

**Developing a monitoring strategy for red squirrels  
(*Sciurus vulgaris*) across the UK**

**Final report**

for

**JNCC and PTES**

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## Executive Summary

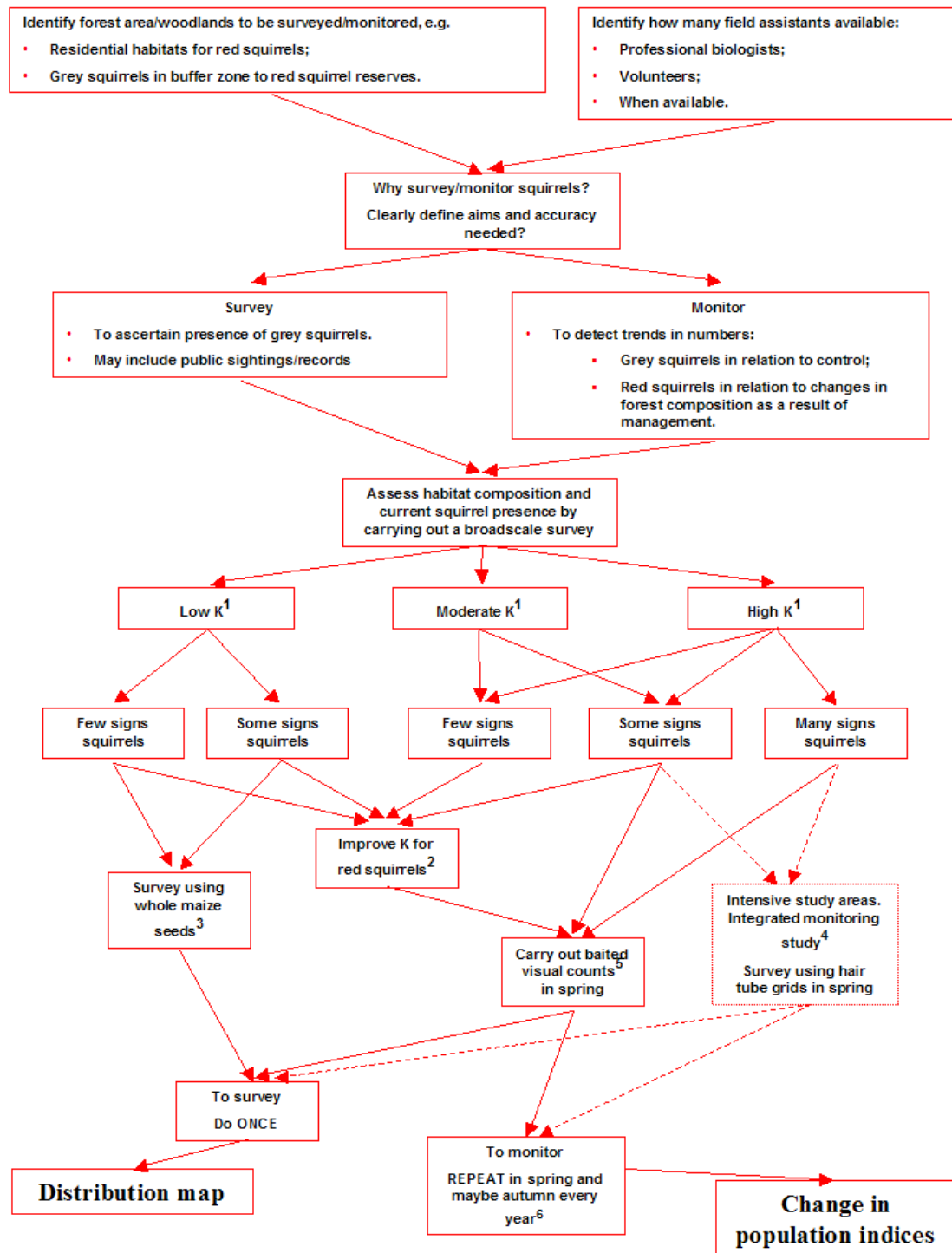
1. This report concerns survey and monitoring methods for squirrels in the UK and was commissioned by the Joint Nature Conservation Committee and the People's Trust for Endangered Species.
2. Glossary. We take the term *census* to mean a process of obtaining information about every member of a population, *survey* to mean the process of systematically sampling at one time in one or more locations to obtain information about a subset of a population, and *monitor* to mean the process of repeatedly and systematically sampling a subset of a population at the same locations to detect trends in numbers and distribution.
3. Aims. These were to:
  - (a) develop protocols to assess and validate known methods of surveying and monitoring that differentiate between red and grey squirrels and where possible reveal population trends;
  - (b) investigate possible new survey and monitoring methods and, if feasible and effective, develop protocols as above;
  - (c) make recommendations on the design of survey and monitoring programmes in the UK.
4. Study period and sites. The study was carried out over two years: Year 1 – 2005, Year 2 – 2006 at 3 field sites in each of Northern Ireland, Wales, northern England and Scotland<sup>1</sup> by experienced field researchers.
5. Methods. In Year 1, a standard programme of work was carried out between April and August in each field site involving replicated visual counts and hair tube surveys with standard live trapping surveys carried out as a means to validate the results from the indirect methods. The power of the sampling methods was considered at the outset. In Year 2 a new technique was trialled between April and November, namely baited visual transects, again with standard live trapping surveys to validate the results from the indirect method. The method of using visual baited transects was carried out by walking each line, stopping every 50 m (0 m, 50 m, 100 m etc), and throwing (scattering) 50g mixed squirrel food over a distance of approximately 10 m behind, 10 m in front and 10 m to either side of the stopping point. This procedure was carried out on a Monday and repeated on the following Friday, before starting the visual counts the following Monday.
6. Volunteer surveys. In Year 2, volunteers surveyed 26 baited visual transects between June and August; these were carried out in close collaboration with the squirrel officers in Cumbria, Northumberland and the Borders (Southern Uplands Partnership).
7. Results.
  - (a) Overall, detection rates using visual transects (baited or unbaited), hair tubes and trapping were low, variable and uncorrelated, and the data, although providing information on presence of red or grey squirrels, were insufficient to provide confidence that they represented estimates of abundance indices.
  - (b) Trapping. Trapping success was low with less than half the sites trapped yielding 3 or more trapped squirrels over the two years,
  - (c) Hair tubes – Year 1. These were not deployed in red squirrel/grey squirrels sites because of the potential for transmitting squirrelpox virus (SQPV). 20

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<sup>1</sup> One site in Scotland was relocated inside the English border for logistical reasons.

tubes placed in a grid layout were examined twice a week for two weeks at an interval of 4 weeks in 8 sites. The proportion of tubes visited varied between 0% and 50% and improved through time. On average, 2% of tubes were visited on visit 1-week 1, 14% visit 2-week 1, 12% visit 2-week 2 and 23% visit 2-week 2. The method of using hair tubes is more labour intensive than visual counts and requires laboratory equipment and expertise at identifying hairs to species.

- (d) Visual transects – Year 1. At each site, 500 m transects were walked at dawn on 5 consecutive days in each of 2 weeks, 4 weeks apart. Sightings were few with no squirrels seen at 7 out of the 12 sites on either of the two weeks. The return on effort was low.
  - (e) Baited visual transects – Year 2. There was a very slight increase in numbers of sightings following baiting, but numbers were very low and of no significance (2 sightings on 11 lines before baiting, 6 sightings after).
  - (f) Visual transects – both years. There were significant negative relationships between the number of squirrels seen and the proportion of Sitka spruce and between the number of squirrels seen and the nearest neighbour (NN) distance between trees. Thus, Sitka spruce, especially at high density, is particularly poor habitat to carry out visual surveys.
  - (g) Volunteer surveys. Provided clear and significant evidence that baiting transects increased the number of squirrel sightings (mean numbers of sightings per transect  $\pm$  SD: unbaited  $0.73 \pm 0.72$ , baited  $1.73 \pm 1.82$ ). Most squirrels were seen in deciduous woodland and least in Sitka spruce, although this was not significant.
- 8) Surveying and monitoring squirrels through time and space. Red squirrel numbers vary widely through space and time as they track tree seed availability. Densities, especially in conifer and especially in Sitka spruce plantation forest, can be very low,  $\ll 1 \text{ ha}^{-1}$ . This makes it very difficult survey and monitor squirrels with any confidence. As a result, we suggest that managers can only ‘manage’ squirrel carrying capacity and not red squirrel populations; grey squirrel populations, of course, can be controlled. Furthermore, target forests and woods should be initially surveyed using a simple broadscale survey to get a crude relative estimate of squirrel carrying capacity, and crude estimates of current squirrel activity and hence numbers of squirrels.
- 9) The effectiveness of baiting visual transects, and indeed hair tube lines or grids, requires further study, as do the power of counts and hair tubes to detect trends in population indices. Drey counts, feeding transects, whole maize bait and nest boxes can be useful in certain situations. Of the range of other direct and indirect techniques that have been used to survey and monitor mammals, with our present state of knowledge there are none that instil confidence that they might be beneficial in detecting trends in numbers, and can distinguish between red and grey squirrels, sufficient to invest large amounts of time and money.
- 10) Recommendations are based on acquiring knowledge about the carrying capacity and squirrel activity in target forests, using baited transects and/or whole maize (for grey squirrels) in spring to detect presence. Monitoring trends in numbers is problematic and can probably only be attempted using intensive studies. In these cases, visual counts and hair tubes should be used, perhaps as part of an integrated monitoring programme incorporating drey counts, cone feeding transects and nest boxes. The main recommendations are presented in the form of a flow chart, reproduced with notes below:



Notes

<sup>1</sup>Broadscale survey to assess habitat composition with respect to squirrel carrying capacity (K) for squirrels, and signs of current usage. With the assistance of maps where possible, all blocks of woodland >15 years old are traversed and notes made on tree species present and their relative age and abundance, the presence of tree seeds or whether the trees and signs of squirrels based on dreys and feeding remains. (Blocks of woodland <15 years are unlikely to hold resident squirrels.)

This is simply done by stopping every 50 m or so and taking quick noting where the signs are few moderate or abundant. Based on trees present, the potential carrying capacity for squirrels can be recorded as low, moderate or high. Sign of squirrels can be recorded as low, moderate or many.

<sup>2</sup>Assess and improve carrying capacity for squirrels in medium/long term if critical by changing age structure and species composition. However, for red squirrel reserve areas vulnerable to grey squirrel incursion, maintain high density of Sitka spruce. Note that carrying capacity can be sufficient but squirrel numbers low due to poor seed crops.

<sup>3</sup>Use whole maize seed to detect for presence of grey squirrels. The maize can be left in small piles every 50 m or so (see Gurnell *et al.* 2001).

<sup>4</sup>Hair tube grids – use these for more intensive studies, maybe integrated with visual counts, drey counts, cone feeding transects and nest boxes (see Gurnell *et al.* 2004). Grids should consist of 20 tubes at 100 m to 200 m spacing between tubes (after Gurnell *et al.*, 2001) and set up for use at 12 monthly intervals to detect changes between years (see Section I.2) – Figure 6b illustrates that sufficient power is retained if the sampling effort is reduced from 30 tubes to 20 tubes per year. Note: lines of tubes may be used for presence surveys.

