

## CHAPTER 5. CONTROL METHODS

### PREDICTING DAMAGE

Kenward (1988) indicates that squirrels do not suddenly strip bark without prior indication.

Having established that bark stripping:

- always occurred when there were more than 0.5 young squirrels /ha in summer;
- that it was unlikely to become serious unless phloem volume was greater than 0.3 cm<sup>3</sup> under each square centimetre of bark in vulnerable trees;
- and was most likely to occur when there had been bark stripping the previous summer

Kenward *et al.* (1996) set about trying to forecast the risk of damage in vulnerable plantations. The level of risk identified was used to apply a minimum intervention management policy that resulted during 5 years in a cost saving of at least 60% compared with continuous squirrel control, and a concomitant reduced risk for other wildlife. Mayle *et al.* (2003) suggest that predicting years of high squirrel damage will enable better targeting of control, reducing both costs and the number of squirrels killed. A new method, 'Index trapping' is currently being developed which explores the relationship between grey squirrel populations, winter food availability, spring breeding success and damage the following summer. However, Mayle *et al.*'s (2003) level for the need to apply control is different to Kenward's *et al.* (1996). The former state that control for tree damage prevention should aim to reduce resident squirrel densities to below damaging levels which they state is less than 5 per ha. Kenward *et al.* (1996) say that damage always occurred once there were more than 0.5 young squirrels /ha in summer. Clarification is needed of the density beyond which bark stripping is inevitable.

Mayle *et al.* (2003) state that for damage prediction to be successful grey squirrel traps should be set during a week in early January in habitats likely to hold high-density squirrel populations (mature broadleaved or mixed woodland) adjacent to damage-vulnerable habitat. If no squirrels are trapped this indicates that either squirrel numbers are very low or that natural food availability is high and that early breeding, and a high risk of damage between April and July is likely. Unfortunately they give no indication how the forester is supposed to differentiate between the two, but they do suggest that he should be able to evaluate the natural food availability during the same week. Dutton (1993) advises that the crucial feature is to survey in late summer the stems and lower branches for squirrel "trials" - the removal of small flakes of bark. Often a single scrape mark by the two upper incisors can



**Figure 5.1** JCF Dutton (1993)



**Figure 5.2** JCF Dutton (1993)

be seen in the phloem beneath. This will enable the correct targeting of poison in the following spring to control squirrels selectively over a larger area than applying control at each plantation every year. This then reduces the control cost per ha. But it also assumes that hopper density is correct. Dutton (1993) also used the 0-5 scale adopted by Kenward *et al.* (1996) and Mountford (1997) to identify squirrel 'trials' in advance of full scale damage and so help forecast the need to apply control. Figure 5.1 shows naturally regenerated beech thinned in 1992. With these patches or trials evident, severe damage is expected in the summer 1995, so control was organised for spring 1994. In figure 5.2, the recently thinned eleven-year-old sycamore exhibits trials all over the tree which is often hard to see for leaf cover. Dutton (1993) decrees that this control should be in place no later than March/April



**Figures 5.3 and 5.4. Scale 1 - 2 'Hand size' trial patches. (JCF Dutton 1993)**

1994. Hand sized trial patches (figures 5.3 and 5.4) were deemed to be scale 1-2 (Chapter 4, Table 4.3 and Figure 4.6) and these appeared on beech 2 years after thinning. He states that if a crop has wide spread hand size patches then squirrel control is essential the following spring.

However, triggering does not usually lead to immediate serious damage. In all Kenward *et al.*'s (1996) 53 study woods where damage started during the study, the first signs were trial flakes of bark from 10-20 trees, with hand-sized pieces stripped from 2-3 more, in the summer before the damage became serious. This suggested that only a small number of squirrels were initially involved. The escalation of the damage resembles a chain reaction, which propagates only if many trees prove rewarding because of high phloem volume (Kenward & Dutton 1996). Escalation is usually likely in plantations, which typically have much larger phloem volumes than in much denser self-seeded stands, except when crowns become relatively crowded just before thinning (Kenward, 1989). Phloem volumes peak 2-3 years after thinning, so this is a time of maximum risk. Damage is most likely to trees at the edge of rides, again probably because reduced crowding enhances their phloem volume; this is convenient during annual inspections for signs of bark stripping (see Tables 5.1 and 5.2).

**Table 5.1. A check list of the steps for minimum intervention management of grey squirrels (After Kenward & Dutton 1996).**

Initial:	Prepare a list of all areas at risk from records of tree species and age (compartment notes).
Each summer:	(i) Consult a thinning plan and previous damage records to identify areas with high risk of bark-stripping. (ii) Survey all areas in July for signs of bark-stripping, most thoroughly in sites with the highest risk.
Each winter:	(i) Identify areas where nut and mast crops, or pheasant feeding, provide abundant food for squirrels. (ii) Liaise with gamekeepers to ensure pheasant feeding serves as pre-bait, but stops when Warfarin is used. (iii) Prepare an annual control schedule, to use each set of hoppers at 2 sites in succession if necessary.
Each spring:	(i) Place hoppers in areas where risk is high in early March and apply pre-bait of whole-maize. (ii) Fill hoppers with Warfarin-coated wheat from 15 March, check and refill as required every 2-3 days. (iii) Move hoppers to secondary sites by mid-April. (iv) Remove hoppers by June - effectiveness reduces as wild food becomes more readily available.

