Forestry Commission

Practical techniques for surveying and monitoring squirrels

Red squirrel (*Sciurus vulgaris*)

Practice Note

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Practical surveying and monitoring techniques are essential for anyone involved in studying or managing squirrel populations in forests and woodland in Britain. Survey methods can be used to establish the presence of squirrels in a particular area and, if used systematically, can detect significant changes in the distribution or abundance of populations and species over time. Data gathered from surveys can be used to monitor how threatened populations of red squirrels are responding to conservation management or to environmental change, and they can also be used to assess the efficacy of grey squirrel control measures. This Practice Note describes how to plan a survey and gives guidance on which method(s) to use. Five indirect survey techniques are described, which are based on either sightings or signs of squirrels, and advice is given on their suitability for different types of habitat at different times of the year.

Introduction

The native red squirrel (*Sciurus vulgaris*) has declined dramatically during the last century and its range is now limited to remnant populations in Northern England, a handful of islands off the south coast of England, scattered sites in Wales, and parts of Northern Ireland. It is still abundant in Scotland. The main reason for its decline has been the spread of the introduced North American grey squirrel (*Sciurus carolinensis*) (Figure 1).

Surveying and monitoring techniques are vital for forecasting how threatened populations respond to conservation management or changes in the environment, and are used to detect trends in numbers and the distribution of populations. A survey is a systematic sampling at one time in one or more locations to obtain information about a local population. Monitoring requires the use of standardised methods to provide information on the status of a species.

Survey and monitoring is usually done to determine:

- the presence of red and/or grey squirrels;
- a relative measure of squirrel abundance or density that can be used to compare populations across different places;
- changes in relative abundance or density through time;
- efficacy of control measures (for grey squirrels);
- impact of woodland changes or management actions.

Surveying and monitoring can be difficult because squirrel numbers can vary widely through space and time as they follow the availability of tree seed. Population densities can be very low in conifer forests, typically less than one squirrel per hectare in Sitka spruce plantation forest. Low densities make it very difficult to estimate population abundance accurately because sample sizes of sightings and signs of animals tend to be small.

Figure 1 The grey squirrel, *Sciurus carolinensis.*

The decision to survey

Any decision to survey and monitor squirrel populations should take into account the reasons for carrying out the work. This should include a consideration of the type of data required and the resources available. Ideally, monitoring techniques should be cost-effective, preferably capable of being carried out by volunteer labour and harmless to the squirrel population. Direct or indirect methods of surveying and monitoring can be used.

Direct methods involve trapping and handling squirrels and require particular skills. As red squirrels are fully protected under the Wildlife and Countryside Act 1981 and the Wildlife (Northern Ireland) Order 1985, a licence is required from the appropriate country agency (see page 12) for any study that would interfere in any way with the animals or their nests. It is also illegal to release any trapped or captive-held grey squirrel back into the wild under the Wildlife and Countryside Act 1981, except under licence.

Indirect methods can include both sightings and signs of squirrels. These methods are not as accurate as direct methods in assessing population abundance but they can be sufficient for monitoring purposes. This Practice Note provides advice on selecting appropriate indirect surveying and monitoring techniques, and the methodology for a number of approaches that do not require trapping or handling squirrels.

Carrying out an initial survey

The monitoring methods that are currently available are not ideal for assessing population trends of squirrels at low densities. It is therefore useful to carry out an initial survey of target forests and woodlands, using a simple, broadscale method, to get a rough idea of the number of squirrels the habitat can support (i.e. its 'carrying capacity'), and a crude estimate of current squirrel activity before embarking on more detailed methods.

Planning the survey

Ordnance Survey and forest stock maps can be helpful during the planning stage. Maps will give the size and position of paths and tracks and may also provide some information on forest and woodland types that can be used to assess the potential carrying capacity of the habitat. For example:

- Forest/woodland type (whether broadleaved or coniferous).
- Dominant tree species.
- Age of forest/woodland (most conifers have to reach at least 25 years to produce a reasonable seed crop. Forests with trees younger than this are unlikely to hold resident squirrels).

Carrying out the survey

You should walk through all areas of forest and woodland more than 15 years old and record the tree species present. Note whether the trees form part of the canopy or the understorey and if they are dominant (i.e. comprise most of the large trees present). The potential carrying capacity of the woodland for squirrels can be recorded as low, moderate or high (see Table 1).