<sup>5</sup>Use baited visual counts in spring at a density of one 1000 m line 10 ha<sup>-1</sup> (after Gurnell *et al.*, 2001) for presence, or up to 30 lines in the spring of each of two successive years to detect a change in numbers between years (see Section I2).

<sup>6</sup>Spring visual counts are best for squirrels at the time when natural food supplies are low and broadleaf trees are without leaves, thus improving visibility in the canopy. However, post-breeding numbers could also be recorded in the autumn if necessary.

## **Acknowledgements**

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## A. Background

The red squirrel (*Sciurus vulgaris*) is listed as a priority species for conservation by the Government in the UK Biodiversity Action Plan. Its distribution has decreased dramatically over the last 70 years and its range, which is now limited to parts of Scotland, Northern England, Northern Ireland and scattered sites in Wales, continues to contract. The main reason for its decline has been the spread of the alien grey squirrel (*S. carolinensis*). The Environmental Protection Act 1990 (133d) calls for the establishment of common standards throughout the UK for the monitoring of species.

Monitoring population trends is vital for forecasting how threatened populations respond to conservation management or changes in the environment (Macdonald, Mace & Rushton, 1998). The Species Action Plan for red squirrels recommends long-term monitoring in different parts of the species range within the UK to assess:

- i. population trends;
- ii. the impact of grey squirrels;
- iii. the effects of conservation management on local populations.

### *A1. Monitoring and survey techniques - general*

Censusing, surveying and monitoring populations of animals are three terms that have slightly different meanings, and their use depends upon the objectives of the study (see below). A census is the process of obtaining information about every member of a population – a complete count (Greenwood 1996). This should be contrasted with surveys in which information is obtained by sampling from only a subset of a population. Monitoring is the repeated sampling of a population to detect trends in numbers and distribution. To understand the conservation status of a species requires information on its distribution (location data in terms of presence and absence of a species) and estimates of abundance. Monitoring implies that it is repeated at the same places and that it should be carried out systematically (Macdonald, Mace & Rushton 1998).

Mammals are monitored for several reasons: determining absolute or relative numbers of a population or populations, determining trends in population numbers, determining distribution and habitat preference of species, guiding conservation efforts, managing introduced or problem species, setting hunting targets for game species, assessing the impact of pollution or road traffic on mammal populations as well as the effects of land use change or fragmentation (e.g. Battersby & Greenwood 2004, Fitzgibbon 1997, Hlavac 2005, Kataev 2005, Macdonald, Mace & Rushton 1998, Philcox, Grogan & Macdonald 1999, Sutherland 1996a). Table 1a illustrates the variety of methodologies for surveying mammal species and Table 1b gives further details of methods that have been used for squirrels and are described in Section A2.

Table 1 Examples of different types of survey methodologies and their application with a selection of mammal species. Also see Sutherland (1996b) for further examples. Note, for some species such as the otter more recent research has used infrared technology (de Leaniz *et al.* 2006) and Davison *et al.* (2002) suggest that surveys for elusive mammals such as rare carnivores should be based on a multi-evidence approach. This should involve DNA methods, cast hair identification, camera traps and sighting questionnaires.

Method	Species	Reference
Systematic survey of field signs: droppings and foot prints	Otter ( <i>Lutra lutra</i> )	Strachan & Jefferies 1996
Live trapping	Mice, voles and shrews	Flowerdew <i>et al.</i> 2004 Gurnell & Flowerdew 2006
Sightings appeal for distribution mapping (incl. use of road casualties)	Polecat ( <i>Mustela putorius</i> )	Birks & Kitchener 1999
Use of radioisotopes	Voles	Albov and Serbenuk 1991
Radiotracking	Voles, mice	Korpimaki <i>et al.</i> 1996
Hair-trapping Footprints and rafts	Mink and Polecat ( <i>Mustela vison</i> , <i>M. lutreola</i> & <i>M. putorius</i> )	Gonzalez-Esteban <i>et al.</i> 2006, Reynolds <i>et al.</i> 2004
Owl pellets	Small mammals	Love <i>et al.</i> 2000
Camera traps Hair-trapping (Fur snagging) Snow tracking	Pine marten ( <i>Martes martes</i> )	J. Birks pers. comm. Lynch <i>et al.</i> 2006 Zalewski 1999
Systematic live-trapping; Sightings, targeted questionnaires, road casualties; Hair-tubes; nest (drey) counts; Field signs and tracks Footprints	Squirrels ( <i>Sciurus vulgaris</i> & <i>S. carolinensis</i> )	Andr�n & Lemnell 1992, Bryce, 1997, Bryce <i>et al.</i> 1997, Brandl <i>et al.</i> 1991, Fitzgibbon 1997, Gurnell <i>et al.</i> 2001, 2004, van Apeldoorn <i>et al.</i> 1993 Wauters & Dhondt 1988
Hair-tubes	Shrews ( <i>Sorex araneus</i> , <i>Neomys fodiens</i> )	Pocock & Jennings 2006
Field signs Nest boxes	Common Dormouse ( <i>Muscardinus avellanarius</i> )	Bright <i>et al.</i> 1996
Constant effort searches using halogen spotlights, field signs: scats; sightings (incl. road kills)	Hedgehogs ( <i>Erinaceus europaeus</i> )	Jackson 2006 Jackson <i>et al.</i> 2004
Systematic survey for field signs (latrines, burrows, lawns, runways, feeding stations) Sightings	Water vole ( <i>Arvicola terrestris</i> )	Strachan <i>et al.</i> 2000
Pellet counts	Deer (e.g. muntjac <i>Muntiacus reevesi</i> , roe deer <i>Capreolus capreolus</i> )	Hemami & Dolman 2005
Systematic sett survey; Field signs, latrines (bait-marking),	Badger ( <i>Meles meles</i> )	Clements <i>et al.</i> 1988 Neal & Cheeseman 1996
Roosts and nurseries	Bats	Thomas & LaVal 1988

## A2. Survey and monitoring techniques for squirrels

Existing methods for surveying and monitoring red and grey squirrels have been described and considered in detail by Gurnell & Pepper (1994), and Gurnell *et al.* (2001, 2004) – also see [www.squirrelweb.co.uk](http://www.squirrelweb.co.uk). Specific problems in relation to surveying and monitoring squirrels have been covered in these papers, but will be returned to later. However, any assessment of monitoring techniques needs to take into account two important factors:

- 1) that the survey and monitoring methods should be able to detect presence and distinguish red and grey squirrels;
- 2) that the methods should take into account and minimise the risk of the transmission of squirrel pox virus (Rushton *et al.* 2000, Sainsbury *et al.* 2000, Tompkins *et al.* 2002) from one animal to another.

Table 1b. Current methods in relation to detection, its ability to distinguish species and the risk of squirrelpox virus (SQPV) transmission.

Method	Can it detect presence?	Can it distinguish species?	Risk of virus transmission?*	Comments
Single-catch Live trapping	Usually <sup>&amp;</sup>	Yes	Low <sup>§</sup>	<sup>&amp;</sup> Sometimes low capture probabilities (e.g. Gurnell 1987, 1996). <sup>§</sup> Traps need to be sterilised and kept clean. Requires training in catching and handling. Time consuming. Only way to validate other methods.
Visual surveys	Yes	Yes	No	Visibility problems in some types of forest habitat and times of the year. Frequently low detection rates.
Hair tube surveys	Yes	Yes	High	Possible red squirrel avoidance of tubes used by grey squirrels. Not tested in many habitat types.
Drey counts	Not always	No	No	Dreys sometimes difficult to detect. Squirrels may use dens.
Feeding transects	Yes	No	No	Only in conifer forests.
Whole maize bait	Yes	No	Low	Useful to check for squirrel presence as grey squirrel bite marks are very characteristic.
Nest boxes	Yes	Yes	High	Health and safety issues when erecting and inspecting boxes. Requires training in handling. Time consuming to inspect boxes.

\*The method of transmission of SQPV is not known; these risk levels must be treated with caution.

## **B. Aims**

The current project was commissioned by JNCC (lead agency) and PTES to build on existing knowledge to develop a monitoring strategy for red squirrels (and grey squirrels) across the UK. The aims were to carry out field studies in different regions within the UK to:

- (a) develop protocols to assess and validate known methods of surveying and monitoring that differentiate between red and grey squirrels and where possible reveal population trends;
- (b) investigate possible new survey and monitoring methods and, if feasible and effective, develop protocols as above;
- (c) make recommendations on the design of survey and monitoring programmes in the UK.

To this end, John Gurnell (Queen Mary, University of London) assembled a Monitoring research team comprising:

- Dr Peter Lurz, Dr. Steve Rushton and Dr. Mark Shirley (IRES, School of Biology, University of Newcastle-upon-Tyne) to cover Scotland and Northern England;
- Dr. Robbie McDonald, David Tosh, Oisín Sweeney (Quercus, Queen's University, Belfast) to cover Northern Ireland;
- Dr Sarah Cartmel to cover Wales.

## C. Study design

### *C1. Project timetable and methodological approach*

The two-year project started in March 2005 and continued through until March 2007. The Monitoring team met with other interested parties<sup>2</sup> at the University of Newcastle-upon Tyne on 20<sup>th</sup> January 2005. The project was discussed and preliminary plans made. It was decided that visual transects and hair tube surveys should be the two monitoring methods to be assessed because they can distinguish red from grey squirrels. The statistical power of the methods was also considered (see C.3). The results would be validated by live trapping. It was envisaged that three sites would be selected in each country according to tree species and the presence of red and/or grey squirrels and used over the two years of the study. Some sites were changed for logistical reasons, ongoing forest operations in the study sites and to adapt to changing local squirrel presence.

A standard programme of work was established for each field site involving replicated visual counts and hair tube surveys<sup>3</sup> with standard live trapping surveys carried out as a means to validate the results from the indirect methods. The field study programme took place between April and August 2005 and April and November 2006. The longer field season in year 2 was due to extensive trials of monitoring protocols using volunteers (see C.2 below).

### *C2. Investigating new monitoring methods*

In the first year, standard protocols for carrying out visual counts and hair tubes were adopted; unlike drey or cone counts, these methods can differentiate between red and grey squirrels. In the second year, the standard protocol was varied to try and improve squirrel detection rates. Based on the concepts of prebaiting and baiting traps and hair tubes, it was hypothesised that baiting visual transects could improve the detection of squirrels in the forest. Focal feeding points were discounted because they would bring squirrels to fixed points and increase the risk of transmitting disease between red and grey squirrels. Thus it was proposed to scatter bait along a band to either side of a visual transect in a standard manner. It was acknowledged that a similar technique could be used with hair tubes but not in red-grey areas. This could be tested in Scotland where greys are not yet infected with SQPV at the present time. It was also decided that baited visual transects should be tested in both the intensive study sites, where sightings could be compared with trapping data, and in the volunteer study. The volunteers would be briefed and given a detailed description of the proposed survey methodology (see Appendix). This work would be organised and carried out in close collaboration with the squirrel officers in Cumbria, Northumberland and the Borders (Southern Uplands Partnership).