Once damage had become serious, woods without squirrel management had an especially high proportion of trees with trial flakes of bark removed, even when phloem volume was low. It is not clear whether a small number of squirrels were responsible for this persistent

sampling of the trees, or whether most of those present had learned the habit, perhaps by watching others (Kenward & Dutton 1996). Nevertheless, the priority when damage has started is to eliminate the offending squirrels. From the above points and recommendations in Gurnell and Pepper (1988), a programme was drawn up by Kenward & Dutton (1996) for implementing squirrel control only when necessary. The steps in the process are shown in Table 5.1.

Where there are few "trials", no action is taken if there is (a) little winter food for squirrels, (b) trees have not been thinned recently and (c) there was little damage in the past. However, the inspection of such areas must be especially thorough the following year. Kenward and Dutton (1996) attribute one "point" each to the presence of good winter food and recent thinning and much damage in the past; on this basis, woods with "trials" and 2-3 points would have priority action, with action less urgent at 1-point sites. Table 5.2 illustrates this decision process. In addition, if low natural food supplies reduce risk and hence the need for action to relatively few areas, prophylactic action is considered in woods isolated by at least 1 km of open land, if risk is normally high there. Prophylactic action will remove squirrels most effectively when there is little natural food, and immediate recolonisation say Kenward and Dutton (1996) will be hindered by poor breeding elsewhere, so that several years may pass before initial signs of bark stripping indicate the need for renewed squirrel management.

**Table 5.2. Examples of observations of damage and decisions for squirrel management.**

Site	Bark-stripping	Other factors	Warfarin priority
A	0/5 (nothing seen)	None	None
B	1/5 (a few trials)	Thinning next year	None
C	1/5 (a few trials)	Much pheasant feeding	Low
D	1/5 (many trials)	Many acorns, trials last year	High
E	3/5 (a few large patches)	Thinned 2 years ago	Essential

Prediction of damage risk is thus based primarily on squirrel behaviour in previous summers, and secondarily on the risk of triggering from breeding and of damage being sustained by high phloem volume. It was hoped that spring weather might also have value for predicting phloem volume but, beyond the effects of crowding, this damage-enhancer seems to be appreciably reduced only by summer drought (Kenward & Dutton 1996).

There are other factors associated with bark stripping which can also be used to predict the risk of damage in each area of woodland in each year, and hence to decide whether or not to remove squirrels that year. The age and species of trees are important factors (Shorten, 1957; Rowe, 1984; Rowe and Gill, 1985). Beech (*Fagus sylvatica*) remains vulnerable for some 30 years, from the age of 12-15 years old. Sycamore (*Acer pseudoplatanus*), oak (*Quercus spp.*),

poplar (*Populus spp.*), larch (*Larix spp.*), Lawson cypress (*Chamaecyparis lawsoniana*) and Scots pine (*Pinus sylvestris*) are typically susceptible for shorter periods, probably because they are younger than beech when their bark becomes too thick for easy removal by squirrels (Kenward & Dutton 1996). Beech and sycamore may be stripped over the whole trunk until they are 25-40 years old, but bark thickens close to the ground relatively early on the other species, so that stem damage is most likely in the canopy, quite often leading to wind-snap of the upper crown.

Kenward and Dutton (1996) noted that the species and maturity of any mature trees nearby, especially oak, chestnut (*Castanea sativa*), hazel (*Coryllus avellana*), beech, pine and others provide food for squirrels in winter. If there are many mature seed-bearing trees near the vulnerable woodland, squirrel breeding is always likely to exceed 0.5 young/ha in spring, so that there is always a relatively high risk of damage being triggered (Kenward & Dutton 1996). They believe that there do not need to be many mature trees to enhance the risk of triggering. Among oaks, for example, squirrels produce 0.5 spring young/ha when there are about 30,000 acorns/ha. In a year with a heavy acorn crop, such as 1987 and 1995 in southern Britain, some individual trees produce more than 150 acorns / m<sup>2</sup> of canopy: just 2 large oaks, with canopies of 100 sq m, could produce 30,000 acorns. In an average year, 30,000 acorns/ha are to be expected in woods where mature oaks form about 15% of the canopy (Kenward & Holm, 1993). The regular feeding of pheasants is also likely to promote squirrel breeding, although the successful weaning of litters will depend on natural food abundance unless feeding continues longer than is usual.

