Squirrel stripping damage and presence of squirrels in woodland in Britain

National Forest Inventory

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Summary

The National Forest Inventory (NFI) provides a record of the size and distribution of forests and woodlands in Great Britain and information on key forest attributes. This report provides estimates of the presence of squirrels, as evidenced by either bark stripping damage of trees found above 1.8m in height, or other evidence within the forests and woodlands in Great Britain. The report is based upon NFI data collected 2010 to 2015 for bark stripping damage and 2015 to 2018 for both bark stripping and squirrel sightings. The report includes estimates for England, Scotland and Wales, broken down by NFI region. The NFI survey did not originally distinguish red squirrels from grey squirrels, so this report does not discern between the species. The NFI suite of reports and a detailed methodology is available at www.forestresearch.gov.uk/inventory.

Key findings

- Squirrel bark stripping occurs within all three countries, England, Scotland and Wales, but the occurrence and intensity of stripping is highest in England, then Wales and lowest in Scotland.
- Squirrel sightings (or other evidence) and bark stripping damage levels in both surveys appear to be highest in the south and south west of England and Wales.
- The extent of grey squirrel presence as evidenced by bark stripping appears to be wider than previous assessments[1], for example the north east coast of Northumbria and Yorkshire now having squirrels and squirrel bark stripping present, when in 1998 none were reported.
- This pattern of high intensity of sightings or other evidence and bark stripping damage in the south and north east of England may be correlated to the release areas for grey squirrels during the late 1880s and early 1900s, with most being in the south east England and a number in north Yorkshire from where the population has subsequently spread.
- In both the 2010 to 2015 survey for bark stripping damage and the 2015 to 2019 survey for both bark stripping and squirrel sightings or other evidence, the observed squirrel presence was lower in northern central England in a strip running from the Mersey to the Wash. This could be related to low levels of woodland in the Liverpool / Manchester conurbation, Pennines and the Wash.
- In Britain, circa 166 thousand hectares of woodland stands are estimated to have bark stripping damage observable from the ground in at least one of their tree components (unique combination of tree age and species).

[1] https://www.forestresearch.gov.uk/research/management-of-grey-squirrels/

- The percentage area of woodland stands with bark stripping damage is highest in England with circa 11% of stands showing damage, circa 6% in Wales and lowest in Scotland at circa 0.3%.
- 26% of 10km grid squares in Britain evidenced bark stripping in the first 2010-15 NFI survey, which was similar to the 27% in the second NFI survey 2015-18.
- The addition of squirrel sightings and other evidence increased this percentage of 10km grid squares having presence of squirrels from 27% to 32% in the second NFI survey 2015-18, suggesting not all sites with squirrels have observable damage.
- The level of bark stripping damage was found to be similar between the susceptible pole stages of tree ages - 10 to 80 years, but less common for younger and older tree ages.
- Susceptible tree species such as beech and sycamore show more bark stripping damage than other less susceptible species.

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Introduction

The National Forest Inventory (NFI) is a programme of assessment of the extent and content of forests and woodlands in Great Britain. It covers all woodlands of 0.5 hectares or more in extent with a minimum width of 20 metres and tree canopy coverage of 20% of the area, or the potential to achieve this. There are two aspects to the assessment of woodland areas in the NFI programme. One of these is the production of a spatial woodland map covering Great Britain (GB), derived mainly from interpretation of aerial photography, but with additional use of information derived from satellite imagery and administrative sources. The other is a field survey of randomly selected one hectare squares which contain woodland according to the NFI woodland map. These sample squares are selected according to a sample survey design covering the whole of Great Britain, ensuring balanced geographic coverage and representative coverage of different woodland types identified by the NFI woodland map. The NFI field survey has recently completed its second five-year cycle, surveying around 10,000 sample squares across Great Britain, with there being 15,000 sample squares in the first five-year cycle. At the time of analysis, not all sample squares had been processed. The results within this report are based upon available data from both cycles.

The survey process involves partitioning the field sample square into woodland and non-woodland. The areas of woodland are then sub-divided by the surveyor into “stands” of relatively homogeneous structure and composition. Within each woodland section, presence of individual tree species are identified and recorded, a sample of trees is measured or visually assessed, and a number of other observations are made and recorded, including the presence of symptoms of disease, insect attack, tree mortality and other tree damage which includes squirrel bark stripping damage.

The squirrel information recorded differed between the first NFI cycle from 2010 to 2015 and the second cycle from 2015-2020. In the first cycle no explicit information on squirrel sightings or other evidence was recorded. However, information on tree stripping damage and the height at which this occurred (whether above or below 1.8 metres) was recorded, and from this data squirrel damage can be determined. The logic being that tree stripping damage below 1.8m could be caused by other species such as deer whereas bark stripping above 1.8m is almost certainly caused by squirrels. Tree stripping damage above 1.8m is thus used as a proxy measure of the presence of squirrels in this analysis. **Figure 1** illustrates squirrel bark stripping damage easily identifiable on a young maple tree.