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<sup>2</sup> Present: Professor John Gurnell (Queen Mary, University of London), Dr Robbie McDonald (Queen's University, Belfast), David Tosh (Queen's University Belfast), Dr Steve Rushton (Newcastle University), Dr Mark Shirley (Newcastle University), Dr Jessa Battersby (JNCC), Louise Bessant (NWT), Corrie Bruemmer (EN, Cumbria Team), Elly Hamilton (Red Squirrel in South Scotland Project), Sue Hearn (Red Squirrel in South Scotland Project), Dr Sarah Cartmel (self employed), Dr Peter Lurz (University of Newcastle)

<sup>3</sup> Hair tube surveys were not carried out in red-grey mixed sites because of the possible transfer of squirrel poxvirus from grey to red squirrel. Traps were cleaned between captures to minimise this possibility when carrying out the live trapping surveys.

### C3. Sample size and power

Using previously published data (authors' data; Gurnell *et al.* 2001) we examined the potential variation of survey data for the different methods. In order to determine required sample sizes that could reliably detect observed population changes we used the methodology of Kraemer & Thiemann (1987).

For hair tubes, we applied a binomial test; a tube is either used or it is not. Previous data from Wauchope Forest (Garson & Lurz 1998) indicated a population change from 42% of tubes used to 72% of tubes used. In order to detect a change of this magnitude with an 80% power, 21 hair tubes would be required in each line. For 90% power, 28 hair tubes would be needed ( $\Delta = 0.55$ , 2-tailed test, 5% level of significance).

Visual Transects are used to detect presence and to calculate a density. Previous data from Spadeadam Forest (Lurz *et al.* 1998), indicated a change in observed density from 0.19 squirrels per hectare to 0.28 squirrels per hectare, with a standard deviation of 0.13.

Using these data describing the variation of annual changes in squirrel density, it is possible to estimate the number of visual transects needed in order to achieve sufficient power to reliably detect changes in density.

Table 2 gives the number of visual transects needed for a range of changes in density and to different within site standard deviations ( $\sigma$ ). The bigger the population change in density and the smaller the standard deviation (variation between samples), the fewer visual transects are needed (Table 2).

Table 2 Sample size calculation for visual transects

Change in density (sq/ha)	$\sigma = 0.07$		$\sigma = 0.13$	
	Power 80%	Power 90%	Power 80%	Power 90%
0.1	<10	10	18	23
0.2	<10	<10	10	<10
0.3	<10	<10	<10	<10

As a result, sampling intensity for visual transects, hair tube lines and trapping (control) in this study were:

- Lines: 5 x 500 m lines walked 10 times (1 per day) at dawn over 2 weeks.
- Tubes: 30 tubes, left for 2 days and inspected 4 times over 2 weeks.
- Traps: 20 traps, prebaited for 1 week and trapped over 4 days.

## D. Study Sites

### D1. Intensive study areas

The study sites selected are shown in Table 3; further site details are shown in Appendix A. Seven sites were red only (albeit with grey squirrels encroaching at Whinfell), three were grey squirrel only and the rest were red/grey sites.

Table 3 Study Sites

Country	Site	Name	Year	Main Tree species	Red/Grey Squirrel	Forest Area (ha)
Wales	W1	Hafod Fawr	1 & 2	95% SS, 5% SP	G	460
	W2	Bron Banog	1	100% SS	R/G	5000
	W3	Bryn yr Wyn	1	90% NS, 10% SS	R/G	5000
	W4	Cefn Du	2	100% SS	R/G	5000
	W5	Pincyn Llys	2	56% Pine, 11% JL, 33% SS	R/G	5000
Northern Ireland	NI1	Ballycastle	1 & 2	61% SS, 15% HL, 10% NS	R/G	335
	NI2	Ballypatrick	1 & 2	90% SS, 10% LP & HL	R	1466
	NI3	Garry Wood	1 & 2	44% SS, 44% LP, SP, NS	G	566
Scotland	S1	Ae Forest 1	1 & 2	DF, HL, NS	R	9400
	S2	Ae Forest 2	1 & 2	70% SS, 30% HL	R	9400
	S3	Spadeadam 2	1 & 2	80% SS, 20% LP	R	5000
England	E1	Spadeadam 1	1 & 2	70% LP, 30% SS	R	5000
	E2	Whinfell**	1 & 2	100% SP	R	303
	E3	Hamsterley	1	OA, HL, BL	G	2000
	E4	Spadeadam 3	2	SS, NS, LP	R	5000

\*\* greys approaching

For logistical reasons and local forest operations, several sites were changed over the course of the two years: one of the pre-selected Scottish sites was abandoned and a second site set up over the border in England in Spadeadam (called Spadeadam 2 – Site S3); the site at Hamsterley was thinned and a third site was set up at Spadeadam (called Spadeadam 3); two sites in Wales were changed again as a result of thinning operations and to ensure squirrels were present, Bron Banog to Cefn Du (W4) and Bryn yr Wyn to Pincyn Llys (W5).

### D2. Volunteer survey sites

Volunteer surveys were carried out in a number of locations across the north of England and the Borders. Sites included the designated squirrel reserves of Thirlmere and Whinfell forest in Cumbria and Kyloe in Northumberland. In addition, volunteers carried out surveys in Duns Castle Nature Reserve (NT 782558), Dornevale (NT 735654), Cally Woods (NX 606551), Killiegowan Wood (NX 585577), Heathhall Wood (NY 009781), Bogrie Wood, Drumlanrig (NX 840980), Newhouse, Drumlanrig (NX850980), Dalbeattie Forest (NX 846585) and Swinnie Wood (NT 621151) in the Borders and Haredean Wood (NZ136927), Thrunton Wood (NU 080098) and Banktop, near Alnwick (NU 130100) in Northumberland.

## E. Methods

### *E1. Study area*

Study areas at each site were ~18 ha in area. Habitat data collection followed Gurnell et al. (2002). Ten measures were recorded in three 900 m<sup>2</sup> randomly placed (or stratified randomly placed) sample plots within each study area:

- SPECIES — tree species;
- AGE — tree age (years);
- THINNING — none or early (1), late (2), final (3);
- StD—stocking density (no. trees/ha);
- DBH—diameter at breast height(average of number of trees in each plot);
- NN — nearest neighbour distance between trees(average from up to 30 trees);
- FIELD COVER—% field vegetation cover to 1 m (average from 15 x 1 m<sup>2</sup> quadrats in each plot);
- FEEDING INDEX—an index of squirrel feeding intensity (the mean number of squirrel fed cone cores in 15 1 m<sup>2</sup> ground quadrats)- except broadleaf site;
- CC—an estimate of % canopy cover (average from 10 measures using a sighting tube);
- CONE INDEX based on the number of cones seen on edge trees of the site using binoculars ranging from 0 (none) to 3 (many) - average of 10 estimates for each site.

Records of weather were kept (cloud cover % - with sighting tube, max/min ground temperature over 24 hours and ambient temperature at time of working, a note of current and past rainfall, preferably taken at time of visual counts and at 9.00 on each day of working). An idealised layout of each study area is shown in Figure 1.

### *E2. Line counts*

These were started at first light and involved stopping for ~2min every 100 m. Different lines were rotated to start each day. The perpendicular distance of each squirrel sighting to the transect line was measured and recorded.

### *E3. Hair tubes*

Tubes 30 cm long with diameter 6.5cm, were fixed on trees at head height. Numbered wooden blocks (2.5x2.5x0.5cm) covered with double-sided sticky tape were placed 3 cm from end on underside of tube top. On each visitation, blocks were removed for later laboratory analysis. The tubes were baited. Hair blocks were examined later for the presence of red and/or grey hairs. No tubes were placed in red-grey sites.

### *E4. Trapping*

Traps were placed on platforms and sited in 'open' areas. Prebaiting was carried out in approved way (food<sup>4</sup>, including whole maize, was scattered, for 10-15 m around the trap tree, and on trap platform and in trap, when the trap was first set up. Bait was scattered 5 m around tree at the midweek prebait, and just in trap with a few grains of bait was placed at the entrance of the trap when it was set. Squirreled maize was noted when a trap was visited. Captured animals were weighed, sexed, and breeding condition noted. The squirrels were marked by clipping off some tail hairs. At mixed

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<sup>4</sup> At least 50% of the bait consisted of maize and made up with equal quantities of peanuts and sunflower seeds. Hazel nuts were placed in the trap, but not used for prebaiting on the ground.

species sites, the traps were cleaned with hypochlorite solution before and between captures. Morning trap rounds were started at about 10.00; evening trap rounds as late as possible.

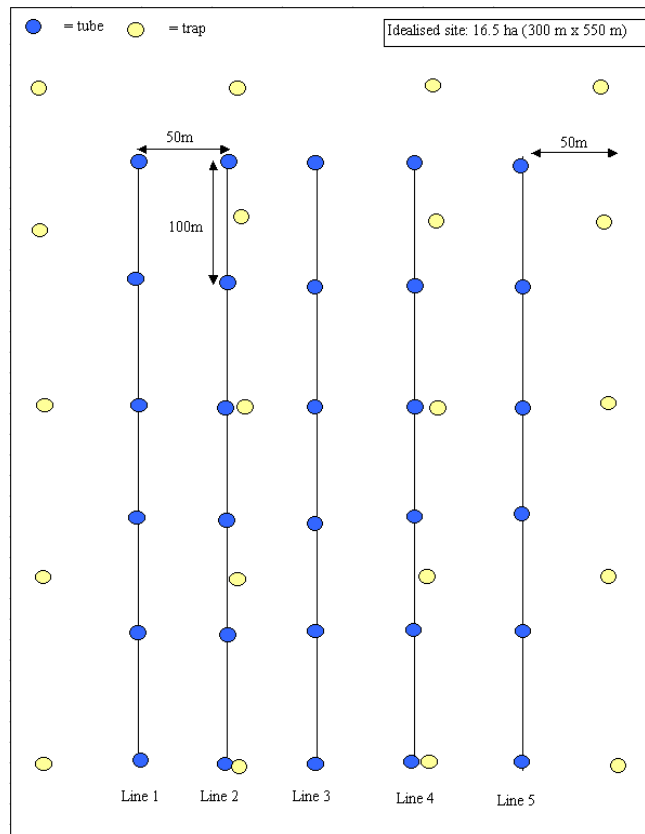


Figure 1 Idealised site layout

#### E5. Timetables

The timetables for years 1 and 2 are presented in the Appendix B.

#### E6. Baited visual transects and volunteer surveys

In order to test if detection of squirrels using visual transects in conifer forests could be improved, we have tested the use of diffuse baiting. This was carried out in the study sites and in order to increase sample size by volunteers in the North of England and Scotland.

After carrying out visual counts on unbaited lines, the lines should be prebaited for one week prior to repeating the counts. Prebaiting should be carried out by walking the line, stopping every 50 m (0 m, 50 m, 100 m etc), and throwing (scattering) 50g mixed squirrel food over a distance of approximately 10 m behind, 10 m in front and 10 m to either side of the stopping point. This procedure should be carried out on a Monday and repeated on the following Friday, before starting the visual counts the following Monday. More details and the information handed out to volunteers are given in the Appendix D.

## F. Results

### F1. Fieldwork results years 1 and 2

Trapping and hair tube surveys at Whinfell, site E2, were not carried out because of an outbreak of squirrel poxvirus disease in red squirrels (Table 4). We did not want to create point sources that could contribute to the spread of the virus. Together with the local wildlife rangers we carried out visual counts.

