An Analysis of the Cost of Grey Squirrel Damage to Woodland

January 2021

Prepared for the Royal Forestry Society

Supported by

Forestry Commission
Cyfoeth Naturiol Cymru / Natural Resources Wales
National Forest Company
Woodland Trust

Prepared by

RDI Associates Ltd

in Association with

Newcastle University

Martin Glynn FICFor

Peter Watson Wildlife Management

Authors

RDI Associates - Will Richardson, MICFor
Newcastle University – Dr Glyn Jones
Martin Glynn FICFor – Martin Glynn FICFor
Peter Watson Wildlife Management – Peter Watson

Version Control

Project reference number:	1261	**Project Title:**	An Analysis of the Cost of Grey Squirrel Damage to Woodland	
Client	Royal Forestry Society			
Date	**Description**	**Revision**	**Author**	**Checked by**
13/03/20	Client Draft	1	MG	WR
31/07/20	Client Draft	2	MG	
30/09/20	Final Draft	3	MG	WR
11/01/21	Publication	4	MG	WR

Acknowledgement

The authors wish to thank all those who have contributed to this study including members of the Steering Group, consultees in the forestry industry and stakeholders with an interest in the sector, all of whom contributed willingly and generously to the study.

Steering Group

Neil Riddle and Rebecca Isted – Forestry Commission
Chris Tucker - Cyfoeth Naturiol Cymru / Natural Resources Wales
Charles Robinson and Daniel Small – National Forest Company
Chris Nichols, Nick Atkinson and Chris Reid – The Woodland Trust
Simon Lloyd – Royal Forestry Society

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1. Introduction

1.1. Brief

The purpose of this report has been to build on and update previous research so as to 'update this work so that members of the UK Squirrel Accord[1] can point to recent, well supported and transparent evidence of the cost of damage' by grey squirrels to woodland in England and Wales.

The objectives of the report are as follows, the full brief is replicated in Appendix A.

Objectives

- Develop a transparent and replicable methodology to estimate with reasonable accuracy the cost of grey squirrel damage in woodlands in England and Wales.
- Ground-truth the methodology by reference to selected landowner case studies.
- Deliver a report with supporting evidence which can be published
- Promote the findings of the report widely within the UK Squirrel Accord signatories, their networks/members and in national media.

The report has been commissioned by the Royal Forestry Society (RFS) and sponsored and overseen by a Steering Group of representatives of the RFS, the Forestry Commission, the National Forest Company, Natural Resources Wales, and The Woodland Trust.

1.2. Grey Squirrel Introduction and Spread

The grey squirrel (Sciurus carolinensis) was introduced into the United Kingdom from its native ranges in North America between the mid 1870s and late 1920s. It is reported that around 30 separate introductions occurred until 1930 when, at this point, the damage caused by the grey squirrel was recognised through seasonal bark stripping activity. It has rapidly increased its population to a current estimate of 2.7 million covering much of England, Wales, Scotland, and Northern Ireland[2].

Figure 1 indicates the distribution of both Red and Grey Squirrels across the British Isles from 1945 to 2010.

[1] https://squirrelaccord.uk/
[2] Natural England (2018). A Review of the Population and Conservation Status of British Mammals (JP025)

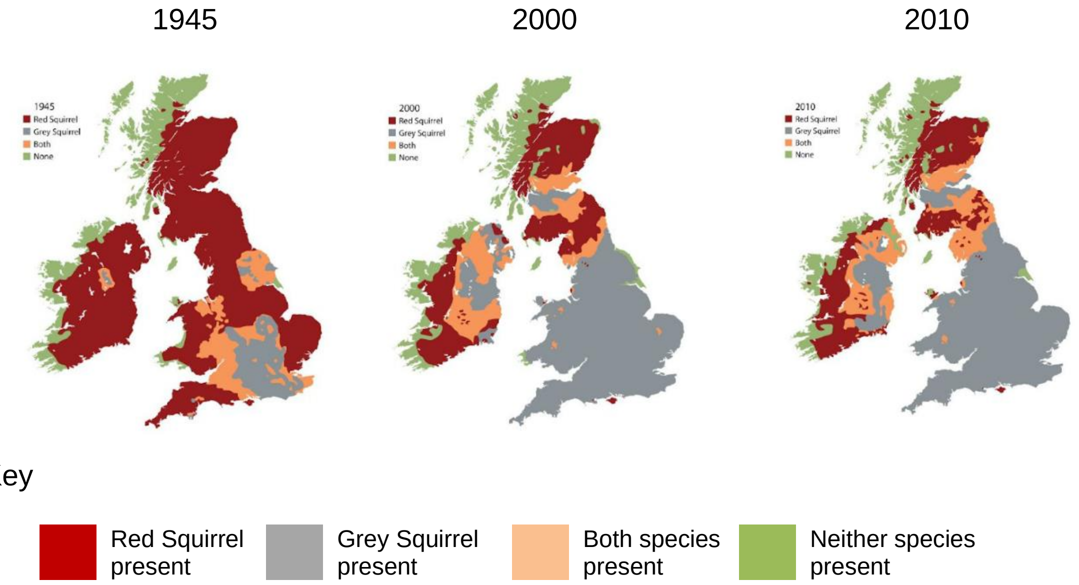

Figure 1: Red and Grey Squirrel distribution in the British Isles 1945 to 2010

1.3. Impact of Grey Squirrel

The expansion of the grey squirrel population has been associated with the decline or extinction of the native red squirrel (Sciurus vulgaris) across much of its original range in Britain[3]. The grey squirrel also causes damage in buildings and has an important role in threatening the development of new woods[4]. They cause substantial damage to forestry through bark stripping that affects tree growth and timber value and increases the susceptibility of trees to various pathogens.

The cost of damage, based on tree loss, reduction in timber quality and reduced yield has been significant and previous studies have estimated values to range from £6 million[5] to £10 million per year[6]. Grey squirrel damage to conifers has been estimated at £224,000 per year[7], representing a cost of £3.40 per hectare of vulnerable conifers. Other sources[8] estimated the cost of squirrel damage to broadleaved trees at £413,140 per annum and the total yield loss to forestry estimated at £684,802. With the inclusion

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[3] Skelcher, G. (1997) The ecological replacement of red by grey squirrels. pp 67-78 In: Gurnell, J. & Lurz, P. W. W. (Eds.). The conservation of red squirrels, Sciurus vulgaris L. People's Trust for Endangered Species, London.

[4] Gill, R. M. A., Gurnell, J. & Trout, R. C. (1995) Do woodland mammals threaten the development of new woods? pp 201-224 In: Ferris-Kaan, R. (Ed.). The ecology of woodland creation. John Wiley & Sons, London

[5] Williams, F., Eschen, R., Harris, A., Djeddour, D., Pratt, C., Shaw, R., Varia, S., Lamontagne-Godwin, J., Thomas, S. & Murphy, S. (2010) The economic cost of invasive non-native species on Great Britain. CABI report, 198pp.

[6] Mayle et al (2013) Changes in the impact and control of an invasive alien: the grey squirrel (Sciurus carolinensis) in Great Britain, as determined from regional surveys. Pest Management Science. 69. 323-333

[7] Mayle B (2002) Grey Squirrel Control and Management in the UK - Lessons for Europe. 6th European Squirrel Workshop. Acqui Terme, Italy.

[8] Williams, F., Eschen, R., Harris, A., Djeddour, D., Pratt, C., Shaw, R., Varia, S., Lamontagne-Godwin, J., Thomas, S. & Murphy, S. (2010) The economic cost of invasive non-native species on Great Britain. CABI report, 198pp.

of estimated control costs the total economic loss to forestry attributable to the grey squirrel has been estimated at £6,097,320 annually and, based on the area of at-risk woodland and the squirrel population in each country, 65% of all costs are incurred in England, 20% in Scotland and 15% in Wales i.e. £3,963,259 in England, £1,219,464 in Scotland, and £914,598 in Wales[9]. It should, however, be noted that these reports are not entirely comparable, given that the model used for this report relies upon statistical data provided by the NFI rather than observational studies using personal experience. Care should therefore be taken in making comparisons between reports.

A further impact of the grey squirrel is the deterrent effect on the planting of new woodland by landowners. Due to climate change and the nature crisis, tree planting has become an increasing priority across England and Wales for government. The UK Government has committed to planting 30,000ha of new woodland by 2025[10] and 30,000ha per year to 2050. This will require a considerable increase over current levels of less than 15,000ha[11]. Anecdotal evidence has for some time indicated that one of the reasons why landowners were reluctant to plant trees, in particular broadleaf trees, was the potential impact of grey squirrels. This was supported by a survey[12] conducted by the RFS in 2020, in which grey squirrel damage to broadleaved trees was cited as one of the six key risks associated with woodland creation. The deterrent effect is likely to be highest amongst those landowners who already have woodland on their property and have recently attempted to plant more or to restock existing sites, and those who would ordinarily be expected to plant broadleaves, for example in lowland England and Wales and around urban areas. It has also led to recommendations that susceptible broadleaf species, including native, should not be planted in areas where red squirrel populations remain, in order to deter grey squirrels[13].

Further information on values and impacts is provided in Appendix D.

1.4. Displacement of the Red Squirrel

Compelling evidence exists that grey squirrels are reservoir hosts of squirrel pox virus (SQPV) which has exacerbated the decline and extinction of the native red squirrel across much of its original range[14]. Prevalence of the poxvirus is high in English and Welsh grey squirrel populations, but greys appear to be unaffected by the disease. Rates of decline of red squirrels are 17-25 times higher in areas where the SQPV is present in grey squirrels[15].

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[9] Ibid.
[10] https://www.gov.uk/government/speeches/budget-speech-2020
[11] Provisional Woodland Statistics: 2020 Edition, Forestry Commission 2020
[12] Woodland Creation Opportunities and Barriers, Royal Forestry Society, 2020
[13] e.g. Woodland for Red Squirrels. Galloway and Southern Ayrshire Biosphere, 2015
[14] Tompkins, D.M., Sainsbury, A.W., Nettleton, P., Buxton, D. & Gurnell, J. (2002) Parapoxvirus causes a deleterious disease in red squirrels associated with UK population declines. Proceedings of the Royal Society of London. Series B: Biological Sciences, 269, 529-533.
[15] Rushton, S. P., Lurz, P. W. W., Gurnell, J. & Fuller, R. (2006) 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? Journal of Applied Ecology. 37(6): 997-1012

Nevertheless, even in the absence of SQPV in some Scottish grey squirrel populations, red squirrels are still susceptible to replacement by greys. Evidence has emerged of adenovirus infection in both squirrel species[16] and the possibility exists of the grey squirrel acting as an adenovirus reservoir in pathological red squirrel cases[17]. On mainland Britain, red squirrel populations have become extinct in the southern counties of England, although they still exist on some offshore islands, and fragmented populations persist in northern English counties, Wales, and Scotland.

