

CHAPTER 6. QUANTIFICATION AND FINANCIAL IMPLICATIONS OF GREY SQUIRREL DAMAGE

Data on the extent of damage

Since its introduction from north America in 1876, the grey squirrel (*Sciurus carolinensis*) has spread throughout Britain and is now resident in almost all areas except the north of Scotland. Grey squirrels damage trees by stripping bark, which allows the entry of rot and staining fungi, and reduces timber quality (Broome & Johnson 2000). Damage is widespread and broadleaved species are more frequently attacked than conifers. Data on the extent and severity of damage are difficult to acquire because of the varied nature of woodland and the large number of owners. So an evaluation of some large scale surveys was done by Broome and Johnson for the Forestry Commission, the first of which is summarised in Table 6.1. This evaluation is the result of broad ranging surveys that were aimed at monitoring the general situation (e.g. Forestry Commission (FC) Squirrel Questionnaires and the Timber Growers Association (TGA UK) Questionnaire). It is not known what percentage of private landowners and forest managers in Britain were invited to take part in or completed the original FC surveys.

Table 6.1. Summary of the large scale survey of grey squirrel damage in Britain (Broome & Johnson 2000).

Survey	FC Squirrel Questionnaire	Private Woodlands Squirrel Questionnaire#	Damage to FC Woodlands *	Damage to private woodlands *
Conservancies covered	Whole of Britain	Whole of Britain	SW(E), NW(E), E(E), SE(E), N(W), S(W)	SW(E), NW(E), E(E), SE(E), N(W), S(W)
Area of (ha) woodland	120,300 (1993) - 271,500 (1990)	84,200	16,100	15,500
Level of data summary	By conservancy	By conservancy	By forest	By estate
Species represented	Beech, sycamore other broadleaves Larch & other Conifers	Beech, sycamore other broadleaves larch & other conifers	Beech, sycamore and oak	Beech, sycamore and oak
Data used in evaluation	No	No	Yes	Yes

* Grey squirrel bark stripping damage to broadleaved trees in southern Britain 1983

TGA(UK) 1991

The second evaluation of surveys that have been done gave more precise estimates of loss in commercial value made from a limited area, as in the Forestry Commission and private

broadleaved woodland surveys of southern Britain in 1983. However, the survey only covers 3 species - oak, beech and sycamore - and only 6 out of the 10 FC conservancy regions where there is a squirrel problem (Broome & Johnson 2000). The results of the 1983 surveys of damage are shown in Table 6.2. Again, the extent of the private woodlands data shown is not known. The scale of damage (as shown in Chapter 4, Table 4.3 and Figure 4.6) adopted in the survey is also not known so there remains a question as to whether the Forestry Commission recognises 'trials' as damage in the surveys done.

Table 6.2. Mean percentage number of trees damaged in a stand in Forestry Commission and private woodlands (Broome & Johnson 2000).

NB Figures for 95% confidence intervals are included to indicate margin of error in the estimates.

Species	FC data			Private Woodlands data		
	Mean % damage	95% confidence interval		Mean damage (%)	95% confidence interval	
Beech	26.9	21.5 32.4		28.7	22.1 35.4	
Sycamore	22.9	16.4 29.3		25.1	17.7 32.4	
Oak	8.8	5.0 12.7		6.3	2.2 10.4	

Broome has since carried out a questionnaire survey in 2000 with the aim of obtaining more detailed information and the results are currently being drafted for publication. However, actual expenditure on control was identified as being too low to achieve damage control (M Ferryman pers comm 2003).

Estimates of the costs of grey squirrel damage

Forestry produces social and environmental benefits, in addition to marketable timber outputs. These non-market benefits include open access non-priced recreation, landscape amenity, biodiversity, carbon sequestration, pollution absorption, water supply and quality, and protection of archaeological artifacts (Willis *et al.* 2003).

A study was undertaken by research staff at the University of Newcastle to provide empirical estimates of each of these social and environmental benefits in terms of

- marginal values, as an input into forest management, and
- their total value across forests and woodlands in Great Britain, to assess the importance of woodlands to the British economy.

The marginal benefits of woodland were estimated by Willis *et al.* (2003) to be:

- £1.66 to £2.75 for each recreational visit;
- £269 per annum per household, for those households with a woodland landscape view on the urban fringe;
- 35p per household per year for enhanced biodiversity in each 12,000 ha (1%) of commercial Sitka spruce forest; 84p per household/year for a 12,000 ha increase in

Lowland New Broadleaved Native forest, and £1.13 per household/year for a similar increase in Ancient Semi Natural Woodland;

- £6.67 per tonne of carbon sequestered;
- £124,998 for each death avoided by 1 year due to PM₁₀ and SO₂ absorbed by trees, and £602 for an 11 day hospital stay avoided due to reduced respiratory illness;
- A cost of 13p to £1.24 per m³ where water is lost to abstraction for potable uses, although for most areas the marginal cost is zero. The externality cost of woodland on water quality has been ‘internalised’ within forestry through the application of guidelines on woodland planting and conditions attached to forest certification.

These, say Willis *et al.* (2003) are indicative values for particular contexts, e.g. for landscape it is the value of seeing some woodland in the urban fringe rather than this landscape without woodland. Different marginal landscape values exist for non-urban periphery woodland views, i.e. woodland in other landscape contexts, and for different woodland configurations in the landscape in terms of woodland shape and species mix. Similarly there are different values for marginal increases in biodiversity in different types of woodland. There is no single marginal benefit or marginal cost value for any of the social and environmental benefits. Marginal benefits will vary for each social and environmental benefit depending upon circumstances. For carbon sequestration, this will depend upon tree type, yield class and forest management regime. With recreation, this will depend upon the recreational attributes of the forest (Willis *et al.* 2003).

The aggregate total annual and capitalised values of the social and environmental benefits of woodland in GB amount to £1.0 billion and £29.2 billion respectively (see Willis *et al.* 2003 Table 6.3). This total aggregate value of woodland is dominated by recreational and biodiversity values, followed by landscape benefits, with carbon sequestration also contributing significantly to the total social and environmental benefit of forests. Air pollution absorption (health effect) of woodland is relatively insignificant because of the absence of significant population numbers in close proximity to areas of woodland.

Table 6.3. Annual and capitalised social and environmental benefits of forests in GB
(Willis *et al.* 2003)
(£ millions, 2002 prices)

Environmental benefit	Annual value	Capitalised value
Recreation	392.65	11,218
Landscape	150.22	4,292
Biodiversity	386.00	11,029
Carbon sequestration	93.66	2,676
Air pollution absorption	0.39	11
Total	1,022.92	29,226

Aggregating individual social and environmental benefit estimates to derive total aggregate benefits of woodland for recreation, landscape, biodiversity, carbon sequestration, and air pollution absorption, is highly dependent upon accurate estimates of the population of relevance in each case. The area of woodland needed to calculate tonnage of carbon sequestered by woodland can also be fairly accurately determined from the National Woodland Inventory Survey. The population of areas containing woodland can be accurately determined from the Population Census. However, there is considerable uncertainty about the number of households with woodland landscape views; and the number of households who enjoy forest views on journeys. Similarly, uncertainty also exists about the number of visitors and visits to the FC estate and private woodlands in Great Britain (Willis *et al.* 2003).

Bark Stripping

Damage to trees caused from bark stripping has proved to have serious economic consequences. In order to calculate the cost of grey squirrel damage to beech, sycamore and oak woodlands in Britain, Broome and Johnson made the following assumptions:

- A discounted rate of 6% is used to bring income and expenditure to a common year;
- The age structure of the damage-vulnerable area is similar to the whole Forest Enterprise estate;
- Only those trees aged between 10 – 40 years are at risk;
- The proportion of public and private forests in the damage-vulnerable area is similar to that for the total forest area in Britain;
- Felling is carried out at the time of maximum discounted revenue (i.e. the economic optimum unconstrained by landscaping etc)
- Trees that have been damaged by grey squirrels have no monetary value.

The discounted rate of 6% is considered to be very high for broadleaved trees and, it could be argued, should be 3-4% (Hart 1993). Broome and Johnson (2000) estimated that about 43,000 ha of beech, sycamore and oak woodland is vulnerable to damage in Britain. They say that the value of this woodland is around £40 million in discounted terms of which approximately £33 million is in private ownership and £7 million is in public ownership. However, this would be higher if the current discounted rate was used. The 1983 grey squirrel damage surveys (see Table 6.2) indicate that 28% of beech, 24% of sycamore and 7% of oak was affected in Britain. The cost of damage caused by grey squirrels to these species is estimated by the Forestry Commission to be about £10 million in total, of which £8 million is the estimated cost to private estates and £2 million to publicly owned woods. This is not an annual cost but the loss of value of the woodlands at the end of the current rotation (Broome & Johnson 2000). Due to the assumption of complete loss through damage, Broome and Johnson see these estimates as an upper limit on the value of damage caused by grey

squirrels. Current research by Broome (including the new national survey) will allow a more precise evaluation (Broome & Johnson 2000).