### **Bark-stripping and woodland design**

As with red squirrel conservation, the design of future woodlands can also be modified by predicting the risk of bark stripping, with the aim of growing vulnerable tree species with minimal risk of damage. Kenward & Dutton (1996) outline 3 main approaches:

1. Maximise ground cover during summer. Little damage occurs in areas where there was more than 50% ground cover at a height of 30 cm. Brambles (*Rubus fruticosus*) in the shade, and nettles (*Urtica dioica*) in the open. Ground cover is also beneficial for pheasant management: pheasant densities tend to be highest in woods with most cover at the 30 cm height that was associated with reduced squirrel damage. Unfortunately, cover tends not to thrive under beech canopies.
2. Create woods that are unfavourable for squirrels, using woodland size, isolation and species composition. Woods less than 2 ha in area have a low probability of containing

grey squirrel dreys if there is no hazel or beech present, and woods up to 8 ha have a reduced probability of occupancy when more than 500-1000 m from another wood of at least 5 ha. For larger woods, avoid planting vulnerable species adjacent to mature seed-bearing trees. There is at least one area in the Chilterns where a large expanse of beech has been planted in this way, and shows few signs of squirrels or bark stripping.

3. Manage the growth of trees so that phloem volume remains below the threshold for serious damage, until the trees have thick enough bark to deter the squirrels. A crucial question to this however, is whether phloem volume can be kept low for long enough without producing a yield reduction greater than the saving from reduced bark stripping. A shade-tolerant species like beech can grow slowly as under-storey with little risk of damage, but this may be more appropriate for amenity beech-woods than for economic forestry. Crowded conditions reduce phloem volume, so a careful blend of spacing and a shade-tolerant conifer nurse-crop, to force beech or sycamore upwards as fast as possible, is required. A moderate spacing (e.g. at least 2 x 2 m) might be used, to ensure that mild crowding starts as trees reach the lower threshold for damage; the policy would be to thin minimally before removing the nurse crop, and then to conduct a thorough thinning operation. With careful management to keep the conifer crown just below that of the deciduous trees, perhaps this could produce a very straight-stemmed crop. Shade tolerant conifers that produce little or no food for squirrels, such as western hemlock (*Tsuga heterophylla*) or western red cedar (*Thuja plicata*), would be nurse crop candidates in suitable soil conditions.

## DAMAGE CONTROL

The impacts of grey squirrels have been manifest almost since their time of introduction in the late 19th and early 20th centuries. Control of grey squirrels has therefore been conducted in Britain and Ireland since they were identified as a pest and has varied from inconsistent shooting in many areas to a concentrated but fruitless bounty scheme organised in the 1950s of a shilling for each squirrel tail. This cost over one million pounds and highlights the fact that methods of control can prove more expensive than the damage prevented. There is little point, say Lawton & Rochford (1999), in conducting a control programme that is more expensive than the damage it manages to prevent. Many commentators would disagree, describing this as shortsighted. The long-term prospects must be considered – being saddled with permanent and continuous damage will ultimately reduce the high forest landscape to scrub and and displace much wildlife. Controlling the pest on a continuous basis at least ensures the continuation of high forest in the landscape, continued biodiversity and the prospect of a quality timber crop.

Grey squirrels continue to expand their range at the expense of the native red squirrel, and there does not appear to be any ecological factor that will stop this spread (Gurnell & Mayle 2002). Biological control is attractive but so far no known parasites or diseases which would naturally control grey squirrels are known (Ratcliffe & Pepper 2002). Such research would need to be carefully monitored and take full account of the potential dangers to non-target species. Bark removal damage to trees continues to be a major problem particularly with mild winters prevailing and good tree seed crops occurring, and damage levels have been increasing in coniferous as well as broadleaved trees.



**Figure 5.5 Drey poking (Forestry Commission 1960)**

Historically, drey poking (Figure 5.5) has been used as a method of control. Nowadays, it can be a useful wet day's activities for beaters on the large estate but is considered ineffective at reducing grey squirrel numbers to successfully prevent summer bark stripping by the Forestry Commission.

Shooting is probably the most common method of removal (Lawton & Rochford 1999), but is generally considered to be the least effective. Trapping has proved very effective but can also cause indiscriminate killing of other woodland inhabitants and is very labour intensive.

Poisoning with Warfarin is a very effective method of reducing grey squirrel numbers but its use is regulated in Britain to areas where no reds exist. Many commercial forests are subjected to grey squirrel control during the damage period using Warfarin. Any lessening of the availability of this form of control could have catastrophic effects on the future of woodland in general (Gurnell & Mayle 2002). No such legislation is present in Ireland except that red squirrels are protected under the 1976 Wildlife Act and so precautions would be required to prevent targeting the wrong species (Lawton & Rochford 1999). They go on to say "Warfarin is not to be recommended because the amount necessary to successfully remove an entire squirrel population would be very large, and despite the use of grey squirrel-only hoppers, the introduction of an anti-coagulating poison into the ecosystem could affect non-target species".