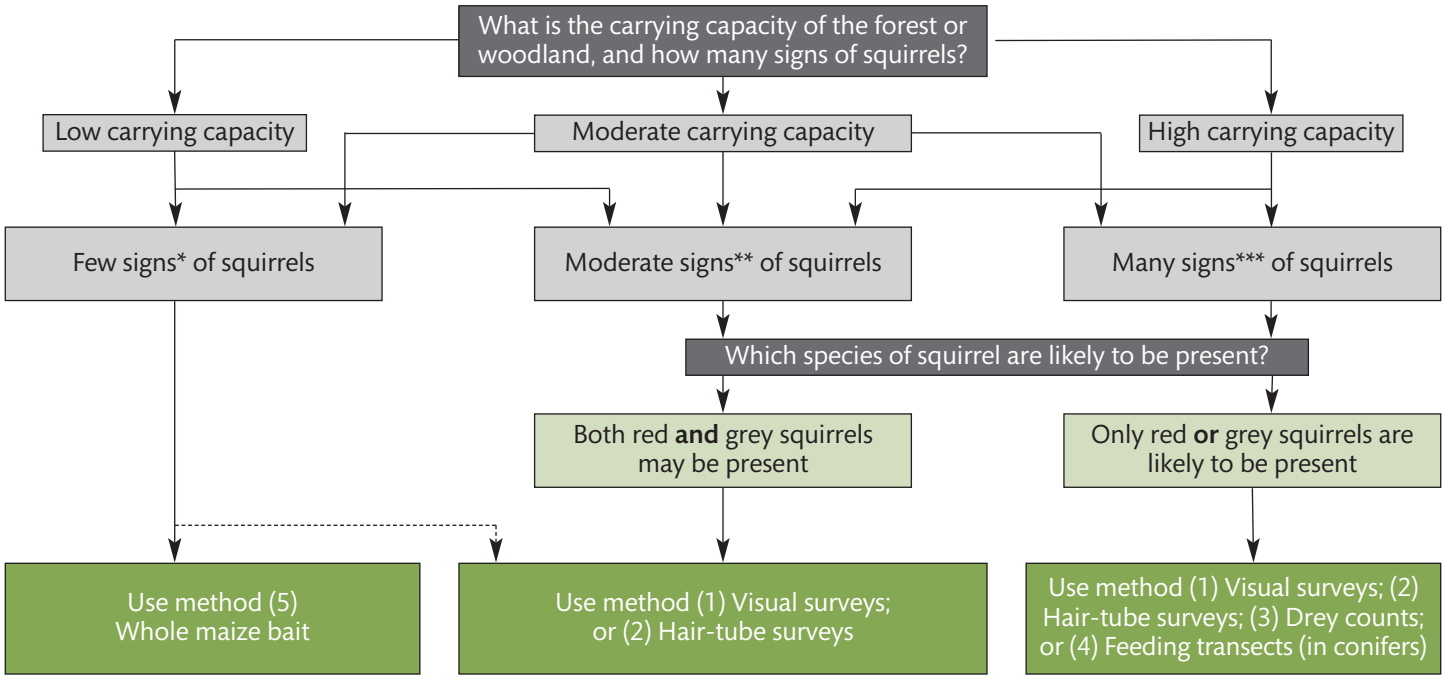
You should stop every 50 m or so to check for signs of squirrels in the area and note whether these are few, moderate or many. This can be done by looking for feeding activity such as the remains of tree seeds, and whether or not there are dreys. Tree seed availability can vary greatly at different times of the year and from year to year. Seeds of broadleaved trees will usually be available from the autumn and the abundance of seeds will decline through winter and spring. Conifer seeds are available from summer, and often through to the following spring or summer. Thus, looking for signs of squirrel feeding activity can provide useful clues as to whether squirrels are currently resident and feeding within the wood.

The flowchart in Figure 2 provides guidance on when to survey or monitor and which techniques may be appropriate.

Table 1 Examples of the potential carrying capacity of forests and woodlands for squirrels in different habitat types.

Squirrel species	Forest type/region	Dominant tree species	Number of squirrels per hectare	Indicative carrying capacity
Red squirrel	Conifer/N. England	Sitka spruce	0.00–0.11	Low
	Conifer/Scotland	Scots pine	0.33	Low
	Conifer/N. England	Lodgepole pine	0.31–0.43	Low–medium
	Conifer/N. England	Norway spruce	0.21–0.41	Low–medium
	Suburban/Jersey	Oak, sweet chestnut, Scots pine	0.68–1.21	Medium–high
	Broadleaved/S. England	Oak–hazel	0.90	High
Grey squirrel	Broadleaved/S. England	Oak–hazel	2.50–18.00	Medium–high
	Broadleaved/Central and S. England	Oak–hazel	3.00	Medium
	Conifer/Central England	Corsican pine	0.20–1.00	Low
	Conifer/Eastern England	Scots pine, corsican pine	0.05–0.20	Low

Figure 2 Decision tree for use when considering techniques to survey or monitor squirrels – based on information gathered in the initial survey. See also Table 2.



To survey: do **once** in spring or autumn

To monitor: **repeat** in spring and/or autumn every year

*Few signs: no dreys, very few seeding signs; **moderate signs: some dreys, some scattered signs of feeding; ***many signs: several dreys, feeding signs abundant.

Surveying and monitoring methods

Five non-invasive methods can be used for surveying and monitoring squirrel populations:

1. Visual surveys
2. Hair-tube surveys
3. Drey counts
4. Feeding sign surveys
5. Whole maize bait

The key features of each of these methods are set out in Table 2. Most of the methods are effective in assessing the presence of squirrels and, to varying degrees, giving abundance estimates. However, only two methods – visual surveys and hair-tube surveys – can distinguish red squirrels from grey squirrels and provide separate population assessments for the two species.

Nest boxes are not included in the surveying and monitoring methods described in this Practice Note. Inspecting nest boxes can provide information on the presence of squirrels: indirectly from hairs left in the nesting material of an unoccupied box, or directly from observing adults and/or young in occupied boxes. However, checking nest boxes for squirrels is a potentially invasive method that can disturb and stress squirrels inside the box; as such their use as a monitoring tool would require a licence from the relevant agency (see page 12 for details).

Survey methods should always be standardised, i.e. use the same protocols each time, to allow surveys carried out at different times or places or by different people to be compared. Surveys can be modified initially to take into account any local circumstances, such as the area of woodland to be surveyed and the number of people who can help with the work. The method, season and survey effort (e.g. how often within one year and over how many years) should be carefully chosen with regard to the objectives of the project. However, to be effective, once a method has been adopted, it should not be changed.

1. Visual surveys

Visual surveys are the most commonly used of all the methods. They involve making standardised 'time–area' counts of squirrels using direct sightings. If the surveys are carried out each season over a number of years this technique can be effective in monitoring changes in squirrel populations over time. It is best to carry out visual surveys in late winter/spring in broadleaved woodlands, if it is not possible to carry out surveys in every season of the year, as visibility is limited when trees are in leaf.