The Forestry Commission quotes similar figures today, 20 years on from the original survey. It cites the economic cost of grey squirrel damage to timber in Great Britain (again discounted at 6% to a common year of 2000) as an estimated reduction in value of current tree crops by around 25% (or £10 million) (FC England Grey Squirrel Policy, in press). No specific estimates of the cost of damage to commercial tree crops in either the public or the private forestry sectors have been published, but together they are likely to exceed a million pounds per year (Gurnell & Mayle 2002). The costs of damage to the 199,000 ha of state owned forests in England have been estimated at £2 million over the period of a crop rotation for damage to sycamore, beech and oak alone. An additional £224,000 per year represents the cost of damage to conifers (Mayle 2002). Red squirrels have also been known to cause damage to woodlands, but the consequences have never been as economically profound mainly because their density is lower.

Value of crops at risk

Given that a significant proportion of the plantations at risk to damage are stocked with broadleaved species, for which the rotations are very long, the estimation of current value by discounting future income is not ideal. The economics of broadleaved plantations, in terms of timber production, are debatable and most investors are more likely to view such investment as a means to hand-on assets to future generations. It may therefore be more realistic to consider the true value of the sunk investment that is at risk. Without that investment the wider benefits of forestry would not be available to society (Inglis pers comm. 2003).

Table 6.4. Areas of plantations of the most vulnerable species planted between 1961 and 1990 (Ha) (Source: National inventory of woodlands and trees. Forestry Commission 2003)

Species	1981-1990	1971-1980	1961-1970
Scots pine	12,471	18,571	44,685
Corsican pine	6,271	7,444	9,547
Norway spruce	3,995	9,202	21,822
Larch	14,992	15,926	23,395
Oak	3,761	2,518	3,590
Beech	1,128	2,066	6,114
Sycamore	1,806	4,019	5,024
Sweet chestnut	578	431	677
Total	44,930	67,450	114,904

The total areas of these plantations, which lie within the most vulnerable age classes, is therefore some 227 thousand hectares (See Table 6.4). The cost of establishment and maintenance will vary over time and from plantation to plantation, and arriving at an accurate estimate of an average cost per hectare is difficult. However, if it is assumed that the cost lies somewhere between £1,000 and £1,500 per hectare the range of the capital invested in these plantations can be estimated to be between £227 and £340 million. This estimate does not allow for the cost of capital, ie the income that could have been generated had the capital been invested elsewhere. Estimates of the full value of the investment, compounded to 2003 at various rates of interest, is presented in Table 6.5.

Table 6.5. Estimated current value of investment including cost of capital (Inglis 2003)

Investment per hectare (£)	Cost of capital and estimated value (£ million)			
	0%	6%	8%	10%
1,000	227	1,522	2,898	5,516
1,500	340	2,280	4,340	8,528

At 8% cost of capital, the full value of the aggregate investment in 'at risk' plantations can be estimated to lie between £2.9 and £4.3 billion. The loss of even 5% of that investment, as a consequence of squirrel damage, would amount to between £145 and £217 million (Inglis pers comm. 2003).

Estimates of the cost of grey squirrel control

During the 1990s, Harry Pepper assessed the costs of grey squirrel control for Forest Enterprise (FE) woodlands as part of an internal FE review. Depending on the method employed, (poisoning with Warfarin or trapping), actual costs were estimated to be between £7 and £17 / ha / annum. Using these figures and estimates of areas with trees at vulnerable age-classes throughout Britain, broad estimates of potential costs can be calculated. These costs, however, did not necessarily provide effective control (Ferryman 2003 pers comm).

Individual examples

Kenward and Dutton's (1996) experiences of costs of damage and control with Warfarin have been examined and discussed in the previous chapter. Examples of others' include woodland in Norfolk where, because of the location, Warfarin cannot be used so it has been necessary to adopt the intensive and costly method of trapping. Spring traps are used (Fenn No 4 traps) in tunnels. Trapping commenced in Holmes Wood in 1996 as a consequence of some bark stripping, and the results (in numbers of squirrels killed) are shown at Table 6.6. As a result of vigorous efforts to prevent further damage, the grey squirrel density has been

kept to a minimum. The numbers caught annually appears to be fairly consistent and damage has lessened substantially in Holmes Wood since the campaign started. An alternative plan might be to use a Legg multi-trap for a more cost effective trap method.

Table 6.6. HOLMES WOOD, NORTH NORFOLK. GREY SQUIRREL CONTROL BY TRAPPING ON 63ha. (Brun 2003)

Month	1996-97	1997-98	1998-99	1999-00	2000-01	'01-'02	'02-'03	1997-02	Average
April	19	8	5	6	10	19	24	72	12
May	212	19	26	30	31	22	30	158	26
June	69	26	50	27	35	23	12	173	29
July	48	14	17	8	14	22	15	90	15
August	24	12	19	9	12	21	14	87	15
September	87	16	47	24	11	32	27	157	26
October	46	32	26	36	37	26	69	226	38
November	22	20	19	18	15	33	71	176	29
December	9	12	11	8	3	2	16	52	9
January	6	6	5	Not Set	F & M	Not Set		11	6
February	11	7	1	15	F & M	Not Set		23	8
March	11	5	3	13	F & M	8		29	7
Total killed squirrels	564	177	229	194	168	208	278	1,254	209
Cost / ha / annum		£12.50							
Cost / squirrel		£4.07							

Table 6.7. FULMODESTON SEVERALS, NORTH NORFOLK. GREY SQUIRREL CONTROL BY TRAPPING ON 77 ha. (Brun 2003)

Month	1999-00	2000-01	2001-02	2002-03	1999-02	Average
April	31	12	18	11	72	18
May	31	23	18	29	101	25
June	21	25	11	8	65	16
July	9	6	20	11	46	12
August	11	13	14	2	40	10
September	29	0	27	12	68	17
October	41	52	9	32	134	34
November	26	25	25	51	127	32
December	7	0	1	8	16	4
January	Not Set	F & M	Not Set		0	0
February	0	F & M	Not Set		0	0
March	7	F & M	Not Set		7	7
Total killed squirrels	213	156	143	164	676	169

In Fulmodeston Severals (Table 6.7) an area of dense natural regeneration developed in 1992, so trapping was introduced in 1999. The compartment was thinned for the first time during the winter 2002/2003. By the summer of 2003, squirrels had completely stripped many

young trees from top to bottom despite another vigorous squirrel campaign, such that it was considered possible that a few squirrels only had done the damage.

At another estate in East Anglia, the current cost of squirrel control also using Fenn tunnel traps and some shooting, including trap replacement, cartridges and labour, is £9.15 per acre (£23.75 / ha) of woodland. This figure is twice that at Holmes Wood and Fulmodeston Severals but is based on the cost of a keeper who is also tasked with other jobs. Also this figure is hardly affected by the numbers killed - a sparse kill will cost as much as a big kill for the traps still have to be checked. So costs per squirrel will vary and are relatively academic. This particular estate killed 1478 squirrels in 2001 when zero tolerance was introduced at a cost of £3.04 per squirrel, while in 1999 when only 241 were killed this cost was £18.70 per squirrel. As at June 2003, the count was running at just half of 2002, so a high level of control is anticipated. However, tree fruiting is expected to be high in the autumn with large crops of acorns, hazelnuts and walnuts developing which will inevitably give rise to a population explosion next spring (2004). Notice that on both these estates, control is practised year round.

A forth example is 500 ha of mixed lowland woodlands on large private estate in The Marches on the Welsh borders. There are approximately 120 ha of oak, sweet chestnut and beech that are particularly susceptible species and are within the 10 - 45 year age bracket. These are planted in mixtures with other broadleaved trees and conifers. Control of grey squirrels is applied using Warfarin and the season lasts from 15 March to mid June. Two weeks pre-baiting with untreated wheat or maize is undertaken to attract hungry squirrels and help them locate hoppers. Experienced woodsmen undertake the work. Hoppers are checked and refilled once a week and the total annual cost as follows:

21 man-days @ £75 (inc. on-cost / NI, etc.)	£1575
Depreciation charge on hoppers	£75
Warfarin - 12 bottles @ £19.50 each	£234
Bait - 150 kg	£20
Travel - 21 days - 20 miles/day @ 50p/mile	<u>£210</u>
	£2114

This equates to £46.98 / hopper / annum, or £17.62 / ha at a rate of 1 hopper / 3 ha of susceptible crop.

These figures exclude supervision costs and non-quantifiable sporting tenant input such as trapping / shooting / drey poking and are fairly typical in comparison with other estates whose costs vary between £35 and £50 / hopper / annum. However, this expenditure does not reduce grey squirrel damage to an acceptable level. According to

Dutton (1993), only whole maize should be used for pre-baiting and hoppers must be checked every two to three days. Once the hopper becomes empty, the whole the control programme has to be re-started. Dutton also recommends applying 1 hopper / ha initially.

In none of the estates illustrated here or in many others does any form of squirrel control provide an acceptable reduction in damage either because the control proves too costly or it is unsuccessful. The only exceptions are those cited by Kenward and Dutton (1996) in the previous chapter who indicate that rigorous prediction and pre-baiting exercises are required on a permanent basis, and errors will still occur. At no time or place is it possible to eradicate the grey squirrel completely with the present mechanisms for control due to the persistent endemic spread and replacement of the animal.