Table 4 Monitoring results for 2005: Hair tubes – number of tubes visited, MNA = minimum number of squirrels known to be alive from trapping, Visual counts = number of squirrels seen on transect lines (totals from 5 replicate early morning walks during each period). Hair tube surveys were not carried out in red/grey sites.

Site	Country	Species	Hair tube				MNA	Visual Counts	
			Period I	Period II	Period III	Period IV		VI	VII
S1	Scotland	Red	0	5	8	6	2	0	1
S2	Scotland	Red	3	6	4	10	3	0	0
S3	England	Red	0	0	5	6	4	0	1
NI1	Ireland	Red	0	2	0	1	1	0	0
NI2	Ireland	Red/Grey	-	-	-	-	3**	0	0
NI3	Ireland	Grey	0	0	0	1	0	0	0
E1	England	Red	0	0	2	8	2	0	0
E2	England	Red*	-	-	-	-	-	3	0
E3	England	Grey	0	10	0	0	15	2	5
W1	Wales	Grey	0	0	0	4	10	0	1
W2	Wales	Red/Grey	-	-	-	-	0	0	0
W3	Wales	Red/Grey	-	-	-	-	6**	0	0

\*first greys sighted and squirrel pox outbreak; \*\* grey squirrels –number corrected from 1<sup>st</sup> year report

In 2005, more hair tubes were visited in Scotland and England than Northern Ireland and Wales where, with the exception of site E2, there was a clear increasing trend in numbers of visits with time. The proportion of tubes visited varied between 0% and 50% and improved through time. On average, 2% of tubes were visited on visit 1-week 1, 14% visit 2-week 1, 12% visit 2-week2 and 23% visit 2-week2. The difference among visits was significant (Kruskal-Wallis  $H_3$ , adjusted for ties, = 8.26,  $P=0.041$ , with the significance arising from the comparison between visit 1-week 1 and visit 2-week 2, Conover-Inman post-hoc test,  $P=0.0071$ ). This indicates that it takes squirrels 2-3 days to locate and find the tubes. It is not clear whether more squirrels are attracted to the tubes or the same squirrels visit more tubes; it is likely to be a mixture of both effects. The results for site NI1, E3 and W1 demonstrate the fickle nature of monitoring studies, where tubes were only visited in one of the four periods.

Squirrels were trapped at all sites bar W2 and NI3 where there were few signs of squirrel activity.

Visual counts were disappointing with no sightings at seven out of the twelve sites on either of the two counts. This was surprising for site W3 where six grey squirrels were trapped. Most squirrels were seen at Hamsterley (site E2) - two greys in the first period and five in the second. However, each visual count period consisted of five replicate walks carried out on successive days, and so the return on the effort put in was very low. One red squirrel was seen at site E1 and one grey squirrel at site W1.

In 2006, the number of squirrels seen on transects showed an increase following baiting and this is analysed further in section F4 (see Table 5). However, there was no discernible relationship between the number of squirrels seen and the number of individuals trapped in the study sites.

Table 5 Monitoring results for 2006: Visual counts = number of squirrels seen on transect lines (totals from 5 replicate early morning walks during each period), results are given pre-baiting and post-baiting of the lines; MNA = minimum number of squirrels known to be alive from trapping,

Site	Country	Species	Visual counts		MNA
			Pre-baiting	Post-baiting	
S1	Scotland	Red	0	3	3
S2	Scotland	Red	0	0	4
S3	England	Red	1	-	-
NI1	Ireland	Red	0	0	0
NI2	Ireland	Red/Grey	0	0	0
NI3	Ireland	Grey	0	0	6
E1	England	Red	0	1*	5
E4	England	Red	0	-	-
W1	Wales	Grey	0	0	5
W4	Wales	Red/Grey	1	2	2 G
W5	Wales	Red/Grey	0	0	2R/4G

\* counts incomplete

Larger numbers of grey squirrels were trapped in the study sites compared to red squirrels (six greys in NI3: highest number of individuals trapped; four greys compared to two red squirrels in W5). The largest number of red squirrels was trapped in Northern England and Scotland, three to five red squirrels per site, compared to nought in Ireland and two in Wales). Overall the number of grey squirrels was lower in year 2 compared to numbers trapped in year 1 whereas there was an increase in the number of red squirrels trapped in S1, S2 and E1.

#### *F2. Hair tube results 2005*

There was no association between the mean number of tubes visited for all periods combined and the number of animals trapped in that site (Figure 2;  $r_s=0.394$ ,  $p=0.337$ ,  $N=8$ ).

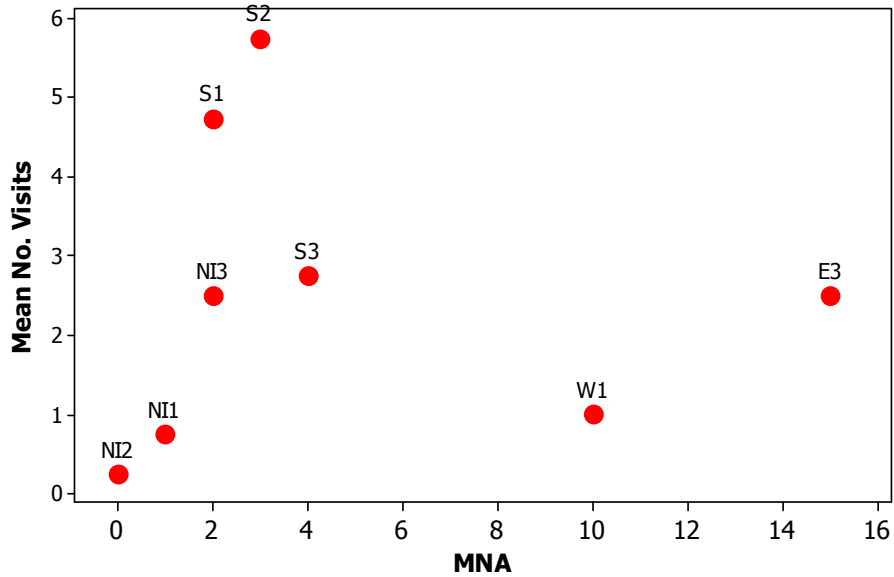


Figure 2 Scatterplot of the mean number of tubes visited and the number of squirrels trapped in the study sites (MNA). Site numbers as Table 4.

*F3. Analysis of visual counts in relation to habitat variables*

We carried out a logistic regression analysis (with Poisson error structure) of the number of squirrels seen during visual counts (total over 5 days) in relation to year, baiting, the proportion of Sitka spruce in a site and the collected habitat variables (see Appendix).

Significant negative relationships between the number of squirrels seen and the proportion of Sitka spruce (%) in the study sites (DF=39, Table 6), and between the number of squirrels seen and the nearest neighbour (NN) distance (DF=39, Table 7) were found. The higher the proportion of Sitka spruce in a study site the fewer squirrels were seen and the larger the distance between trees in a study site (measure of how thinned the site is) the more squirrels were recorded.

Table 6. Results of a logistic regression analysis with a Poisson error structure relating the number of squirrels seen on a visual count (total over 5 days) with the proportion of Sitka spruce in the study site.

Predictor	Coefficient	SD	Z	P<
Intercept	0.135	0.329	0.411	0.681
Proportion of SS	-0.026	0.008	-3.228	0.001

Table 7 Results of a logistic regression analysis with a Poisson error structure relating the number of squirrels seen on a visual count (total over 5 days) with the nearest neighbour distance (m) of trees within the study site.

Predictor	Coefficient	SD	Z	P<
Intercept	-2.677	0.8017	-3.342	0.001
NN	0.641	0.2527	2.539	0.011

#### F4. Baited transect lines and volunteer surveys

We tested the effect of baiting visual transects on the number of squirrels seen by comparing the results of the un-baited survey followed by the baited survey (only the first and last transect in each location was compared; sightings of squirrels during the bait visits were ignored in the analysis; Table 8). Data were analysed using a one-sided, non-parametric Wilcoxon test; there was a significant increase in the number of squirrels seen on the baited transects (Figure 3;  $N=26$ ;  $W=138$ ,  $P<0.002$ ).

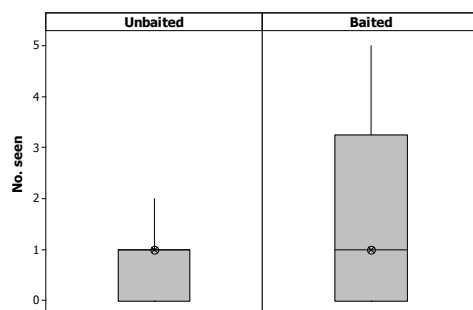


Figure 3 Box plot of the number of squirrels seen on matched-pair visual transect lines with 1: un-baited and 2: baited lines.

Table 8. Volunteer study sites and baited visual survey results

Site	Month	Habitat	Transect No.	No, Squirrels seen	
				Unbaited	Baited
Whinfell	July	Scots pine	1	1	1
Whinfell	July	Scots pine	2	0	2
Whinfell	July	Scots pine	3	1	0
Whinfell	July	Scots pine	4	2	3
Swinnie	August	Sitka spruce	5	0	0
Swinnie	August	Sitka spruce	6	0	0
Dalbeattie Forest	June	Mixed	7	1	2
Drumlanrig	June	Mixed	8	1	0
Bogrie Wood	June	Mixed	9	1	2
Heathall*	June	Mixed	10	0	0
Killiegowan	June	Deciduous	11	2	3
Cally Woods	June	Mixed	12	0	2
Dornevale	June	Deciduous	13	0	0
Kyloe Wood	June	Mixed	14	0	0
Kyloe Wood	June	Mixed	15	0	1
Haredean Wood	June	Mixed	16	0	0
Duns Castle	July	Mixed	17	0	0
Duns Castle	July	Mixed	18	1	0
Thrunton	August	Sitka spruce	19	0	1
Thirlmere	August	Conifer	20	1	5
Thirlmere	August	Mixed	21	1	1
Thirlmere	August	Deciduous	22	2	5
Thirlmere	August	Deciduous	23	1	4
Thirlmere	August	Mixed	24	1	5
Thirlmere	August	Mixed	25	1	4
Thirlmere	August	Mixed	26	2	4

\*Squirrels not known to be present

Few animals were seen in the intensive study sites (Table 5); no animals were seen before and after baiting at six sites, and there was an increase in numbers seen after baiting at three sites. Overall numbers seen do not reflect numbers present from live trapping, although squirrels seen matched the number of individuals trapped at sites S1 and W4 (Table 5).

The volunteer reports indicate that additional squirrel sightings were made during the baiting periods in between the first transect and the second, and the method certainly appears to increase overall detection of the presence of squirrels (Figure 4).