In 1976 Phillipson & Wood studied the use of Warfarin-baited hoppers to control grey squirrels and concluded that they were ineffective in preventing free access to the poisoned bait by large numbers of other species. In addition they raised a question mark of the possibility of secondary poisoning from Warfarin and consider that widespread control the grey squirrel is unnecessary. They further pointed out in 1977 that a number of species may feed from the grain because the majority of bait was removed during the hours of darkness when the grey squirrels were not active. They considered that at a conservative estimate between 55% and 65% of the grain entered the environment via animals other than squirrels. In 1996 Kenward *et al.* conceded that until effective selective hoppers are used universally it is likely that woodland rodents would be killed by Warfarin that is used to kill grey squirrels. Their use of Warfarin during their research endeavoured to reduce exposure while still preventing damage through a policy of minimum intervention and rapid uptake of bait through careful siting and pre-baiting of hoppers. However in 1997, Pepper devised a hopper that excludes all non-target species smaller than the grey squirrel which naturally has implications for the prevention of both red squirrels and small woodland mammals from being unnecessarily poisoned. The trials of this modified hopper with an essentially heavier door to exclude all small mammals have proved very successful. Entry to the hopper was monitored using sticky blocks and only grey squirrel hair was found and at one trial location where red squirrels were present and active throughout the trial period, none gained access and fed from the hopper at any time (Pepper 1997). This should have major implications for the use of Warfarin in areas where red squirrels are present and are threatened with replacement by grey squirrels, although a change in legislation is first required.

Warfarin has been shown to be of limited persistence in animal tissues generally (Townsend *et al.* 1981) and in wheat baits buried in forest soils (Odham *et al.* 1979). Warfarin is

metabolised by the body, so although it takes 8 – 10 days feeding by a squirrel before death occurs the carcass will only contain active Warfarin from the last few feeds (3 – 4 days) (Mayle 2002). Hence the risks to predators / scavengers which may find the carcass is reduced. Based on this assumed bodyweight Forest Research have estimated that a fox would need to eat 10 – 20 poisoned squirrels a day over a period of 9 – 10 consecutive days to succumb to Warfarin poisoning. In recognition of the risks to non-target rodents the concentration of Warfarin used for grey squirrels (0.02%) is below that used for rats and mice (0.025%) (Mayle 2002).

Investigations of secondary poisoning effects on tawny owls (Townsend *et al.* 1981) concluded that it was unlikely that tawny owls would receive a lethal dose of Warfarin by consuming contaminated mice following recommended poisoning techniques for grey squirrel control in commercial woodlands (Ratcliffe & Pepper 2002). However, they did note that a sub-lethal effect caused changes in pro-thrombin levels, but these returned to normal after 9 days. Townsend *et al.* (1984) found that weasels were at risk to secondary poisoning effects using the experimental techniques. The weasels in the experiment were fed exclusively on contaminated mice and it is not known whether weasels living under wild condition would consume these quantities.

Similar work on magpies has suggested that magpies are no more vulnerable to poisoning from ingesting Warfarin than tawny owls. However no attempt was made to investigate whether this sub-lethal dose of Warfarin had any effect on vitamin K dependant systems such as blood coagulation or other physiological processes which might affect survival of magpies in the wild (Ratcliffe & Pepper 2002). Birds that had received dietary Warfarin, did show slight haemorrhaging in the pectoral muscles and in addition, some had small livers and two had discoloured bile. Further research is required on assessing residue levels in squirrels recovered during poisoning campaigns in order to "assess the total body burden and also the tissue levels which remain in dead squirrels so as to more precisely assess the risk associated with scavenging species" (Ratcliffe & Pepper 2002).

Many of the alternative rodenticides now in use on other species are faster acting than Warfarin but have high toxicity, particularly to birds, rendering them unacceptable. Reproductive inhibitors are a possible alternative. However the appropriate time to administer a reproductive inhibitor is October – November in order to inhibit spring breeding, but grey squirrels will not take artificially laid baits at this time (Ratcliffe & Pepper 2002). Unfortunately reproductive inhibitors can only be administered orally through baits. In addition, some modern chemical inhibitors appear to increase aggression in male rats. A

similar response in grey squirrels may cause increases in damage levels as damage to trees is known to be related to aggression in males (Ratcliffe & Pepper 2002).

The grey squirrel is a highly successful opportunist species. There is no easy way of reducing their numbers, which would be acceptable. In the short term there is unlikely to be an effective alternative to Warfarin poison that provides effective tree protection and control of grey squirrels with low risks to other wildlife (Ratcliffe & Pepper 2002). The volume of poison used has been substantially reduced in recent years and future improvements in damage prediction may result in further reductions. The risks of primary poisoning of non-target species have been virtually eliminated while the danger of secondary poisoning appears to be very low. At present, in the absence of other information, it is felt that the conservation benefits of increased survival of red squirrels and the establishment of maintenance of broadleaved woodland considerably outweigh the risks to non-target wildlife (Ratcliffe & Pepper 2002).

Whatever method of control is employed for grey squirrels, it must be intensive and instantaneous, for removing low numbers over a long period of time will only provide space for other squirrels to become incorporated into the population. Even a moderate removal rate will be compensated for by higher reproduction (Lawton & Rochford 1999). The ability of the squirrel to replace lost individuals even in isolated woodlands ensures that, particularly in years of high squirrel population density, the population will not be below capacity for long. In the event of all squirrels having been cleared from an area, the incoming squirrels will interact strongly to establish a new social hierarchy resulting in an increased possibility of agonistic encounters. This may well increase the risk of damage – the complete opposite effect to the desired outcome (Lawton & Rochford 1999). Dutton (pers comm 2003) found that by wiping out the grey from a wood, this was then followed by 2 – 3 almost damage free years. It was then possible to target control effectively.