Forestry Commission Statistics

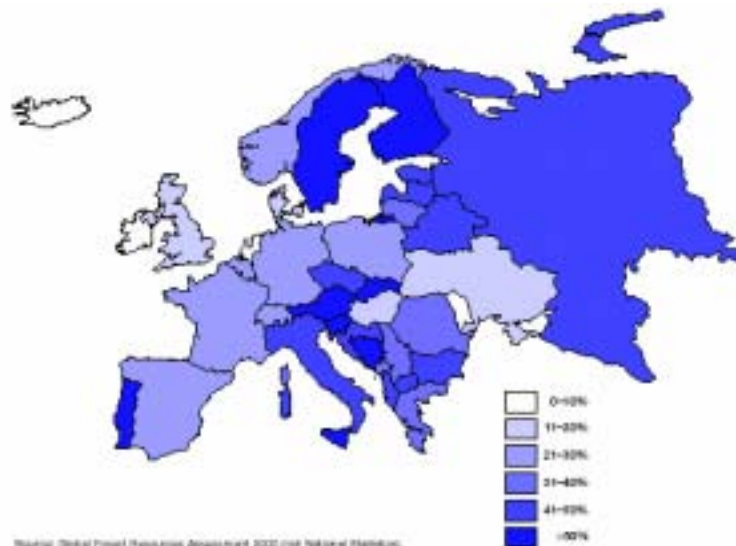


Figure 6.1. Percentage of woodland cover in Europe by country (Forestry Statistics 2002)

The British Isles are relatively lightly wooded compared to continental Europe (Figure 6.1). The total area of woodland for Great Britain in 2002 as stated by the Forestry Commission (Forestry Statistics 2002) is 2.7 m ha, (11.6% of total land area) of which 794,000 ha is Forestry Commission (or state) owned, 971,000 ha is broadleaved woodland, 1,406,000 ha is coniferous woodland. The coniferous element is influenced by the large percentage of woodland in Scotland of which less than 20% is broadleaved. In England, only one third of all woodland is coniferous, while in Wales over half is coniferous. The nature of British woodland has changed quite considerably since the mid-19th century as illustrated in Table 6.8 which identifies how substantial coniferous planting, particularly in Scotland in the mid- 20th century (post World War II) has played a key part in creating the present day British landscape.

Table 6.8. Area of woodland in Britain by planting year classes (000s ha) (Forestry Statistics 2002)

Planting year	GB	England	Scotland	Wales
Conifers				
Pre-1861	6	2	4	0
1861-1900	14	5	9	0
1901-1910	3	1	1	0
1911-1920	13	8	7	0
1921-1930	22	7	13	1
1931-1940	37	18	17	4
1941-1950	89	38	43	10
1951-1960	228	67	129	33
1961-1970	314	74	203	38
1971-1980	317	59	234	34
1981-1990	273	38	215	21
1991-	89	32	41	17
Total	1 406	340	916	149
Broadleaves				
Pre-1861	48	34	12	1
1861-1900	144	89	31	34
1901-1910	27	19	5	4
1911-1920	75	55	11	9
1921-1930	85	60	16	9
1931-1940	91	58	15	20
1941-1950	126	85	25	16
1951-1960	121	80	27	15
1961-1970	90	59	22	8
1971-1980	63	42	17	4
1981-1990	52	33	15	4
1991-	50	38	11	3
Total	971	648	206	118
Total				
Pre-1861	52	35	16	1
1861-1900	157	94	40	34
1901-1910	30	21	6	4
1911-1920	88	61	18	9
1921-1930	107	67	29	10
1931-1940	128	72	31	25
1941-1950	215	121	69	26
1951-1960	350	148	156	47
1961-1970	404	133	225	46
1971-1980	380	101	251	38
1981-1990	325	70	230	26
1991-	140	68	52	20
Total	2 377	988	1 123	266

Source: 1965-99 National Inventory of Woodland and Trees (not National Statistics).

Much modern day planting has been eligible for government grant aid under the Forestry Commission's Woodland Grant Scheme (WGS). Table 6.9 issued by the Forestry Commission (2003) shows that the total amount of money paid by the Forestry Commission in grant for new planting of private woodlands since 1993 is nearly £200 million. These figures under new planting include additional contributions such as Better Land Supplement, Community Woodland Supplement and Locational Supplement.

Table 6.9.WGS monies paid to private British woodlands '93-'03(Source Forestry Commission'03)

Year	New Planting	Restocking	AMG	WIG (2&3)
BRITAIN	TOTAL: £195,757,551	£34,919,126	£62,997,422	
1993/94	£16,872,970	£3,509,551	£1,780,028	£0
1994/95	£19,789,478	£4,232,650	£4,460,194	£0
1995/96	£17,346,046	£3,948,481	£6,398,329	£0
1996/97	£16,227,836	£3,438,277	£7,240,837	£0
1997/98	£17,936,988	£3,384,297	£8,463,722	£0
1998/99	£23,576,663	£3,748,750	£8,048,144	£1,865,364
1999/2000	£21,011,571	£3,671,733	£6,911,947	£2,116,844
2000/2001	£23,905,524	£3,570,093	£6,818,353	£1,910,532
2001/2002	£19,230,293	£2,763,657	£6,364,192	£1,827,279
2002/2003	£19,860,182	£2,651,637	£6,511,676	£2,350,113
SCOTLAND	TOTAL: £105,140,059	£18,426,165	£16,735,155	
1993/94	£8,014,876	£1,677,232	£180,863	£0
1994/95	£11,807,908	£2,214,448	£924,884	£0
1995/96	£9,760,130	£2,297,793	£1,674,320	£0
1996/97	£9,821,447	£1,816,755	£2,118,587	£0
1997/98	£10,660,644	£1,655,595	£2,453,100	£0
1998/99	£12,563,611	£1,826,318	£2,533,709	£218,530
1999/2000	£10,512,461	£1,924,980	£2,021,948	£333,292
2000/2001	£12,853,950	£1,953,950	£1,779,373	£331,273
2001/2002	£10,175,640	£1,593,093	£1,608,226	£853,145
2002/2003	£8,969,392	£1,466,001	£1,440,145	£1,157,870
ENGLAND	TOTAL: £81,984,751	£12,632,360	£43,199,978	
1993/94	£8,183,087	£1,640,661	£1,518,222	£0
1994/95	£7,306,114	£1,665,946	£3,346,918	£0
1995/96	£7,005,449	£1,314,285	£4,453,869	£0
1996/97	£5,861,691	£1,226,504	£4,761,536	£0
1997/98	£6,453,708	£1,319,808	£5,607,942	£0
1998/99	£9,582,596	£1,432,733	£5,099,722	£1,398,018
1999/2000	£8,971,948	£1,275,445	£4,529,372	£1,373,945
2000/2001	£9,962,368	£1,188,634	£4,659,397	£1,157,718
2001/2002	£8,588,644	£765,153	£4,437,965	£853,145
2002/2003	£10,069,146	£803,191	£4,785,035	£1,157,870
WALES	TOTAL: £8,632,741	£3,860,601	£3,062,289	
1993/94	£675,007	£191,658	£80,943	£0
1994/95	£675,456	£352,256	£188,392	£0
1995/96	£580,467	£336,403	£270,140	£0
1996/97	£544,698	£395,018	£360,714	£0
1997/98	£822,636	£408,894	£402,680	£0
1998/99	£1,430,456	£489,699	£414,713	£248,816
1999/2000	£1,527,162	£471,308	£360,627	£409,607
2000/2001	£1,089,206	£427,509	£379,583	£421,541
2001/2002	£466,009	£405,411	£318,001	£120,989
2002/2003	£821,644	£382,445	£286,496	£34,373

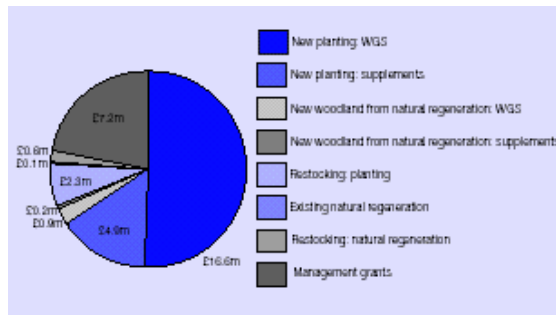


Figure 6.2. Woodland Grant money paid out in year ending 31 March 2002 by type of grant (Forestry Statistics 2002).

Figure 6.2 shows total grant support for the year 2002 alone with £21.4 million granted for new planting including all supplements. With grey squirrel damage so prolific, a thorough survey is required to establish how much grant aided new woodland (both in its monetary value and hectareage) has been lost or is vulnerable to grey squirrel damage to identify

- the loss of public funds granted on both private and state woodlands that have been harmed, sometimes irreparably, as a result of subsequent squirrel damage;
- the additional cost that has been paid, or will have to be paid for grey squirrel control. This will be both public and private landowners money.

These figures should then be compared with the amount of monies paid out in both grant aid for new planting and Annual Management Grant (AMG - the grant that can be available towards the cost of grey squirrel control, amongst other items), and then be considered against the Forestry Commission estimated figures for costs of damage quoted for private woodlands (estimated to be £8 million) and the 200,000 ha of state owned forests in England (estimated at £2 million over the period of a crop rotation for damage to sycamore, beech and oak alone; and an additional £224,000 per year represents the cost of damage to conifers (Mayle 2002)).