Under the Wildlife and Countryside Act 1981 (schedule 9) it is now illegal to release a grey squirrel to the wild.

1.5. Comparison with other Pests and Diseases

The threat to trees and woodlands from grey squirrels exists alongside a number of other pests and diseases, which are increasing at an unprecedented rate[18]. In addition to the threat from each individual pest or disease, there is a complex interaction between those present in any ecosystem – for example, a tree which has suffered bark stripping from grey squirrel is weakened and thus more prone to infection or attack by another pest or disease. The UK Plant Health Register[19] has been found to have 48 tree pests and diseases which have the potential to create losses to the British economy in excess of £1bn each[20].

The following examples – Chalara Ash Dieback and wild deer – provide some context for the value of grey squirrel damage, although the total values expressed should not be considered comparable given the differing approaches to valuing, or the inclusion of, various elements.

Chalara Ash Dieback, caused by Hymenoscyphus fraxineus, is estimated to have an economic cost in Great Britain over the next 100 years of £14.8bn[21], of which more than half (£7.6bn) will occur in the first ten years. This is one third more than the estimated cost of the 2001 Foot and Mouth epidemic in Great Britain. Non-woodland and woodland ecosystem service losses were estimated to be the single largest cost at £9.4bn, due to the poor natural regeneration of other species, followed by the costs of safety felling at £4.7bn. Promoting tree planting and natural regeneration would reduce the overall cost by £2.5bn and be highly cost effective.

Wild deer are known to cause considerable economic and environmental damage to woodlands across Great Britain. Damage occurs to agricultural crops (which are frequently attributed to woodlands due to deer tending to shelter in them), damage to

[16] Everest, D.J., Grierson, S.S., Stidworthy, M.F. & Shuttleworth, C. (2009) PCR detection of adenovirus in grey squirrels on Anglesey. Veterinary Record, 165, 482.
[17] Duff, J., Higgins, R. & Farrelly, S. (2007) Enteric adenovirus infection in a red squirrel (Sciurus vulgaris). The Veterinary Record, 160, 384.
[18] Forestry Commission (2011). Protecting Britain's Forests and Woodland trees against Pests and Diseases.
[19] https://secure.fera.defra.gov.uk/phiw/riskRegister/
[20] Louise Hill, Glyn Jones, Nick Atkinson, Andy Hector, Gabriel Hemery, Nick Brown (2019). 'The £15 billion cost of ash dieback in Britain' in Current Biology, Vol. 29, Issue 9, R315–R316
[21] Ibid

trees, road traffic accidents, and ecosystem services losses[22]. Unlike grey squirrels, there is counter balancing income to be derived from der, including stalking, the sale of venison and tourism. Attempts to assess the overall costs of deer damage at a national level have commonly floundered on disagreements of comparative values and are thus difficult to ascertain[23]. A report[24] on the economic impacts of deer in the East of England found that costs varied from a minimum of £7.02m to a maximum of £10.24m per annum, with potential increases of up to 44% over a ten year scenario.

1.6. NFI Squirrel Report

The Forestry Commission National Forest Inventory Squirrel Report ‘Squirrel stripping damage and presence of squirrels in woodland in Britain’[25] was published in December 2020. The NFI report utilises the same data as used by this report but has utilised different methodology to compile the results. An explanation of the methodology is contained within the NFI report.

[22] Parliamentary Office of Science and Technology (2009). Postnote Number 325: Wild Deer.
[23] Deer Working Group (2020). The management of wild deer in Scotland: Deer Working Group report
[24] Piran C.L. White, James C.R. Smart, Monika Bˆhm, Jochen Langbein & Alastair I. Ward (2003). Economic impacts of wild deer in the East of England.
[25] National Forest Inventory (2020). NFI Squirrel Report - Squirrel stripping damage and presence of squirrels in woodland in Britain. Forestry Commission

2. The Model

2.1. Conceptual Model

Prior to the development of the model, a conceptual model was developed in order to establish basic principles and data requirements. This conceptual model is outlined in Appendix B.

2.2. The Functional Model

Figure 1 is an illustration of the connections between the data, assumptions, calculations, and impacts estimated.

2.2.1. Data

Box 1: Data from the National Forest Inventory (NFI) provides estimate of the area having indications of grey squirrel damage by species and age class. See Section 3 for more detail here since the findings are highly sensitive to this estimate. Two methods within the NFI data to produce area estimates differed by a factor of 6 with the damage estimate produced here using the smaller NFI figure.

Box 2: The NFI area data refers to “frequency” that relates to the proportion of the area exhibiting damage. There are 3 categories of frequency: less than 20%, 20-80%, more than 80%. If, for example, 10ha was in the category “<20%” frequency, less than 20% of that 10ha showed actual damage. The age classes provided were 0-20 years, 21-40 years, 41-60 years, and 61+ years.

Box 3: For severity, the NFI uses “Most die” or “Most survive” for each species and age class

NFI frequency and severity estimates were provided in the following age classes: 0-20, 21-40, 41-60, and 60+

2.2.2. Assumptions

Box 2a: For the frequency categories we assumed the mid-point of the range. That is, if, for the “<20%” category, we used the midpoint of that range (0.1) and multiplied that by the area in the category for the area actually damaged (e.g. for 10ha in that category, area actually damaged = 10 x 0.1 = 1 ha). An alternative assumption is to ignore frequency and assume, for example, all the 10ha is damaged

Box 3a: We have simple assumed that “Most” means “All”. That is, the working assumption in the current estimates assumes that all the area defined as “Most die” (adjusted for frequency), all die. An alternative would be to assume that a proportion of each category die/survive e.g. for “Most die” assume 75% die and 25% survive.

Figure 2: Data, Assumptions, Calculations & Impacts

DATA

1. NFI data: species area with GS damage by age group

2. Frequency (for each age class):

- *<20%*
- *20-80%*
- *80%+*

Use midpoint of each group – 0.1, 0.5, 0.9

3. Severity (for each age class):

- *Most die*
- *Most survive*

CALCULATIONS

4. Calculations: Damaged area by species and age class

Total Most die =

(0.1 x 0-20yr *Most die*) +

(0.5 x 0-20yr *Most die*) +

(0.9 x 0-20yr *Most die*)

Then same for other age classes and same for *Most survive*

ASSUMPTIONS

2a. Assumption: Frequency = % of trees damaged i.e. only 10% of those in <20% group are damaged.

Alternative: ignore frequency – all area is damaged

3a. Assumption:

Most die = all

Most survive = all

Alternative: 75/25 in each category

IMPACTS

5. Impact of those that die:

- 0-20: no current losses, lost timber value at age 80
- 21-40 & 41-60: lost thinning and lost timber value at age 80
- 60+: downgrade to firewood from timber
- Future values discounted to present value and annualised over relevant time period

6. Impact of those that survive:

- All reach harvest but downgraded to firewood from timber
- Future values discounted to present value and annualised over relevant time period

7. Impact on non-timber values Carbon:

- For those that die, carbon volatilised now – use Woodland Carbon code look-up table and BEIS value for 2018
- This overestimates the carbon value as the carbon from these trees would still be volatilised post-harvest either at harvest as firewood or at harvest plus c25years depending on end use. This would require many more assumptions

IMPACTS NOT INCLUDED

8. Impact on non-timber values biodiversity, landscape, and recreation – not included:

- Biodiversity: GS are part of BD and could be argued that they are neutral. Or can argue positive value of return of red squirrel
- Recreation: can be argued that spotting wildlife is a positive part of recreation but then again more so for red squirrel?
- Landscape: limited effect given small areas?
- Other: flooding, air quality etc. Some effect if large areas die

2.2.3. Calculations

Box 4: The current estimates (by species and age class) account for both frequency and severity in order to produce an area whose values are negatively impacted. These areas by species and age class are then used to estimate impacts as follows.

2.2.4. Impacts

The impacts recognise that some costs will occur now (e.g. lost thinning for those that die and downgrades of trees in harvest age class) as well as in the future (e.g. downgrades of those that survive and lost harvest of those that die)

Box 5: Impact of trees that die varies by age class:

- 0-20 age class: no current losses but complete loss of final harvest which is assumed to be 70 years hence. Lost future value is based on average yield per hectare and current timber prices[26]. Future values discounted to present values and annualised. A more conservative assumption would be to use a blended price across different products (this would reduce the impact).
- 21-40 and 41-60 age classes: assume lost thinning volumes as well as future harvest values as for the 0-20 age class
- 61+ age class: downgraded from timber to firewood

Box 6: Impact on trees that survive. Assume all reach harvest but downgraded to firewood. Future values discounted to present value and annualised over relevant time period.

Box 7: Impact on carbon. This is a complex area depending upon when carbon is released to the atmosphere. For those that die now we assume the carbon is volatilised now. We do not account for the fact that it would be volatilised at some point in the future as this would require a host of assumptions on end use and the lifetime of that end use. To this extent, the carbon estimates are something of an overestimate of the impact. Carbon volumes by species per hectare comes from the Woodland Carbon Code look-up tables and carbon values from BEIS stated value for 2018[27] which are deemed appropriate for appraisal purposes.

Box 8: Non-timber impacts excluded from the estimates. The section on environmental values from trees (Appendix D) shows that such values are taken into account when considering policy options to protect the treescape. However, for the purposes of this project they have been excluded for a number of reasons. Values exist for services that trees provide for biodiversity, recreation, landscape, and air pollution. For biodiversity, grey squirrels are a part of this, but it could be argued that overall biodiversity is diminished if they damage the tree. There are a number of

[26] Timber prices were based on the Grown in Britain Price Size Curves (2018) for hardwoods and Forestry & Timber News Magazine (June 2019) for softwood. Values are displayed in the 'Timber' tab of the model and can be adjusted.

[27] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/794186/2018-short-term-traded-carbon-values-for-appraisal-purposes.pdf

fundamental uncertainties here and it does not seem sensible to provide estimates the rational of which could be challenged. The same can be said for their impact on air pollution. Similarly, it is unclear what impact squirrels have on recreation and landscape impacts – grey squirrels might be viewed as a positive attribute of recreational visits and the landscape.

There are a number of gaps in the environmental valuation literature, not least in the area of health and well-being. But even this could represent something of a trade-off with grey squirrels – loss of trees versus loss of a common and identifiable component of wildlife.