From the second cycle of the NFI surveys, squirrel sightings and other evidence (dreys, fur or hairs, scats, tracks and prints) were also measured as these are often easier to observe than bark stripping damage especially in high canopy. See **Figure 2**, where even in winter, with no leaves to obscure a view of the bark, the bark stripping can be harder to identify than the squirrel itself. Underreporting of squirrel presence is likely to be low as squirrels

are one of the most conspicuous UK land mammals, the NFI surveys are undertaken by experienced forest surveyors and our results mirror other data showing squirrel presence[2]. Squirrel sightings recorded between 2015 and 2018 of the second survey cycle (2015-2020) did not distinguish between the two species found in GB: red squirrels *Sciurus vulgaris* and grey squirrels *Sciurus carolinensis*.

[2] Mathews F, Kubasiewicz LM, Gurnell J, Harrower CA, McDonald RA & Shore RF (2018). *A Review of the Population and Conservation Status of British Mammals*. Natural England, Peterborough.

Figure 1 Squirrel bark damage

Figure 2 A grey squirrel adjacent to an area of bark stripping damage

Methodology

When conducting a presence/absence analysis of species such as squirrels that are geographically spread, the geographic survey unit of assessment and its size in relation to the whole area is key to understanding the results of the survey. The larger the survey unit of assessment, the higher the probability that a 'thinly' spread population such as squirrel presence will be found and this in turn leads to a higher prevalence being associated with larger units of assessment. For example, if the geographic survey unit of assessment for squirrel presence utilised was 'Britain' then we would have 100% prevalence as there is a squirrel somewhere in Britain. If a 1mx1m square grid was used as the unit of assessment, then the prevalence would be much lower as the chances of a squirrel being in that smaller area is lower.

This issue of scale concerning the unit of assessment is important when interpreting the NFI results and comparing them to other estimates. The NFI, in assessing bark stripping damage at each unique tree component (combination of tree age and species) within a stand, uses a very small unit of assessment allowing for precise reporting. With this in mind, we have reported the damage at four different scales, identifying presence or damage rates by:

1. **A 10km grid with absence vs squirrel presence or damage.**
2. **Each one hectare NFI field survey square with squirrel presence or damage.**
3. **Stands within woodland with squirrel damage.**
4. **Area of damaged trees only.**

10km grid assessment of squirrel damage or presence

Here, we extrapolated the findings from NFI survey squares to a 10km National Grid system which covers Great Britain, where each grid square can contain multiple NFI survey squares. This resolution was chosen as it has been used by past assessments concerning squirrels[3][4][5][6]. The 10km grid is designated as having squirrel presence if any of the NFI survey squares within it contain squirrel damage or squirrel sighting/signs (second NFI

[3] Shorten M (1946). A survey of the distribution of the American grey squirrel (*Sciurus carolinensis*) and the British red squirrel (*S. vulgaris leucourus*) in England and Wales in 1944-5. *Journal of Animal Ecology* **15:** 82-92.

[4] Shorten M (1957). Squirrels in England, Wales and Scotland, 1955. *Journal of Animal Ecology* **26**: 287-294.

[5] Lloyd HG (1962). The distribution of squirrels in England and Wales, 1959. *Journal of Animal Ecology* **31:** 157-165.

[6] Tee LA, Rowe JJ & Pepper HW (1985). *Mammal Bird Damage Questionnaire 1983*. Forestry Commission Research and Development Paper 137.

survey cycle only). This method reduces resolution of the NFI survey data but has the advantage of being more comparable to previous assessments.

NFI one hectare field survey square with squirrel damage or presence

This assessment relates to finding damage or presence anywhere within each NFI one hectare field sample. The NFI field survey is a field sample of woodlands and forests, where field sample squares are ground surveyed on a 5-year rolling cycle.

Stands within woodland with squirrel damage

Within each NFI survey square, detailed information of the number and type of stands is recorded. Within each stand there may be several tree species, of many ages and for each unique set of tree species and age, these sets are named tree 'components'. Squirrel damage is assessed for each component[7]. For this geographic unit of assessment, we consider that if any single tree component within the stand has signs of squirrel damage (stripping above 1.8m), then the entire geographic area of the stand in which it falls is tallied as subject to squirrel damage. The approach should be used in instances such as when a view is taken that the whole stand is materially affected by the squirrels and undamaged trees will eventually be damaged due to their proximity to damaged trees within the same stand, or that the management and the economic value of the whole stand will alter due to presence of squirrels. This means that all trees within a damaged stand are counted in this assessment, even though a proportion of the trees themselves are not currently or may never be damaged. Thus, this unit of assessment relates to the estimated area of 'stands with squirrel damage'.