The areas of new plantings, restocking and natural regeneration funded by WGS for the past 30 years are all at risk from destruction by grey squirrel damage unless protected. The evidence is clear that using current mechanisms and the Forestry Commission's present recommendations, full protection is unachievable. Even with control there have been and will continue to be substantial losses, with a large amount of taxpayers' and private investment already wasted. This is set to continue under the present regime. Kenward and Dutton (1996) have shown that a high level of protection requires a rigorous and persistent programme of control. But their method is not usable nationwide in Britain. An alternative method of control is required to ensure 100% effective control.

In England there are 648,000 ha of privately owned broadleaved woodland. To calculate the cost of control nationally, either an assumption would have to be made or careful analysis would be required to calculate the percentage of woodland needing protection, and the percentage of woodland actually being protected. It is possible, on the examples of grey squirrel control shown earlier, to take an arbitrary figure of the cost of controlling squirrels as (say) £12.50/ha and calculate that the annual cost nationally, if all private woodland were protected, would then be £8.1 million. If the control cost was £25/ha, the annual national cost of grey squirrel control would be £16.2 million per annum, very nearly as much as the government contributes to new planting each year (£21.4 m 2002). However, not all woodlands are vulnerable to damage, but most harbour the species, and so provide a reservoir of grey squirrels.

Such comparisons should also be made with the amount of Annual Management Grant (AMG) paid out each year. Table 6.10 shows the total areas approved for AMG (which includes grey squirrel control) paid for private woodlands since 1993. Paid at £35/ha, AMG is an insignificant contribution towards the costs of grey squirrel control. This is because

Table 6.10. Woodland in Britain approved for Annual Management Grant under the Woodland Grant Scheme (Forestry Statistics 2002)

(000s ha)

Year ending 31 March	GB	England	Scotland	Wales
Broadleaves				
1993-94	46.9	39.3	5.8	1.8
1994-95	30.9	21.7	8.1	1.0
1995-96	21.2	15.5	4.3	1.4
1996-97	18.9	12.7	4.9	1.3
1997-98	23.6	18.5	3.9	1.2
1998-99	29.6	24.6	3.6	1.5
1999-00	30.3	24.9	4.3	1.0
2000-01	22.5	18.5	2.6	1.4
2001-02	27.5	21.1	4.3	2.1
Conifers				
1993-94	64.1	18.2	42.0	3.9
1994-95	40.7	7.6	31.3	1.8
1995-96	14.8	4.5	9.1	1.2
1996-97	8.8	3.3	5.1	0.5
1997-98	12.6	5.9	5.8	0.9
1998-99	13.6	6.2	6.6	0.8
1999-00	14.9	8.6	5.4	0.9
2000-01	11.7	4.9	6.3	0.4
2001-02	16.9	5.3	10.4	1.2
Total				
1993-94	111.1	57.5	47.7	5.8
1994-95	71.5	29.4	39.4	2.8
1995-96	36.0	20.0	13.5	2.5
1996-97	27.7	15.9	10.0	1.8
1997-98	36.1	24.4	9.7	2.1
1998-99	43.3	30.8	10.1	2.3
1999-00	45.1	33.5	9.7	1.9
2000-01	34.2	23.4	8.9	1.9
2001-02	44.4	26.4	14.7	3.3

grey squirrel control is only considered as part of a package of activities within the AMG which provides financial help only if the application complies with overall objectives of the grant such as:

- improving conservation and biodiversity within a woodland;
- improving or introducing public access.

The grant will also only be paid on those specific areas within the woodland to which the objectives apply. So while AMG was paid out for 44,400 ha in 2001/2002 (See Table 6.10), this should be compared with the total area of private woodland of 1,877,600 ha in Britain that was unaided. As such there is no financial assistance purely for squirrel damage control within the Woodland Grant Scheme.

The National Forest

In considering the amount of public money spent each year by the Forestry Commission on new woodland planting, restocking and woodland management, it is also important to put that spending in perspective with the amount the government, and therefore the taxpayer, is spending on the National Forest each year. A description of The National Forest taken from its own website (National Forest Company 2003) is:

“The National Forest is a forest in the making: a place of 200 square miles spanning three counties in the English Midlands whose physical creation can now be witnessed and enjoyed. The National Forest is for the nation: welcoming to visitors and home to local people, all of whom can participate in its development as part of the nation’s future heritage.

The National Forest is one of Britain’s biggest, boldest long-term environmental initiatives. The vision of a completely new forest for the nation is becoming a reality.

It is a vast working example of sustainable development fulfilling environmental, social and economic objectives for present and future generations, the Forest brings a wide range of benefits for local people, the UK as a whole and for the world environment:

- To create a diverse landscape and enhance biodiversity.
- To make a significant contribution to the UK’s efforts to reduce atmospheric carbon dioxide.
- To create a major resource for tourism, recreation and education.
- To provide a productive alternative use for farmland.
- To make a contribution to the UK’s timber needs.
- To stimulate the economy and to create new jobs.

Before the Forest initiative got underway, woodland cover across the area accounted for just six per cent of land use, well below the national average.

The ambitious goal for The National Forest is for about one third of all the land within its boundaries to be wooded, a task that will involve planting a total of 30 million trees.”

In order to plant 30 million trees, a large package of grants is available to landowners to create a landscape that:

“.. will bring new business opportunities and jobs to the whole area. Its beautiful surroundings and leisure facilities will provide enjoyment for local people and visitors alike. In the midst of this a valuable timber resource will be created while the growing trees will improve our air quality.

The Forest will bring a radical change to the landscape and embrace many differing land uses. But the whole area will not be masked with trees: forestry and all other activities will be woven into the existing landscape character. (Copyright National Forest Company website 2003)."

The total amount of public funds paid to the National Forest Company (NFC) each year is core funded by DEFRA (Department for Environment, Food and Rural Affairs). The total grant in aid from DEFRA for the period 1995 – 2003 is £22 million of which the grant in aid for 2002/03 was £3.7 million. The annual commitment by The National Forest Company to Tender Schemes each year has increased from 1995 (£1.08 million) to 2003 (£2.93 million), totalling £18.47 million, of which between 16% and 25% is paid from the Forestry Commission Woodland Grant Scheme (total: £4.5 million). The balance of the total amount granted to National Forest Company of £6.76 million for this period is spent on running costs which in 2002/03 were 17.5 staff complement, non-pay costs, land acquisition, and the Programme Development Fund.

As at 30 September 2002, 125 schemes have been successfully approved and commenced with 2,364 hectares committed of which up to 70% is new woodland. The average payment by The National Forest Company (including FC payments) for this is £7,813 / ha, while the unit cost to the taxpayer including NFC running costs is £9,306.26 /ha. As shown in the website extract above, the balance of this land may remain partly in agriculture or, more likely, it will be converted to open access land, parkland, wildlife and conservation areas with ponds and so on. The Tender Scheme is competitive, has a 25-year contract and the landowner submits a bid price per hectare within the application. This will include full details of the cost of planting and maintenance, anticipated loss of income, loss of land value and illustrating all existing schemes present or proposed for the site such as Countryside Stewardship, Environmentally Sensitive Area, Site of Special Scientific Interest etc. Each application is assessed on its contribution to achieving the National Forest objectives.

At present the National Forest Company has no specific pest control policy beyond that noted in the Forest Strategy and the Woodland Grant Scheme. It is well aware that the earliest planted trees are now becoming vulnerable not only to squirrel damage but also to damage by deer that are prevalent in Leicestershire, Derbyshire and Staffordshire. Of the eight rounds of Tender Schemes to 30 September 2002, in each round, the single largest scheme has increased in size quite dramatically with the most recent one being 104 ha (which could potentially receive £812,552), but the average is 17 ha. It is clear that if the large sums of public money already put into the project are not to be jeopardised, an effective National Forest policy to prevent grey squirrel damage is urgently needed.

The funding of The National Forest should be compared with the other 12 community forests such as the Forest of Avon, Red Rose Forest and Great Western Forest, and a number of challenge funded areas e.g. South West Forest. In South West Forest the usual WGS new planting grants with Better Land and Community supplements are available as applicable for new planting schemes and the only additional payment is the locational supplement. This is now available on a points scoring system, but until this year (2003) was paid at a rate of £600 / ha for schemes of 5 – 10 ha and £1000 / ha for schemes over 10 ha. By this method, the maximum payable (by the Forestry Commission) up to 2003 to the landowner in the South West Forest has been:

£1350 / ha for broadleaved trees

£600 / ha for Better Land Supplement (BLS) (eligibility infrequent)

£950 / ha for Community Woodland Supplement (CWS) (eligibility infrequent)

£1000 / ha for Locational Supplement

£3,900 / ha, TOTAL

although this is more likely to be less BLS and CWS, i.e. £2350 / ha.

Both these total figures are far removed from the payment per hectare in the National Forest. It should be noted that the South West Forest also has no pest control policy, but has only been in existence since 1998 and has averaged new planting areas at 400 ha / annum over the last 5 years. The South West Forest is therefore effectively planting twice the area of woodland that The National Forest is planting each year for less than half the money.