Identifying red and grey squirrels

Red and grey squirrels can be distinguished by their relative size, as adult greys are about a third larger than adult reds. However, this distinction is not always immediately obvious, as sightings can often be just a fleeting glimpse of the animal as it moves through the tree canopy. Surprisingly, general fur colour is not a reliable guide to identification. The upper coat of red squirrels varies considerably in colour from grey to brown or dark brown, or from sandy to bright red; the underside is whitish or creamy. Frequently the tail may be darker than the rest of the coat. During the autumn red squirrels grow distinctive ear tufts that are at their most obvious in mid-winter (cover). They thin during the spring and by the summer have largely disappeared. The coat of grey squirrels also varies in colour, but is generally grey with some reddish brown on the back, sides, limbs and paws. The underside is white or pale grey. The underfur is grey but the longer 'guard hairs' have a characteristic 'salt-and-pepper' mottled appearance resulting from their grey bases, black and brown shafts and white tips. Grey squirrels never have prominent ear tufts (Figure 1).

Visual survey methods

There are two methods of carrying out visual surveys: the Basic method and the Distance sampling method. These are similar as both involve walking along predetermined survey lines, through or alongside woodland, and recording all the squirrels observed.

Table 2 Methods of surveying and monitoring squirrels

Method	Can it detect squirrel presence?	Can it distinguish red from grey?	How good is it for estimating densities?	What type of woodland?	Comments
Visual surveys	Yes	Yes	Moderate	All	Poor results in dense conifer plantations
Hair-tube surveys	Yes	Yes	Poor–moderate	All	Can be labour and equipment expensive
Drey counting	Not always	No	Poor–moderate	All	Not always reliable. Poor results in dense conifer plantations
Feeding sign surveys	Yes	No	Moderate	Conifer	Usually only carried out in conifer forests*
Whole maize bait	Yes	No	No	All	Quick and easy method to confirm the presence of either species of squirrel.

*where hazel trees are present, the characteristic split shells can also be used to detect squirrel presence.

Basic method

The Basic method is easy to carry out and will give you a relative index of numbers to compare dates and sites. The method is not sufficiently accurate to assess fluctuations in abundance over time as sightings depend upon tree canopy density and seasonal variation in squirrel activity.

1. Select the survey area of woodland within suitable squirrel habitat; it can be any size or shape.
2. Identify a number of survey lines (ideally between 6 and 12) at about one line per 10–20 hectares. Each line should be between 500 m and 1000 m long, where possible situated along rides or inspection racks, or between rows of trees.
3. Walk a survey line on pre-determined days of the year, starting as soon after first light as possible as this is the time when squirrels are most likely to be active.
4. Stop at intervals of approximately 100 m for 2–5 minutes, taking about 5 minutes to walk each intervening 100 m.
5. Record all squirrel sightings by species, and note the time and place seen and squirrel behaviour.
6. Repeat the survey 2–4 times within a 2-week period to take into account variations in weather and squirrel activity.
7. Increase the number of survey lines if the number of squirrels seen is very variable (ranging from zero to several).
8. Record the highest number of squirrels seen on a single visit.

Note: in areas where woodlands are small and fragmented and cannot accommodate a 500 m survey line, you could combine several nearby woods (e.g. those within a kilometre) of similar tree species and age composition.

Distance sampling method

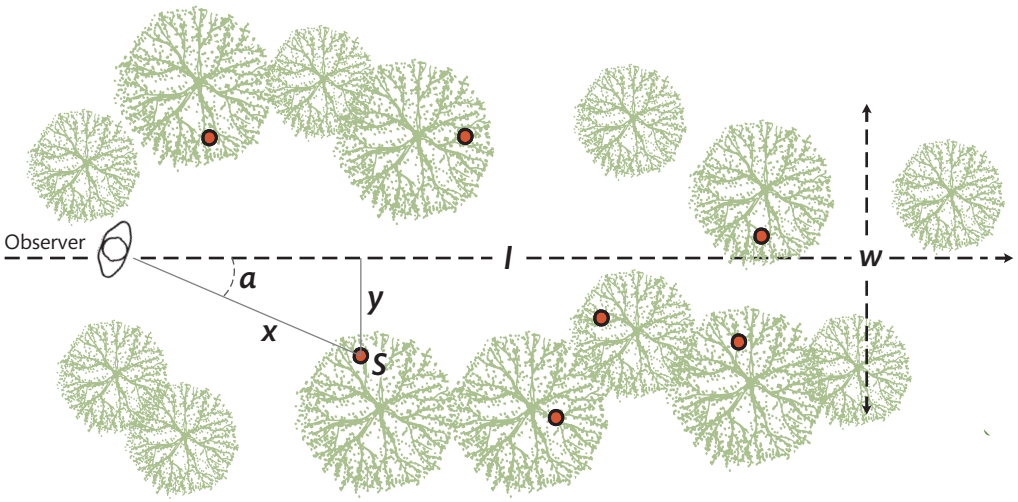
The Distance sampling method is essentially the same as the Basic method, but accuracy is improved by using a technique to calculate the size of the survey area from the width of the sampling belt and the length of the survey line. This allows squirrel density, i.e. the total number of squirrels per hectare, to be estimated.