Area of damaged trees only

This damage assessment relates to the area under dripline of the single tree 'components' where we found damage and excludes the area of undamaged trees within stands. Therefore, this is generally a subset of the class above, and sets aside the assumption that if a single tree component is damaged in the stand then the rest of the stand is materially affected. When comparing squirrel preference for certain age classes or species of trees this is a more helpful measure than a stand level assessment. We can use this data to quantify the scale of actual damage as when NFI surveyors take note of bark damage at component level they also assess the frequency and severity of damage.

[7] For information on survey design and protocols, see https://www.forestresearch.gov.uk/tools-and-resources/national-forest-inventory/

To derive all area estimates, those stands or components which are identified as having squirrel presence are scaled up to the total woodland area using standard statistical survey methodology. Along with these estimates, associated sampling standard errors have also been calculated and reported. The sampling standard error will account for random variation arising from the selection of the sample, and random measurement errors, but not for any systematic biases in the field measurements. However, because of the NFI quality assurance process it is thought unlikely that any substantial biases of this nature are present in the survey data. The statistical method used is proven and robust but identifying squirrel stripping damage in the high canopy from the ground can be problematic and may be missed. This is may to lead to some underreporting of squirrel bark stripping and adds to the value of the proxy of damage, presence being provided.

Results

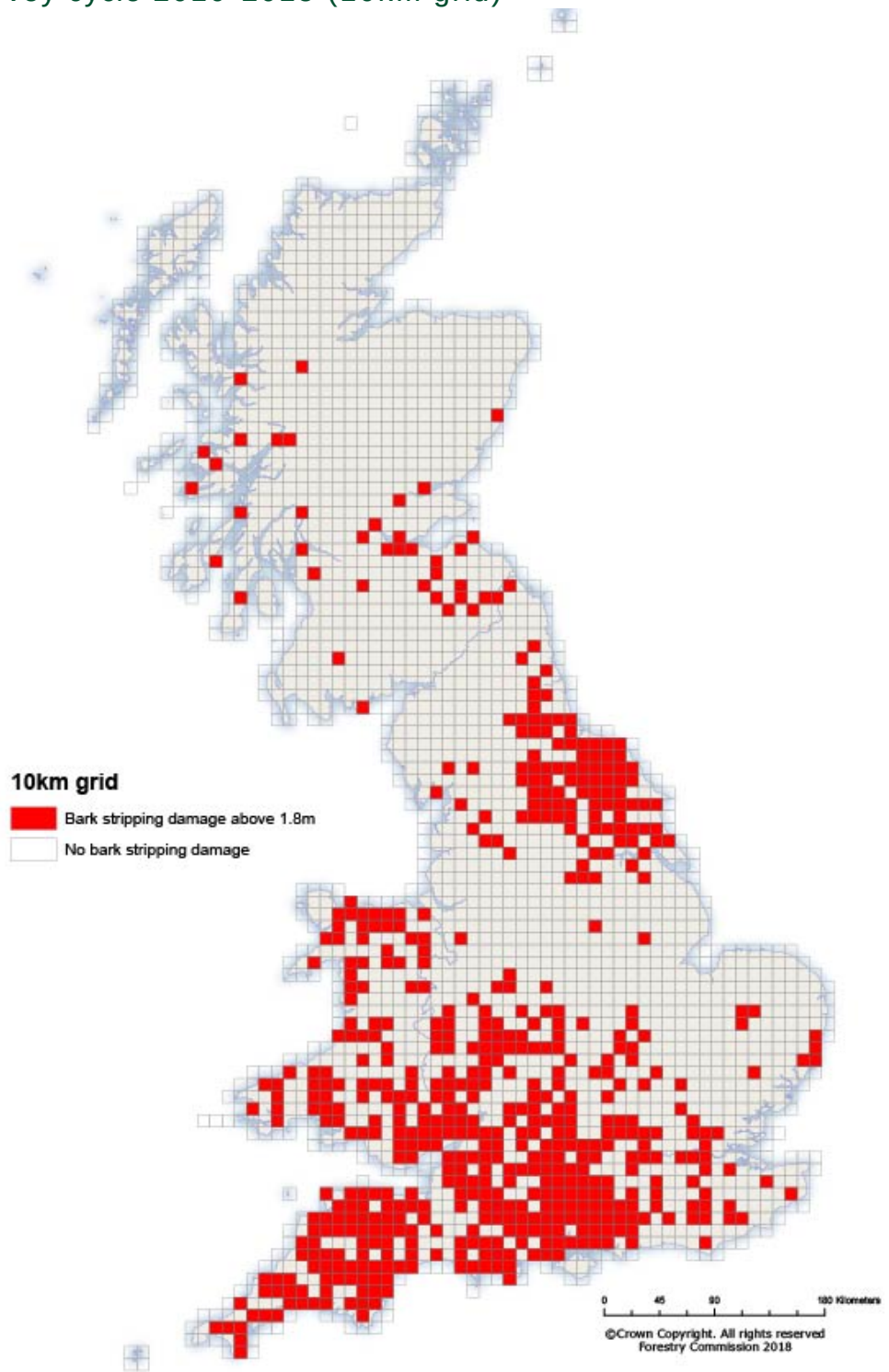
The values in the tables which follow have been independently rounded, so may not add to the totals shown. Sampling standard errors are attached to estimates where appropriate and are expressed in relative terms (%) to the relevant estimate.