The urban community Forest of Avon has been less successful in achieving its target of 250 – 300 ha / annum. Actual committed planting each year is nearer 100 ha. The usual WGS package is available for applicants including a Locational Supplement, but this is limited to £600. Although approximately 80% of schemes approved and committed for planting are eligible for Better Land Supplement (BLS) and thus the Farm Woodland Premium Scheme (FWPS), more than 50% of initial applications are withdrawn before submission because the applicants find that they are not eligible for either the BLS or FWPS. The Countryside Agency and the local authorities for the area undertake the running costs of the Forest of Avon equally. Again no actual squirrel policy is in place but Forestry Commission practice is followed and the local conservancy actively encourages grey squirrel control and offers the Woodland Improvement Grant (WIG) towards it as part of the biodiversity package.

The actual financial implications of grey squirrel damage are much wider than the majority of people might appreciate. To quantify the true extent of damage has been difficult in the absence of empirical evidence. The benefits that forestry brings to society are wide ranging

and to assess the real cost of grey squirrel damage to biodiversity would entail extensive surveying with an agreed method of establishing plausible values. The question this review asks is: how much these values will be harmed if grey squirrel damage continues to escalate unabated? The list of areas to survey is surprisingly long. Besides damage to trees, birds, birds eggs, bird tables, bird food, gardens, flowers, shrubs, buds, bulbs, seeds, roofs, roofing felt, electric cables, high forest, landscape, recreation, air quality, carbon sequestration, water supply and ecosystems all suffer the ravages of the grey squirrel. A simpler method would be to dispose of the grey squirrel once and for all. Clearly, new and effective approaches to grey squirrel control are urgently needed.

Reference list

- ADAS Wildlife and Storage Biology (1987) *Control of Grey Squirrels* MAFF P3083.
- Anderson ML (1967) *A History of Scottish Forestry* vol 2.
- Amori G & Genovesi P (1999) *Conservation of Sciurus vulgaris and eradication of Sciurus carolinensis in Italy*. In: Workshop on the Control and Eradication of Non-native Terrestrial Vertebrates. Council of Europe, Environmental Encounters, No 41.
- Armitage, J.L., Rushton, S.P., Lurz, P.W.W. & Fuller, R.M. (1997). *Modelling the dynamics of red squirrel populations in relation to invasion by grey squirrels: an individual-based modelling approach*. In The conservation of Red Squirrels, *Sciurus vulgaris* L. (eds J. Gurnell & P.W.W. Lurz), pp. 97-118. PTES, London.
- Bailey, B. (1923) Meat eating propensities of some rodents of Minnesota. *Journal of Mammalogy*, 4,129.
- Barber S (2003) 'Treatment of grey Squirrels to benefit red squirrels and trees'. Discussion paper presented at Red Squirrel In South Scotland Project Steering Group.
- Barne M (May 03) *Cost of grey squirrel control on Sotterley estate*.
- Barr JF, Lurz PWW, Shirley MDF, Rushton SP (2002) Evaluation of Immunocontraception as a Publicly Acceptable form of Vertebrate Pest Species Control: The Introduced Grey Squirrel in Britain as an example in *Environmental Management* 30(3), 342-351.
- Barratt EM, Malarky G, Boddy S, Gurnell J & Bruford MW (1997) *Genetic Diversity among fragmented populations of red squirrel: a preliminary study*. In The Conservation of Red Squirrels, *Sciurus vulgaris* L. (eds J. Gurnell & P.W.W. Lurz), pp.61-66 Peoples Trust for Endangered Species, London.
- Barry J (2003) *The Grey Squirrel (Sciurus carolinensis)* in Crann 61:7.
- Bath AJ (1999) *Human dimension in Wildlife Management - Gaining Public Acceptance*. In: Workshop on the Control and Eradication of Non-native Terrestrial Vertebrates. Council of Europe, Environmental Encounters, No 41.
- Bertolino S & Genovesi P (2001) *Human dimension aspects in invasive alien species issues: the case of the failure of the grey squirrel eradication project in Italy*. In: McNeely JA (Ed), *The Great Reshuffling: Human Dimensions of Invasive Alien Species*. IUCN, Gland Switzerland and Cambridge, UK, pp 113-119.
- Bertolino S & Genovesi P (2002) *Spread and attempted eradication of the grey squirrel in Italy, and consequences for the red squirrel in Eurasia*. In *Biological Conservation* 109:351-358.
- Binnian D (Apr 03) *Destruction of a Proud Industry* in QJF 97:143-144.
- Bevan RM & Lurz PWW (2003) *Comparative energetics of red and grey squirrels and the constraints of habitat*.
- Brainard J, Lovett A & Bateman I (2003) *Carbon Sequestration Benefits of Woodland*. Report to the Forestry Commission. Centre for Research in Environmental Appraisal & Management.
- Brun E (2002) *Grey Squirrel control results*.
- Brunton C F A, MacDonald D W, Buckle AP, (1992) *Behavioural Resistance Towards Poison*.
- Bryce J, Johnson PJ & Macdonald DJ (December 2002) *Can niche use in red and grey squirrels offer clues for their apparent coexistence?* *Journal of Applied Ecology* volume 39 Issue 6 Page 875.
- Bryce JM & Macdonald DW (2002) *Projected Changes in Red Squirrel Habitats in Craigoinean Forest in Scottish Forestry*: 54(2), 87-90.

- CAFFARA M & A. SCAGLIARINI (1999) *Study of diseases of the grey squirrel (Sciurus carolinensis) in Italy*. In *Medical Mycology* volume 37 Issue 1 Page 75.
- Cartmel S (1997) *A study of Red and Grey squirrels in Cloacaenog Forest, North Wales: a preliminary study*. In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp.89-96 Peoples Trust for Endangered Species, London.
- Cartmel S (2001) *Red Squirrel Survey of Central Wales 2001*. CCW Contract No.FC 73-01-310.
- Cartmel S (2002) *Review of Red Squirrel Habitat in Central Wales 2002*. Joint funded by Carmarthenshire County Council, Ceredigion C.C. & CCW.
- Clover C (8 May 2002) *Invaders driving Red Squirrel and Vole to extinction*. Report for Mammals Trust.
- Clover C (14 December 2002) *Hedgehogs in Western Isles with a taste for bird eggs face a cull*. In *Daily Telegraph*.
- The Confederation of European Paper Industries (CEPI) *Position on Forest-related Sinks (August 2002)*.
- Corbet G & Ovenden D (1980) *The Mammals of Britain and Europe*.
- Corne G (13 November 2002) *Squirrels are hard workers and tenacious*. In the *Eastern Daily Press*.
- Cowan D *et al* (1994) *The impact of resistance of the use of second generation anticoagulants against rats on farms in Southern England*.
- Davidson AM & Adams W (19) *The grey squirrel and tree damage* QJF 237-247
- Davidson AM (19) *British Squirrels – between ourselves* in QJF 225-232
- Davidson AM (19) *Red squirrels in Thetford Chase – II* in QJF 211-222
- Davidson AM (19) *Red Squirrel in Thetford Chase – III* in QJF 52 - 64
- DEFRA (2001) *Urban Grey Squirrels*. *vertebrate Wildlife Management*.
- Dutton JCF(1993) *Grey Squirrel Control in Britain*.
- Eason, P.K. (1998) *Predation of a female House Finch, Carpodacus mexicanus, by a grey squirrel, Sciurus carolinensis, Canadian Field-Naturalist, 112, 713-714.*
- Eastern Daily Press (3-13 Feb 03) *Deer culling in Bacton Wood, Norfolk by FE stopped by protesters*.
- Eastern Daily Press (28 June 02) *Breeding Red Squirrels at Kelling Heath, Weybourne and releasing in wild*.
- Economist (Aug 02) *Problems caused by the ruddy duck*.
- English Nature Species Recovery Programme: *The Red Squirrel*.
- Fitzgibbon CD (1993) *The distribution of grey squirrels in farm woodland: the influence wood area, isolation and management*. In *Journal of Applied Ecology* 30, 736-742.
- Forestry Commission (21 November 2001) *Deer and Grey Squirrel threat to woodlands*. East of England Seminar at Audley End Group 3.
- Forestry Statistics and Forestry Commission Annual reports (2001 and 2002).
- Forestry Commission Practice Guides 1– 8 *The management of Semi-Natural Woodlands:*
 FPG1 Lowland Acid Beech & Oak Woods;
 FPG2 Lowland Beech – Ash Woods;
 FPG3 Lowland Mixed Broadleaved Woods;
 FPG4 Upland Mixed Ashwoods;

FPG5 Upland Oakwoods;
FPG6 Upland Birchwoods;
FPG7 Native Pinewoods;
FPG8 Wet Woodlands.

Forestry Commission *Grey Squirrel Liquid Concentrate (Warfarin) Permitted Areas* 2003.

Forestry Commission (1960) *The Grey Squirrel – A woodland pest*. Leaflet No 31.

Forestry Commission *Control of Grey Squirrels* Leaflet 56.

Fulford F (2003) *Red Squirrels: How the West is being won* in Country Illustrated Issue 63.

Fuller, R.J. (1995) *Bird Life of Woodland and Forest*. Cambridge University Press.

Garrod G (2003) *The Landscape Benefits of Forests* Report to the Forestry Commission. Centre for Research in Environmental Appraisal & Management

Genovesi P (1999) *IUCN Guide Lines and Activities for the Prevention of Biodiversity Loss due to Biological Invasions*. In: Workshop on the Control and Eradication of Non-native Terrestrial vertebrates. Council of Europe, Environmental Encounters, No 41.