2.3. Developing Scenarios

The frequency and severity of damage indicated by the NFI data are inconsistent with the experience of practitioners, in particular for species more prone to damage. A number of reasons for this were cited, including: -

- that NFI surveys are conducted throughout the year and thus damage would be difficult to detect in the summer when trees were in full leaf
- damage was recorded from ground surveys, without any investigation of the upper layers of the canopy by other means e.g. climbing surveys, and thus precluding detection of damage in the upper canopy
- long standing damage by grey squirrels is difficult to differentiate from damage caused by other factors (wind, frost, other pests and diseases etc.)
- the means by which damage in one part of the survey square were extrapolated to other areas, which in the current interpretation resulted in no damage being recorded elsewhere
- damage recorded below 1.8m is not attributed to grey squirrels, when there is evidence that they do strip bark from the ground in young trees

In recognition of this, it was decided to develop the model so that, using the frequency and severity data from the NFI to provide a cost per hectare, a range of scenarios could be presented. These scenarios are described as low, medium, and high: -

- Low – the area data provided by the NFI (14/01/20)
- Medium – damage to 15% of the broadleaf area and 5% of the conifer area of woodland in each country (as defined by the NFI)
- High – damage to 25% of the broadleaf area and 10% of the conifer area of woodland in each country (as defined by the NFI)

These % can be adjusted in the model to reflect developing knowledge and evidence.

The medium scenario broadly reflects the data provided in the NFI Woodland Ecological Condition Report.

3. NFI Data

Three versions of the NFI data were provided, each based on different assumptions.

The first version of data (undated, supplied 11/06/19) assumed that where grey squirrel damage was observed in a survey plot, even if it was limited to a certain species of tree or part of the plot, squirrels would be present in the entire area and thus damage would occur regardless of species. Whilst it is reasonable to assume that squirrels will range over an entire plot, assuming that all trees will be equally affected disregards evidence on the differing palatability of various species. This led to unexpectedly high damage levels on some species which were previously considered to be at low risk. In the second version, the recorded area for each species was restricted to actual damage observed, with no assumptions made regarding further damage to other trees of other species in the same stand. This more conservative basis has resulted in significantly lower areas of recorded damage. The third version used assumptions regarding contagion similar to that used by the NFI Woodland Ecological Condition Report[28]

Table 1 is a summary of the second version (dated 14/01/20, supplied 20/01/20) of the NFI data provided to the project and used to compile the per hectare costs used in the model.

Table 1: Area of grey squirrel damage by species and country according to NFI data

Species	Area (ha)		
	England	Wales	Total
Ash	482	142	624
Beech	4979	449	5428
Birch	1300	581	1882
Oak	926	240	1167
Sweet Chestnut	295	11	305
Sycamore	7677	518	8194
Other BLs	2607	278	2885
Total Broadleaves	**18267**	**2219**	**20486**
Fir	82	89	171
Larch	253	168	421
Norway Spruce	9	59	68
Pine	1279	11	1290
Sitka Spruce	24	170	194
Other Conifer	193	2	195
Total Conifer	**1839**	**499**	**2337**

[28] https://www.forestresearch.gov.uk/tools-and-resources/national-forest-inventory/what-our-woodlands-and-tree-cover-outside-woodlands-are-like-today-8211-nfi-inventory-reports-and-woodland-map-reports/nfi-woodland-ecological-condition/

The total area estimated from the NFI to exhibit grey squirrel damage In England and Wales is close to 23,000 ha. Broadleaves in England account for 80% of this with beech and sycamore accounting for 55% of the total. These totals are several times smaller than the alternative NFI method of estimation. Thus, other things being equal, using the NFI method with the higher estimates would produce damage estimates several times higher.

As an example of the distribution by frequency and severity, Figure 3 shows the area of broadleaves in England by each. It indicates that the proportion of *Most die* increases with frequency, but that category is always a minor part of the total.

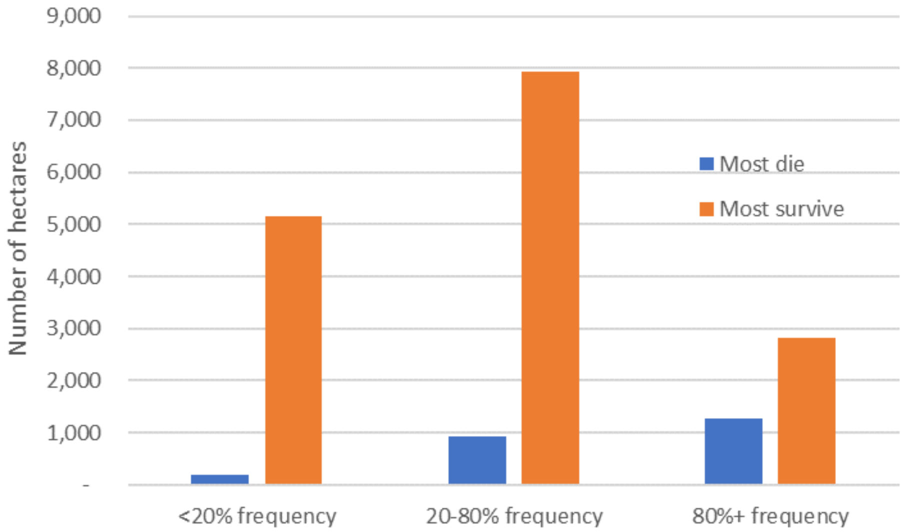

Figure 3: Number of hectares of English broadleaves damaged by frequency and severity

4. Results

Appendix C presents the detailed results from the model described above and gives the total cost of damage per hectare by species and age class. Current timber losses represent the immediate losses due to lost thinnings and downgrades of age classes close to harvest. Future losses are unrealised income at eventual harvest. These values would be realised in the future thus they are discounted to the present and annualised for comparison.

Applying this cost of damage per hectare data to the total areas of woodland in each country provides the values in Table 7.

Table 2: Cost of damage per year by grey squirrels to woodlands in England and Wales

Total Cost (£m) p.a.			
	England		
Scenario	Low	Medium	High
Broadleaves	£1.845	£17.226	£28.710
Conifer	£0.081	£1.386	£2.773
Total	£1.926	£18.613	£31.483
	Wales		
Scenario	Low	Medium	High
Broadleaves	£0.196	£3.986	£6.643
Conifer	£0.031	£0.160	£0.320
Total	£0.227	£4.146	£6.963
	England & Wales		
Scenario	Low	Medium	High
Broadleaves	£2.041	£21.212	£35.353
Conifer	£0.112	£1.547	£3.093
Total	**£2.153**	**£22.758**	**£38.446**

5. Mitigation

5.1. Area

The area of woodland receiving mitigation measures (i.e. control of Grey Squirrels) has been based on NFI data for the total area of broadleaf woodland. For the purposes of this estimate it has been assumed that as conifer woodland does not exhibit significant levels of damage from Grey Squirrels, no mitigation measures take place in them. Clearly this is a simplification of what will be happening in reality but given the paucity of data is a 'best estimate' scenario.

Initially it was intended to base the area of woodland receiving mitigation on the area of woodland under management, according to FC and NRW data. However, discussions with stakeholders indicated that this would be unlikely to be a fair reflection of what was happening on the ground, given that the area of woodland in management is assessed by, primarily, the area in one or other grant scheme or regulatory process (e.g. Felling Licence). For the control of Grey Squirrels it was thought that this would be an underestimate, given that significant areas of woodland will be managed for game shooting but not be in any form of grant scheme, and that these areas would be more likely to have control measures in place.

The table below shows low, medium, and high scenarios of areas under mitigation measures, based on 5%, 25% and 50% of the total broadleaf woodland resource.

Table 3: Area of woodland with squirrel control

Scenarios	England ('000ha)	Wales ('000ha)
5%	48	8
25%	242	40
50%	484	79

5.2. Cost

As with the level and cost of damage, cost of squirrel control varies significantly. This depends on the methods of control used. Most common is the use of Fenn type traps and live traps and sources tend to agree that these are the most successful, albeit more expensive, methods of control if they are used correctly. There is good evidence and advice available to practitioners in the effective use of traps. Drey poking and shooting are widely used but not considered to be the most effective method and best applied in combination with trapping.

Recent case studies produced by the RFS provide estimates of between £49[29] and £58[30] per ha per year to control squirrels using traps. Other sources have shown that

[29] RFS (2018) Counting the Cost of Squirrel Damage in a Small Wood
[30] RFS (2018) Counting the Cost of Squirrel Control in an Oak Plantation

this cost can be as low as £12.50/ha/yr and as high as £81/ha/yr. A 2002 study[31] put cage trapping costs at £54.49 per ha over a 9-month control period each year. Recent research shows that an estate growing oak that is proactive in squirrel control have costs of £33.33/ha/yr[32]. Cost per squirrel varies more widely with the lowest cost at just over £3 and the highest at £100. Sources tend to agree that cost per animal is academic as traps must be inspected and maintained regardless of a capture or not.

High levels of damage occurred when less than £10/ha/yr is spent on control[33]. Cost of control plus the cost of damage must equal less than the cost of damage when no action is taken for cost of control to be worthwhile. It is widely agreed that control is only effective when carried out at a landscape scale and that complete eradication of the grey squirrel would be extremely difficult but at a local level, removal is possible[34].

For the purposes of this model we have applied low, medium, and high level of cost of control with low at £20.00/ha/year, medium at £50.00/ha/year and high at £80.00/ha/year. We can apply these low, medium, and high levels of cost of control to the areas receiving mitigation measures to provide a total cost of mitigation.

Table 4: Cost of grey squirrel damage by scenario

		England	Wales	Total
Scenario	Cost £/ha	£'000	£'000	£'000
Total cost - low				
Low	£20	968	158	1,126
Medium	£50	2,420	395	2,815
High	£80	3,872	632	4,504
Total cost - medium				
Low	£20	4,840	790	5,630
Medium	£50	12,100	1,975	14,075
High	£80	19,360	3,160	22,520
Total cost - high				
Low	£20	9,680	1,580	11,260
Medium	£50	24,200	3,950	28,150
High	£80	38,720	6,320	45,040

31 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*. Journal of Wildlife Management 66: 683-697.
32 Pers comm. Anderson, S (2019).
33 Shuttleworth, C et al (2016) Chapter 19
34 Shuttleworth, C et at (2016) Chapter 19

We can add to this the cost of restocking, based on the area where according to the NFI the majority of trees die. Standard costs and further assumptions are set out in the table below.

Table 5: Cost of restocking woodlands due to grey squirrel damage

	England	Wales
Area where majority of trees die (ha)	2382	302
Restocking cost per ha[35]*	£7,156	£7,156
Total cost of restocking	£17,046,307	£2,163,545
Annual restocking cost (assume 70-year rotation)	£243,518	£30,907
Scenarios		
Low (33%)	£80,361	£10,199
Medium (66%)	£160,722	£20,399
High (100%)	£243,518	£30,907

5.3. Impact of Warfarin Ban

The use of warfarin (an anticoagulant medication used to treat blood clots) as a poison to kill grey squirrels in areas where red squirrels were not present was first permitted in the UK in 1973[36]. In 2014 the EU licence to produce and sell warfarin as a rodenticide was not renewed, although users had until September 2015 to use up existing stocks.

