek and endweek hits for hairs at both high and low density tube placement (r = 0.81, P<0.001; r = 0.83,

[3] Data from the first two weeks on Grids A and B were left out of these analyses due to problems with tube design.

P<0.001 respectively). However, there was no correlation between the number of midweek and endweek hits for scats, for tubes at high density (r = 0.47, P = 0.124), and particularly those at low density (r = 0.19, P = 0.561). Again, this demonstrates that scat collection is a less reliable survey method than hair collection.

For four weeks of the study period, peanut butter was placed in alternate tubes to see whether this encouraged the animals to stay longer in the tubes, and thus improved the number of hits (of scats). However, the addition of peanut butter did not have a significant effect on either the number of scats collected ($X^2_1 = 0.099$, P=0.583), or on the number of hairs collected ($X^2_1 = 0.064$, P=0.801).

### 3.4 Reliability of indirect sampling as a index of small mammal abundance

Data for each of the hedges[4] were tested to see whether the number of hits of hairs and scats were comparable to the estimates of numbers of animals produced by live trapping. Figure 3.4a shows the estimated number of wood mice, bank voles and all species combined, against indices derived from hair hits for each time period in Hedge A[5].

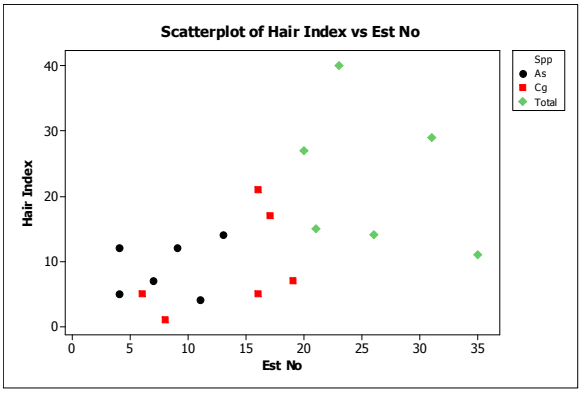


**Figure 3.4a Estimates of numbers of small mammals derived from live trapping captures, plotted against the indices of hair hits from hair tube sampling. Hair indices were pooled from midweek and endweek counts. As – *Apodemus sylvaticus*, Cg – *Clethrionomys glareolus*, Total includes other small mammal species.**

[4] There were much fewer data for Hedges C and D so data from these hedges were combined. In addition, results from the first week of tubing were omitted due to problems with the tube design.
[5] Data from the first two weeks were omitted due to problems with tube design.

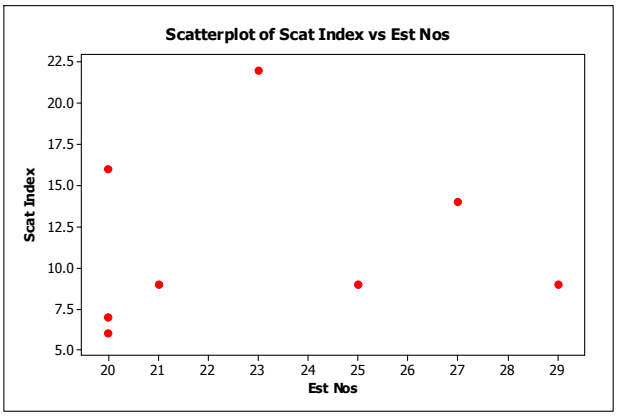


**Figure 3.4a Estimates of numbers of small mammals derived from live trapping captures, plotted against the indices of scat hits from bait tube sampling. Scat indices were pooled from midweek and endweek counts.**

The data sets were not significantly correlated for wood mice ($r_s$ = 0.25, P = 0.633), bank voles ($r_s$ = 0.57, P = 0.234), or for all species combined ($r_s$ = -0.37, P = 0.468). Figure 3.4b shows the estimated number of rodents derived from live trapping against the indices derived from hits of scats for Hedge A[5]. There was no significant correlation between the two estimates ($r_S$ = 0.30, P = 0.47).