There are two strategies available to controlling the problem of grey squirrel damage to broadleaved woodlands: controlling the number squirrels and controlling the extent of damage. Timing of control, say Mayle *et al.* (2003) is also important. Starting too early will allow grey squirrels in neighbouring areas to move in before the beginning of the damage period (Mayle pers comm 2003). This results in a greater control effort and unnecessary killing of animals. Starting too late may not allow time to reduce the population sufficiently to prevent damage. Gurnell & Pepper (1988) state that there is no reason to control squirrels outside the damage periods because the population will have recovered long before the damage period restarts. Squirrels are extremely mobile and can re-colonise isolated

woodland within 3 months and a non-isolated one within 1 month. Dutton (1993), however, considers that if control is not started early, and at a higher hopper density, control of all the grey squirrels will not be achieved. By starting later ensures some are missed which will compete with the newcomers, the young males of which will quickly learn the bark stripping habit.

Effective squirrel control may be difficult where the holding and adjacent damage-vulnerable woodlands are in different ownerships. Collaborative control, through either informal or formal 'Squirrel Control Groups' enables better planning of control over wide geographic areas (Mayle *et al.* 2003). Co-ordinated action is very important, but there is potential for disagreement with neighbours who do not adopt the same stringent practices, particularly those who are not certified under the UK Woodland Assurance Scheme (UKWAS). Some owners / managers do not carry out a policy of control but now those who do and are certified can now take action under the certification scheme. Under requirement 5.1.3 of UKWAS "Management of wild mammals, excluding deer, is undertaken in co-ordination with neighbours .....". If a certified neighbour is not controlling his grey squirrels, the stakeholder can write to the non-participating owner requesting that he establishes an acceptable level of control. Such action could cause considerable embarrassment if the neighbour proved to be a public body.

The British government has already considered an equivalent scenario for legislation. DEFRA (Department for the Environment, Farming and Rural Affairs) is proposing to help horse owners that suffer persistent reseeding due to a neighbour's negligence by drawing up the Code of Practice ahead of the Ragwort Control Bill becoming law. DEFRA's draft Code of Practice (2003) to control and prevent the spread of ragwort works on the premise that "landowners will wish to comply when the problem is drawn to their attention" (Rural Affairs Minister Alun Michael MP to Horse and Hound 31 July 2003). Ragwort is thought to kill at least 6,500 horses each year and, despite spraying by the M25 authority every 3 weeks, it thrives on many of Britain's road and motorway verges.

Warfarin poisoning and live trapping using baited cages say Mayle *et al.* (2003) are the most effective methods of reducing grey squirrel populations. The use of Warfarin has been favoured in most commercial woodlands because it is less time consuming and hence less expensive an operation and is probably more effective than trapping. However the future availability of Warfarin is uncertain and it is currently under review from the Plant Protection Directorate of the European Union. It is also not permitted where red squirrels are present or have been known to occur. Shooting is generally ineffective at reducing grey squirrel

numbers because they are less visible at the necessary time. Squirrels killed in winter will usually be replaced before the summer damage period and so the Forestry Commission does not recommend it.

IUCN guidelines state that steps to mitigate adverse impacts of alien species should include eradication, containment and control (McNeely *et al.* 2001 cited by Gurnell & Mayle 2002). Eradication refers to the complete removal of the invasive species, control refers to reducing their numbers and containment is a type of control that aims to limit the spread of the alien species and to contain its presence within defined geographical boundaries. It is now too late, say Gurnell & Mayle (2002) to eradicate the grey squirrel from the British mainland. Not only are they too well entrenched in our woodlands, parks and gardens, but also “they are appreciated and liked by many people, especially for those people living in the south of the country who may never have seen a red squirrel” (Gurnell & Mayle 2002). They consider, however, that every effort should be made to prevent grey squirrel colonisation on islands where greys are not present and if they are present then eradication should be considered. This approach is currently being adopted in Anglesey, an island off the north west coast of Wales and could also be considered in key conservation areas on the British mainland to prevent an incursion into areas where red squirrels exist (Gurnell & Pepper 1993).

Pepper (2003) in a letter to the Woodland Heritage Journal states that in Britain we rely on poisoning with Warfarin and to a lesser extent cage trapping to protect vulnerable woodlands from bark stripping damage and on cage trapping only to control greys to reduce competition with red squirrels. As well as the risk of an unfavourable result from the review of the use of Warfarin by the Plant Protection Directorate, there is also an increasing pressure for the continued reduction of the use of chemicals in the countryside. There is at present no direct alternative to poisoning and no effective substitute for Warfarin and cage trapping is a very labour intensive exercise and therefore too expensive to be justified in many areas for tree protection alone. Population control using an immuno-contraceptive is a suggested alternative and it has many potential advantages. Its efficacy in the wild is not yet known and it will take many years of research to establish an effective and practical method of administration. During this time the grey squirrel invasion will continue and tree damage levels will increase.