Overall, most squirrels were seen at the deciduous sites and least in Sitka spruce (Figure 5), although the differences among habitat types was not significant (Kruskal-Wallis  $H_3 = 5.25$ ,  $P = 0.154$ , adjusted for ties)

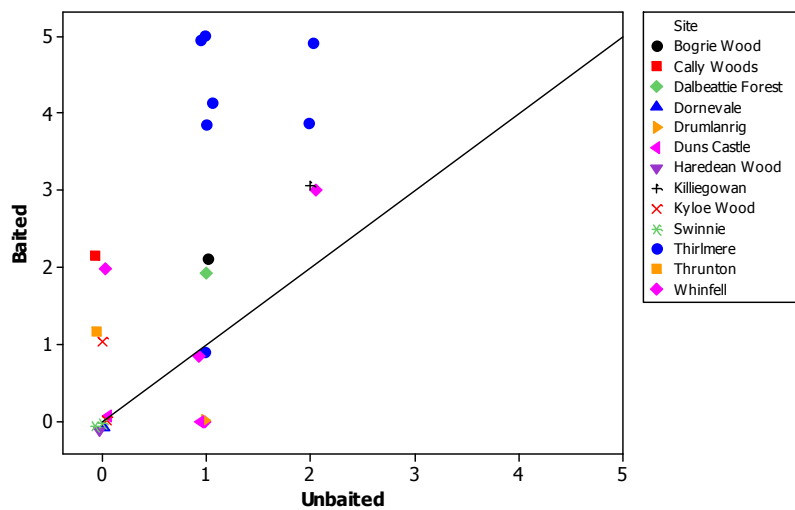


Figure 4 The relationship between the number seen at each site and whether the transect was baited or unbaited. The cross-diagonal is the line of equal counts; most points lie above the line indicating that more squirrels were seen on the baited transects. Note: the Heathall site was not included.

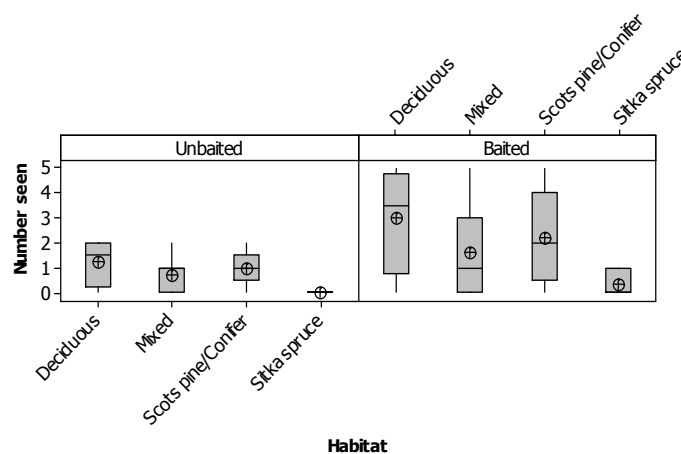


Figure 5 Boxplots of numbers seen in different habitat types before and after baiting the transects. The means are indicated by the circle-cross symbols.

## G. Discussion

### *G1. The main findings*

Live trapping results show that squirrels were trapped in 12 of the 13 sites studied over the two years, albeit captures were low in many of these sites. Site E2 (Whinfell) was known to have red squirrels but due to the SQPV outbreak at this site, no trapping was carried out. Trapped squirrels give the minimum information that squirrels were present, but not catching squirrels does not mean to say they were absent. Moreover, only 6 sites captured  $\geq 3$  squirrels in any one year: NI2 (Year 1), NI3 (Year 2), S1 (Year 2), S2 (Years 1, 2), S3 (Year 1), E1 (Year 2), E3 (Year 1), W1 (Years 1, 2), W3 (Year 1) and W5 (Year 2). Again, the number of squirrels trapped may not reflect the number of squirrels active in the study areas. However, trapping data compared to estimates of radio-tagged animals present within an area over three years suggested that most animals are trapped in low-density spruce habitats (Lurz 1995). In addition, the same individual red squirrels, for example, were trapped in this study in S2 in both years. Three were trapped in year 1 and the same 3 plus a new squirrel were trapped in year 2.

Hair tube surveys were carried out at eight sites. In seven of these sites, squirrels were captured over the four survey periods; and in all of these seven sites, squirrel presence was detected with hair tubes. However, only 53% of hair tube survey periods were successful. In contrast, visual counts only detected squirrels in four of the sites where squirrels were captured in Year 1 and three in Year 2. Overall, hair tubes were better than visual counts at detecting presence based on trapping results, but neither method was particularly economic in terms of effort. None of the data are sufficient in terms of quality or quantity to extrapolate to animal densities with any accuracy.

The trials of baited transect lines in the 2<sup>nd</sup> year of the study using volunteers indicated that this method significantly increases detection of squirrels. However, the comparison of visual and baited transect lines in the study areas clearly showed that the number of squirrels seen does not relate to the number of squirrels trapped in the sites. This baited line method requires more effort when compared to unbaited visual transects since volunteers are present three times as often (two baiting walks plus one walk to detect squirrels).

All methods used to monitor squirrels (Table 1b) rely on direct sightings (which are sporadic and low in number), field signs (e.g. cones, feeding remains or dreys) or hairs left on pads in hair tubes. Such data collected on squirrel presence are likely to vary significantly both spatially within a site and temporally between sample periods, seasons or years because of changes in numbers and distribution of squirrels, especially as they track tree seed food supplies (Gurnell 1987, 1996, Lurz 1995, Lurz *et al.* 1996). It is difficult to calculate squirrel abundance accurately because of this patchiness in detection of squirrel presence. The results of the power analyses carried out as part of this study emphasised the inherent limitations in the available squirrel monitoring methods. The larger the variation the more transect lines would be required to accurately detect a population change, which has implications on monitoring effort (see later).

Overall, detection rates using visual transects (baited or unbaited), hair tubes and trapping were low and the data, although providing information on presence of red or grey squirrels, were insufficient to provide estimates of indices of their abundance.

### *G2. Squirrel survey and monitoring in UK*

Data on the distribution and abundance of species play an important part in understanding and detecting changes in our local environment. They inform the establishment of conservation priorities, help assess the impacts of human or management activities and indicate the spread of introduced alien species (Battersby & Greenwood 2004, Harris & Yalden 2004). There is therefore a need to consider the effort required to obtain reliable data at the appropriate scale and the assumptions different survey methods are based on. A UK mammal monitoring network is currently being set up to provide a co-ordinated programme for the collection of surveillance and monitoring data (Battersby & Greenwood 2004).

Monitoring for squirrels in relation to conservation efforts encompasses two different types of data:

1. distribution data for red and grey squirrels at local, regional and national scales;
2. local data on red (or grey) squirrel abundance and population trends.

Distribution data either at regional or national scale are usually based on sightings recorded at 1 km<sup>2</sup> resolution (Lurz *et al.* 2005) and these are submitted by the general public or by landowners to Wildlife Trusts or local record centres (e.g. Tullie House Museum, Cumbria). Monitoring within some sites may also provide an index of population trends over time. Red squirrels are monitored for presence (e.g. to update warfarin map) and to monitor population fluctuations in some sites in relation to local management or perceived hazards (e.g. grey squirrel arrival, large scale windthrow or felling operations). Grey squirrels are monitored to determine range expansion and possible disease spread in order to target control efforts for red squirrel conservation (Gurnell *et al.* 2006). Note: strategy for controlling grey squirrels for tree damage prevention is not the same as controlling them for red squirrel conservation.

### *G3. Use of hair tubes and visual counts*

Methods for monitoring squirrels include drey counts, feeding transects, whole maize bait, nest boxes, hair tubes and visual transects (Table 1b). In this study we focused on visual transects and hair tubes as these two methods distinguish between red and greys squirrels (Gurnell *et al.* 2001). Both methods make a number of assumptions (e.g. Gurnell *et al.* 2001):

Assumptions of visual counts.

1. Squirrels directly on a line will never be missed – however, it is easy to miss squirrels on branches above the observer, especially in dense canopy e.g. spruce plantations;
2. Squirrels do not move in relation to observer and none are counted twice – it is possible that some individuals may move through the forest and be counted twice, especially if they react to the presence of the observer;

3. Distances and angles are measured without bias, sightings are independent events, i.e. seeing one squirrel does not influence probability of seeing another – estimating distance can be difficult in forests.

#### Assumptions of baited transects for visual counts

1. The bait does not attract animals from outside the study area, but simply makes residents “more visible” – the challenge is to bait just long enough with as little bait as possible to make resident squirrels “visible” but not draw animals in (e.g. to only use a small quantity of bait for a few days);
2. The presence of bait does not increase the probability of red and grey squirrels coming into contact and the risk of disease spread – bait should therefore be diffusely distributed in order to minimise the risk.

#### Assumptions of hair tubes

1. When used to estimate densities in conifer plantations, the bait does not attract animals from outside the study area – as in baited transects it is important to bait with as little bait as possible (one handful of bait scattered in and around hair tube once at the beginning of survey).
2. The number of tubes used by squirrels at a site is related to squirrel numbers at that site, and so numbers or relative numbers can be estimated – at high densities all tubes may show squirrel hair and the hair tube transect line or grid may be saturated. Studies here are needed on the density of tubes needed and how long they should be left between inspections.
3. Squirrels do not learn to associate food with the tubes - data collected may differ between the first and subsequent surveys.
4. In areas where both species are present, the current assumption is that the use of tubes by grey squirrels does not deter red squirrels. In other words, the presence of grey squirrels does not mask the presence of red squirrels and the presence of the latter can still be detected.

Hair tubes are labour and equipment expensive and require training in identifying the hair of the two squirrel species. They are good for detecting the presence of squirrel species and if calibrated can provide an index of population trends.

The results of our study indicated the utility of visual transects (without bait) is limited to open woodlands with a low proportion of spruce. They work well, for example, in open pine woodlands typical of the Sefton area and Whinfell in Cumbria. Baited transects significantly increased the detection rate of squirrels but are more labour intensive. The protocol adopted in this study is easy to use and lends itself to be applied in areas where volunteers are willing to assist with the monitoring.

#### *G4. Population trends through time and space and squirrel monitoring*

This study was too short to study population trends through time and the data were too few to look at spatial synchrony in population indices. Survey methods can be used to determine presence, and they have been successfully used for recording the changing distributions of red and grey squirrels in North Italy (S. Bertolino pers. comm.). However, it is important to note that squirrel population size in any one area can change markedly from one year to the next as they track tree seed food abundance

(Gurnell 1987). For example, Gurnell (1996) noted a 6-fold difference in the density of grey squirrels from one year to the next in deciduous woodland in southern England and Lurz (1995) reported a 34-fold difference in food availability and a complete disappearance of red squirrels from some upland conifer sites in response to low seed crops. Overall, densities of squirrels can be low, especially in conifer and especially in Sitka spruce plantation forest (e.g.  $\ll 1 \text{ ha}^{-1}$ ). These annual changes in number and low densities mask trends and make prediction of future population levels difficult.

Thus we put forward for discussion that managers should and in fact can only 'manage' squirrel carrying capacity and not red squirrel populations; grey squirrel populations can be controlled of course. This can be done by considering the age, species mix and forest size of the forest in question and forest management can be directed to make the forest more favourable for red squirrels and less favourable for greys (Gurnell & Pepper, 1993). This can be done by considering stock maps when available (i.e. a desk top study), together with a broadscale field survey (Smith, 1999). This type of survey is straightforward and involves walking through the different blocks of woodland stopping every 50 m or so and recording information about tree species, age, density and potential seed crops, and squirrel signs such as dreys and feeding remains. This should provide two simple subjective indices: one about the potential squirrel carrying capacity (denoted  $K$ ) of the forest in question (low, moderate or high), and the other about current squirrel occupation of the forest (few signs, some signs, many signs). In the case of red squirrels, where  $K$  is low or moderate, management may be undertaken to increase  $K^5$ , for example, by modifying harvesting and restocking prescriptions (Gurnell & Pepper 1993, Gurnell *et al.*, 2002, Lurz *et al.* 1998, Pepper & Patterson 1993). On the other hand, in the case of grey squirrels and where  $K$  is high, forest management may be undertaken to decrease  $K$ . Following from this; we believe that red squirrel populations can only be monitored on a presence basis or in the form of a simple index.