Prior to the withdrawal of the Warfarin, landowners and woodland managers indicated that its non-availability would have a significant impact on their ability to control grey squirrels[37]. Whilst the outcome is difficult to determine, given the complex factors around grey squirrel populations, there is anecdotal evidence[38] that where warfarin was previously used as a bait, grey squirrel numbers have increased significantly.

[35] Standard costs based on £2.88 supply, plant and protect a tree at 2000 stems/ha. Total also includes management and maintenance costs.
[36] Grey Squirrels (Warfarin) Order 1973
[37] Survey of RFS Members' Views and Experiences of Grey Squirrel Control. Royal Forestry Society, 2014.
[38] pers comm

Appendices

Appendix A: The Brief[39]

Objectives

- Develop a transparent and replicable methodology to estimate with reasonable accuracy the cost of grey squirrel damage in woodlands in England and Wales.
- Ground-truth the methodology by reference to selected landowner case studies.
- Deliver a report with supporting evidence which can be published
- Promote the findings of the report widely within the UK Squirrel Accord signatories, their networks/members and in national media.

Scope

In scope:

- Loss of timber value mitigated by firewood value
- Cost of grey squirrel management (trapping and shooting) including opportunity cost of land management activities foregone
- Cost of restocking and establishment
- Cost of loss of species diversity
- Cost of loss of natural capital

Out of scope

- Domestic property damage
- Bird predation
- Impact on red squirrel populations
- Scotland

[39] As issued June 2018

Appendix B: Conceptual Model

Pests cause damage to trees which can be prevented to varying degree by applying mitigating measures. The damages can be in the form of reduced timber yield or in the reduced function of the tree in providing a wide range of ecosystem services. They are a stock of natural capital from which many services flow.

Figure 1 represents the case of the damages caused by pests on trees. The total value that tree provide to society is represented by the blocks A plus B plus C. The total damage caused by a pest, in the absence of any mitigating actions would be A plus B. However, it can be expected that some managers of trees will seek to prevent such damages and that to do this they spend an amount D. This mitigation spend reduces the total losses by amount B. Thus, the benefit of mitigation/managing the pest are the avoided losses due to this management. The cost benefit ratio of management is B divided by D – when this is greater than 1, the mitigation is worth undertaking.

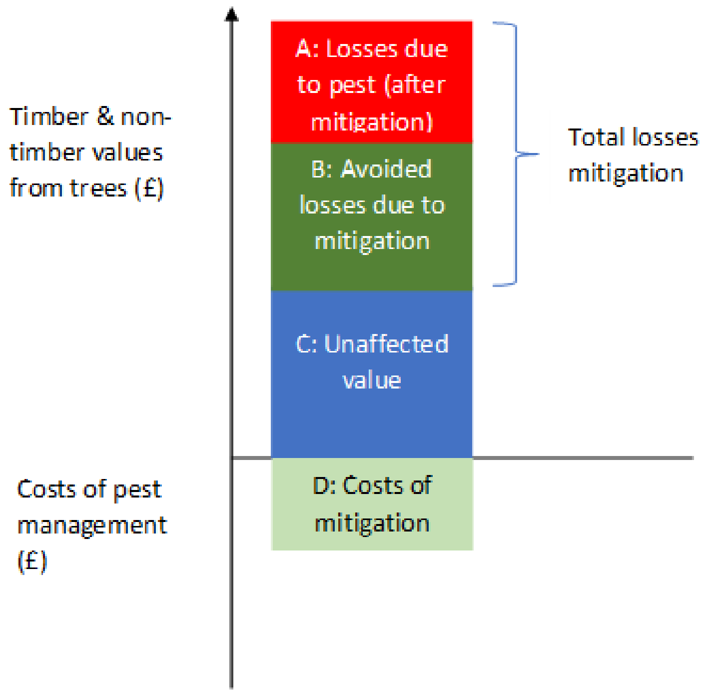

Figure 4: Conceptualisation of the impact of pest damage to values from trees

This conceptualisation outlines the method for estimating the damages caused by squirrels. It can be translated into a set of simple equations:

- Total value (A+B+C) = (Species/age class area affected * value/unit area)
- Losses due to pest (A+B) = (Total value * damage/unit area)
- Avoided losses due to mitigation (B) = (Area mitigated * effect of mitigation/unit area)
- Costs of mitigation (D) = (Area mitigated * mitigation cost/unit area)

Whilst this is conceptually relatively straightforward there are several significant gaps in the data available across all the individual components.

- Squirrel presence and damage caused. The National Forest Inventory dataset provides estimates of the presence of squirrel damage and its severity
- Damage mitigation
- Non-timber values
- Timber values – the least significant gap

Appendix C: Results

This appendix presents the detailed results from the model described above and gives the total cost of damage per hectare by species[40] and age class.

Table 6: Cost of damage per hectare for broadleaves in England

Species		Area	Timber/ha	Carbon/ha	Future/ha	Total/ha
Acer	0-20	224	£ -	£ 60.2	£ 8.0	**£ 68.2**
Acer	21-40	179	£ 10.8	£ 135.2	£ 13.5	**£ 159.4**
Acer	41-60	33	£ 7.0	£ 323.0	£ 56.2	**£ 386.2**
Acer	60+	49	£ 0.1	£ 0.7	£ 152.3	**£ 153.1**
Ash	0-20	347	£ -	£ 7.5	£ 4.3	**£ 11.8**
Ash	21-40	47	£ 5.8	£ 44.5	£ 11.0	**£ 61.3**
Ash	41-60	65	£ -	£ -	£ 16.1	**£ 16.1**
Ash	60+	23	£ 107.3	£ 361.9	£ 87.3	**£ 556.4**
Beech	0-20	1,170	£ -	£ 10.0	£ 9.0	**£ 19.0**
Beech	21-40	1,555	£ 9.9	£ 192.7	£ 25.0	**£ 227.6**
Beech	41-60	1,379	£ 3.3	£ 93.2	£ 47.0	**£ 143.6**
Beech	60+	875	£ 10.2	£ 57.7	£ 137.9	**£ 205.8**
Birch	0-20	529	£ -	£ 9.7	£ 2.5	**£ 12.2**
Birch	21-40	430	£ 7.0	£ 88.1	£ 8.7	**£ 103.8**
Birch	41-60	187	£ 0.9	£ 41.0	£ 18.0	**£ 59.9**
Birch	60+	155	£ 12.6	£ 91.9	£ 30.5	**£ 135.0**
Oak	0-20	528	£ -	£ 2.6	£ 18.9	**£ 21.4**
Oak	21-40	191	£ 4.1	£ 108.4	£ 46.8	**£ 159.3**
Oak	41-60	45	£ 0.4	£ 17.2	£ 108.6	**£ 126.2**
Oak	60+	162	£ 8.6	£ 7.6	£ 399.9	**£ 416.1**
Sweet chestnut	0-20	164	£ -	£ 0.0	£ 11.0	**£ 11.0**
Sweet chestnut	21-40	110	£ 0.1	£ 1.8	£ 55.7	**£ 57.6**
Sweet chestnut	41-60	1	£ 2.8	£ 157.1	£ 87.9	**£ 247.8**
Sweet chestnut	60+	19	£ 45.1	£ 49.6	£ 987.5	**£ 1,082.1**
Sycamore	0-20	2,708	£ -	£ 22.7	£ 7.0	**£ 29.7**
Sycamore	21-40	3,558	£ 6.4	£ 53.3	£ 20.9	**£ 80.5**
Sycamore	41-60	1,066	£ 2.0	£ 79.3	£ 39.9	**£ 121.2**
Sycamore	60+	344	£ 33.9	£ 114.3	£ 227.0	**£ 375.2**
Other broadleaves	0-20	1,338	£ -	£ 12.6	£ 3.5	**£ 16.1**
Other broadleaves	21-40	447	£ 4.6	£ 60.5	£ 11.4	**£ 76.6**
Other broadleaves	41-60	172	£ 0.2	£ 11.3	£ 24.0	**£ 35.6**
Other broadleaves	60+	165	£ 102.8	£ 311.5	£ 134.7	**£ 549.0**

[40] Species listed as presented by the NFI, thus 'Acer' is all maple species, excluding sycamore.

Table 7: Cost of damage per hectare for broadleaves in Wales

Species		Area	Timber/ha	Carbon/ha	Future/ha	Total/ha
Acer	0-20	1	£ -	£ -	£ 7.4	**£ 7.4**
Acer	21-40	1	£ -	£ -	£ 18.6	**£ 18.6**
Acer	41-60	2	£ -	£ -	£ 23.6	**£ 23.6**
Acer	60+	-	£ -	£ -	£ -	£ -
Ash	0-20	52	£ -	£ 14.5	£ 6.0	**£ 20.5**
Ash	21-40	16	£ -	£ -	£ 12.9	**£ 12.9**
Ash	41-60	8	£ -	£ -	£ 29.3	**£ 29.3**
Ash	60+	67	£ -	£ -	£ 182.3	**£ 182.3**
Beech	0-20	131	£ -	£ 12.5	£ 10.0	**£ 22.5**
Beech	21-40	184	£ 2.0	£ 38.8	£ 11.7	**£ 52.5**
Beech	41-60	32	£ -	£ -	£ 35.9	**£ 35.9**
Beech	60+	102	£ 5.4	£ 30.8	£ 223.6	**£ 259.8**
Birch	0-20	323	£ -	£ 11.7	£ 2.1	**£ 13.8**
Birch	21-40	219	£ 4.5	£ 56.0	£ 6.5	**£ 67.0**
Birch	41-60	19	£ -	£ -	£ 19.8	**£ 19.8**
Birch	60+	21	£ -	£ -	£ 39.3	**£ 39.3**
Oak	0-20	102	£ -	£ 2.9	£ 21.2	**£ 24.1**
Oak	21-40	61	£ 2.8	£ 74.9	£ 50.6	**£ 128.4**
Oak	41-60	44	£ -	£ -	£ 67.2	**£ 67.2**
Oak	60+	33	£ 376.3	£ 331.4	£ 734.1	**£ 1,441.8**
Sweet chestnut	0-20	-	£ -	£ -	£ -	£ -
Sweet chestnut	21-40	11	£ -	£ -	£ 42.3	**£ 42.3**
Sweet chestnut	41-60	-	£ -	£ -	£ -	£ -
Sweet chestnut	60+	0	£ -	£ -	£ 242.2	**£ 242.2**
Sycamore	0-20	341	£ -	£ 42.7	£ 8.5	**£ 51.2**
Sycamore	21-40	88	£ 24.4	£ 203.8	£ 26.4	**£ 254.6**
Sycamore	41-60	51	£ 0.5	£ 19.6	£ 47.3	**£ 67.4**
Sycamore	60+	37	£ -	£ -	£ 204.2	**£ 204.2**
Other broadleaves	0-20	134	£ -	£ 17.0	£ 3.8	**£ 20.8**
Other broadleaves	21-40	58	£ 0.5	£ 6.9	£ 4.5	**£ 11.9**
Other broadleaves	41-60	18	£ -	£ -	£ 5.7	**£ 5.7**
Other broadleaves	60+	64	£ -	£ -	£ 95.9	**£ 95.9**