Genovesi P (2000) *The Grey Squirrel in Italy: Risks of expansion and related threats to the survival of the Red Squirrel in Europe*. Proceedings of 19th vertebrate Pest Conference 2000.

Genovesi P & Bertolino S (2001) *Guidelines for control of the American grey squirrel in Italy*. Ministry of Environment - National Wildlife Institute Quaderni Conservazione della Natura N4 pp51.

Genovesi P (2002) Biotic invasions in Europe: the case of the grey squirrel in Italy; general trends, threats and strategies for the future. In Bulletin de l'Institut Royal des Sciences Naturelles de Belgique Biologie 72: 231-234.

Gewin (6 May 2002) *Grey squirrels nick reds' nuts*. www.nature.com/nsu.

Greaves J H (1971) *Resistance to anticoagulants in rodents*.

Green E *The last remnants of Europe's Rainforest - the UK's ancient trees*. Talk at the National School of Forestry, Newton Rigg to The Ancient Tree Forum.

Gregory S (Sept 00) *Control of Grey Squirrels - Warfarin and European Pesticide Legislation* Paper for ESF adjoining a Briefing note for FC staff.

Gurnell J & Pepper H (1987) *Perspectives on the Management of Red and Grey Squirrels*.

Gurnell J & Pepper HW (1991) *Conserving the Red Squirrel* Research Information Note 205 FC.

Gurnell, J., Lurz, P.W.W. & Halliwell, E.C. (1991). *Red squirrel*. In Handbook of British Mammals 4th edition, S. Harris (ed.). Mammal Society.

Gurnell J & Pepper H (1993) *A critical look at conserving the British Red Squirrel Sciurus vulgaris*. In Mammal Review 23, 127-137.

Gurnell J (1996) *The effects of food availability and winter weather on the dynamics of a grey squirrel population in southern England*. In Journal of Applied Ecology 33(2), 325-338.

Gurnell J & Pepper H (1996) *UK review of grey squirrel control for red squirrel conservation*.

Gurnell J, Clark MJ & Feaver J (1997) *Using Geographic Information Systems for Red Squirrel Conservation management*. In The Conservation of Red Squirrels, *Sciurus vulgaris* L. (eds J. Gurnell & P.W.W. Lurz), pp.153-160 Peoples Trust for Endangered Species, London.

- Gurnell J & Lurz PWW (1997) Red Squirrel Conservation in Britain and Europe- The Future. In The Conservation of Red Squirrels, *Sciurus vulgaris* L. (eds J. Gurnell & P.W.W. Lurz), pp.161-162 Peoples Trust for Endangered Species, London.
- Gurnell, J. & Lurz, P.W.W. (1997). *The Conservation of Red Squirrels, Sciurus vulgaris* L. Peoples Trust for Endangered Species, London.
- Gurnell, J. Lurz, P.W.W. & Pepper, H. (September 2001). *Practical techniques for surveying and monitoring squirrels*. FCPN11.
- Gurnell J, Mayle B, Lurz PWW, (2002) *The Grey Squirrel in Britain and Ireland: Past, Present and Future*. 6th European Squirrel Workshop, Acqui Terme, Italy.
- Gurnell J & Mayle BA (2002) *Ecological Impacts of the Alien Grey squirrel (Sciurus carolinensis) in Britain*. At MammAliens - A One day conference on the problems caused by non-native British mammals.
- Hale M & Lurz PWW (2003) *Patterns of genetic diversity in the red squirrel (Sciurus vulgaris L): footprints of biogeographical history and artificial introductions*.
- Hale M L, Bevan R & Wolff K (March 2001) PRIMER NOTE *New polymorphic microsatellite markers for the red squirrel (Sciurus vulgaris) and their applicability to the grey squirrel (S. carolinensis)* Molecular Ecology.
- Halliwel EC (1997) *Red squirrel predation by Pine martens in Scotland*. In The Conservation of Red Squirrels, *Sciurus vulgaris* L. (eds J. Gurnell & P.W.W. Lurz), pp.39-48 Peoples Trust for Endangered Species, London.
- Hanley N, Willis K, Powe N, & Anderson M (2002) *Valuing the Benefits of Biodiversity in Forests*, Report to the Forestry Commission. Centre for Research in Environmental Appraisal & Management.
- Harris S, Morris P, Wray S & Yalden D (1995) *A review of British mammals: population estimates and conservation status of British mammals other than ectaceans*. JNCC.
- Hart C (1993) *Practical Forestry for the Agent and Surveyor*
- Hodge S & Pepper HW (1998) *The Prevention of mammal damage to trees in woodland* FCPN3.
- Invasive Species Specialist Group (2002) *A Hundred of the World's Worst Invasive Alien Species* selected from the Global Invasive Species database (www.issg.org/database).
- IUCN 5 (April 2002) *IUCN Guidelines for the prevention of Biodiversity Loss caused by Alien Invasive Species* prepared by the SSC Invasive Species Group, Approved by the 51st Meeting of the IUCN Council, Gland, Switzerland February 2000. Taken from web site www.iucn.org.
- IUCN (April 2002) *Recommendations – 6th Meeting of the Conference of the Parties to the Convention on Biological Diversity (COP6)*, The Hague, Netherlands 7-19 April 2002. Agenda Item 22 Alien Species that threaten ecosystems, habitats or species.
- IUCN 5 (April 2002) SSC Invasive Specie Specialist Group – aims.
- Jackson B, Ashton AD (1996) Anticoagulant Resistance in North America.
- James P (1991) *Red Alert* in Country Life 2 May 1991.
- Kaukeren (1982) *Effects on Birds of Feeding on Anticoagulant Rodenticides* MAFF, ertebrate Biochemistry Section.
- Kaukeinen D E (1984) *Potential Non-Target Effects from the Use of Vertebrate Toxicants*.
- Kaukeinen DE (1984) Activity Indices to determin trends in vertebrate pest populations.
- Kenward RE (1982) *Bark stripping by grey squirrels – some recent research* in QJF 76: 108-121.

- Kenward RE & Parish T (1986) *Bark-stripping by Grey squirrels (Sciurus carolinensis)* in *Journal of Ecology* 210, 473-481.
- Kenward RE (1988) *The Potential of radio-tagging in trials of agrochemicals - a review* in BCPC Mono. 40 environmental effects of pesticides.
- Kenward RE, Parish T, Holm J, Harris EHM (1988a) *Grey Squirrel Bark-stripping I. The Roles of Tree quality, squirrel learning and food abundance* in *QJF* 82, 9-20.
- Kenward RE, Parish T, & Doyle FIB (1988b) *Grey Squirrel Bark-stripping II Management of Woodland Habitats* in *QJF* 82, 87-94.
- Kenward RE (1989) *Bark-stripping by grey squirrels in Britain and North America: why does the damage differ?* In Putman RJ (Ed) *Mammals as Pests*.
- Kenward RE (1989) *What future for British red squirrels?* In *Biological Journal of the Linnean Society*, 38: 83-89.
- Kenward RE to Pepper HW (1992) Correspondence re the use of warfarin for GS control inc success rates v rates of us.
- Kenward RE, Parish T, & Robertson PA (1992) *Are tree species mixtures too good for grey squirrels?* In Cannell MGR, Malcolm DC & Robertson PA (Eds) *The Ecology of Mixed-Species stands of Trees*.
- Kenward RE & Holm JL (1993) *On the replacement of the red squirrel in Britain: a phytotoxic explanation*.
- Kenward RE, Dutton JCF, Parish T, Doyle FIB, Walls SS, Robertson PA (1996) *'Damage By Grey Squirrels I. Bark-stripping correlates and treatment'* *QJF* 90:135-142.
- Kenward RE, Dutton JCF (1996) *'Damage By Grey Squirrels II. The Value of Prediction'* *QJF* 90: 211-218.
- King WB (1985) *Island Birds: Will the Future repeat the Past?*
- Kitchener AD, Peacock G, Lynch JM & Gurnell J (2003) *Geographical variation in British red squirrels Sciurus vulgaris*.
- Koh HS, Suhin Dong S, Ryu MH, (2003) *Sequence of diversity of mitochondrial control region in red squirrel Sciurus vulgaris L, from two most disjunct populations of Korea and England*.
- Langston, R., Gregory, R., & Adams, R. (2002) *The status of the Hawfinch in the UK 1975-1999, British Birds*, 95, 166-173.
- Lowe PW, & Gardiner AS (1983) *Is the British squirrel (Sciurus vulgaris leucourus, Kerr) British?* In *Mammal Review* 13, 83-89.
- Lurz PWW & Garson PJ (1992) *The distribution of red and grey squirrels in Northeast England in relation to available woodland habitats* in *BES Bulletin* 23(2): 133-139.
- Lurz, P.W.W., Garson, P.J. & Rushton, S.P., (1995). *The ecology of squirrels in spruce dominated plantations: implications for management*. *Forest Ecology and Management*, 79, 79-90.
- Lurz, P.W.W., Garson, P.J., Wauters, L. (1997). *Effect of temporal and spatial variation in habitat quality on red squirrel, Sciurus vulgaris, dispersal behaviour*. *Animal Behaviour*, 54, 427-435.
- Lurz P. W. W. & Garson, P. J. (1997). *Forest management for red squirrels in conifer woodlands: a northern perspective*. In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp.145-152 Peoples Trust for Endangered Species, London.
- Lurz, P.W.W. & Garson P.J., (1998). *Seasonal changes in ranging behaviour and habitat choice by red squirrels (Sciurus vulgaris) in conifer plantations in Northern England*. In M.A. Steele, J.F. Merritt and D.A. Rogers (eds). *Ecology and Evolutionary Biology of Tree Squirrels*. Special Publication, Virginia Museum of Natural History 6, 79-85.