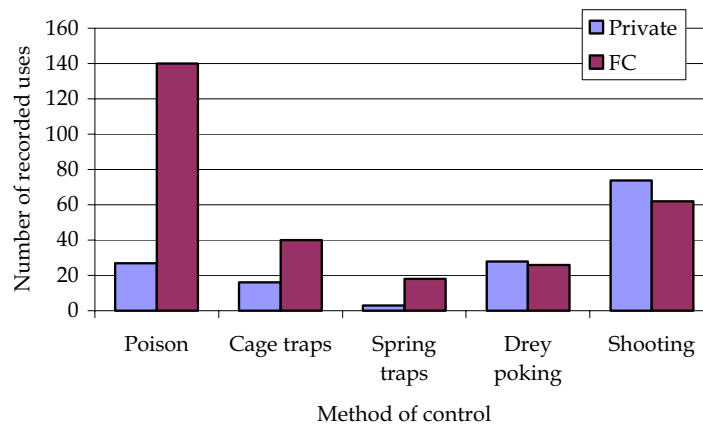
“It is already known that because of the severity of damage, there will be no more beech planted in the Forest of Dean. The future of beech in the Chilterns Area of Outstanding Natural Beauty (AONB) must also be in doubt. The vulnerability of oak is likely to increase in the absence of beech – there is already a trend towards this in the Forest of Dean. The

landscape and amenity value of these and many other areas of Britain will be devalued and will probably be changed for ever in the 21<sup>st</sup> century as a result of landowners at around the beginning of the last century introducing an alien arboreal mammal into their woodlands. There is nothing to suggest that mainland Europe will fare any better!" (Pepper 2003).

### **The effectiveness of squirrel control**

In 1984, Rowe gathered information on squirrel control methods from woodland managers, by means of a questionnaire filled in by the assessor during discussion. Some quantitative data were obtained on the use of control techniques, but no information is available as to the effectiveness of control strategies at preventing damage. Some inferences can be made from the fact that while control was practised more rigorously on Forestry Commission properties, the amount of squirrel damage is not significantly less than that found on privately owned lands. Ineffective control may be explained by the mobility of squirrel populations. Gurnell (1996) reported that squirrel home ranges can be as large as 10 ha and individual squirrels may move up to 1 km per day in search of food. Squirrels can readily invade managed woodlands from uncontrolled areas. Other evidence for the effectiveness of control is inconclusive. As already stated, Mountford (1997) reported that despite vigorous efforts to control squirrel populations in Lady Park Wood using warfarin-poisoned bait, the degree of squirrel damage to beech increased from around a third of stems in 1983 to over half of stems in 1993.

However, the effectiveness of poison hoppers is supported by Kenward *et al.* (1996), by evidence from Bottom Wood in the Chilterns (J. Morris pers. comm. to Rayden 2002) and by Gurnell and Pepper (1998). The latter is an especially useful example, as suppression of squirrel numbers in the experimental area appeared to induce in-migration of squirrels from neighbouring stands, but still prevented significant damage to trees. Dutton (1993) also advocates the use of poison hoppers and notes that their effectiveness can be improved if control is commenced in mid March or even earlier. Kenward *et al.* (1996) show how warfarin baited hoppers completely eradicated the squirrel population from four woods in southern Britain in four weeks! The numbers of occasions on which different control strategies were practised has been recorded both for Forestry Commission and privately owned woodland (Rowe 1984). These show that poison is by far the most widely used method on Forestry Commission owned land but shooting is favoured in private woods. The results are shown in Figure 5.6.



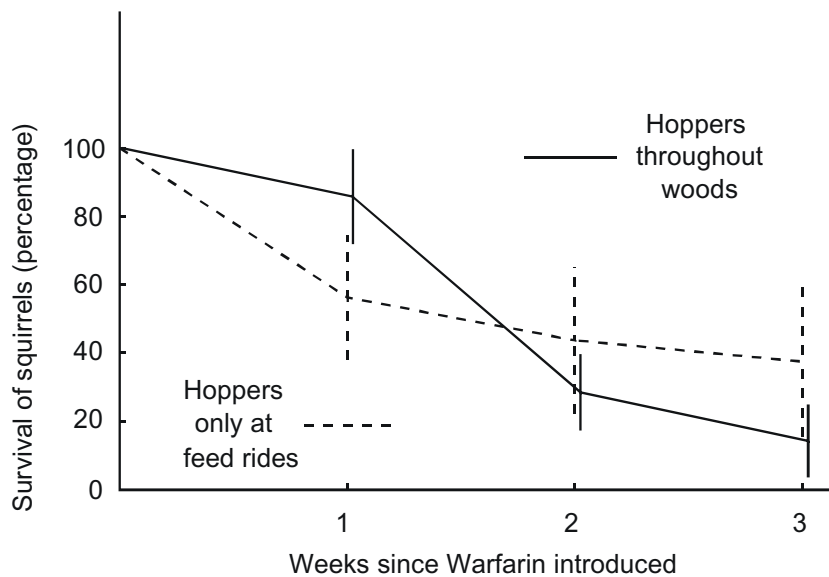
**Figure 5.6. Squirrel control strategies on FC and private land (Rowe 1984)**

Rayden (2002) assumed that squirrel control would be being practised as part of a Woodland Grant Scheme (WGS) management plan, and that control would be less likely at sites with no current WGS. However, no significant differences were found in the levels of squirrel damage between sites that are currently under a WGS and those that are not. There is, therefore, still considerable room for debate as to the best methods for controlling squirrel populations. Results from his study indicate that the current extent of squirrel control in the Chilterns is insufficient to maintain squirrel populations at levels that will not cause economically relevant damage to trees.