1. Carry out steps 1–3 of the Basic method.
2. Walk the length (l) of the survey line in the direction of the arrow in Figure 3 until you see a squirrel.
3. Estimate the perpendicular distance (y) in metres between each squirrel (s) observed and the survey line, **or** estimate the distance between the observer and the squirrel (x) and angle (a) as shown in Figure 3. As it can be difficult to assess distances and angles in woodland, it is a good idea to measure out some distances accurately with a tape measure or laser range-finder until you get your 'eye in', or use the regular spacing of trees in planted forests as a guide.
4. Repeat Stages 2 and 3 each time a squirrel is seen and record the cumulative number of sightings.
5. Estimate the width of the sampling belt (w) using the graphical technique shown in Box 1.
6. Calculate the sample area ($w \times l$)
7. Estimate squirrel density (d) using the equation $d = n/2wl$. where n is the number of squirrels observed.

Note: the width of the belt will depend on habitat, and will vary along the line according to habitat structure and 'visibility'. In areas where there are both red and grey squirrels, density should be estimated separately for each species.

Visual surveys should not be carried out in bad weather; squirrels are unlikely to be very active in heavy rain, strong winds or when it is very cold. Binoculars can be used for surveys, but are not essential.

Figure 3 How to calculate the width of the sampling belt when estimating squirrel density using the Distance sampling method.



If the perpendicular distance (y) is difficult to assess, it can be worked out using the estimated distance (x) and the angle (a) using the formula:

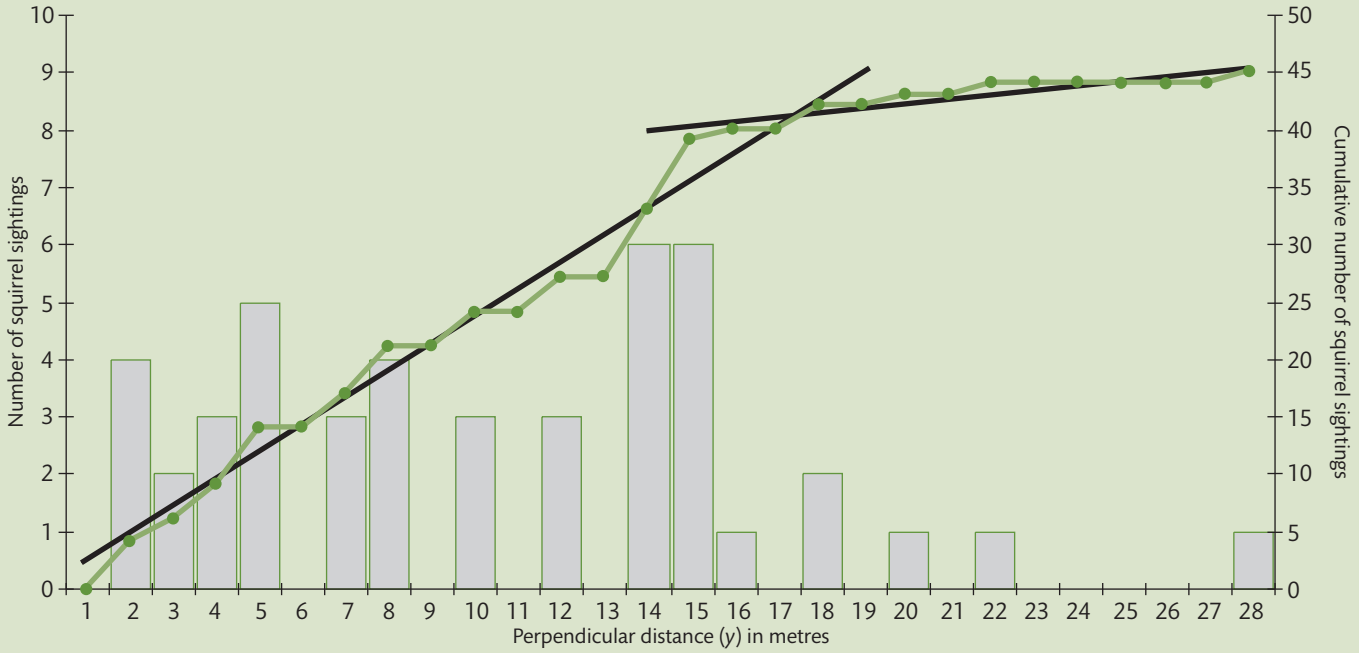
$y = x \sin a$

Box 1 – Calculating squirrel density from the Distance sampling method

Squirrel densities are calculated from the number of squirrels observed (n) in a survey area of known size (i.e. w x l). The length (l) of the survey line can be directly measured as described above and the width of the sampling belt (w) can be estimated by plotting the cumulative number of squirrel sightings (from most distant to least distant) against distance. The 'fall-off' distance (the distance beyond which squirrels cannot reliably be seen) can then be calculated by drawing two 'trend' lines through the data points by eye. The first line is drawn through the series of steeply rising points on the curve and the second through the points on the curve where it starts to level off as the detection rate falls away. The intersection of the two lines is taken as the width of the fall-off distance and hence the belt width.

This can be illustrated using a worked example. Forty-five squirrel sightings have been used in the plot below, the data having been pooled together from 8 walks along a 1000 m transect, i.e. l = 8 x 1000 = 8000 m. The belt width (*w*) is taken as the point where the number of detections drops to approximately half the previous interval, about 17 m in this example. The number of squirrels seen within 17 m either side of the line (*n*) is 42. The density (*d*) of squirrels is calculated using the equation $d = n/2wl$.

$d = 42/(2 \times 17 \times 8000) = 0.000154$ squirrels per m^2 or ~1.5 squirrels per hectare.



This calculation assumes that all animals will be seen within the belt width to either side of the line. This is unlikely to be the case. Computer software, such as Distance (www.ruwpa.st-and.ac.uk/distance) and DfD, Density from Distances (www.irchouse.demon.co.uk), can be used to estimate the detection curve (i.e. the probability of detecting an animal that is a certain distance from the transect line) mathematically.