- Lurz, P.W.W., Garson P.J. & Ogilvie J.F. (1998) *Conifer species mixtures, cone crops and red squirrel conservation*. *Forestry*, 71, 67-71.
- Lurz P.W.W. & South A.B. (1998) *Cached fungi in non-native conifer forests and their importance for red squirrels (*Sciurus vulgaris* L.)*. *Journal of Zoology*, London, 246, 468-471.
- Lurz, P.W.W., Garson, P.J., Wauters, L. (2000). *Effects of temporal and spatial variations in food supply on the space and habitat use of red squirrels, *Sciurus vulgaris* L.* *Journal of Zoology*, 251, 167-178.
- Lurz, P.W.W., Rushton, S.P., Wauters, L.A., Bertolino, S., Currado, I., Mazzoglio, P. and Shirley, M.D.F. (2001) *Predicting grey squirrel expansion in North Italy: a spatially explicit modelling approach*. *Landscape Ecology* 16, 407-420.
- Lurz PWW (June 2002) *Kielder Forest and the Red Revolution* in *Forest Machine Journal*.
- Lurz PWW, Gurnell J & Rushton SP (2003) *Managing forests for red squirrels*.
- Lurz PWW, Geddes N, Lloyd AJ, Shirley MDF, Rushton SP & Burlton B (2003) *Planning a red squirrel conservation area: using a spatially explicit population dynamics model to predict the impact of felling and forest design plans*. In *ICF Forestry* 76(1), 95-108.
- Lurz, P.W.W. & Cooper M. *Red Squirrel*. Naturally Scottish Series, SNH, Edinburgh.
- Nixon SJ & Kirk PG (1997) *Behaviour of Red Squirrels at Feeding Hoppers*. In *The Conservation of Red Squirrels, *Sciurus vulgaris* L.* (eds J. Gurnell & P.W.W. Lurz), pp.33-38 Peoples Trust for Endangered Species, London.
- Macmillan D (2002) *The Value of Forests for Archaeology*. Report to the Forestry Commission. Centre for Research in Environmental Appraisal & Management
- Magris L, Morris PA & Gurnell J (1997) *Human Impacts on Red Squirrel Ecology on the Island of Jersey*. In *The Conservation of Red Squirrels, *Sciurus vulgaris* L.* (eds J. Gurnell & P.W.W. Lurz), pp.49-60 Peoples Trust for Endangered Species, London.
- Mallinder D (29 May 2003) *Not nuts about squirrels*. Letter to the Editor in *Evening Standard*.
- The Mammal Society - *The Red Squirrel (*Sciurus vulgaris*)* Fact Sheet No. 3.
- Mammals UK (2002) 'Designer' Forests for Squirrels one page article.
- Marsh RE (1985) *Techniques used in rodent control to safeguard non-target wildlife*.
- Matthew NR & Bevan JMS (2000) *The Red Squirrel in Central Wales: A Preliminary Study*. Countryside Council for Wales.
- Moller, H. (1983) Foods and foraging behaviour of Red (*Sciurus vulgaris*) and Grey (*Sciurus carolinensis*) squirrels. *Mammal Review*, 13, 81-98.
- Mayle B (2002) 'Use of Warfarin targeted on grey squirrel'.
- Mayle BA (2002) *Grey Squirrel Control and management in the UK - Lessons for Europe*. 6th European squirrel Workshop Acqui Terme, Italy.
- Mayle B, Pepper H & Ferryman M (April 2003) *Controlling Grey Squirrel Damage to Woodlands FCPN4* (Revised).
- Micklewright Steve 10 May 2002 'Living with Grey Squirrels' London Wildlife Trust.
- Middleton AD (1930) *The ecology of the American grey squirrel (*Sciurus carolinensis* Gmelin) in the British Isles* in *Proceedings of the Zoological Society of London* 1930: 809-43.

- Middleton AD (1931) *The grey squirrel*.
- Montague, C.L. & Montague, W.H. (1985) Grey squirrel kills and eats Blue Jay fledgling. *Florida Field Naturalist*, 2, 46-47.
- Moore HDM (1997) *On developing an immunocontraceptive vaccine for the grey squirrel*. In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp.127-132 Peoples Trust for Endangered Species, London.
- Moredun Research Institute Directors report (2003) (re parapox virus and Orb).
- Morris J (1998) *Hungry squirrels lay waste to Chilterns*.
- Mosby Henry S (1969) *The influence of hunting on the population dynamics of a woodlot gray squirrel population* in *Journal of Wildlife Management* 33 v 1: 59 -73.
- Mountford EP (1997) *A decade of grey squirrel bark-stripping in Lady Park Wood, UK* in *Forestry* 70(1), 17-29.
- Mountford EP & Peterken GF (1999) *Effects of stand structure, composition and treatment on bark-stripping of beech by grey squirrels* in *Forestry* 72(4), 379-386.
- Myllymaki A (1992) *Anticoagulant Resistance in Europe*.
- National Forest (2003) *Review of costs 1995-2003*.
- Nour, N., Matthysen, E. & Dhondt, A.A. (1993) *Artificial nest predation and habitat fragmentation: different trends in bird and mammal predators*. *Ecography*, 16,111-116.
- Oakley S (2003) '*Red Squirrel Salvation*' *Smallwoods* Issue 4 Winter 2003.
- News (31 July 2003) *We'll help horse owners beat ragwort, promises minister* in *Horse and Hound*.
- Odam EM, Pepper HW, Townsend MG (1979) *A study of the persistence of Warfarin on wheat bait used for the control of grey squirrels* in *Annals of applied Biology*, 91, 81-89.
- O'Teangana DO, Reilly S, Montgomery WI & Rochford J (March 2000) *Distribution and status of the Red Squirrel (Sciurus vulgaris) and Grey Squirrel (Sciurus carolinensis) in Ireland* *Mammal Review* olume 30 Issue 1 Page 45.
- Patterson A, Bourgh C (1999) *Small mammal survey on the Island Canna*.
- Patterson A Lloyde L (2000) *Small mammal populations on the inner Hebridean Island of Canna*.
- Patterson A (2002) *Rat Eradication programme and safeguarding non-target species on the Island of Canna and Sanday*.
- Pepper HW (1990) *Grey squirrel damage control with warfarin* *Research Information Note* 180 FC.
- Pepper HW (1990) *Hopper modification for grey squirrel control* *Research Information Note* 153 FC.
- Pepper HW (1990) *Grey squirrels and the law* *Research Information Note* 191 FC.
- Pepper HW (1991) *Squirrel Questionnaire Report* *Forestry Commission*.
- Pepper HW (1992) *Survey of Squirrels in Britain*.
- Pepper HW (1992) *Timber Growers Association and Forestry Commission Squirrel Questionnaire reports 1991*. Unpublished report.
- Pepper HW & Stocker D (1993) *Grey Squirrel Control using modified Hoppers* *Research Information Note* 232 FC.

- Pepper HW (1997) *Hopper design and targeted grey squirrel control*. In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp.121-126 Peoples Trust for Endangered Species, London.
- Pepper HW (1998) *Nearest Neighbour method for quantifying wildlife damage to trees in woodland* FCPN1.
- Pepper HW & Currie F (1998) *Controlling Grey Squirrel damage to Woodlands* Practice Note 4 FC.
- Pepper HW & Moore H (2001) *Development of a contraceptive vaccine for the grey squirrel in Squirrel Management*, Forest Research Annual Report and Accounts 1999-2000.
- Pepper HW, Bryce J & Cartmel S (2001) *Co-existence of red and grey squirrels in Squirrel Management*, Forest Research Annual Report and Accounts 1999-2000.
- Pepper H & Patterson G (April 2001) *Red Squirrel Conservation* FCPN5 (Revised).
- Pepper HW & Ratcliffe P (2002) *A Rationale for the control of Grey Squirrels*.
- Pepper H (Apr 03) *The Grey Squirrel Threat*. Letter to Woodland Heritage Journal.
- Phillips DH, & Rowe JJ (1976) *Warfarin - a question of balance*. *Scientist* 20, 471-477.
- Philpison J & Wood D (1976) *Poisoning grey squirrels - a threat to wildlife?* *New Scientist* 20, 398-400.
- Powe N & Willis K (2002) *Mortality and Morbidity Benefits of Air Pollution Absorption by Woodland* Report to the Forestry Commission Centre for Research in Environmental Appraisal & Management
- Rayden T (2002) *The Grey Squirrel (Sciurus carolinensis) in Potentially assured timber supplies from the Chilterns AONB*. TWIG.
- Red Alert (31 May 2002) *Grey Squirrel Control*.
- Reynolds J (1981) *The Interaction of Red and Grey Squirrels*. NCC Research Contract HF3/03/59.
- Reynolds JC (1985) *Details of the geographic replacement of the red squirrel (Sciurus vulgaris) by the grey squirrel (Sciurus carolinensis) in Eastern England* in *Journal of Animal Ecology* 54,149-162.
- Ritchie (1920) '*The Influence of Man on Animal Life in Scotland*' in Anderson Mark Loudon (1967) *A History of Scottish Forestry* ol 1.
- Rooney S & Hayden TJ (2002) *Forest mammals - Management and Control*. Coford, Dublin.
- Rowe JJ (1980) *Grey squirrel control* FC leaflet no. 56.
- Rowe JJ (1983) *Squirrel management* in *Mammal Review* 13, 173-181.
- Rowe JJ & Gill RMA (1985) *The susceptibility of tree species to bark-stripping damage by grey squirrels (Sciurus carolinensis) in England and Wales* in *QJF* 79(3), 183-190.
- Rushton, S.P., Lurz, P.W.W., Fuller, R. & Garson, P.J. (1997). *Modelling the distribution of the red and grey squirrel at the landscape scale: a combined GIS and population dynamics approach*. *Journal of Applied Ecology*, 34, 1137-1154.
- Rushton, S.P., Lurz, P.W.W., South, A.B. & Mitchell-Jones, A. (1999). *Modelling the distribution of red squirrels (Sciurus vulgaris) on the Isle of Wight*. *Animal Conservation*, 2, 111-120.
- Rushton S P, Lurz P W W, Gurnell J* & Fuller R (December 2000) *Modelling the spatial dynamics of parapoxvirus disease in red and grey squirrels: a possible cause of the decline in the red squirrel in the UK?* In *Journal of Applied Ecology* 37 (6), 997-1012.