Table 8: Cost of damage per hectare for conifer in England

Species		Area	Timber/ha	Carbon/ha	Future/ha	Total/ha
Fir	0-20	77	£ -	£ -	£ 4.3	**£ 4.3**
Fir	21-40	3	£ 2.2	£ 32.7	£ 28.7	**£ 63.6**
Fir	41-60	2	£ -	£ -	£ 128.9	**£ 128.9**
Fir	60+	-	£ -	£ -	£ -	£ -
Larch	0-20	97	£ -	£ -	£ 6.3	**£ 6.3**
Larch	21-40	129	£ -	£ -	£ 8.0	**£ 8.0**
Larch	41-60	27	£ -	£ -	£ 14.0	**£ 14.0**
Larch	60+	-	£ -	£ -	£ -	£ -
Norway spruce	0-20	5	£ -	£ -	£ 13.0	**£ 13.0**
Norway spruce	21-40	4	£ -	£ -	£ 8.3	**£ 8.3**
Norway spruce	41-60	0	£ -	£ -	£ 99.1	**£ 99.1**
Norway spruce	60+	-	£ -	£ -	£ -	£ -
Pine	0-20	45	£ -	£ 11.9	£ 5.2	**£ 17.1**
Pine	21-40	631	£ 0.0	£ 0.2	£ 16.8	**£ 17.0**
Pine	41-60	603	£ -	£ -	£ 75.1	**£ 75.1**
Pine	60+	1	£ 737.1	£ 1,520.4	£ 873.4	**£ 3,131.0**
Sitka	0-20	10	£ -	£ -	£ 9.7	**£ 9.7**
Sitka	21-40	-	£ -	£ -	£ -	£ -
Sitka	41-60	13	£ -	£ -	£ 17.5	**£ 17.5**
Sitka	60+	1	£ -	£ -	£ 439.2	**£ 439.2**
Other conifer	0-20	8	£ -	£ -	£ 2.6	**£ 2.6**
Other conifer	21-40	21	£ 0.2	£ 1.3	£ 29.4	**£ 30.9**
Other conifer	41-60	160	£ 0.1	£ 1.2	£ 20.0	**£ 21.3**
Other conifer	60+	5	£ 2,108.4	£ 931.3	-£ 115.9	**£ 2,923.7**

Table 9: Cost of damage per hectare for conifer in Wales

Species		Area	Timber/ha	Carbon/ha	Future/ha	Total/ha
Fir	0-20	22	£ -	£ -	£ 4.3	**£ 4.3**
Fir	21-40	11	£ 2.2	£ 32.7	£ 28.7	**£ 63.6**
Fir	41-60	6	£ -	£ -	£ 128.9	**£ 128.9**
Fir	60+	50	£ -	£ -	£ 274.5	**£ 274.5**
Larch	0-20	26	£ -	£ 176.1	£ 13.1	**£ 189.2**
Larch	21-40	45	£ -	£ -	£ 16.1	**£ 16.1**
Larch	41-60	97	£ -	£ -	£ 14.0	**£ 14.0**
Larch	60+	-	£ -	£ -	£ -	£ -
Norway spruce	0-20	-	£ -	£ -	£ -	£ -
Norway spruce	21-40	11	£ -	£ -	£ 6.6	**£ 6.6**
Norway spruce	41-60	48	£ -	£ -	£ 19.8	**£ 19.8**
Norway spruce	60+	-	£ -	£ -	£ -	£ -
Pine	0-20	-	£ -	£ -	£ -	£ -
Pine	21-40	2	£ -	£ -	£ 32.3	**£ 32.3**
Pine	41-60	10	£ 7.7	£ 472.5	£ 135.0	**£ 615.3**
Pine	60+	-	£ -	£ -	£ -	£ -
Sitka	0-20	6	£ -	£ -	£ 4.9	**£ 4.9**
Sitka	21-40	164	£ -	£ -	£ 10.3	**£ 10.3**
Sitka	41-60	1	£ -	£ -	£ 14.7	**£ 14.7**
Sitka	60+	-	£ -	£ -	£ -	£ -
Other conifer	0-20	2	£ -	£ -	£ 23.4	**£ 23.4**
Other conifer	21-40	-	£ -	£ -	£ -	£ -
Other conifer	41-60	-	£ -	£ -	£ -	£ -
Other conifer	60+	-	£ -	£ -	£ -	£ -

Appendix D: Values and Impacts

This is at the core of the problem of providing an estimate of the value of the damage due to squirrels. Conceptually it is not difficult:

- What is the value of trees?
- How much damage do squirrels cause?
- How much does this damage reduce value?

The Forestry Commission Research Report 'Valuing the social and environmental contribution of woodlands and trees in England, Scotland and Wales'[41] provides an excellent and detailed report into the values produced for society by forests, woodlands and trees. The basic premise for the need to assess such values is described thus: *diverse resources provided by trees and woodlands contribute to the production of a wide array of benefits ranging from timber to wildlife habitats and from carbon storage to water purification. This diversity is further complicated by the fact that, while some of the goods associated with forests are traded in markets and hence have associated prices, others arise outside markets and, while valuable, lack prices. The need to make evidence-based decisions regarding woodlands, including decisions such as how much public funding should be allocated to support the non-market benefits they generate, has necessitated the estimation of the value of those benefits*.

They use an ecosystems services approach to establish a structured method for assessing such values. They state that: "*The central idea behind the ecosystem services approach is to characterise the role of nature in delivering human well-being using the same concepts as are applied to describing the economy. In this sense, the environment can be characterised as a complex natural factory engaged in a myriad of productive processes. These natural productive processes combine environmental inputs to produce final environmental goods and services, which have direct and immediate consequences for productive activities in the human economy. To understand the role of nature in delivering human well-being it is important to understand how these environmental production functions feed into the production activities of firms and households*".

With respect to tree health, the FC Report[42] provides some interesting conclusions of relevance to this report. They suggest that the evidence base on the impact of tree health on the value of the benefits provided by trees and woodlands is small but emerging. However, they state that there is a substantial need for research in this area, in particular to address difficulties in understanding the counterfactual – what would have happened if the trees were healthy.

Not only are there significant issues with value data, there is also a significant issue the lack of accurate data that describes i) the distribution of squirrels and ii) the damage they have caused.

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[41] Binner et al (2017) (Binner, A., Smith, G., Bateman, I., Day, B., Agarwala, M. and Harwood, A. (2017).
[42] ibid

With respect to values, for non-timber we use those published by Defra in the Tree Health Resilience Strategy[43].

- Timber

In deciding what financial value to attribute the damage to timber, a number of options are available. These include: -

- Gross Value Added (GVA)
- Capital Values
- Revenue Cashflows

Gross Value Added at basic prices[44] (aGVA) represents the income (turnover) of UK businesses, less the cost of goods and services purchased by businesses, and can measure the contribution of an individual enterprise, sector, or area. It is widely used by government and others to assess the relative merits of such entities as it can be viewed against other competing demands for investment (either public or private). As such, there are benefits in using the impact on GVA as a measure of the damage caused by Grey Squirrels. However, there are also features relating to aGVA which would limit the veracity of values provided in doing so. These include: -

- the relatively small size of the UK forestry sector which, once further split into England and Wales, could provide aGVA figures of questionable accuracy
- the nature of businesses within the sector, many of which are not registered for VAT and/or incorporated, meaning they are not captured by aGVA statistics
- the difficulty in attributing the impact of damage across the various sectors[45] against which aGVA is reported by the ONS
- the lack of comparative aGVA data relating to hardwood and softwood forest management and timber processing sectors, given that softwood represents 93% of timber harvested in the UK[46]

Capital values can be described in terms of the value of the woodland or forest as a property, or the standing value of the timber, as it might be expressed in the balance sheet of an incorporated entity.

- The value of a woodland as a property will relate to a number of features, including timber values, location, access etc. However, the market value of woodlands made up primarily of broadleaves (which are those mostly affected by Grey Squirrels) will in many cases be determined primarily by its amenity value i.e. for uses other than timber production[47]. It is therefore debatable as to what extent damage caused by Grey Squirrels would impact on the market

43 (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/710719/tree-health-resilience-strategy.pdf)
44 ONS website accessed 11/03/20
45 Includes 02.1 Silviculture and other forestry activities; 02.2 Logging; 02.4 Support services to forestry; 16.1 Sawmilling and planning of wood; 16.21 Manufacture of veneer sheets and wood-based panels.
46 UK Forestry Statistics 2019 - https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/
47 The UK Forest Market Report Issue 20 2018. John Clegg & Co and Tilhill Forestry.

value of a property. In addition, the number of primarily broadleaved properties which come to market each year is negligible and thus setting a value would be problematic.

- The capital value of standing timber is simpler to assess. Data on market prices is readily available, as is data on the standing volumes of timber of different species. The disadvantage of this method is that the standing value is largely theoretical, that is until the timber is harvested and sold, the value is not realised, nor is any loss attributable to damage from grey squirrels. It does not impact in the short term on the cashflow or profitability of an enterprise and thus may not affect its viability.

Revenue cashflows are to an extent assessed using the same data as capital values i.e. timber prices and volumes, but limited to the value of timber that will be harvested in the short term and thus likely to impact on the day to day viability of an enterprise. This will in turn impact on employment, investment in equipment and tax revenues, amongst others. Using revenue cashflows might mask the impact of long-term spending decisions and thus underestimate the true value of damage.

  - Safety works (felling of damaged unsafe trees)

This aspect of grey squirrel damage is becoming more of an issue. Forest managers are reporting[48] an increase in more immediate costs of making safe roadside trees that have been damaged by grey squirrels. There are two costs associated with this - the first being safety inspections carried out by the landowner or forest manager and the second being the work to make safe the dangerous tree. Safety inspections are often carried out annually and landowners with roadside trees should be doing this regardless of squirrel damage or not. It can therefore be argued that this cost should not necessarily be fully attributed to squirrel damage rather partly apportioned. The cost of inspection will vary greatly depending on length and extent of roadside trees and woodlands. The cost of making safe damaged trees can only be ascertained once the level of damage is known.

What assumptions/evidence can be made/do we need to put a price on this?

- Length of roadside woodlands in England and Wales
- Proportion of roadside woodlands with trees at the susceptible age
- Proportion of roadside woodlands with susceptible species
- Assume that road traffic control measures are required
- Assume that unsafe trees must be climbed and or elevated work platforms used
- What about trees adjacent to public rights of way, parks, gardens, car parks, open access areas etc….?