In Hedge B[6], live trapping estimates were not significantly correlated with indices of hair for wood mice ($r_s$ = -0.15, P = 0.774) or for all species combined (data includes unidentified hairs) ($r_s$ = 0.11, P = 0.819). However, hair indices were positively correlated with estimates of numbers for bank voles ($r_s$ = 0.76, P = 0.045). This was probably an effect of the small sample size. Scat indices were not significant correlated with estimates of small mammal numbers ($r_s$ = 0.58, P = 0.170).

The combined data from Hedges C and D[4] revealed that there was no correlation between the estimated numbers of wood mice and hair indices ($r_s$ = 10.15, P = 0.781) or between wood mice estimates and rodent scat indices ($r_s$ = 0.06, P = 0.906). When all species were considered, there was no correlation between number estimates and hair indices ($r_s$ = 0.05, P = 0.932), or between number estimates and scat indices ($r_s$ = -0.19, P = 0.722).

## 3.5 Vegetation

The canopy layer of the vegetation in each of the four hedgerows and the surrounding filed vegetation were analysed using a detrended correspondence analysis (Figure 3.4). The analysis shows that all four hedgerows are different in plant species composition and thus can be described as different hedgerow habitat types. As has been described above, these hedgerow habitat types support different small mammal communities.

[6] Data from the first week were omitted due to problems with tube design

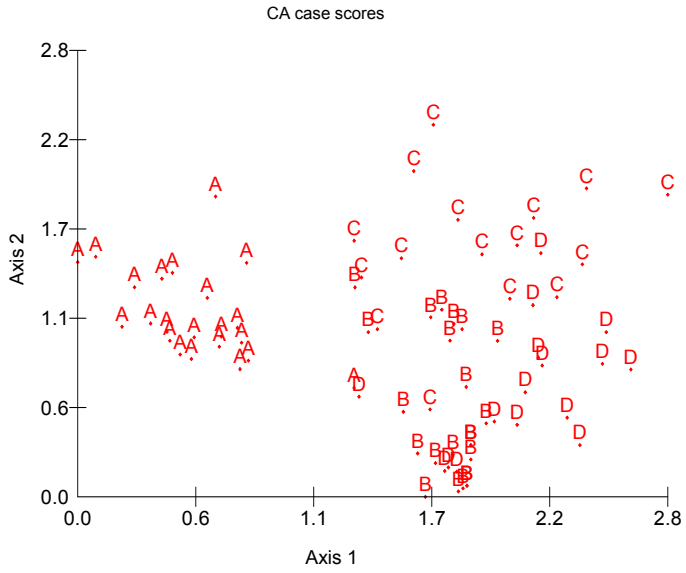


**Figure 3.4 Detrended correspondence analysis of the field and canopy vegetation at four hedgerow sites (A-D). Data were ln transformed, and rare species downweighted. This analysis was performed in MVSP software.**

## 4.0 Discussion

### 4.1 Small mammal assemblage and trap success

The small mammal assemblage in the four study hedgerows was fairly typical for this type of habitat. Previous studies have also found that wood mice often account for the largest proportion of small mammal captures in hedges and whilst bank voles are also relatively common, other species (e.g. shrews and field voles) are only occasional visitors (Kotzageorgis & Mason, 1997). The presence of house mice in Hedge A was probably due to the proximity of this hedgerow to a large farm building. Hedge A contained the largest number of small mammal species. It was the largest (nearly 2 m wide in places) and most dense hedgerow, and thus provided good cover for the animals from aerial and larger ground predators.