Estimates and their standard errors with relative standard errors exceeding 25% are shown in amber in the tables as an indication that these estimates need to be treated with caution. Higher standard errors result from either high variability or rare occurrences within a category. More precise estimates of these statistics would require additional samples.

10km grid assessment of squirrel damage or presence

Map 1 shows the distribution of squirrel tree damage recorded during the first cycle of the NFI field survey extrapolated to the 10km grid, which is also summarised in **Table 1**. The second cycle of field survey also record squirrel sightings and other evidence (see **Map 2** & **Table 2**), and it can be seen there is a wider distribution of squirrel presence. As the second survey cycle is not yet completed (data shown is from 2015-2018 period of survey) many of the grid squares are marked as ‘NFI fieldwork not completed’.

Map 1 Locations where evidence of squirrel bark stripping was observed in the first NFI survey cycle 2010-2015 (10km grid)



Map 2 Locations where squirrels were sighted or other evidence of squirrels including bark stripping was observed in the second NFI survey cycle 2015-2018 (10km grid)

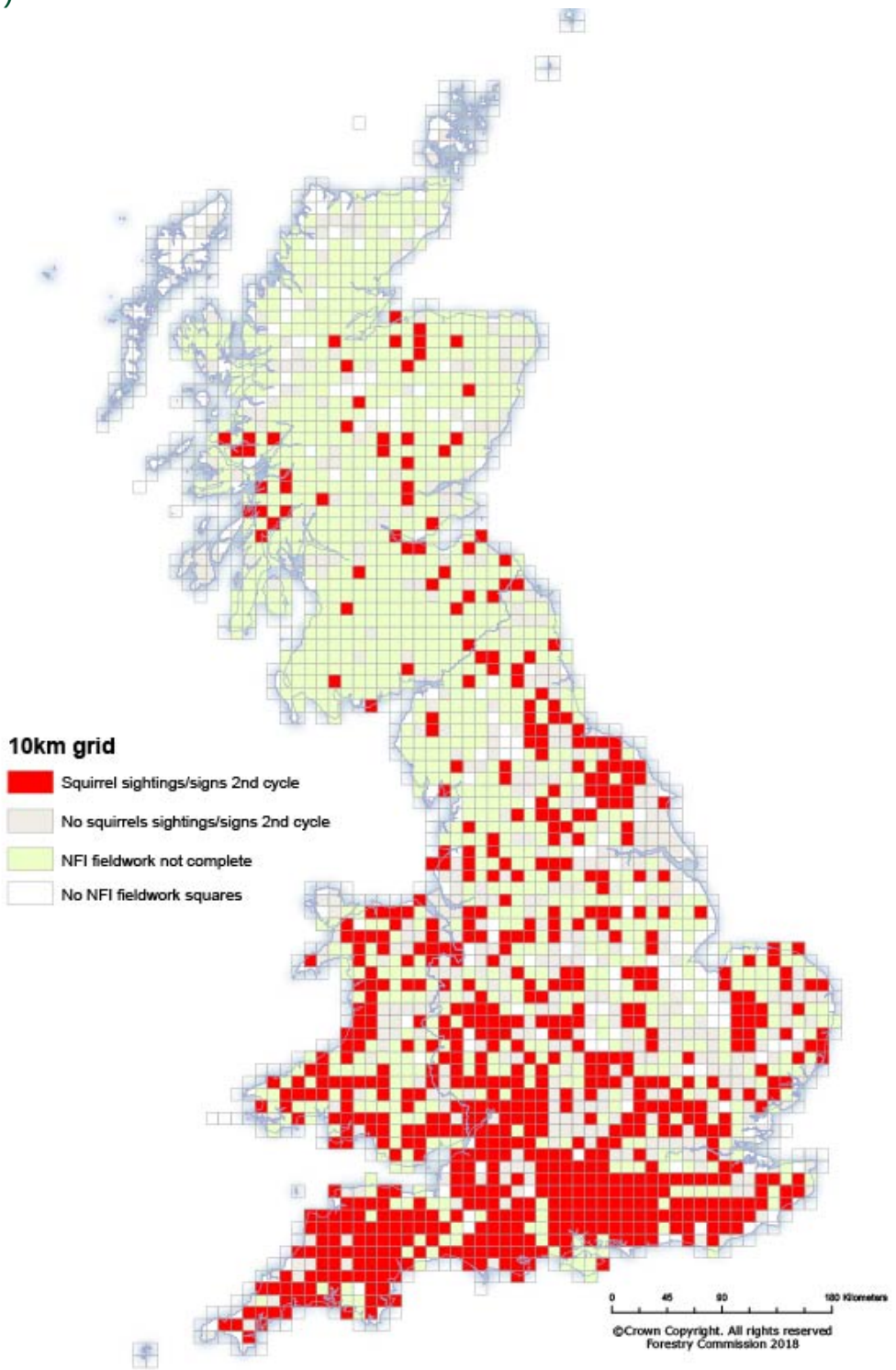


Table 1 Prevalence of squirrel bark stripping observed within a 10km grid – first NFI field survey cycle data (2010 to 2015)

No. of 10km grid squares in GB	2,662
No. of 10km grid squares with survey data collected	2,208
No. of 10km grid squares with squirrel damage sighted	578
Squirrel damage prevalence	26%

Note: The prevalence estimates above utilise a 10km grid as the unit of assessment and therefore concern the % of 10km grid squares within Britain with squirrels present.

Table 2 Prevalence of squirrel bark stripping or squirrel sightings or other evidence observed within a 10km grid – second NFI field survey cycle data (2015 to 2018)

No. of 10km grid squares in GB	2,662
No. of 10km grid squares with survey data collected	2,188
Squirrel sightings or other evidence only prevalence	12%
Squirrel damage only prevalence	27%
Squirrels sightings (or other evidence) or squirrel damage prevalence	32%