[48] Pers comm Wilding, J, Mumford, J and Anderson, S (2019)

- Non-timber

Estimates of the non-timber values from woodlands are not particularly common and those used most often for Government Policy are somewhat dated and have a number of issues. They need careful interpretation when used away from their original study.

The Government's 25 Year Environment Plan supplementary evidence report (2018)[49] states that the value from healthy trees and plants contribute to the UK economy, society, and environment, is estimated partially at £8 billion per year. This is comprised of an: *estimated £3 billion of Gross Value Added (GVA) from crop and horticulture sectors, £1 billion of GVA from forestry and logging sector, and around £4 billion of social/environmental value from forestry and trees from carbon sequestration, air pollution absorption, biodiversity, recreation and landscape value (excluding many elements that cannot easily be monetised – water quality/availability, noise, flood and heat reduction, physical and mental wellbeing, and cultural, symbolic education benefits).* The full details of the £4 billion estimate of social/environmental annual value we derive from forestry and trees was subsequently published in the Defra Tree Health Resilience Plan.

The THRS provides some detail of the non-timber benefits from the 3 million hectares of forests and woodland in Great Britain plus the wide range of other trees (small woods, clusters of trees, linear tree features such as those alongside transport routes, lone trees and hedgerows in trees, across the rural and urban/peri-urban landscape) comprising a further 0.75m ha. With respect to the valuation of these the THRS states: *UK wide estimates of monetary value are more developed for forestry and woodlands than for the range of other trees (where estimates of value are quite partial and mainly limited to air pollution absorption in some key cities). Other elements of value can be expressed in a qualitative or quantified way only (including physical health and mental wellbeing, cultural symbolic and educational benefits, woodland conservation, noise, flood and heat reduction, and water quality and availability*). The estimates reflect the annual flow of benefits from current stock of forests, woodlands, and trees. The total value for the UK, *using current very partial estimates*, is £4.9bn per year.

In more detail, the annual value we receive from our forestry and trees has been estimated based on:

- Additional forestry/woodland value to the economy per year of £1bn-£2bn of UK GVA (see discussion above on timber values), this does not include wider sector benefits (e.g. contribution to value of tourism, tree fruits)
- Forestry/woodland carbon sequestration value (environmental) £1.2bn per year, UK: estimated by multiplying data on carbon sequestered (Forestry sector) (https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1703161052_LULUCF_Projections_to_2050_Published_2017_03_15.pdf) non-market carbon price (latest central BEIS Values).

49 (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/673492/25-year-environment-plan-annex1.pdf)

- Forestry/woodland value from a partial assessment of recreation (social 'active use'), landscape (social 'passive use'), biodiversity (environmental and social 'non-use' of £1.9bn per year across GB. Estimates for recreation, landscape and biodiversity based on eliciting a sample of households' willingness to pay for enjoyment/benefit of these forestry features, and then aggregating across the whole population. Based on a Forestry Commission report[50] where estimates have since been updated (i) in a 2013 Defra report[51] for landscape to £0.2bn per year, and subsequently (ii) to reflect the latest relevant MENE survey data on trip estimates, resulting in an aggregate increase in the value of recreation to £0.9bn per year, noting that a range of different willingness to pay estimates could be applied to calculate this value, and (iii) to reflect a wider range of biodiversity value, where the latest estimate is now £0.8bn per year. Note that this biodiversity value is a cautious estimate as higher biodiversity value estimates do exist, where (a) it is assumed that people value biodiversity in each other's countries of GB as well as their own leading to a higher estimate of £1.7bn per year, or (b) a much wider coverage of woodland has its value estimated by applying similar per hectare 'willingness to pay' estimates. We will develop our understanding of this key value in future, noting existing estimates are based on a small sample of people's 'WTP' estimates. Note also that these estimates are partial because (i) only 3m hectares of woodland >0.5 hectares is reflected in the National Forest Inventory (but there is also an extra 0.75m hectares of smaller woodland and other trees); (ii) for biodiversity (1m of total 3m hectares of woodland included, reflecting ancient semi-natural, replanted & new broadleaf/conifer woodland); (iii) landscape (excludes woodland not visible beyond urban fringe); and (iv) recreation (excludes casual/high value visits).
- Woodland value from air filtration (social 'passive use') of £0.77bn per year, across UK. The value of woodland vegetation removing harmful pollution was estimated to be £0.77 billion in 2015, based on the 2007 Land Cover Map. This value is based on the avoided health costs associated with respiratory and cardiovascular illnesses, and subsequent years of life gained, and deaths avoided[52].
- Forestry/woodland value from benefits of flood reduction (environmental) - estimate completed for one catchment and plans in development to estimate a GB wide value. A recent FC case study provides a flood alleviation estimate for a catchment (Southwell) in Nottinghamshire at £250 per hectare per year – noting this per hectare value decreased as further areas were planted to cover 310 hectares total as this involved extending tree planting to sites where trees were less effective at flood alleviation (further similar case studies are also being considered as well as a plan to estimate a national flood alleviation value for woodland).
- Forestry/woodland value from water quality/availability (environmental), and health/wellbeing (social 'active use') value not well known, often captured qualitatively, or included within broader green space valuation

[50] Willis et al. (2003) The Social and Environmental Benefits of Forests in Great Britain.
[51] Defra (2013) Chalara in Ash Trees: A framework for assessing ecosystem impacts and appraising options.
[52] ONS (2017) Ecosystem Account for Woodland (Table 8).

- Cultural, symbolic, spiritual, education/social development (social 'passive use') value from experiencing forests/woodlands including ancient trees Internal Defra Report entitled "Social and Cultural Values in Plant Health – Scoping Study and Review" provides further details [available on request]. Note that there may be an element of overlap between these and the estimates of biodiversity value (value non-monetisable), and woodland conservation (social 'non-use') value from preserving trees for the future.
- Urban woodland/trees annual value including for many of the benefits above such as landscape, pollination, flood reduction, carbon sequestration, biodiversity, physical/mental health, and quality of life improvements[53] as well as value from shade, heat, and noise reduction. Partial assessment of noise and local climate regulation value, expected to be significant, included in a 2017 scoping study[54] (further work in development to refine estimates - environmental, social 'active/passive/non-use') - values are not well known, often captured qualitatively or included within broader green space valuation.
- Urban woodland/trees annual value of air pollution absorption (social 'passive use') estimated at £0.2bn per year[55], across GB. This value has been estimated in for the ONS and is based on the OS Master Map. It is likely to be a lower-bound estimated when compared to an extrapolation of the approach used in the i-Tree project entitled Valuing London's Urban Forests, a 2015 London i-Tree Eco Project. In this project, London urban tree/woodland annual value is estimated which mainly reflects air pollution removal (£0.13bn). Although some similar studies are available for several other cities with much lower £estimates, this approach could be extrapolated to reflect air pollution removal value from urban trees across the key cities in the UK (estimated at potentially into the hundreds of £millions). Small values have also been estimated as part of the London i-Tree project for carbon sequestration (£5m per year) and flood alleviation (£3m) – this estimate is partial and included in the £0.77bn
- Annual value from other trees including hedgerows, garden and park trees, trees on transport corridors (mix of environmental and social 'passive use') - not well known

There is ongoing work producing estimates of the annual value of woodland in the UK woodland accounts Note that recent reports for the ONS[56] and the Woodland Trust[57] provide figures that reflect a similar set of values although some are provided on a different basis. The £4.9bn estimate in this analysis is an annual value, whereas the Woodland Trust (£270bn) estimate is the total value of benefits in perpetuity, to indicate the value of the entire forestry asset, for a similar but not identical set of ecosystem services. The £4.9bn annual estimate is also based on applying valuation methods more cautiously than Woodland Trust (e.g. for biodiversity and landscape value). Compared to the £2.3bn estimate of annual value in the ONS 2017 Woodland

[53] Urban FWAC Network (2016). Our vision for a resilient urban forest.
[54] eftec (2017). A study to scope and develop urban natural capital accounts for the UK.
[55] CEH (2017). Developing Estimates for the Valuation of Air Pollution Removal in Ecosystem Accounts' (Table 16)
[56] ONS (2017). Environmental Accounts
[57] Europe Economics (2015). The Economic Benefits of Woodlands.

Accounts[58], which are part of the overall ONS Environmental Accounts 2017, figures are similar for some of the components of the £4.9bn value presented here – but it is worth noting that this analysis provides a broader coverage of value (for instance includes non-use biodiversity value that individuals benefit from, the economic value reflects Gross Value Added for a broader coverage of activity as described above) and there are also some further differences due to methodologies used (for instance the recreation value here is higher due to using a higher estimate of 'willingness to pay'/wider coverage of recreational trips). The £4.9bn value is an analysis of value that is a snapshot for 2015 and so this value will change over time. The ONS Woodland Accounts are part of a long-term programme of joint work with Defra to develop annual natural capital accounts for the UK, both physical and monetary, flow and stock accounts. These accounts are improved each year as new information becomes available and can be incorporated into any future versions of this analysis where appropriate. The reasons for the differences are set out in the footnotes below.

It is worth also noting however, that trees may also reduce the value of services, for instance through tree root damage or obstructing views. Therefore, many factors (including location and species mix) should be considered carefully when designing policies, in order to mitigate negative value and maximise positive value.

The core themes for which there is some valuation data are:

- Biodiversity
- Landscape
- Carbon
- Recreation
- Air quality

Shuttleworth et al[59] states that biodiversity could be negatively affected by grey squirrel damage, as the loss of trees from mature woodland would result in the loss of associated fungal and invertebrate species.

58 https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/landandhabitatecosystemaccounts

59 The Grey Squirrel Ecology & Management of an Invasive Species in Europe, Chapter: 26, Publisher: European Squirrel Initiative, Editors: Craig Shuttleworth, Lurz P W W, Gurnell J, pp.517-520

Appendix E: Species Susceptibility

Whilst there is no definitive list of susceptible species, several lists have been produced which are based on local knowledge and experience of grey squirrel damage (Shuttleworth et al. 2016[60]; Mayle et al. 2013[61]; Lawton unknown[62]). We have attempted to bring some of the more widely recognised ones together to form a list of common species which suffer from grey squirrel damage. The table below shows the most common species susceptible to grey squirrel damage.

Table 10: Species susceptibility to grey squirrel damage

Scale (1 being most susceptible)	Hardwoods	Softwoods
1	Sycamore/maple	Lodgepole pine
2	Beech	Norway spruce
3	Oak	Scots pine
4	Sweet chestnut	Larch
5	Ash	Douglas fir
6	Birch[63]	Western Hemlock
7	Alder	
8	Lime	
9	Cherry	
10	Hazel	

Furthermore, some studies have attempted to assess the severity and proportion of damage in a woodland. The table below is taken from Robinson (2016)[64]. 5% of woodland plantations in the National Forest were surveyed covering an area of approximately 500ha with all woodland being less than 25 years old.