Throughout the summer period, captures of wood mice decreased, whilst captures of bank voles increased. All of the hedges in this study were bordered by at least one field of set-aside land. At the beginning of the study the vegetation in the surrounding fields was fairly short (after being mowed the previous year) but this quickly grew during the summer period. Therefore, it is likely that many of the mice from the hedgerows moved into the surrounding fields when the vegetation became tall enough to provide adequate cover from predators. Conversely, bank voles are rarely found in grassland unless it is bordered by scrub, hedgerow or woodland (Corbet & Harris, 1991). Unsurprisingly, captures of bank voles increased throughout the summer breeding season.

Wood mice were the most frequently captured species overall and significantly more mice were captured during the morning than evening rounds. This is because wood mice are mainly nocturnal (e.g. Montgomery & Gurnell, 1985). Captures of bank voles were positively correlated with the minimum overnight temperature and the maximum daytime temperate. However, this probably results from numbers of voles

increasing over the summer breeding season, which coincided with the seasonal rise in temperature. Weather was found to have a significant effect on the number of captures of small mammals but mainly because there were fewer captures during rainy periods. This suggests that small mammals were less active above ground in these conditions.

### 4.2 Bait and hair tube design

Various models of tube were trialled during this study. The original tube was largely based on that of Churchfield *et. al*'s (2000) bait tube design, with thick tights secured over one end of the tube to encourage the animals to stay and feed (and therefore defecate) within the tube. However, after the first inspection of the first set of tubes, it became clear that this was not an appropriate covering. In over 95% of tubes, the animals had chewed through (and in some cases completely removed!) the tights in order to eat the bait, rather than pass through the tube. One possible explanation for this peculiar behaviour is that the small polystyrene blocks secured at the front of the tunnel (needed to lower the roof to catch the back hairs of the animal as they passed through) had an odour that deterred the animals. Chemical odours (e.g. detergents and lubricating oils) have been shown to deter small mammals from entering traps (Shore & Yalden, 1991). However, a large proportion of these polystyrene blocks had also been chewed, and in some case removed, therefore it is unlikely that these were the real cause of the problem.

After the first week, the tights were substituted with square plastic seedling pots. These were chosen because they were cheap and easy to assemble. However they also had the advantage of preventing the round tubes from rolling around when placed on the ground. This proved to be essential for collecting hairs from the backs of the animals. Because the tubes were larger than normal hair tubes (so that the animals could turn around inside them), blocks had to be inserted into the entrance of the tunnel to ensure contact. The most successful tube design used blocks of 16 mm quadrants of wood (available in 2 m strips from Homebase). These were rounded on one side and thus stuck to the tube easily, and did not block off as much of the entrance as a 16 mm square block wood have (Figure 4.1)

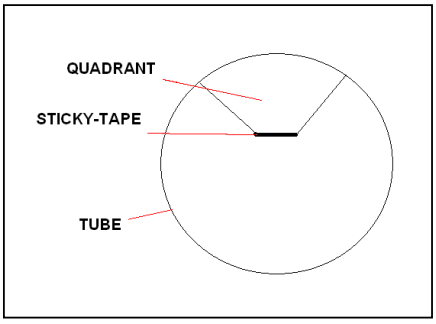


**Figure 4.1 Cross-section diagram of tube design (front entrance).**

### 4.3 Efficiency of indirect sampling methods

Once the tubes had been modified to that of the design pictured in Figure 4.1, the number of hair 'hits' in tubes increased greatly. However, many of the collected hairs were unidentifiable because of damage. Dickman (1986) also reported a relatively high percentage of unidentifiable hairs using this method (around 8%). However, during this study, most of the damage to hairs was caused by trying to remove them from the extremely sticky adhesive tape. Different solvents and detergents were trialled but none seemed to solve the problem entirely. Whilst a less strong adhesive was trialled for one week (Sellotape Sticky-Fixers®), these failed to collect as many hairs. Ideally an alternative should be found for future studies.