Note: The prevalence estimates above utilise a 10km grid as the unit of assessment and therefore concern the % of 10km grid squares within Britain with squirrels present somewhere within that 10km grid square.

NFI one hectare field survey square with squirrel damage or presence

The occurrence of damage attributed to squirrels recorded in first cycle NFI field survey squares is aggregated by country and region, showing that South West England and Yorkshire and the Humber were the two regions in the UK with the highest prevalence, 32% and 23% respectively, followed by South East England and London at 17% (see **Table 3**). All three of these regions had a prevalence higher than the national average for England which was 16%. Wales had a prevalence of 11% while Scotland had one or less than one percent prevalence in all regions.

Table 4 gives squirrel presence at NFI first cycle survey squares aggregated by tree species found within the same squares. Beech, ash, acers (maples, sycamore) and 'Other Conifer' where the most often found in squares with squirrel damage, while Sitka spruce and pine were least often found in association with squirrel damage. **Table 5** has the squirrel damage in NFI squares aggregated by the age classes of trees which are also found in the squares. Here, we see there is a similar prevalence of squirrel damage across all tree age class occurrences. An overall picture of the geographic prevalence of damage and squirrel sightings is given in **Map 3**, making use of available second cycle NFI survey data.

Table 3 Prevalence of squirrel bark stripping observed within the NFI field survey squares by region – first NFI field survey cycle data (2010 to 2015)

Region	No. of NFI squares	No. of NFI squares with squirrel damage observed	Prevalence
Great Britain	14,447	1,261	9%
England	6,510	1,024	16%
East England	723	28	4%
East Midlands	475	17	4%
North East England	564	38	7%
North West England	550	11	2%
South East England and London	1,505	249	17%
South West England	1,202	388	32%
West Midlands	544	78	14%
Yorkshire and the Humber	947	215	23%
Scotland	6,109	39	<1%
East Scotland	583	4	<1%
North East Scotland	1,036	1	<1%
North Scotland	987	2	<1%
South Scotland	1,898	21	1%
West Scotland	1,605	11	<1%
Wales	1,828	198	11%