- Rushton SP, Gurnell J, Lurz PWW, Fuller RM (2002) *Modelling impacts and costs of grey squirrel control regimes on the viability of red squirrel populations* in *Journal of Wildlife Management* 66(3), 683-697.
- Sainsbury A, Nettleton P & Gurnell J (1997) *Recent developments in the study of Parapoxvirus in Red and Grey Squirrels* In *The conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp. 105-108. PTES, London.
- Sanders E (1937) *A Beast Book for the Pocket* The vertebrates of Britain Wild and Domestic other Birds and Fishes.
- Saunders CM & Garson PJ (1993) *Estimating the cost of grey squirrel damage - study proposal.*
- Savill P (1991) *The Silviculture of trees used in British Forestry* CAB International.
- Sayer M (1997) *The Squirrel Forum and the control of grey squirrels* in CLA regional news.
- Sayer M (2002) *The Grey Squirrel and the threat the European Woodlands.*
- Scarpa R (2003) *The Recreational Value of Woodlands.* Report to the Forestry Commission. Centre for Research in Environmental Appraisal & Management
- Shorten M (1957) *Damage caused by squirrels in Forestry Commission areas 1954-56* in *Forestry* 30, 151-172.
- Shuttleworth CM (1997) *The effect of supplemental feeding on the diet population density and reproduction of red squirrels.* In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp.13-24 Peoples Trust for Endangered Species, London.
- Shuttleworth C (2002) *Red Squirrels respond to Grey Squirrel removal from the Isle of Anglesey.* 6th European Squirrel Workshop, Acqui Terme, Italy.
- Shuttleworth C (7 May 2003) *Synopsis of presentation to South Scotland Squirrel Group 'A Triumph for Tufty: Red Squirrels on Anglesey'* Red Squirrel Conservation on Anglesey.
- Skelcher G (1993) *The spread of grey squirrels into red squirrel populated woodlands in the north-west of England.*
- Skelcher G (1993) *A Strategy for Red Squirrel Conservation in the Northwest of England.* Northwest Red Squirrel Initiative.
- Skelcher G (1997) *The Ecological replacement of red by grey squirrels.* In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp.67-78 Peoples Trust for Endangered Species, London.
- Smith D & Gurnell J (1997) *The Ecology of the Grey squirrel in Conifer forest.* In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp.109-120 Peoples Trust for Endangered Species, London.
- South, A.B., Lurz, P.W.W. & Rushton, S.P. (1997). *Simulating foraging movements of red squirrels to generate hypotheses regarding spacing patterns.* In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp.25-32 Peoples Trust for Endangered Species, London.
- Southern Uplands Partnership (2001) *'Woodlands for red squirrels.'* Red Squirrels in South Scotland Project.
- Steele J & Gurnell J (2003) *Controlling grey squirrels for red squirrel conservation in conifer forests.*
- Stewart D (1997) *Red Squirrel Conservation - Past and Present.* In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp. 1-4 Peoples Trust for Endangered Species, London.
- Taylor D (May 2003) *Grey Future in forester's fight* in *Forestry and British Timber.*

- Teaford JW (1986) *Eastern Gray Squirrel (Sciurus carolinensis)*: Section 4.7.1 US Army Corps of Engineers Wildlife Resources Management Manual.
- The Thames & Chilterns Grey Squirrel control group *Save Our Broadleaved Trees* (Jun 94).
- Tompkins D M, White A R & Boots M (2003) *Ecological replacement of native red squirrels by invasive greys driven by disease* in *Ecology Letters* volume 6 Issue 3 Page 189 – 196.
- Townsend MG, Gletcher MR, Odam EM, & Stanley PI (1981) *An assessment of the secondary poisoning hazard of Warfarin to Tawny owl*. *Journal of Wildlife Management* 45, 242-247.
- Townsend MG, Bunyon PJ, Odam EM, Stanley PI, & Wardall HP (1984) *Assessment of secondary poisoning hazard of Warfarin to weasels* in *Journal of Wildlife Management* 48, 628-632.
- Usher MB, Crawford TJ & Banwell J (1992) *An American invasion of Great Britain: the case of the native and alien squirrel (sciurus) species* in *Conservation Biology* 6 (1), 108-115.
- venning, Sainsbury & Gurnell J (1997) *Red Squirrel translocation and population reinforcement as a conservation tactic*. In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp.133-144 Peoples Trust for Endangered Species, London.
- berbeylen G, Bruyn L De, & Matthysen E (2003) *Patch occupancy, population density and dynamics in a fragmented red squirrel Sciurus vulgaris population*. In *Ecography* 26: 118-128.
- iner D (31 May 02) *Enhancing carbon sinks in the UK - the threat of pests*.
- Watt HB (1023) *The American Grey squirrel in Ireland* in *Irish Naturalist* 32, 95-353.
- Wauters LA (1997) *The Ecology of Red Squirrels in Fragmented Habitats: a Review*. In *The Conservation of Red Squirrels, Sciurus vulgaris L.* (eds J. Gurnell & P.W.W. Lurz), pp.5-12 Peoples Trust for Endangered Species, London.
- Wauters LA, Currado I, Mazzoglio PJ & Gurnell J (1997) *Replacement of Red Squirrels by introduced Grey squirrels in Italy: Evidence from a distribution survey*. In Gurnell, J. & Lurz, P.W.W. (eds). *The Conservation of Red Squirrels, Sciurus vulgaris L.* Peoples Trust for Endangered Species, London.
- Wauters L A & Gurnell J December (1999) *The Mechanism of Replacement of Red Squirrels by Grey Squirrels: A Test of the Interference Competition Hypothesis* in *European Journal of Forest Pathology* volume 29 Issue 6 Page 1053.
- Wauters, L.A., Lurz, P.W.W. & Gurnell, J. (2000) *The interspecific effects of grey squirrels (Sciurus carolinensis) on the space use and population dynamics of red squirrels (S. vulgaris) in conifer plantations*. *Ecological Research*, 15, 271-284. Conference Proceedings.
- Wauters L A, Lurz P W W 2 and Gurnell (2000) *Interspecific effects of grey squirrels (Sciurus carolinensis) on the space use and population demography of red squirrels (Sciurus vulgaris) in conifer plantations*. In *Ecological Research* volume 15 Issue 3 Page 271 Notes volume 1 Issue 1-2 Page 47.
- Wauters LA, Gurnell J (2002) *The mechanism of Replacement of Red by Grey Squirrels: Recent findings and new questions*. 6th European Squirrel Workshop, Acqui Terme, Italy.
- Wauters LA, Tosi G & Gurnell J (2002) *Interspecific competition in tree squirrels: do introduced grey squirrels (Sciurus carolinensis) deplete tree seeds hoarded by red squirrels (S vulgaris)?*. In *Behavioral Ecology and Sociobiology*.
- Wild J (1994) *Blood-clotting Response Test for Bromadiolone Resistance in Norway Rats*.
- Willis K (2002) *Benefits and Costs of Forests to Water Supply and Water Quality* Report to the Forestry Commission. Centre for Research in Environmental Appraisal & Management.

Willis K, Garrod G, Scarpa R, Powe N, Lovett A, Bateman I, Hanley N, & Macmillan D (2003) *The Social and Environmental Benefits of Forests in Great Britain*. Report to the Forestry Commission. Centre for Research in Environmental Appraisal & Management

Wood DA, & Philipson J (1977) The utilisation of poison hoppers designed for grey squirrel control in *Biological Conservation* 11, 119-127.

Woods M (August 2002). *Grey Squirrels. Is it time to accept them?* Country Living.

Wren E (June 2003) *The thin red line* in Cumbria Life.

onfrillo B (1994) *Ailsa Craig Rat Eradication Project*.