Kenward *et al.* (1996) claim that shooting and trapping squirrels has no effect on the long term incidence of damage, although Pepper (1998) concedes that shooting in spring may be a useful component of control, when practised together with the use of poison hoppers and or cage traps. In summary, the effectiveness of control using poison hoppers is supported in some cases and contested in others, with many private owners preferring shooting to the use of hoppers. However, the use of Warfarin with hoppers still remains the most cost-effective way to reduce squirrel numbers, and should provide the basis of a squirrel control strategy.

Kenward *et al.* (1996) reported findings from a large Dorset estate where Warfarin was used for squirrel control. The acorn crop was unusually heavy in autumn 1995 and the consequences, they predicted, would trigger damage in 1996. In order to determine how Warfarin might be used with least risk to other wildlife and minimal cost to the operator, they radio-tagged squirrels in woods where bark stripping the previous year had required squirrel control. Grey squirrels were captured in 8 woods, using Legg multi-capture traps baited with whole maize, and equipped with 25g radio collars. The radios had a thermistor to

change the rate of signal pulses when the animal was alive and warm in its drey, or colder during foraging or after death. After allowing the squirrels to regain their normal routine for at least 3 weeks, hoppers were laid in the woods and pre-baited for 10 days with whole maize, before being filled with Warfarin-coated wheat (Rowe, 1980). In 4 of the woods, the hoppers were placed only beside feed sites for pheasants (drums or straw-covered rides), and pheasant feeding was stopped. A hopper containing Warfarin was placed for every 2 hectares throughout the other 4 woods. Hoppers with Warfarin were placed in different locations to those used originally for traps to mark the squirrels. The fate of the 16 radio-tagged squirrels in woods with pheasant-site hoppers and the 21 in woods with general hoppers was then checked at intervals of 2-3 days.



**Figure 5.7. The survival rate of squirrels where control was widespread or only at pheasant feed sites (Kenward *et al.* 1996)**

The survival rate of squirrels differed between the two treatment types. By the end of the first week, survival was significantly lower in the pheasant-site woods ( $z = 2.03, P < 0.05$ ). However, by the third week the squirrel survival was least where hoppers were throughout the woods (Figure 5.7), and by 25 days all the squirrels there were dead. In contrast, 6 of 16 survived at the other sites (Fisher exact test,  $P = 0.019$ ). Radio-tracking showed that these survivors were not visiting the pheasant feed sites. This also raises the question of whether 1 hopper / 2ha is sufficient.

Of the 30 radio-tagged squirrels that died, 13 (43%) remained in their dreys. The others were mostly on the ground under their dreys. Twenty squirrels, including 3 poked from dreys, were left on the ground to record the incidence of scavenging, which might lead to secondary

poisoning. From the fate of these it could be estimated that about 25% of poisoned squirrels were liable to be scavenged, mostly in this case by foxes and rats (Kenward, 1988), but that even this low proportion could have been reduced by searching for corpses under dreys while Warfarin was available.

Kenward *et al.* (1996) concluded that if Warfarin is to be used, squirrels would be removed thoroughly only if hoppers are spread throughout the vulnerable woodland. Hoppers placed at pheasant feed sites may serve only to reduce local density of squirrels, which will enhance breeding among the survivors (Kenward and Holm, 1993). The reason that shooting and trapping generally does not appreciably reduce damage (Kenward *et al.* 1988a), or squirrel numbers (Fitzgibbon, 1993), is likely to be due to rapid compensation through enhanced breeding. When hoppers were spread widely and pre-baited adequately, squirrels were removed within 4 weeks. This may mean that small mammals living between the hoppers may not have been drawn outside the boundaries of their normal home ranges before the Warfarin was withdrawn. That effort could also be transferred to other woods after a month, thus reducing the cost of squirrel control.

### Costs of bark-stripping and squirrel control

The economic cost of bark stripping by grey squirrels can be estimated very approximately from the reduction in yield expected in damaged woods. In Table 5.3, Kenward and Dutton (1996) show, using 1992/3 timber prices, that the cost of moderately serious squirrel damage could be approximately £1700/ha in a beech plantation over an 85 year rotation. This loss is probably conservative, because it does not allow for reduced volume through the creation of gaps where several trees together are killed. Moreover, the entire crop is sometimes killed.