Considerations when using this method

The accuracy of results when estimating squirrel densities using visual surveys will be affected by the following:

- Squirrels directly on the line may not be counted; in practice it is quite easy to miss a squirrel, even if it is sitting on a branch above the observer's head.
- Transects are placed randomly with respect to squirrel distribution, i.e. squirrels are not more or less likely to be found near to or away from the transect than anywhere else.
- Squirrels may move in reaction to the observer before being seen and some may be counted twice.
- Distances and angles are difficult to measure without bias.
- There is an assumption that seeing one squirrel does not influence the probability of seeing another squirrel.
- Visual surveys are not reliable in dense conifer plantations, particularly spruce-dominated conifer plantations.
- For estimates to be precise, it is generally recommended that large numbers of individuals need to be observed with 60–80 being the recommended minimum – it is very unlikely that these numbers of squirrels will be seen when carrying out visual counts.

Despite these potential problems, the estimated densities can still be useful as a guide and are worth doing.

Box 2 – Accuracy of the results of visual surveys

It is important to know what magnitude of change can be confidently detected using visual survey methods. Results that suggest a decline in squirrel population size between years in a particular forest or woodland are dependent on the ability to detect a *true* decline when it happens (a statistical 'power') and reject an *apparent* change when there is none (a statistical 'significance').

The commonly accepted values for statistical power and significance are 80% and 5% respectively.

As an example, the sample size needed to achieve 80% power for various levels of population change between years can be calculated and is shown in the table below.

% change in population	Number of transects needed
10	348
20	70
40	18
60	9*
80	6*

*A minimum of 10 transects are recommended.

Visual transects are therefore only useful in detecting large changes in squirrel population size. The large number of transects to detect small changes in population size is unrealistic, both logistically and economically, and not an appropriate method to give information on small fluctuations in squirrel density.

The more variable the number of squirrels seen (e.g. many 'zero counts' and some sightings of several squirrels) the more transects are needed.

Baited visual transects

Research has shown that baiting transect lines before surveys start can improve detection rates as it makes resident squirrels more visible. However, it must be done in such away that it does not attract animals from outside the study area, and in areas where both squirrel species may be present, bait should be scattered widely to minimise risk of disease transmission. Transect lines should be baited one week prior to the survey date (and then again four days later) by scattering 50 g of mixed squirrel food (peanuts, maize, wheat, sunflower seeds) at intervals of around 50 m. The bait should cover an area around 10 m behind, in front and either side of each stopping point.

2. Hair tube surveys

Hair tube surveys are used to establish whether red or grey squirrels are present in an area. The method uses specially adapted lengths of plastic drainpipe (Figure 4) which are baited to attract squirrels. Hairs are collected on sticky tapes inside the tubes as the animals enter the tubes to get the food. Collected hair is removed from the tubes periodically for examination. Hair tube surveys can be labour and equipment expensive and training is required to identify the hairs from the two squirrel species. However, they are good for detecting the presence of squirrels and if calibrated by carrying out comparative trials with other methods can provide an index of population trends.

1. Make the hair tubes from 300 mm lengths of plastic drainpipe: 65 mm diameter round, or 65 mm x 65 mm square ended.
2. Place a wooden or plastic block (2.5 x 2.5 x 0.5 cm) covered with double-sided sticky tape inside the roof at either end of each tube around 3 cm in from the entrance. Hold the blocks in place with the sticky tape or clips made out of fencing wire. (Make sure the tubes are dry if using sticky tape).
3. Attach the tubes to the branches of trees at a convenient height, i.e. it should not be necessary to use a ladder (Figure 5). The tubes can be attached using wire, straps or terry clips. (Note that permission must be obtained if nails or screws are used to fix clips to trees.) Clips allow the tubes to be removed and replaced quickly.
4. Use up to 20 tubes to survey an area of woodland by placing them 100–200 m apart in lines or in a grid pattern. A standard number of tubes should be used for each site in any survey.
5. Bait the tubes sparingly using sunflower seeds, peanuts or maize, once at the start of the survey.
6. Retrieve and number by location the sticky blocks after a standard time period (such as 3, 7 or 14 days). Protect the hairs by covering the blocks with a strip of waxed paper or polythene sheet to prevent them being damaged.
7. Leave the tubes in place if needed for future surveys.

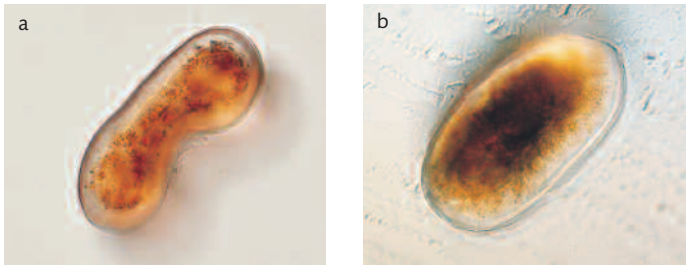
Figure 4 A hair tube and removable sticky block with squirrel hair attached.

Figure 5 A hair tube fixed to a branch.

Identifying red and grey squirrels

You can identify squirrel hair by comparison with a reference collection of hairs from other mammals small enough to enter the tubes (e.g. mice, voles, weasels, stoats as well as squirrels; polecats and pine martens are too big to enter). Colour alone cannot be used to separate red and grey squirrel hairs, and the hairs have similar medullar and cuticle scale patterns. When viewed under a microscope (×400) however, the cross-section differs: red squirrel hairs have a concave or a dumb-bell shaped cross-section whereas grey squirrels have a round one (Figure 6). An ink staining technique can be used on the hair samples to enable the type of cross-section to be seen more easily (Box 3).