Very few shrew hairs or scats were collected during the study but the live trapping results suggest that there were not many of these animals in the hedgerows anyway. The hair tubes failed to detect the presence of pygmy shrews, which were captured on two occasions. One possible reason for this is that these shrews are probably small enough to pass under the tape without touching it. Dickman (1986) encountered the same problem. Realistically, it would be very hard to design a tube that was small enough to collect hairs from these tiny animals as well as being wide enough to let large mice through. Hair tubes also failed to detect the presence of house mice, although the reason for this was unclear. Dickman (1986) found that this naturally cautious species more readily entered tubes than traps, and were more likely to be detected by hair tubes. However, unlike in this study, Dickman's hair tubes were not covered at one end and this may have affected the likelihood of animals entering.

The tubes were left in place for two days and by the end of this period, it was rare for the tubes to contain any bait. Therefore, it seems unlikely that any more hits would be achieved if the tubes were left *in situ* for longer. Moreover, comparisons between the number of midweek and endweek hits revealed that there was no significant difference in the number of hits between first and second inspection, for scats or hairs at either high or low density tube placement. This seems to confirm the idea that two days was a sufficient sampling period in this type of habitat. In previous studies, hair tubes and bait tubes have been left in place for much longer periods, often up to 14 days (Dickman, 1986; Dickman,1987; Churchfield *et al*., 2000). However, longer baiting times may be necessary to detect more cautious species, such as water shrews and harvest mice.

Comparisons between midweek and endweek hits also show that there is no tendency for the animals to enter the tubes more readily during the latter half of the week than during the first two days. This is slightly surprising because it is well documented that small mammals exhibit neophobia (Chitty & Kempson, 1949) and are more likely to enter sampling tubes as familiarity increases with time (e.g. Gurnell, 1980, 1982). However, due to the problems described above concerning tube design, data from the first few weeks of the study were omitted from these analyses. It was probably during this period that most tube avoidance occurred, and thus was not detected by this study.

Throughout the study, there were significantly more hits of hairs than scats. Whilst it was expected that most animals would leave hairs as they entered the tunnel, but that not all would defecate, the number of scats deposited was surprising low. A relatively large amount of bait was deposited in each tube, thus the reason for this is unclear.

Similar studies have reported much better results from bait tubes (Churchfield *et al*., 2000). The addition of peanut butter to the tubes did nothing to improve scat collection rates. The theory was that it would take more time for animals to lick the peanut butter from the tube than simply eating or collecting grain and pupae. Thus it was hypothesised that the animals would stay in the tubes longer and would be more likely to defecate inside the tube. Whilst the peanut butter was removed entirely in most cases, it could have been eaten by the multitude of molluscs or other invertebrates commonly found in the hedgerow. Alternatively, perhaps the scats were consumed by other species. One way to test this would be to set up camera traps in the field to monitor tube usage.

One advantage of bait tubes over hair tubes is that in some cases a vast number of hairs were deposited on the adhesive tape. Due to the sheer volume of samples and the time involved in identifying hairs, it was impossible to identify all of the hairs from one tape. Therefore a selection of two or three was chosen randomly. In a few cases, both shrew and rodent scats were deposited in tubes where hair hits indicated only the presence of rodents.

One of the aims of this study was to determine whether density of tubes had a significant effect on estimates of small mammal abundance and species detection rates. Whilst it was shown that the number of hits of both scats and hairs was in proportion to the number tubes laid out (i.e. high density tubes were no more effective than low density tubes), tubes placed at low density frequently failed to detect the presence of less abundant species present in the hedgerows such as field voles and shrews. Therefore it is recommended that in habitats where high numbers of small mammals are expected, that sampling tubes be placed at around 5 m intervals. This sampling regime is also more likely to detect species with relatively small home ranges (e.g. field voles) than if tubes are placed at lower density.

Whilst isolating and examining hairs is a laborious process that requires some degree of skill, hair tubes revealed the presence of several species in hedges where they were not detected by live trapping. Dickman (1986) also found that hair tubes were an efficient way to detect species that were either too large or too cautious to enter Longworth traps. However, the tube design used for this study was unlikely to result in the collection of hairs from the larger small mammals, such as mustelids and rats (*Rattus* sp.), because the limited size of the tube entrance. Perhaps for future studies it would be wise to dispense tubes of varying sizes so that mammals as small as pygmy shrews and as large as rats could be detected simultaneously.