Furthermore, to defend red squirrel forests against grey squirrel intrusion, grey squirrel immigration should be blocked by targeted control in previously identified sites within forest buffer zones. This will require monitoring buffer zones for grey squirrel presence, and structured or unstructured visual surveys are the easiest way to do this, although hair tubes may be useful in areas favoured by grey squirrels, such as broadleaf/mixed copses and spinneys (Gurnell *et al.*, 2006). In addition, it may involve a public information campaign and the setting up of a sightings database or the use of a local records centre for the collections of squirrel records on a regional basis.

## **H. Future research**

The experience from Whinfell and the SQPV outbreak during this study has highlighted the limitations of existing monitoring methods with regard to problems of disease. Hair-tubes and trapping, for example, may contribute to disease spread. Visual transects are unsuitable to provide a population estimate in denser woodlands and cone transects, as well as drey counts, do not distinguish between red and grey

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<sup>5</sup> This may not be the case where extensive Sitka spruce plantations, typically of low carrying capacity, are believed important as a grey squirrel deterrent.

squirrels. Monitoring of red squirrels once grey squirrel are present in an area is therefore difficult.

Baited transects significantly increase the detection of squirrels compared to visual transects without bait. This makes them a useful method that can be used with volunteers, for example, in spruce dominated woodlands. However, they do not at present provide a reliable estimate of population density and insufficient work has been done to assess their power to detect statistically true changes in numbers when they occur (see below). Nor have they been tested in areas where both red and grey squirrels are present. There is a need to further refine this method, for example, to determine which is the most effective period of baiting before carrying out the survey, and to determine if it can be adapted to provide population estimates or a population index over time. More general baiting of the area around hair tubes could also be profitable, but would require detailed study. Detailed research on using novel methods (e.g. thermal imaging, and Table 1a) to survey and monitor squirrels would seem fanciful, time-consuming and expensive with our present state of knowledge.

There is a need to develop a methodology to monitor the impact of a SQPV outbreak on a local red squirrel population within a squirrel reserve or priority woodland. Mortality rates of local red squirrels, particularly in dense spruce plantations, may go unrecorded following the introduction of the disease. Detecting the duration and impact of outbreaks on the local population may have to be addressed by new protocols (e.g. transect lines looking for diseased or dead squirrels in areas within reserves where grey squirrels have been seen).

In terms of general ecology, there is a need to know more about the population and spatial dynamics of grey squirrels in conifer woodlands and movement patterns in poor quality or highly fragmented habitats that occur, for example, in buffer zones around red squirrel reserve areas.

## **I. The way forward**

### *II. General considerations*

#### II.1. Reasons for carrying out work

Survey and monitoring for squirrels should consider, as a first step, the reasons for carrying out the work, the types of data required and the resources (money, personnel) available.

#### II.2. Presence data, distribution maps and national/regional/local schemes

Presence data based either on structured or un-structured (namely *ad hoc*) visual surveys, public sightings, and the use of whole maize grain to detect the presence of grey squirrels should be used to produce up-to-date distribution maps on a national and regional level and on a local level to target grey squirrel management within-buffer zones of red squirrel reserves or priority woodlands. Hair tubes can also be used if there are sufficient time, resources and experienced surveyors available.

Following Tonkin (2005), we propose that a national survey scheme based on sightings, supplemented where appropriate with visual transect surveys, to determine the presence of red and grey squirrels should be implemented. Targeted hair tube

surveys may also be used if experienced personnel are available. This information would provide distribution maps on a national and regional level (e.g. to inform on grey squirrel spread and enable warfarin-use maps to be updated). For this purpose there is a need for a dedicated record centre or centres and the setting up of an agreed network to share squirrel records (e.g. between northern England and Scotland). At present squirrel records are held by many different organisations in a non-systematic manner and are shared willingly but not consistently; there is no centre that actively collates all information and which can be approached for information.

On a regional level there is a need to detect grey squirrel population expansion. In particular in the north of England-Borders region, information on grey squirrel spread and the concomitant spread of SQPV is important to inform efforts to limit the spread of the disease into Scotland. This should be done through public information campaigns and the collection of sightings and through targeted visual transects and hair tubes where information on grey squirrel presence is sparse.

On a local level within red squirrel reserves and their buffer zones there is a need for a concerted effort to obtain frequent grey squirrel sightings and to determine grey squirrel presence in order to target grey squirrel control efforts (Gurnell *et al.* 2006).

### 11.3. *Indices of population size*

Population estimates or indices of numbers for red squirrels may only be needed in reserves or priority woodlands where extensive forest management operations or disturbances are taking place (e.g. felling operations) in order that these activities can be adjusted to minimise impacts. In these situations, standard, repeat surveys should be carried out at yearly or six-monthly intervals in the same places based on structured visual counts or as an integrated monitoring programme using some or all of: visual counts, hair tubes, cone line transects in conifer forests, and drey counts. We would recommend baited visual transect lines where possible to increase detection rates. We suggest that baiting should be carried out as describe above, that is by walking the line, stopping every 50 m (0 m, 50 m, 100 m etc), and throwing (scattering) 50g mixed squirrel food over a distance of approximately 10 m behind, 10 m in front and 10 m to either side of the stopping point. Further work is required on the most effective period of baiting, but we would suggest that this could be carried once, two-three days before carrying out the visual counts (in contrast to the seven days used in these studies).

### 12. *What population decline can we accurately detect?*

Confidence in detecting a decline in squirrel population size between years is dependent on the ability to detect statistically a true decline when it occurs (i.e. statistical power) and to reject an apparent change where there is none (i.e. statistical significance). The commonly accepted values for power and significance are 80% and 5% respectively. Assuming that the current sampling methodology (Section E) stays constant, what magnitude of change are we able to confidently predict?

To answer this question, we artificially decreased the population size by a certain percentage (12.5%, 25%,...87.5%) between years, and then calculated the power of a one-tailed test (at the 5% level of significance) to detect that change.

For visual transects we used a paired two-sample t-test to detect the decline in population size. In this case, the sample size is 20 (that is, 10 in each of two years). The magnitude of change was calculated as:

$\delta = (\mu_1 - \mu_2) / \sigma$ , where  $\mu_1$  is the observed population size (Section C3),  $\mu_2$  is the artificially-reduced population size, and  $\sigma$  is the within-site standard deviation. The value for effect size ( $\Delta$ ) was calculated from  $\delta$  for a two-sample t-test using the method of Kraemer & Thiemann (1987). The calculated values for effect size are plotted against number of samples in Figure 6A.

For hair tubes, a binomial test is required to detect year-on-year changes in population size. We used the equation of Lurz & Garson (1998) to convert the percentage of tubes used ( $\pi_1$ ) to an estimate of squirrel population size. These were then artificially reduced by the desired population decline, and then back-transformed into predicted percentage of tubes used ( $\pi_2$ ). The sample size was 60 (30 in each of two years). For a binomial test, the magnitude of change was calculated as:

$\delta = 2(\arcsin \pi_1^{1/2} - \arcsin \pi_2^{1/2})$ . The value for effect size ( $\Delta$ ) was calculated from  $\delta$  for a binomial test using the method of Kraemer & Thiemann (1987). The calculated values for effect size are plotted against number of samples in Figure 6B.

Visual transects (Figure 6a) require a greater than 50% decline in squirrel population size in a year to give the requisite power of 80%. A 25% decline in population size has a less than 50% power. This analysis is based on the assumption that the pooled standard deviation between years remains constant, which is unrealistic given the large declines in population size needed to achieve sufficient statistical power. It is likely that large declines in population size will result in a greater pooled standard deviation, giving less power for the same sample size. However, the heterogeneity of habitat use of populations before and after the decline will have a large impact on the pooled standard deviation, and an increase in standard deviation may not necessarily occur.

Hair tubes (Figure 6b) have much more statistical power to detect changes in population size: a 25% decline in squirrel numbers has a greater than 95% power. However, because of the methodology used to calculate squirrel numbers based on hair tube hits, the heterogeneity of habitat use is ignored. The results, therefore pertain to a decline within the area sampled by the hair tube grid. Nevertheless, we can be confident that the power to detect a significant change in population size is accurately estimated with this method because the hair tubes have a greater hit rate with respect to squirrels than visual transects (Section G), and the probability that a tube will be used is strongly correlated to the local population size (Lurz & Garson 1998). Given this, hair tubes (Figure 6b) provide sufficient power to detect smaller changes in population size (a 25% population decline can still be detected with >95% power). This result still holds true for a reduced effort employing only 20 tubes per line (40 tubes pooled; Gurnell *et al.* 2001). It is worth noting that hair tubes are only effective in low-density sites such as these; where the squirrel population is high, the hair tubes may saturate and population sizes cannot be accurately estimated.

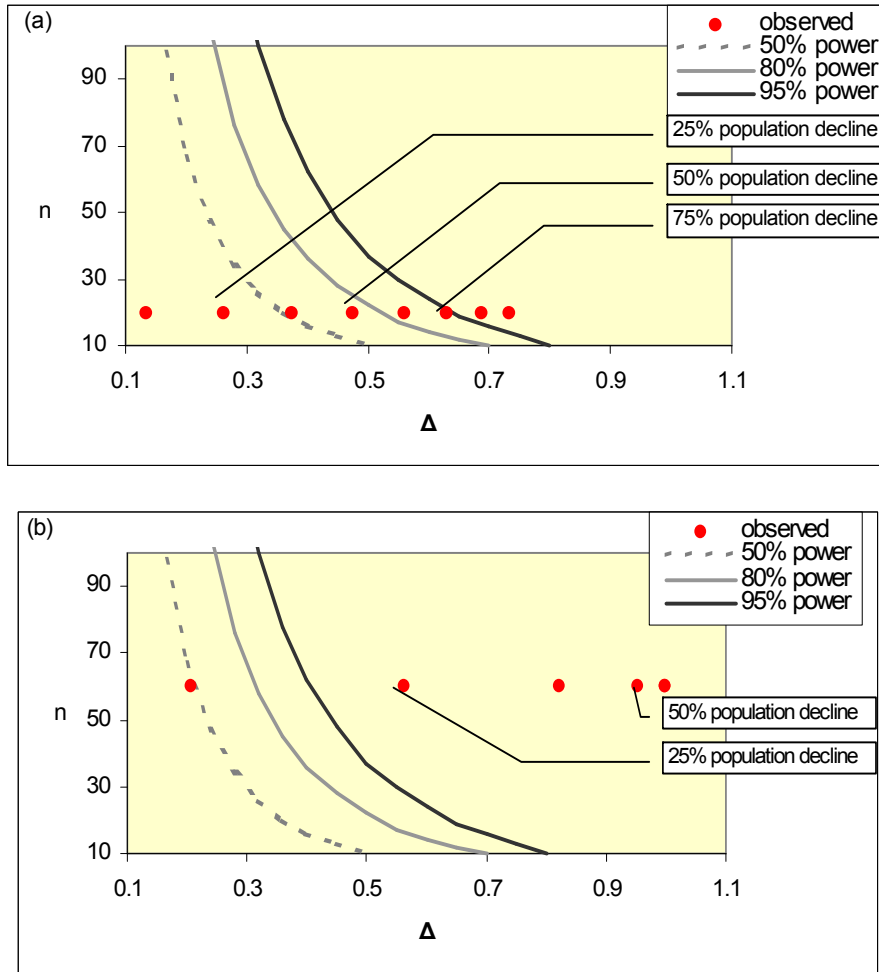


Figure 6 Power curves for one-tailed statistical tests, showing: (a) results of visual transects; and (b) hair tubes.  $n$  = the pooled number of samples (60 visual transects or 20 hair tubes) over two years.  $\Delta$  = the statistical effect size, a measure of the magnitude of population change.