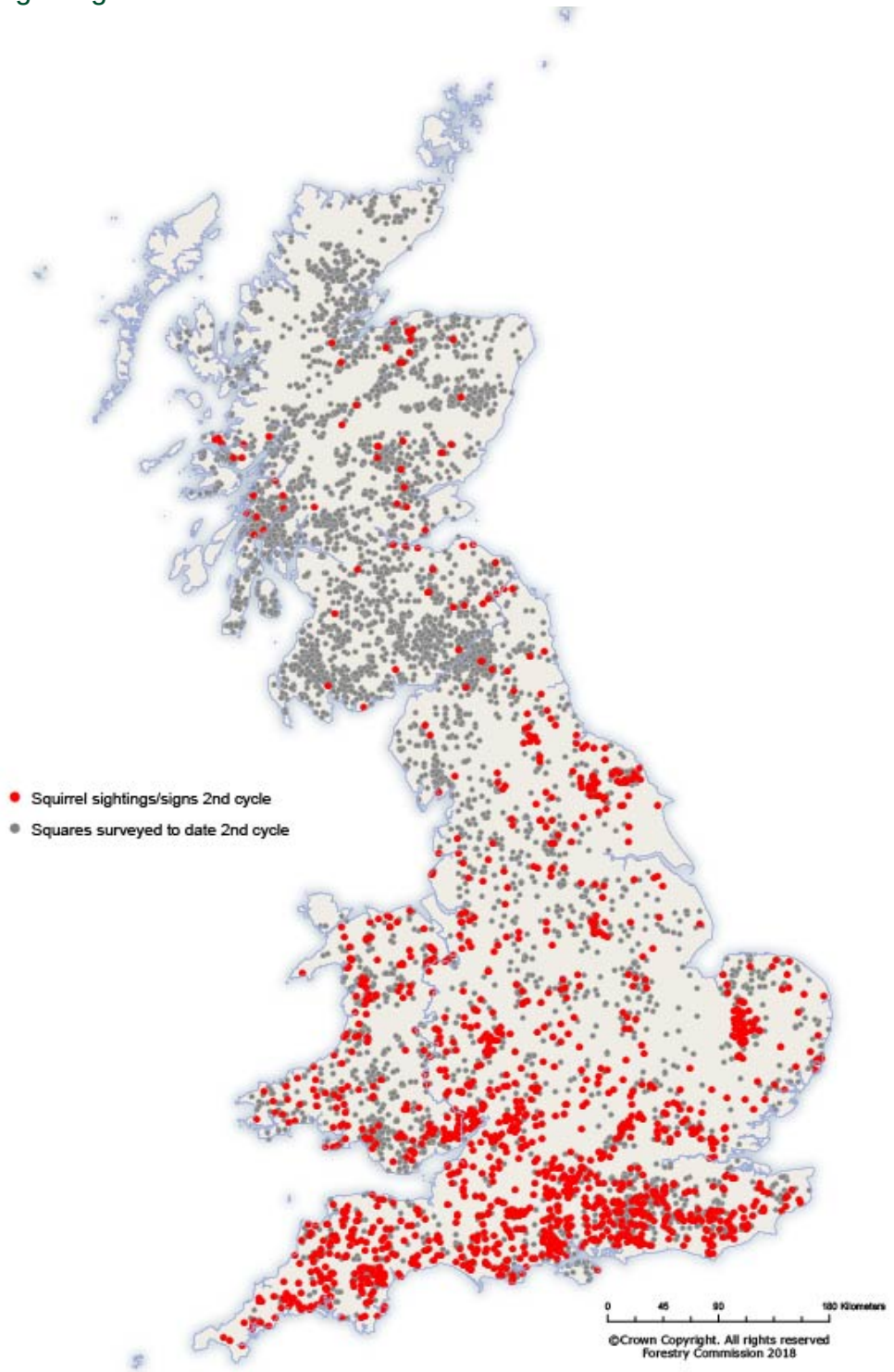
Table 4 Prevalence of squirrel bark stripping observed within NFI squares by tree species – first NFI field survey cycle data (2010 to 2015)

Species	No. of NFI squares	No. of NFI squares with damage observed	Prevalence
Acer	3,583	506	14%
Ash	4,207	606	14%
Beech	2,586	399	15%
Birch	6,370	518	8%
Oak	5,181	613	12%
Sweet chestnut	718	70	10%
Other Broadleaves	8,932	1,041	12%
Fir	1,493	168	11%
Larch	2,771	213	8%
Norway spruce	1,165	112	10%
Pine	4,581	210	5%
Sitka spruce	5,767	129	2%
Other Conifer	871	126	15%
All species	14,447	1,261	9%

Table 5 Prevalence of squirrel bark stripping observed within NFI squares by age class – first NFI field survey cycle data (2010 to 2015)

Age class	No. of NFI squares	No. of NFI squares with damage observed	Prevalence
0-10	6,788	615	9%
11-20	7,147	732	10%
21-30	7,097	716	10%
31-40	6,273	538	9%
41-60	7,254	726	10%
61-80	3,745	414	11%
80+	3,057	395	13%
All age classes	14,447	1,261	9%

Map 3 NFI second cycle survey squares (2015-2018) where squirrel bark stripping or squirrel sightings or other evidence have been observed



Stands within woodland with squirrel damage

The estimated total area of woodlands which were subject to woodland damage was circa 166 thousand hectares in Great Britain, see **Table 6**. Regionally, England had the largest proportion of woodland with squirrel presence, estimated at 11%, followed by Wales (6%) and then Scotland (less than 1%).