**Table 5.3. The potential value of beech in yield-class 8 at 85 years, assuming 300 cu m/ha of wood at prices pertaining in 1992/3, without squirrel damage and with moderately severe bark-stripping (Kenward & Dutton 1996).**

Category	Felled		Undamaged		Damaged by squirrels		
	Value/m <sup>3</sup>	Proportion	Volume	Value	Proportion	Volume	Value
1st quality	£69	25%	75 cu m	£5175	15%	45 cu m	£3105
2nd quality	£27	25%	75 cu m	£2025	15%	45 cu m	£1215
Firewood	£20	50%	150 cu m	£3000	70%	210 cu m	£4200
Total values:				£10200	£8520		

Spread over a vulnerable period of 30 years, the cost of squirrel damage is therefore in the order of £55 pa (sic). Against this cost may be set the cost of effective squirrel control, with and without minimum intervention. Recent estimates of using Warfarin have varied between £2/ha and £5/ha each year (Kenward *et al.* 1988;). They were £3.92/ha treated each year on the Dorset estate where this research was conducted. Another view of the savings is obtained by comparing the area actually treated during the minimal intervention regime, with the area that would have been treated if Warfarin had been applied in all sites every year.

Table 5.4 shows the areas managed during the period 1986 to 1991. From the total of 147 ha of vulnerable woodland in which there was squirrel control, an average of 56 ha (37%) were treated each year. The cost saving from minimum intervention alone was therefore more than 60%, compared with continuous control. This was close to £1.45/ha of vulnerable woodland each year, or about 2.6% of the estimated annual cost of damage if squirrels were not controlled.

**Table 5.4. The use of Warfarin based on minimum intervention, in 13 woods during a 6-year period (Kenward & Dutton 1996). Each x represents treatment years.**

Site	Areas (ha)		1986	1987	1988	1989	1990	1991
	Total	Treated						
A	1.3	1.3		x			x	
B	3.3	3.3	x				x	
C	1.6	1.6			x		x	x
D	6.9	5.3		x		x		
E	2.8	2.8		x			x	
F	5.9	5.9	x				x	x
G	13.4	6.0	x				x	
H	11.1	11.1		x				x
J	21.7	21.7	x			x	x	
K	6.6	6.6				x		
L	53.9	49.4		x		x		
M	1.2	1.2	x			x		x
N	88.3	30.6	x		x		x	
Totals:	218.0	146.8	68.7	64.8	32.2	84.2	57.9	19.8

Damage at level 3 (See chapter 5, Table 5.3 and Figure 5.4) is the highest that has been recorded in these 13 woods since the start of this policy, on two occasions in two separate woods. This is of no commercial significance.

### Density of hoppers

There are varying views about the density and timing of control by Warfarin in hoppers. Dutton (1993) cites Rowe and Pepper (1980 & 1991) as recommending 1 per 3 – 5 ha depending on squirrel density and to control annually. He then cites Kenward as

recommending 1 hopper per 2 ha and to start poisoning as soon after 15 March as possible. Pre-baiting is not affected by the Pesticides Regulation Act (1986) and can start sooner. Excellent results say Dutton (1993), can be obtained at this time of year when fresh wild food is in short supply and winter stores are low. Using an annual summer assessment in each vulnerable plantation with risk factors shown previously for predicting damage (Tables 6.1 and 6.2, this chapter), Dutton (1993) found that with high hopper density, an earlier start to control and the linking of poison control to the summer assessment, control could be economically targeted in space and time. This control method of surveying and then targeting the poison in the following spring enabled Dutton to control squirrels selectively over a larger area than could be done if Warfarin were used at each plantation every year. This method was not only very effective but substantially reduced the control costs per ha. Dutton (pers comm. 2003) has subsequently produced his own:

#### **Grey Squirrel Control and Hoppering Programme**

- 1 Carry out summer damage survey and assess results.
- 2 Consult thinning programmes for the current and previous year.
- 3 Purchase any new hoppers, whole maize, wheat and poison concentrate.
- 4 End of February site hoppers and start pre-baiting with whole maize. Hopper density to be carefully chosen. Usually one per hectare.
- 5 Pre-bait with whole maize, fill the hoppers and broadcast widely around each hopper up to 10-15 metres radius.
- 6 Pre-bait for 10-14 days reducing the broadcasting as uptake increases, until at the end of the period only hopper contains whole maize.
- 7 On 15<sup>th</sup> March remove all maize from hoppers and replace with treated wheat. **Do not broadcast wheat.**
- 8 Keep hoppers topped up at all times. Do not allow the hoppers to run out of either maize or wheat. If this does happen, restart the whole process from point No. 5 above.
- 9 Uptake from hoppers will stop after about 10 days.
- 10 When feeding stops remove the contents of the hoppers into a bag and lift hoppers ready for re-siting.
- 11 Re-site hoppers at the next control area and restart the control programme from point No. 5.
- 12 By early June uptake will be reducing in effectiveness. Lift all hoppers, clean, repair and store until next year.
- 13 End of July is the peak date for carrying out summer damage survey. New damage is usually very visible.

Experience since 1973 has shown that the use of Warfarin coated bait is a more cost effective method of controlling grey squirrels for tree protection than the labour intensive alternative of cage trapping (Pepper 1997). The annual control figures show approximately 140,000 squirrels are poisoned each year compared with 11,000 trapped (Pepper 1992).