### 4.4 Reliability of indirect sampling as an index of small mammal abundance

When the indices of hairs, produced from the number of 'hits' in tubes, were compared to the estimates of numbers produced by live trapping, there was a very poor relationship between the two, for all hedges and all species, except one. There was a significant positive correlation between the indices of bank vole hairs and estimated numbers of bank voles in Hedge B. However, both bank vole estimates and the number of bank vole hair 'hits' were very low. Thus, this significant result could be an effect of small sample size. In addition, bank voles in Hedge B were often trapped around the same trap point, situated underneath a large, dense holly

bush (*Ilex aquifolium*), whilst mice were rarely trapped in this area. Most of the hair hits from bank voles were also concentrated around this area, so this 'hot-spot' effect may have influenced the results. When the indices of rodent scats (there were too few shrew 'hits' to analyse these results), were compared to estimates of rodent numbers, there was a very poor relationship between the two for all hedges.

Overall there was a very poor relationship between the indirect and direct sampling estimates. Thus, based on the results from this study, it is not possible to predict numbers of animals from indirect sampling. However, live trapping also has drawbacks when trying to estimate small mammal population size. Animals tend to differ in their trappability (Gurnell, 1982). Some are easily trapped and tend to visit traps repeatedly (trap-addicted), whilst others are more cautious and avoid the traps (trap-shy). Therefore, live trapping may not be a particularly good validation method for indirect sampling. However, with more work, it may be possible to produce and index of low, moderate and high numbers of animals from tube results.

In conclusion, hair tubes were found to be far more efficient than bait tubes at detecting small mammals. A high density of tubes was found to be the best way to detect a wide range of species. However, indirect sampling cannot be used to produce reliable estimates of animal numbers. This method still needs to be tested in an area of higher shrew density (e.g. grassland). For future studies, it may be beneficial to pre-bait both traps and tubes for a short period before collecting data (Gurnell & Flowerdew, 1990). In addition, it would be interesting to conduct further studies with high density hair tubes and a higher density of traps. The design of the experiment could be improved if trapping and tubing were carried out alternately for three day periods, and sampling was carried out continuously over a period of several weeks.

## 5.0 References


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Appendix 1 Work schedule

| Week starting | WEEK NO. | TUBES HIGH DENSITY | TUBES LOW DENSITY | TRAPPING |
|---|---|---|---|---|
| 11th April | 1 | Hedge A | Hedge B | |
| 18th April | 2 | Hedge D | Hedge C | Hedges A + B |
| 25th April | 3 | Hedge B + C | Hedge A + D | |
| 2nd May | 4 | | | Hedges C + D |
| 9th May | 5 | LAB WORK | | |
| 16th May | 6 | Hedge A | Hedge B | |
| 23rd May | 7 | Hedge C | Hedge D | Hedges A + B |
| 30th May | 8 | Hedge B | Hedge A | Hedges C + D |
| 6th June | 9 | Hedge D | Hedge C | |
| 13th June | 10 | LAB WORK | | |
| 20th June | 11 | Hedge A | Hedge B | C+ D cancelled |
| 27th June | 12 | | | Hedges A + B |
| 4th July | 13 | Hedge B | Hedge A | |
| 11th July | 14 | LAB WORK | | |
| 18th July | 15 | LAB WORK | | |
| 25th July | 16 | Hedge A | Hedge B | C+ D cancelled |
| 1st August | 17 | | | Hedges A + B |
| 8th August | 18 | LAB WORK | | |
| 15th August | 19 | Hedge B | Hedge A | |
| 22nd August | 20 | LAB WORK | | |

Appendix 2 Map of study area