Table 6 Area of woodland stands with evidence of squirrel bark stripping observed – first NFI field survey cycle data (2010 to 2015)

Country	Area woodland stands with damage present (000 hectares)	Area woodland stands with damage present (%)	SE%
Great Britain	165.6	5.4	*3.4*
England	142.6	10.7	*3.9*
Scotland	4.2	0.3	*9.1*
Wales	18.7	6.0	*2.7*

Note: Estimates are based on assumption of squirrel presence in entire tree stand when at least one tree component is observed with stripping damage above 1.8m. Values and associated standard errors are scaled up from NFI field survey data to the total woodland area using standard statistical survey methodology.

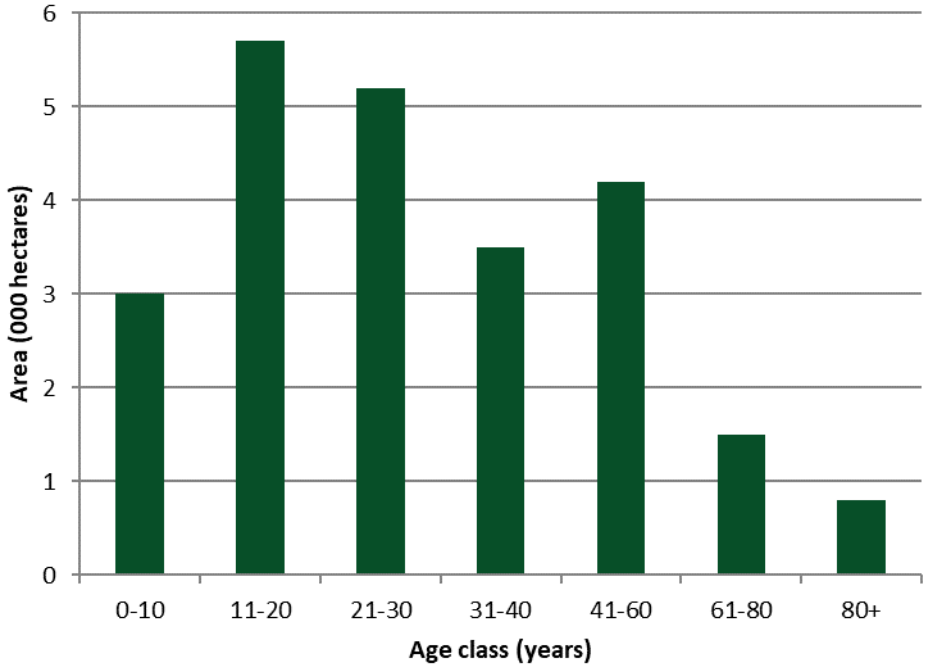
Area of damaged trees only

Table 7 to **Table 8** and **Figure 3** to **Figure 6** provide a breakdown of the area of damaged trees attributed to squirrels by tree species and age class as recorded in tree components during the NFI field survey, they also give the area as proportion of the total area for each tree species or age class. We found that squirrels appear to have less visible damage on very young and very old trees (**Table 7** & **Figure 3**) and show a preference for certain tree species, notably beech and sycamore (**Table 8** & **Figure 6**). **Table 9** presents data concerning the extent of damage to the tree component, and whether the trees are likely to survive. Analysis suggests that although younger tree classes are less likely to be damaged, the level of damage is more severe, and a greater proportion are likely to die as a result of the damage.

Table 7 British trees within woodland with evidence of squirrel damage observed in NFI first cycle by age class

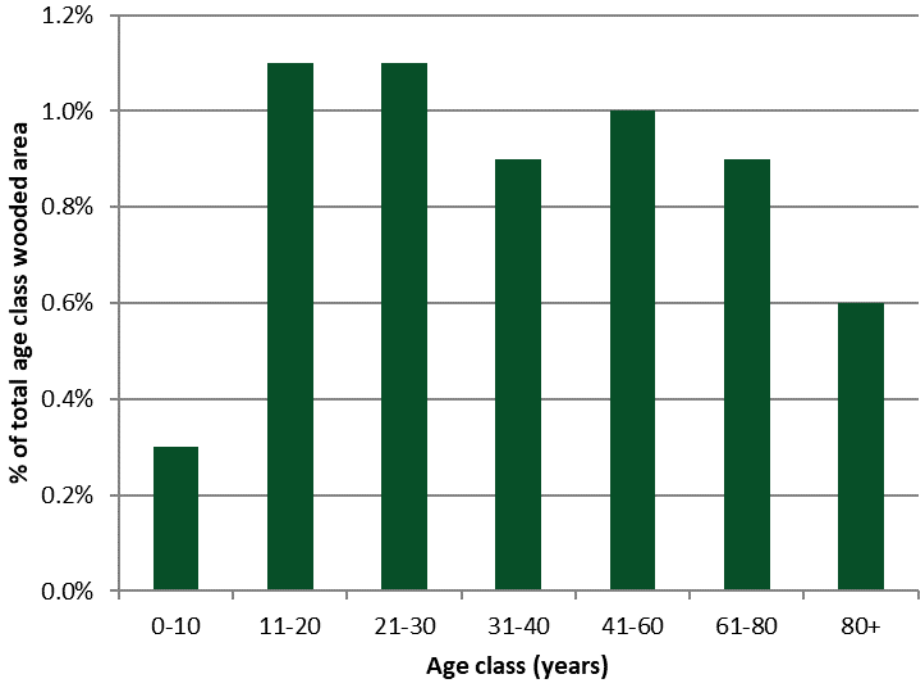
Age Class	Area of trees with squirrel damage (000 hectares)	Damage as % of total area of age class	SE%
0-10	3.0	0.3%	8.8
11-20	5.7	1.1%	5.2
21-30	5.2	1.1%	32.7
31-40	3.5	0.9%	9.1
41-60	4.2	1.0%	8.0
61-80	1.5	0.9%	17.6
80+	0.8	0.6%	12.4
Total (all classes)	24.0	0.8%	7.7