Obviously, when planning to first survey a forest, no information is available on current squirrel numbers, although a broadscale survey will provide some information. To survey for presence absence, baited visual transects at a density of one 1000 m line per 10 ha can be used (see Gurnell *et al.*, 2001). For changes in population indices, 30 1000 m baited transects should be used in the spring of each of two years. Hair tubes for presence surveys can be set up in lines or grids with 100 m to 200 m spacing between tubes (see Gurnell *et al.*, 2001). Grids of 20 tubes should be used in the spring of each of two years to monitor an annual change in population indices

### 13. Summary recommendations

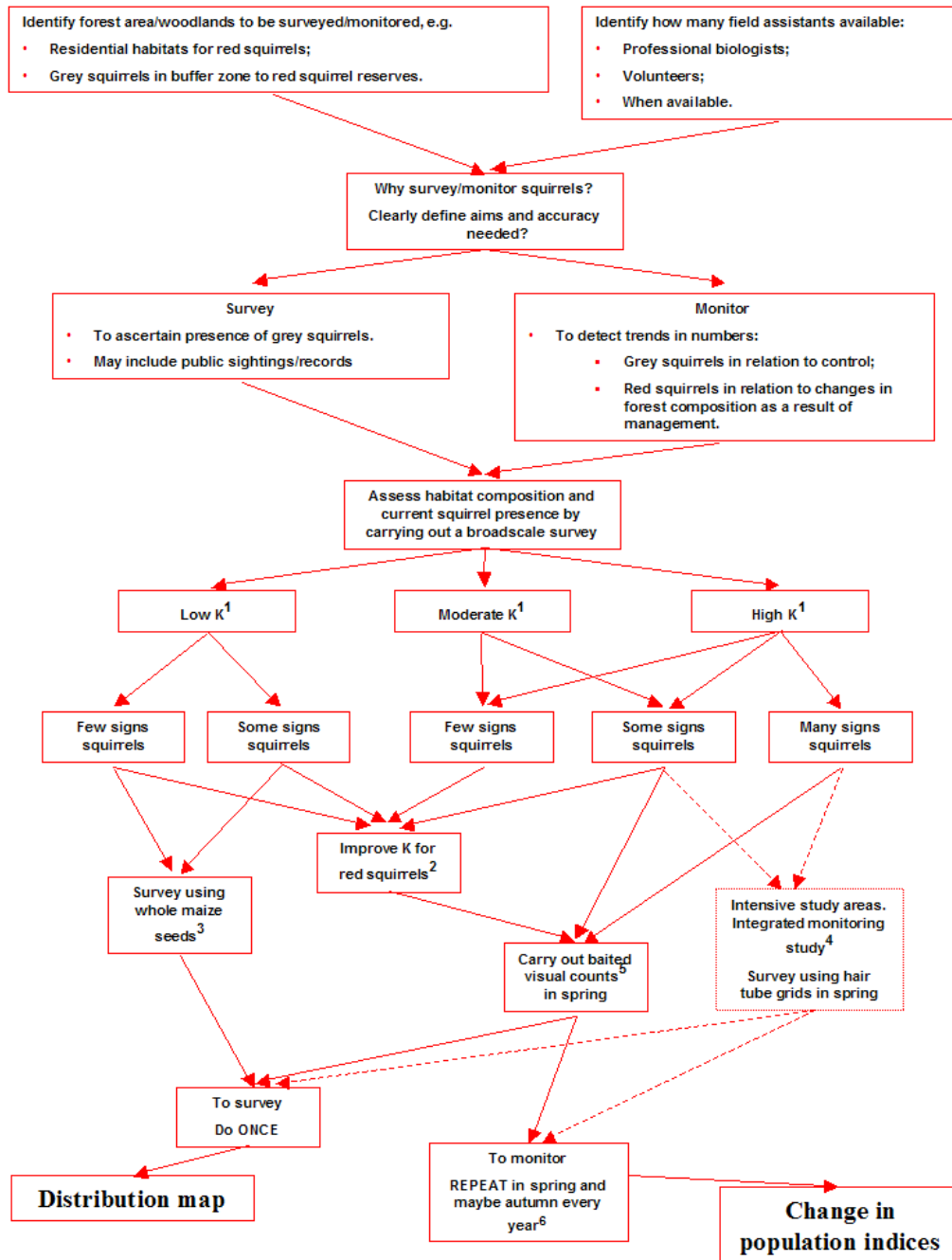


Figure 7 Flow diagram on stages and considerations for surveying and monitoring squirrels in UK. See below for numbered comments

<sup>1</sup>Broadscale survey to assess habitat composition with respect to squirrel carrying capacity (K) for squirrels, and signs of current usage. With the assistance of maps where possible, all blocks of woodland >15 years old are traversed and notes made on tree species present and their relative age and abundance, the presence of tree seeds or whether the trees and signs of squirrels based on dreys and feeding

remains. (Blocks of woodland <15 years are unlikely to hold resident squirrels.) This is simply done by stopping every 50 m or so and taking quick noting where the signs are few moderate or abundant. Based on trees present, the potential carrying capacity for squirrels can be recorded as low, moderate or high. Sign of squirrels can be recorded as low, moderate or many.

<sup>2</sup>Assess and improve carrying capacity for squirrels in medium/long term if critical by changing age structure and species composition. However, for red squirrel reserve areas vulnerable to grey squirrel incursion, maintain high density of Sitka spruce. Note that carrying capacity can be sufficient but squirrel numbers low due to poor seed crops.

<sup>3</sup>Use whole maize seed to detect for presence of grey squirrels. The maize can be left in small piles every 50 m or so (see Gurnell *et al.* 2001).

<sup>4</sup>Hair tube grids – use these for more intensive studies, maybe integrated with visual counts, drey counts, cone feeding transects and nest boxes (see Gurnell *et al.* 2004). Grids should consist of 20 tubes at 100 m to 200 m spacing between tubes (after Gurnell *et al.*, 2001) and set up for use at 12 monthly intervals to detect changes between years (see Section I.2) – Figure 6b illustrates that sufficient power is retained if the sampling effort is reduced from 30 tubes to 20 tubes per year. Note: lines of tubes may be used for presence surveys.

<sup>5</sup>Use baited visual counts in spring at a density of one 1000 m line 10 ha<sup>-1</sup> (after Gurnell *et al.*, 2001) for presence, or up to 30 lines in the spring of each of two successive years to detect a change in numbers between years (see Section I2).

<sup>6</sup>Spring visual counts are best for squirrels at the time when natural food supplies are low and broadleaf trees are without leaves, thus improving visibility in the canopy. However, post-breeding numbers could also be recorded in the autumn if necessary.

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## Appendix A Further site details<sup>6</sup>

Country	Scotland	Scotland	Scotland	England	England	England	Wales	Wales	Wales
Site No.	1	2	3	1	2	3	1	2	3
Site	Ae 1	Ae 2	Spadeadam 2	Spadeadam 1	Hamsterley	Whinfell	Hafod Fawr	Bron Banog	Bryn yr Wyn
<b>Squirrel Species</b>	Red	Red	Red	Red	Grey	Red/Grey	Grey	Red/grey	Red/grey
<b>Tree species</b>	DF, L, NS	SS, L	SS, LP, NS	SS, LP	Oak, Larch, BI	SP/DF/Larch	SS, SP	SS	NS
<b>Age</b>	59	46	47	43	68	>40	45	56	56
<b>Thinning</b>	2	1	1	1	1	2	2	3	3
<b>Stocking Density</b>	211	358	417	331	300	242	113	32	57
<b>Nearest Neighbour (m)</b>	4.18 (±1.30)	2.47 (±0.78)	1.68 (±0.60)	2.21 (±0.61)	3.57 (±1.02)	4.24 (±1.00)	1.68(±0.45)	3.97 (± 0.88)	2.49 (± 0.67)
<b>Diameter at Breast Height</b>	1.28 (±0.23)	0.74 (±0.20)	0.66 (±0.16)	0.64 (±0.18)	1.06 (±0.42)	1.18 (±0.25)	0.91(±0.26)	1.22 (±0.0.29)	0.94 (±0.0.20)
<b>Cone Index</b>	0.29	0.58	0	0.08	N/A	0.13	0	0	0
<b>Feeding Index</b>	1.2 (±1.39)	0.33 (±0.52)	0.18 (±0.48)	1.08 (±3.32)	N/A	1.36 (±1.85)	0	0	0.33
<b>Canopy Cover</b>	37	78.8	59.7	78	58.6	27	90	73	90
<b>Field Cover Plants</b>	Bramble, brackedn, grasses	Mosses	Mosses, Polytricum, Sphagnum	Mosses, Polytricum, Sphagnum	Grasses, mosses, bramble	Bracken, bramble, grasses	Moss Polytrichum, Fern Dryopteris, Juncus spp.	Fern, moss, SS seedlings, bramble	Moss Polytrichum, Fern Dryopteris, bramble

<sup>6</sup> Data for Northern Ireland currently being compiled.