Figure 6 Cross-sections of (a) red and (b) grey squirrel hair.



Box 3 – Using ink staining to aid identification

- Place the tapes in warm water containing a strong detergent and leave to soak overnight.
- Remove at least 10 representative hairs from each identifiable cluster using forceps. Avoid very fine, small underfur hairs, and those cracked or damaged. Discard hairs <1.5 mm long as these will be from mice or voles.
- Measure the length of complete hairs from the bulb to the tip. Note the colour bands along the hair. A binocular microscope at a x80 magnification is useful here.
- Place the hairs in a 5:1 solution of Indian ink:water.
- Place two or three hairs on a slide together with a few drops of ink solution. Cover with a cover slip and examine using a light microscope (x400 magnification is best).
- Look at the widest part of the hairs; examples that show a continuous dark band along this part of the hair are likely to be from red squirrels.

Calculating squirrel density

Squirrel presence is confirmed by finding hairs in at least one of the tubes, however the number of squirrel hairs left in a tube is not necessarily related to the number of individuals visiting it. One squirrel may visit many tubes, and the sampling area of each tube is not known. However, the number of tubes visited in a given time period within a forest or woodland may be used as a relative index of squirrel numbers. Furthermore, where tubes are placed in a grid pattern, it has been found that there may be a relationship between the number of tubes visited in a particular forest and squirrel density (Box 4). Where squirrel densities are found to be 0.5 per hectare or greater, the time between hair tube inspections should be reduced to 3–7 days.

Considerations when using this method

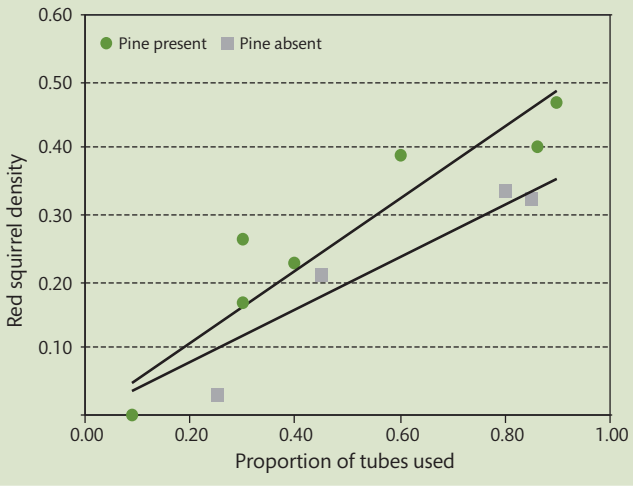
- The bait may attract animals from outside the study area – as with baited transects, use as little bait as possible.

Box 4 – Estimating red squirrel numbers using hair tubes

Research at sites in the north of England has shown that there is a relationship between the proportion of hair tubes used by red squirrels and squirrel density, as shown in the graph below. The sites surveyed were forests composed of Sitka spruce or mixtures of spruce, pine and larch of cone-bearing age and where there were no grey squirrels present.

The graph can be used to predict red squirrel densities (up to 0.5 squirrels per ha) in forests dominated by Sitka spruce, and in the absence of grey squirrels, by reading off the proportion of tubes used by squirrels from the appropriate line (i.e. whether pine is present or absent).

For example, given a proportion of 0.4 tubes used by squirrels, it is predicted that there will be a density of 0.23 red squirrels per ha if the forest contains pine of cone-bearing age, and 0.15 squirrels per ha if it doesn't.



- The number of tubes used by squirrels at a site is related to squirrel numbers at that site – at high squirrel densities all tubes may show squirrel hair and the hair tube transect line or grid may be saturated.
- Squirrels learn to associate food with the tubes – data may therefore differ between the first and subsequent surveys.
- It is currently assumed that the use of tubes by grey squirrels does not deter red squirrels in areas where both species are present, i.e. the presence of grey squirrels does not mask the presence of red squirrels and the latter can still be detected.
- Hair samples may contain hair from both red and grey squirrels in areas where both species are present. Hairs selected for examination should be chosen with care, taking account of hair colour (e.g. grey squirrel hair often shows a distinctive silver, black and orange banding).
- Damaged or broken hairs may give the false impression of a concave or dumb-bell cross-section.

3. Drey counting

Drey counts are used to establish the presence of squirrels in a forest or woodland. Active dreys are a reliable indication of squirrel presence, and the density of dreys can give some idea of squirrel numbers. Dreys tend to be semi-permanent when squirrels are resident, and thus the number of dreys tends to reflect squirrel numbers over a season, a year or even longer.

Dreys are usually built close to the main stem of a tree, with support from one or more side branches, at heights of 3 m and above (Figure 7). They are usually greater than 50 cm in diameter and more than 30 cm deep. There is no obvious difference between a drey built by a red squirrel and a drey built by a grey squirrel, and both species will use the same dreys at different times. Sometimes squirrels make nests in holes in trees, called dens. It is easier to see dreys in broadleaved woodland when there are no leaves on the trees and so it is best to count them in mid–late winter. In addition, squirrels build temporary, platform structures in the summer, which should not be counted.

Figure 7 A drey and den entrance in an oak tree.

Dreys can be counted by one person, but is better with several observers, walking 20–25 m apart through the forest, in line, abreast and in view of each other. In planted woodland, the rows of trees can be used to maintain direction; if this is not possible, a compass may be needed. Observers may need to be closer together in woodlands with a high stocking density, or if visibility is poor. If dreys look unkempt (ragged, with falling twigs and daylight passing through) they are unlikely to be in use and should not be counted. If dreys are not found, then it does not mean that squirrels are absent, because dreys in the canopy may be difficult to see in some forest and woodland habitats.