Table 11: Age class susceptibility to grey squirrel damage

Age Category	Mean Damage Severity	% trees damaged
21-25 Years	3.83	29.20
16-20 Years	1.92	23.30
10-15 Years	2.45	14.20
All Sites	2.73	22.30

[60] The Grey Squirrel: Ecology and Management of an Invasive Species in Europe (2016) Eds Shuttleworth, C. et al. European Squirrel Initiative.
[61] Mayle et al (2013) Changes in the impact and control of an invasive alien: the grey squirrel (Sciurus carolinensis) in Great Britain, as determined from regional surveys. Pest Management Science. 69. 323-333.
[62] Lawton, C (unknown). Controlling Grey Squirrel Damage in Irish Broadleaved Woodlands. Coford Connects - Silviculture/Management No. 7.
[63] NFI data indicates that contrary to this other evidence, birch is more susceptible than ash.
[64] Robinson, C (2016) An investigation into the two principal biological threats facing woodlands in the National Forest in 2016. Thesis submitted as part of the MSc degree in Forestry Management.

The table below identifies the damage scores used.

Table 12: Scores for grey squirrel damage

Damage scores	Description	Example cost of damage
1	Coin sized flakes of bark removed	5% reduction in timber value
2	Hand sized areas of bark stripped	15% reduction in timber value
3	Stripped area large enough to kill <50% of canopy	50% reduction in timber value
4	Stripped area large enough to kill >50% of canopy	50% reduction in timber value

Most sources agree that trees are most susceptible to damage between 10 and 40[65] years of age but damage has been noted on younger trees and indeed trees over 40 years old. However, the age of the tree section is more important than the age of the tree itself in determining damage likelihood[66]. Mountford (2006)[67] found 54% of trees in a study woodland to be damaged with a mortality rate of between 2.3 to 5.4% per year. Lawton (unknown)[68] identified 40% of sycamore and beech to be damaged in a study area in Ireland and 5-40cm dbh trees are damaged more often than others. This compares to data from Shuttleworth et al (2016) (Chapter 19) Mayle et al (2013)[69] Dutton (2016)[70] and Huxley (2003)[71]. Other factors that will increase risk and severity of damage include trees growing vigorously and rapidly, trees in less competition with neighbours such as edge trees and thinned stands, woodlands with increased species diversity, woodlands with high squirrel densities (4 to 5 per ha), good autumn mast years leading to increased damage the following spring, winter pheasant feeding and agonistic behaviour by juvenile and adult squirrels.

Other sources show that sycamore and beech are consistently reported as the most frequently and severely damaged, with damage reported for over 65% of sites in 2000 and with up to 12% of sites having 50-75% of trees in a stand damaged[72]. Oak is the next most frequently reported species damaged with levels of 40% in 2000.

Others have attempted to put a figure on the reduction in timber value per ha. Dutton (2016) provides an example of a beech stand where the reduction in value per ha over an 85-year rotation is £1,700. Shuttleworth (2016) reports that a high value stand can sell at £15,000/ha (2015 prices) and if severely damaged by bark striping, the same

[65] Shuttleworth, C et al (2016) Chapter 19
[66] Shuttleworth, C et al (2016) Chapter 19
[67] Mountford, P (2006) Long term patterns and impacts of grey squirrel debarking in Lady Park Wood young growth stands (UK) Forest Ecology and Management. 232. 100-113.
[68] Lawton, C (unknown) Controlling Grey Squirrel Damage in Irish Broadleaved Woodlands. Coford Connects – Silviculture/Management No.7.
[69] Mayle et al (2013) Changes in the impact and control of an invasive alien: the grey squirrel (Sciurus carolinensis) in Great Britain, as determined from regional surveys. Pest Management Science. 69. 323-333.
[70] Dutton, C (2016) Grey Squirrel Management Handbook. European Squirrel Initiative.
[71] Huxley (2003). The Grey Squirrel Review. European Squirrel Initiative.
[72] Mayle et al (2013).

crop may only be suitable for firewood worth 30% of that figure. An evaluation, by Broome and Johnson (2000)[73], of the costs of bark stripping estimated 43,000ha of beech, sycamore and oak woodland were vulnerable to damage. The estimated undamaged value of the woodland was around £40m. Others have assessed the loss in value as a reduction in yield class and a more straightforward analysis that if a tree is damaged enough, then its potential value to grow high quality sawlog will be reduced to nothing more than firewood value. What is more is that damaged trees become more prone to infection from diseases which can be triggered in bark wounds.

[73] Broome A, and Johnson A (2000) *An evaluation of the costs of grey squirrel bark stripping damage in British Woodlands* Forestry Commission Internal Report Edinburgh

Appendix F: Alternative Methods of Control

Trapping

Alternative methods of trapping include the Remoti[74] system and the Good Nature A18 Grey Squirrel Trap[75]. These systems may help to reduce the cost of control, but it is not known what the effectiveness and cost of these systems are at the time of writing.

Contraception

Contraception is also seen as an alternative method of control. Oral contraceptives given in baits may be effective in reducing population size. A five-year study by the National Wildlife Management Centre[76] will show results in due course. This method may indeed reduce the cost of control and could be on the market within 6 to 8 years.

Pine Martens

In recent years, research from Ireland has indicated that the presence of a healthy pine marten (Martes martes) population coincides with declining grey squirrel numbers whilst promoting recovery of the red squirrel population. This is considered to be due to one or more reasons, including direct predation by pine martens on grey squirrels, disturbance caused to grey squirrels thus increasing their range and decreasing breeding potential, and competition for food. It is thought that red squirrels, having co-existed with pine marten in natural habitats, have developed a 'coping mechanism' to deal with them, rather than the 'flight' mechanism adopted by the non-native grey squirrel

Spencer et al 2018[77] reports that where pine marten populations have recovered in Ireland, grey squirrel populations have declined significantly, resulting in a regional recovery of the red squirrel population. Research by Sheehy et al (2018) in Scotland provides similar results whereby pine marten populations increase, grey squirrel populations decrease, and red squirrel populations recover. The article goes on to report on recent and planned reintroductions in regions of England and Wales.

Pine martens are the UKs second rarest native mammal and as such are worthy of recovery and reintroduction programmes in their own right. However, the emerging evidence of their ability to reduce grey squirrel populations, allowing red squirrels number to recover, has increased interest in these programmes. A number of projects, led by the Vincent Wildlife Trust, are either in place or under consideration, including in Ceredigion (around Devil's Bridge) from 2015 onwards and the Forest of Dean, commending in 2019. A population recovery project in the north of England is supporting the recolonisation of Northumberland and Cumbria by the southward

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[74] http://www.remotisystems.com/
[75] https://goodnaturetraps.co.uk/news/goodnature-grey-squirrel-trap/
[76] Massei, G (2018) Oral Contraceptives from Grey Squirrels. Quarterly Journal of Forestry. 112. 181-183
[77] Spencer, J et al (2018) Martens, Squirrels & Forestry. The return of the pine marten to lowland England and Wales. Quarterly Journal of Forestry. 112 257-261.

expansion of the Scottish population. Initial monitoring of grey squirrel populations around the Ceredigion release site indicate a significant reduction in grey squirrel numbers.

Feasibility studies have indicated that suitable habitat exists in the Chilterns, South West, and South East England, although the potential mortality rate due to the relatively high density of roads could be a limiting factor. Future reintroduction projects would also need to ensure that they did not have a detrimental impact on the source population in Scotland. In addition, the cost of reintroduction programmes is significant, the Forest of Dean project budgeted at approximately £700,000. Notwithstanding these barriers, the potential for pine martens to provide a natural, low (ongoing) cost means to assist in the reduction of grey squirrel numbers and the recovery of red squirrels is thought to be significant.

Chemical or Physical Barriers

Chemical repellents such as Aaprotect[78] have been shown to be effective at preventing bark stripping and can be painted or sprayed onto the bark. Predator odours, such as pine martens, can also be employed as a potentially effective deterrent. These methods, in combination with physical barriers such as tree collars[79] and wider habitat management techniques may be effective in certain situations however, the cost of employing these techniques at a landscape scale would be prohibitive.
Other theories have been presented most notably the Calcium Hypothesis[80]. The authors argue that causal understanding of bark stripping is lacking and a better understanding of what motivates grey squirrels to strip bark may enable better control strategies to be developed and adopted. The Calcium Hypothesis states that grey squirrels strip bark to ameliorate a calcium deficiency, but further research is required to better understand how grey squirrels utilise calcium found in bark and seasonal variations in calcium deficiency. Further research and the development of this hypothesis may assist forest managers to better predict timings and levels of potential damage following silvicultural interventions and to target resources for control more effectively.

[78] Not currently approved for use in the EU
[79] Only effective on individual isolated specimen trees
[80] Nichols et al (2016) A novel causal mechanism for squirrel bark stripping: The Calcium Hypothesis. Forest Ecology and Management. 367 12-20.

Appendix G: The National Forest Inventory Squirrel Report: Squirrel stripping damage and presence of squirrels in woodland in Britain[81]

The NFI Squirrel Report ‘Squirrel stripping damage and presence of squirrels in woodland in Britain’ provides information on the methodology for obtaining and analysing the data utilised in this report. Further information relating to the NFI is available on the Forest Research website[82].

Figures 5 and 6 indicate the data fields relating to grey squirrel presence and damage, and the information collected only in the second cycle of the NFI.