## Appendix B Timetable of work Year 1

Week	Day	SITE 1 RED	SITE 2 RED-GREY	SITE 3 GREY
1	1	PREPARE SITE	PREPARE SITE	PREPARE SITE
1	2	PREPARE SITE	PREPARE SITE	PREPARE SITE
1	3	PREPARE SITE	PREPARE SITE	PREPARE SITE
1	4	PREPARE SITE	PREPARE SITE	PREPARE SITE
1	5	PREPARE SITE	PREPARE SITE	PREPARE SITE
2	6	WALK 1 Lines 1-5 Replicate 1		PREBAIT TRAPS
2	7	WALK 1 Lines 1-5 Replicate 2		
2	8	WALK 1 Lines 1-5 Replicate 3		PREBAIT - Check for activity
2	9	WALK 1 Lines 1-5 Replicate 4		
2	10	WALK 1 Lines 1-5 Replicate 5		PREBAIT - Check for activity
3	11	TUBES BAIT	WALK 1 Lines 1-5 Replicate 1	TRAP Set am (check activity) Round 1 pm
3	12		WALK 1 Lines 1-5 Replicate 2	TRAP Rounds 2 and 3
3	13	TUBES CHECK 1 REBAIT	WALK 1 Lines 1-5 Replicate 3	TRAP Rounds 4 and 5
3	14		WALK 1 Lines 1-5 Replicate 4	TRAP Rounds 6 and 7
3	15	TUBES CHECK 2	WALK 1 Lines 1-5 Replicate 5	TRAP am Round 8; remove traps
4	16	PREBAIT TRAPS		WALK 1 Lines 1-5 Rep. 1
4	17			WALK 1 Lines 1-5 Rep. 2
4	18	PREBAIT - Check for activity		WALK 1 Lines 1-5 Rep. 3
4	19			WALK 1 Lines 1-5 Rep. 4
4	20	PREBAIT - Check for activity		WALK 1 Lines 1-5 Rep. 5
5	21	TRAP Set am (check activity) Round 1 pm	PREBAIT TRAPS	WALK 1 Lines 1-5 Rep. 6
5	22	TRAP Rounds 2 and 3		WALK 1 Lines 1-5 Rep. 7
5	23	TRAP Rounds 4 and 5	PREBAIT - Check for activity	WALK 1 Lines 1-5 Rep. 8
5	24	TRAP Rounds 6 and 7		WALK 1 Lines 1-5 Rep. 9
5	25	TRAP am Round 8; remove traps	PREBAIT - Check for activity	WALK 1 Lines 1-5 Replicate 10
6	26	WALK 1 Lines 1-5 Replicate 6	TRAP Set am (check activity) Round 1 pm	TUBES BAIT
6	27	WALK 1 Lines 1-5 Replicate 7	TRAP Rounds 2 and 3	
6	28	WALK 1 Lines 1-5 Replicate 8	TRAP Rounds 4 and 5	TUBES CHECK 1 REBAIT
6	29	WALK 1 Lines 1-5 Replicate 9	TRAP Rounds 6 and 7	
6	30	WALK 1 Lines 1-5 Replicate 10	TRAP am Round 8; remove traps	TUBES CHECK 2
7	31	TUBES BAIT	WALK 1 Lines 1-5 Replicate 6	TUBES BAIT
7	32		WALK 1 Lines 1-5 Replicate 7	
7	33	TUBES CHECK 3, REBAIT	WALK 1 Lines 1-5 Replicate 8	TUBES CHECK 3, REBAIT
7	34		WALK 1 Lines 1-5 Replicate 9	
7	35	TUBES CHECK 4	WALK 1 Lines 1-5 Replicate 10	TUBES CHECK 4

## Timetable of work Year 2

Week	Day	SITE 1 RED	SITE 2 RED-GREY	SITE 3 GREY
1	1	PREPARE SITE		
1	2	PREPARE SITE		
1	3	PREPARE SITE		
1	4	PREPARE SITE		
1	5	PREPARE SITE		
2	6	WALK 1 Lines 1-5 Replicate 1	PREPARE SITE	PREPARE SITE
2	7	WALK 1 Lines 1-5 Replicate 2	PREPARE SITE	PREPARE SITE
2	8	WALK 1 Lines 1-5 Replicate 3	PREPARE SITE	PREPARE SITE
2	9	WALK 1 Lines 1-5 Replicate 4	PREPARE SITE	PREPARE SITE
2	10	WALK 1 Lines 1-5 Replicate 5	PREPARE SITE	PREPARE SITE
3	11	PREBAIT LINES	WALK 1 Lines 1-5 Replicate 1	PREBAIT TRAPS
3	12		WALK 1 Lines 1-5 Replicate 2	
3	13		WALK 1 Lines 1-5 Replicate 3	PREBAIT - Check for activity
3	14		WALK 1 Lines 1-5 Replicate 4	
3	15	PREBAIT LINES - Check for activity	WALK 1 Lines 1-5 Replicate 5	PREBAIT - Check for activity
4	16	WALK 1 Lines 1-5 Replicate 1	PREBAIT LINES	TRAP Set am (check activity) Round 1 pm
4	17	WALK 1 Lines 1-5 Replicate 2		TRAP Rounds 2 and 3
4	18	WALK 1 Lines 1-5 Replicate 3 Bait lines		TRAP Rounds 4 and 5
4	19	WALK 1 Lines 1-5 Replicate 4		TRAP Rounds 6 and 7
4	20	WALK 1 Lines 1-5 Replicate 5	PREBAIT LINES - Check for activity	TRAP am Round 8; remove traps
5	21	PREBAIT TRAPS	WALK 1 Lines 1-5 Replicate 1	
5	22		WALK 1 Lines 1-5 Replicate 2	
5	23	PREBAIT - Check for activity	WALK 1 Lines 1-5 Replicate 3 Bait lines	
5	24		WALK 1 Lines 1-5 Replicate 4	
5	25	PREBAIT - Check for activity	WALK 1 Lines 1-5 Replicate 5	
6	26	TRAP Set am (check activity) Round 1 pm	PREBAIT TRAPS	WALK 1 Lines 1-5 Replicate 1
6	27	TRAP Rounds 2 and 3		WALK 1 Lines 1-5 Replicate 2
6	28	TRAP Rounds 4 and 5	PREBAIT - Check for activity	WALK 1 Lines 1-5 Replicate 3
6	29	TRAP Rounds 6 and 7		WALK 1 Lines 1-5 Replicate 4
6	30	TRAP am Round 8; remove traps	PREBAIT - Check for activity	WALK 1 Lines 1-5 Replicate 5
7	31		TRAP Set am (check activity) Round 1 pm	PREBAIT LINES
7	32		TRAP Rounds 2 and 3	
7	33		TRAP Rounds 4 and 5	
7	34		TRAP Rounds 6 and 7	
7	36		TRAP am Round 8; remove traps	PREBAIT LINES - Check for activity
8	37			WALK 1 Lines 1-5 Replicate 1
8	38			WALK 1 Lines 1-5 Replicate 2
8	39			WALK 1 Lines 1-5 Replicate 3 Bait lines
8	40			WALK 1 Lines 1-5 Replicate 4
8	41			WALK 1 Lines 1-5 Replicate 5

## **Appendix C**

### **Additional Meetings**

Meetings to organise Volunteer work were held with Ian Court and the local volunteer group at the North Yorkshire Dale National Park on the 15<sup>th</sup> October 2005. In addition discussions on using volunteers to carry out visual transects (baited and unbaited) took place at Bonschester Bridge on 17.1. 06 with Mel Tonkin (SNH), Louise Bessant (NWT), Jana Kahl (CWT) and Elly Hamilton (Red Squirrels in South Scotland). A training day for volunteers was held at Kylee Wood, 19.6.2006 and at Ae Forest.

## **Appendix D**

### **Protocols for Volunteers**

The monitoring of squirrel populations is vital to assess how they respond to conservation management or changes in the environment. JNCC and the People's Trust for Endangered Species (PTES) have commissioned research into developing a monitoring strategy for red squirrels and we would like your help!

Walked transect surveys involve walking through a wood along a chosen route (transect), and recording any squirrels seen. It sounds simple, and it is!

When carried out over a number of years these standardised time-area counts can monitor changes in the squirrel population.

The choice of site or woodland can be made by the volunteer or done with help of the local red squirrel officer (RSCO). Volunteers should discuss sites with their RSCO and get necessary permissions to enter the woodland.

### **Study design**

At each site, visual counts along pre-selected transect lines should be followed by prebaiting the lines, followed by repeating the visual counts. The purpose of the work is to determine if baiting of transect lines will increase the detectability of squirrels and thus increase the precision of this type of survey method. The trial involves:

#### 1. Unbaited transect lines

Visual surveys involve making standardised time-area counts of squirrels to monitor changes over time. Predetermined survey lines will be walked, through or alongside woodland, recording all the squirrels seen. The line should be between 500 m and 1000 m long, and situated along rides or inspection racks, or between rows of trees within suitable squirrel habitat.

Start after first light (this is the time when squirrels are most likely to be active). If you carry out the survey at a different time of day, please ensure that the baited repeat survey the following week is carried out at the same time of day, as it is important that the two samples are equivalent and can be compared.

The observer should walk slowly and stop at 100 m intervals for 2-5 minutes, taking about 5 minutes to walk each intervening 100 m. All squirrel sightings are recorded, together with time and place seen and behaviour. If the weather is unsuitable then the survey should be postponed. Squirrels, for example, are unlikely to be very active in heavy rain, strong winds or when it is very cold.

Estimate the perpendicular distance of each squirrel seen to the survey line. This is done by noting down the perpendicular distance (d) of each squirrel (S) seen to the survey (see Figure D1).

The simplest way to carry out the method above is to note down the distance of the squirrel to the transect line you have chosen. The reason the distance is important, is that the further a squirrel is away from your chosen transect, the less likely you are to detect it. The recorded distances allow us the calculation of a detection probability

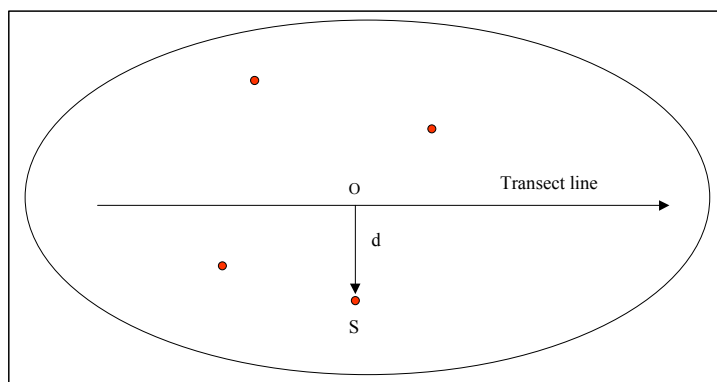


Figure D1 How to estimate the distance between the position of the squirrel seen (S) and the survey transect line. Red circles are squirrels in a wood (outline) and the length of the transect line is walked in the direction of the arrow. The observer (O) sees a squirrel (S) and notes down the perpendicular distance  $d$  in meters.

and help estimate the number of squirrel present in the study site. So as a simple example, you walk the transect line and note down the distance the squirrel is away from the line in meters. You do this for all squirrels seen or record no sightings when none were detected (it is important to have the 0s). This procedure is then repeated following baiting – see below.

## 2. Baited transect lines

After carrying out visual counts on unbaited lines, the lines should be prebaited for one week prior to repeating the counts. Prebaiting should be carried out by walking the line, stopping every 50 m (0 m, 50 m, 100 m etc), and throwing (scattering) 50g<sup>7</sup> mixed squirrel food (66% yellow whole maize, 16% peanuts, 16% sunflower seeds) over a distance of approximately 10 m behind, 10 m in front and 10 m to either side of the stopping point (e.g. using the amount a baked bean can holds). This procedure should be carried out on a Monday and repeated on the following Friday, this time baiting between the points baited on the Monday (i.e. at 25 m, 75 m, 125 m etc.) before starting the visual counts the following Monday (other days for survey and prebaiting can be picked as long as the interval between surveys is 1 week and the prebaiting is spaced out in between).

### Further notes on methods.

1. Each site should be about the same area (18 ha) – but could be smaller for volunteers. Any type of woodland (deciduous, mixed or conifer) can be chosen as long as it is known to have red squirrels! If you are unsure the RSCO may be able to help
2. Weather records – note if it is sunny, cloudy or raining.
3. Record woodland description: approx. size, conifer, deciduous, mixed, age and tree species if known, location (name and OS grid if possible) and date of surveys.
4. Pass on collected data to red squirrel conservation officer

**Please note that all surveys are carried out by volunteers at their own risk.**

<sup>7</sup> This would mean ~2½ kg bait for each 1000 m line