Calculating squirrel density

The density of dreys can be used as a crude index of squirrel abundance and it may be useful as a relative measure of habitat use. However, assessing the relationship between drey density and squirrel density can be problematic. Firstly, some dreys in an area of woodland may be missed during a count; secondly, dreys can be confused with birds' nests, such as crows, magpies and some raptors. Thirdly, dreys are semi-permanent features of a wood and cannot easily be related to any particular day or month; and finally, squirrels use several dreys at any one time, so it is necessary to know the average number of dreys per squirrel before density estimates can be calculated.

Research in Belgium has shown that, for red squirrels, there are about four dreys per squirrel. Therefore dividing the number of dreys by four will provide a crude estimate of red squirrel density. For grey squirrels, research in broadleaved woodland in England indicates that there are about four dreys for every three grey squirrels. Information is not available on the relationship between the number of dreys and grey squirrel density in conifer forests. Since grey squirrels live at similar densities to red squirrels in conifers, the red squirrel relationship may be used with caution.

Considerations when using this method

- Drey counting to establish the levels of presence of red or grey squirrels is difficult in areas where both species occur as it is not possible to distinguish between their dreys.
- It can be difficult to see dreys in some woodland habitats and at certain times of the year. For example, it is difficult to detect dreys in deciduous woodland in spring, summer and autumn, when there are leaves on the trees, and it is difficult to detect dreys in conifer habitats at all times of the year.
- In mature deciduous habitats dens in tree holes may be used. These are difficult to detect and will lead to an underestimate of the number of nests being used.
- Squirrels will often build dreys in thick clumps of vegetation, such as ivy, growing up the trunks of trees. These are impossible to see and lead to underestimates of dreys being used.

4. Feeding sign surveys

Feeding sign surveys involve the systematic assessment of the remains of cones eaten by squirrels in conifer forests. This will provide information on squirrel numbers, habitat use and the timing and spatial distribution of seed availability. This method will only give an estimate of total squirrel density, where both red and grey squirrels are present, as there is little difference between feeding signs made by both species.

1. Mark out line transects (or quadrats) on the forest floor using small sticks or similar (Figure 8). The number required for an assessment will depend on the size of the forest, the mix of tree species and the resources available. One line for every 4 hectares is a reasonable guide.
2. Ensure that transects cross the most important cone producing areas where possible; cone-producing trees can be patchily distributed throughout a forest and edge trees generally produce more cones than centre trees.
3. Make each transect around 50 m long and 1 m wide. The lines do not have to be straight, and should not avoid natural objects such as logs or stumps.
4. Rake each transect to remove all cones.
5. Visit each transect at regular intervals (around every 2–3 weeks) to collect all complete cones and cone cores and re-rake each transect clean.
6. Count the total number of cone cores.
7. Estimate the quantity of seed eaten based on the number of seeds in an average-sized cone (see Box 5).
8. Estimate the amount of energy in each seed (Table 3) and scale up to the amount contained in each cone.
9. Estimate the density of squirrels as set out below.

Figure 8 Line transects are easier to manage than quadrats.

Box 5 – Estimating the number of seeds in a cone

- Collect a sample of up to 100 ripe, average-sized cones.
- Heat the unopened cones in an oven at 40 °C for 2 hours before gradually increasing the temperature to 60 °C. Heat for a further 8–10 hours.
- Allow the cones to cool before tapping the seeds out onto a sheet of white paper.
- Count the total number of seeds contained in each cone.

For more accurate results, estimate the relationship between the number of seeds and cone size. This requires measuring the length of cones and cone cores removed from transects.

Table 3 Energy value* of seeds from common conifer trees in Britain

Tree species	Average energy value of seed (kJ)	Location of tree
Scots pine	0.05-0.10	Sweden
Scots pine	0.17	East Jutland
Scots pine	0.18	East Anglia
Corsican pine	0.29	East Anglia
Lodgepole pine	0.098	British Columbia
Sitka spruce	0.04	British Columbia
Norway spruce	0.07-0.13	Sweden
Larch	0.09	Central Europe
Douglas fir	0.26	British Columbia

*Obtained from laboratory studies; see *The natural history of squirrels* (Christopher Helm) for source references.

Calculating squirrel density

Squirrel density can be calculated by converting the number of conifer seeds eaten per unit area into numbers of squirrels per unit area. The amount of energy contained in a cone can be scaled up to the amount of energy consumed per unit area per day and, from knowledge of the energy requirements of adult red or grey squirrels, a crude estimate of minimum squirrel abundance can be worked out. Estimates of the amount of energy consumed by a squirrel vary so it is advisable to use a range of values. An adult red squirrel consumes between 400 and 700 kJ of energy a day and an adult grey squirrel between 500 and 800 kJ of energy a day. Using these figures, the density of squirrels can be estimated as shown in Box 6.

Considerations when using this method

- Cone length and seed size for a particular tree is very variable and changes with tree age, time of year and site factors such as soil type and climate.
- Estimating the energy value of seeds is difficult to do without specialist laboratory apparatus. Conifer seeds are very small and squirrels only eat the material inside the seed coat.