[81] Squirrel stripping damage and presence of squirrels in woodland in Britain (Draft). Forestry Commission 2019

[82] https://www.forestresearch.gov.uk/tools-and-resources/national-forest-inventory/

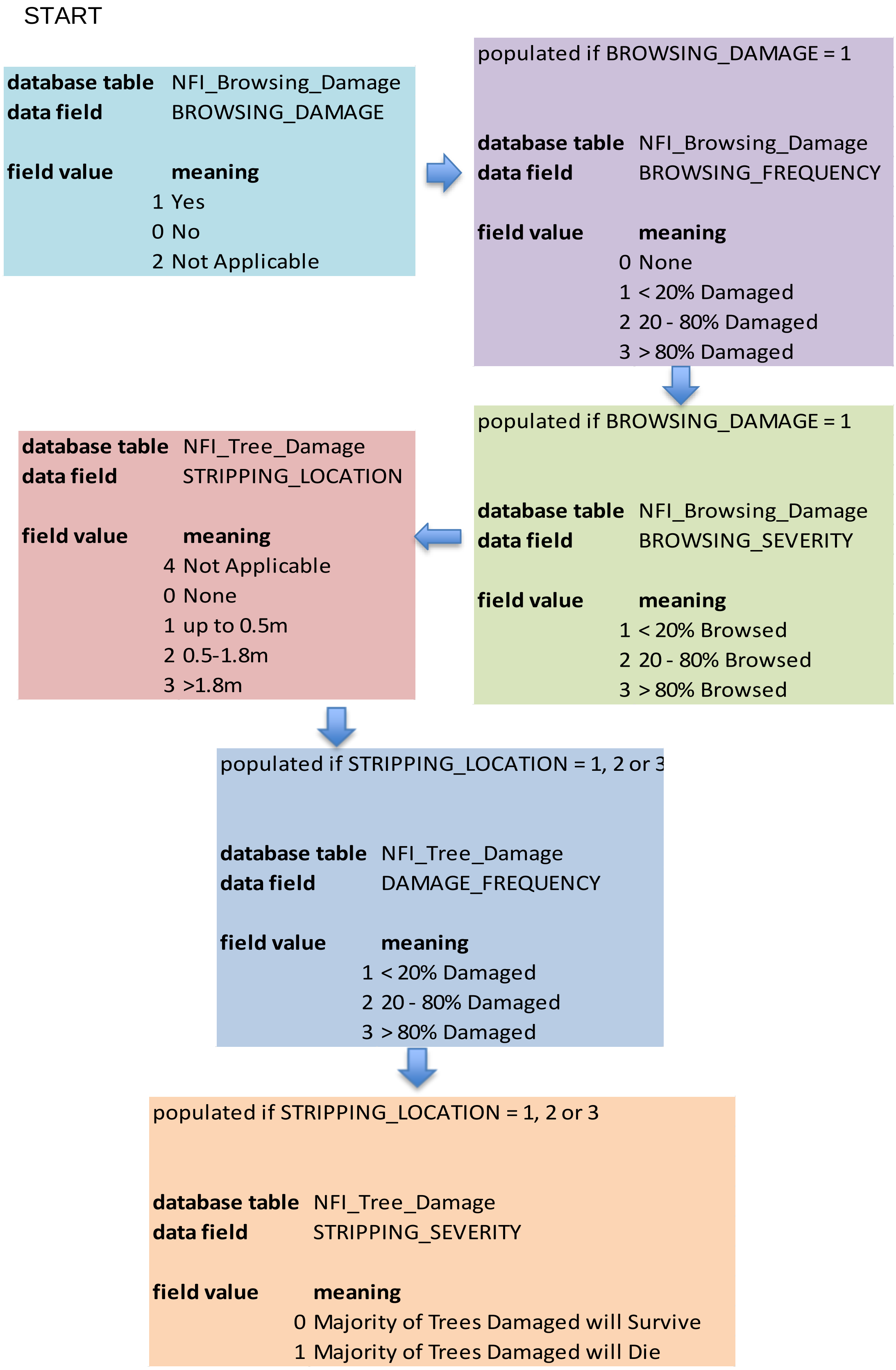

Figure 5: Data fields used by the NFI relating to presence or impact of grey squirrels

database table	NFI_Herbivores
data field	EVIDENCE
field value	**meaning**
1	None
2	Sighting
3	Sign of herbivory
4	Scats
5	Tracks/prints
6	Ground disturbance
7	Burrows/drays/dens
10	Fur/wool/hair
11	Browse line on trees
12	Browse line on vegetation
13	Location/type of tree damage
8	Not Surveyed
9	Not Applicable

database table	NFI_Herbivores
data field	HERBIVORE
field value	**meaning**
1	None
2	Deer
3	Squirrels
4	Sheep
5	Cows
6	Horses
7	Rabbits
8	Hares
9	Pigs/ wild boar
13	Beaver
12	Other
10	Not Surveyed
11	Not Applicable
14	Red squirrels
15	Grey squirrels

Figure 6: Data fields recorded during 2nd cycle of NFI only

Appendix H: Case Studies

The methodology and summary model were ground-truthed with six case study participants. These case studies are presented below.

Neill Scott MICFor - forest manager Pembrokeshire and Carmarthenshire

Neill manages private estates throughout Pembrokeshire and Carmarthenshire including conifer, broadleaved and mixed stands. 20% to 80% of broadleaved trees that he manages show signs of GS damage and approximately 20% of broadleaves and 5% of conifers will die as a result. Neill has previously spent up to £45 per ha to control GS's and would advise clients to allow for £50+ per ha to control GS's if they wished to grow quality timber. He does not now advise clients to plant broadleaves on a commercial basis anymore due to the threat of damage from GS's. He does not expect to get value out of broadleaved woodlands planted in the last 20 or so years. The majority of broadleaved woods are for amenity so are not restocked with broadleaves and the reduction in timber value over each rotation is conservatively estimated at £4,000 per ha. His experiences suggest that the high scenario figure of £38 million of damage per year is more realistic.

His other concerns are that the GS issue has been overtaken by ash dieback, but it is just as apparent if not more so. He also has concerns that the reintroduction of pine martens in Wales, although generally a good idea, will dilute the message of GS control. One major nationwide effort at culling GS's is required which could include alternative methods such as pine martens and contraception.

Justin Mumford FICFor - forest manager Midlands and North

Justin has recently felled 1000m3 of oak and beech P1955 on an estate in the Midlands. At least 20% of the logs were damaged with significant signs of callusing and staining of the wood. This has led to a significant reduction in value from sawlog to firewood. He pointed out that when the trees were standing in the forest, damage was not visible, and the extent of the damage only became evident when trees were felled and dressed out.

He expects this scenario to be repeated across many young and mid rotation hardwood stands that he manages. Once damaged, the tree will never reach full potential and in nearly all cases will be reduced to firewood value at best.

Justin agrees that the high cost scenario of £38 million of damage per year would be more realistic but mitigation costs across his estates, although not assessed directly, are closer to £20/ha.

The presence of GS does affect decisions on restocking and new planting and advice to clients and he is now advising to plant more conifer across all areas.

Graham Taylor FICFor - forest manager West Midlands, South West and Wales

Graham believes the high scenario is the correct one. His response is based on 30 years' experience and his recent analysis of GS impacts as set out by the Squirrel Accord in June 2019. The findings of this show an annual cost of GS damage to woodlands in the region of £40m.

Graham stressed the importance of the effect of change to woodland composition caused by GS and this is as big a problem as the damage itself. A cumulative effect is happening - we are losing the ability to grow species like oak, beech, sycamore and chestnut and other species like ash, willow, alder and cherry are dominating. This is leading to the confidence of hardwood processors being weakened.

In terms of mitigation costs, Graham broadly agrees with the cost scenarios presented in the model. He gave an example of an 800ha mixed woodland where £10,000 is being spent on GS control of which about 400ha are being damaged so cost is around £25/ha. High levels of GS control success are achieved at around £50/ha.

Graham's final point was on broadleaf policy and that it is not currently working and needs to be rethought – 'either spend serious money on eradicating GS or face the reality'.

Jez Ralph - forest manager and timber consultant South West

Jez recently produced a study on the South West Forest[83]. The study looked into the impact of the South West Forest initiative in Devon and Cornwall between 1997 and 2005.

A total of 3,107ha of new woodland was created of which 1,988ha was broadleaved and 1,118ha were conifer. 20% of the area was surveyed as part of the study and all had extensive GS damage. The extent of the damage was significant and none of the broadleaved woodlands visited will reach their full potential and will only produce firewood grade material at best. This issue of loss of potential value is a big factor. Jez thinks income lost is more or less comparable to the value of substitute imports.

Jez's thoughts on the model are that the high scenario is more realistic but mitigation costs for small schemes in the SW Forest study area is closer to £20/ha.

Simon Anderson - forest manager Herefordshire

Simon manages the Brockhampton and Perrystone Estates in Herefordshire with approximately 210ha of broadleaves and 115ha of conifers. His experience shows that 0% to 20% of broadleaved trees are damaged and that there is less than a total of 5ha of damage across the total woodland area. The estates carry out fairly intensive control with shooting and trapping and the use of the Remoti system across 40% of the

[83] J. Ralph (January 2020). Review of New Planting under the South West Forest Scheme and Notes on Publicly Funded New Planting Schemes for the Future'

woodland area. The remaining 60% is too mature for damage. Gamekeepers, woodland workers and volunteers are employed. Simon estimates the annual cost of GS control to be in the region of £8,000 but this is difficult to assess accurately as the gamekeepers carry out control whilst doing other tasks.

Simon puts the limited levels of damage down to having a strong GS control plan which has been in place for the last 12 years. Broadleaf planting is still done, especially in areas where clearfells are carried out in ASNW.

Simons other comment on GS damage is that differing age classes of woodland cover has a significant impact on potential damage and so any forest cover, particularly broadleaf over 50 years old, will not get damaged.

A further consideration needs to be made of squirrel control (or lack of it) on woodland adjacent but not under the same ownership. There are parts of the estate where neighbours do carry out control which in turn helps them, but elsewhere neighbouring woodland owners are more relaxed about control. Although the estate carries out successful control, this is counteracted by GS's migrating in from woodland outside their control.

Simon believes that the medium scenario of £23 million of annual damage is closer to the reality but stresses that GS control cannot be done on the cheap and needs ongoing annual input to deliver results.

David Brown MICFor - forest manager North Yorkshire

David manages the Hovingham Estate in North Yorkshire with approximately 290ha of conifers and 70ha of broadleaves. David describes the level of damage as over 25% in broadleaves and over 10% in conifers over the rotation.

Trapping and shooting is carried out over 250ha of the estate and they can spend as much as £215 per ha on control measures in some years although the annual average is lower and would be closer to £50/ha. David estimates that GS's cause around £100 per ha per year of damage to broadleaved woodlands on the estate which would equate to £8,000 over an 80+ year rotation. Given this level of damage, David would select the high cost scenario to reflect more closely the reality of the cost of GS damage to woodlands.

Appendix I: Recommendations for Future NFI Data Collection

In recognition of the variances from observed experience as outlined in 2.3, the authors of the report have made a number of observations as to how future NFI Data collection could be supplemented in order to address these issues.

These observations are as follows: -

1. Additional sampling should be undertaken within sample squares in order to indicate the degree to which ‘contagion’ occurs and thus existing results can be extrapolated more widely.

2. A selection of sample squares which have been visited during the spring/summer/autumn should be revisited during winter in order to determine whether significant frequency and/or severity of squirrel damage has been obscured by leaf cover.

3. Intensive sampling of a number of squares, including climbing inspections of individual trees, should be undertaken in order to determine whether significant frequency and/or severity of squirrel damage has been not detected from ground-based surveys.

4. Consideration should be given as to whether it would be beneficial to provide additional training for surveyors in order to be able to identify squirrel damage which might otherwise be attributed to other causes due to age of damage, compounding by other causes (e.g. fungal invasion of a bark wound initially caused by squirrels) etc.