Box 6 – Estimating squirrel density from feeding signs

Woodland type: **Scots pine** Woodland size: **20 ha**
Number of transects: **5** Length: **50 m** Width: **1 m**

Total area sampled: 5 x 50 x 1 = 250 m²

Cone cores collected every 7 days between December and February inclusive (i.e. 12 collections over 84 days)
Total number of cone cores collected on all 5 transects from all 12 collections = 240

Average number of seeds per cone = **25** (estimated)
Average energy value per seed = **0.18 kJ** (Table 3)

Total energy consumed = 240 x 25 x 0.18 = 1080 kJ

Since there are 10 000 m² in 1 hectare, the total amount of energy consumed per hectare per day =
1080/84 x 10 000/250 = 514 kJ per day per hectare

Assuming that adult red squirrels consume between 700 and 400 kJ per day, the estimated density of squirrels for the 20 hectare woodland between December and February = **514/700 to 514/400 = 0.74–1.29 squirrels per hectare**.

- The amount of energy consumed by a squirrel varies considerably and depends on location, season, breeding condition and body weight.
- Transects may have many feeding remains one day and very few the next because squirrel feeding is not uniform across a woodland. To help overcome this problem, it is better to use several lines and make collections every one or two weeks for a period of a season or a year.

Given these considerations, density figures derived from this method are approximate at best. If this method is also used to estimate cone crops, transects should be cleared in the autumn taking account of any stripped green cones which can appear on lines as early as June/July in pine and August/September in spruce. A total count of stripped and normal cones over the course of one year will provide an estimate of the annual cone crop.

5. Whole maize bait

The presence of squirrels can be determined from the remains of yellow whole maize put out as feed or bait. Red and grey squirrels are the only species to remove the germ from the maize grain and discard the rest intact (Figure 9), although there have been some reports that red squirrels do not readily eat whole maize and that the characteristic signs of squirrel feeding on whole maize are not always clear. It is not possible to determine which species is present, or level of presence, unless used in conjunction with another method such as hair tubes.

Figure 9 Whole and eaten maize grains.

Using the data from surveys

Data on the presence of squirrels based either on structured or ad hoc visual surveys and public sightings should be used to produce up-to-date distribution maps at national and regional level. Hair tubes enable survey in more remote areas if there are sufficient time, resources and experienced surveyors available.

Although the power to detect changes in numbers is not high using the methods described in this Note, information on grey and red squirrel presence at the 10 km² scale allows changes in distribution over time to be monitored. At a local scale it will assist with decisions on priority areas for red squirrel conservation management and can be used to target grey squirrel management within buffer zones of designated red squirrel reserves or priority woodlands. Knowing when grey squirrels are moving into an area, for example, will enable targeted grey squirrel control.

Population estimates or indices of numbers for red squirrels may only be needed where extensive forest management operations or disturbances are taking place (e.g. felling) in order that these activities can be adjusted to minimise impacts. In these situations, standard, repeat surveys should be carried out at yearly or 6-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, feeding signs in conifer forests, and drey counts.

Records of squirrel presence, showing species, date, grid reference, survey method (including quality controls) and observer, should be stored in a readily retrievable manner and copied to the local/county mammal recorder. Information on why the survey was organised, by whom and over what time scale should be included to allow confirmation of the integrity of the data. The local Wildlife Trusts, Natural England, Countryside Council for Wales or Scottish Natural Heritage can provide contact names and addresses where required (see page 12 for contact details). Country or UK scale information can be easily collated from these sources as required.

Useful sources of information

Publications

Controlling grey squirrel damage to woodlands.
Forestry Commission Practice Note (FCPN004).

Red squirrel conservation.
Forestry Commission Practice Note (FCPN005).

The natural history of squirrels.
Christopher Helm, London.

Mammals of the British Isles: Handbook. 4th edition.
Mammal Society, Southampton.

Research articles and other literature

DON, B.A.C. (1985). The use of drey counts to estimate grey squirrel populations. *Journal of Zoology* **206**, 282–286.

GURNELL, J., RUSHTON S.P., LURZ, P.W.W., SAINSBURY, A.W., NETTLETON, P., SHIRLEY, M.D.F., BRUEMMER, C. and GEDDES, N. (2006). Squirrel poxvirus; landscape scale strategies for managing disease threat. *Biological Conservation* **131**, 287–295.

Contacts

UK Red Squirrel Group – www.snh.org.uk/ukredsquirrelgroup
Responsible for the UK red squirrel Biodiversity Action Plan and Species Action Plan (Secretariat provided by SNH)

Joint Nature Conservation Committee – www.jncc.gov.uk
Hosts the Tracking Mammals Partnership
www.trackingmammals.org

Natural England – www.naturalengland.org.uk
Scottish Natural Heritage – www.snh.org.uk
Countryside Council for Wales – www.ccw.gov.uk
NI Environment Agency – www.ni-environment.gov.uk
Responsible for regional red squirrel strategy through the regional squirrel fora, and grants and advice through various mechanisms including the Species Recovery Programme (Natural England) and Species Action Framework (Scottish Natural Heritage).

Forestry Commission England – www.forestry.gov.uk/england
Forestry Commission Scotland – www.forestry.gov.uk/scotland
Forestry Commission Wales – www.forestry.gov.uk/wales
Assists red squirrel conservation by encouraging management for red squirrels in private woodlands, provision of habitat management advice and management of selected areas for red squirrel conservation. Funding for woodland management and grey squirrel control is provided under the English Woodland Grant Scheme in England, under the Scotland Rural Development Plan (www.scotland.gov.uk/Topics/rural/SRDP/RuralPriorities) in Scotland and under the Better Woods for Wales scheme in Wales.

Forest Service of Northern Ireland – www.forestserviceni.gov.uk
Advises on red squirrel conservation including habitat management in Northern Ireland.

Forest Research – www.forestresearch.gov.uk
Responsible for research and technical advice.

The Wildlife Trusts – www.wildlifetrusts.org
Responsible for The Wildlife Trusts red squirrel projects, groups and contacts, and general regional and local advice.

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