Figure 3 Total wooded area with tree damage attributed to squirrels in GB, broken down by tree age class – NFI first survey cycle data



Note: Estimates relate to individual tree components within stands observed with stripping damage above 1.8m. Values and associated standard errors are scaled up from NFI field survey data to the total woodland area using standard statistical survey methodology.

Figure 4 Tree damage attributed to squirrels as a percentage of wooded area in GB, broken down by tree age class - NFI first survey cycle data



Note: Estimates relate to individual tree components within stands observed with stripping damage above 1.8m. Values and associated standard errors are scaled up from NFI field survey data to the total woodland area using standard statistical survey methodology.

Table 8 Area and % area of trees within woodland in Britain with evidence of squirrel bark stripping damage as observed in NFI first cycle, aggregated by species

Species	Area of trees with squirrel damage (000 hectares)	Area of trees with squirrel damage (%)	SE%
Sycamore	8.7	6.0%	19.8
Beech	5.5	5.2%	6.6
Other broadleaves	2.5	0.4%	11.2
Birch	2.0	0.6%	9.3
Pine	1.5	0.5%	18.8
Oak	1.2	0.7%	11.0
Ash	0.6	0.3%	14.4
Acer	0.5	3.2%	15.0
Larch	0.4	0.5%	25.7
Sitka spruce	0.4	0.1%	27.9
Sweet chestnut	0.3	1.2%	39.5
Other conifers	0.2	1.1%	66.9
Fir	0.2	0.3%	37.2
Norway spruce	0.1	0.1%	41.1
Total (all species)	24.0	0.8%	7.7

Note: Estimates relate to individual tree components within stands observed with stripping damage above 1.8m. Values and associated standard errors are scaled up from NFI field survey data to the total woodland area using standard statistical survey methodology. Here, acer includes all maple species other than sycamore which is given separately.

Figure 5 Tree damage attributed to squirrels in Britain, total wooded area affected, broken by tree species - NFI first survey cycle data

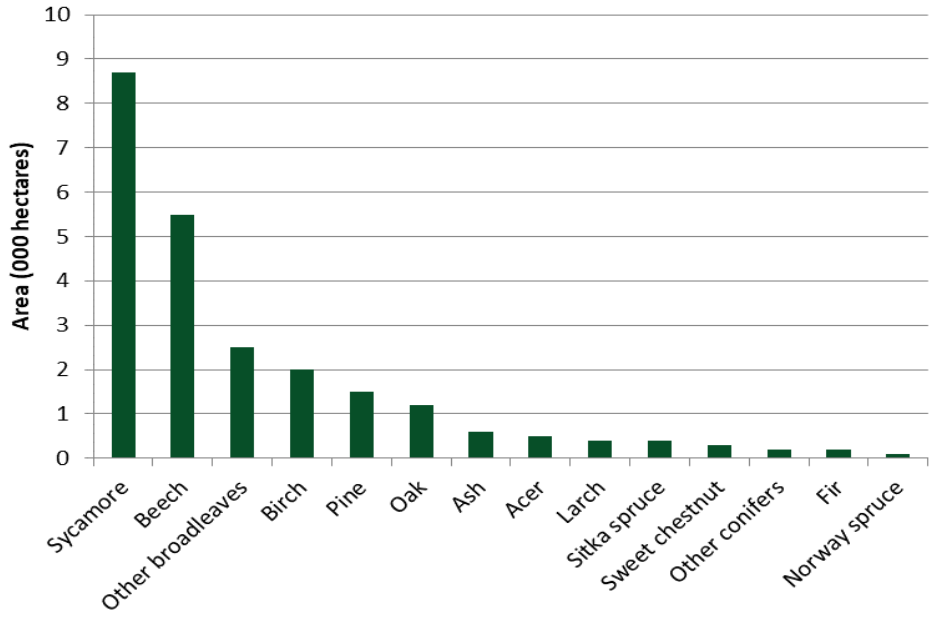
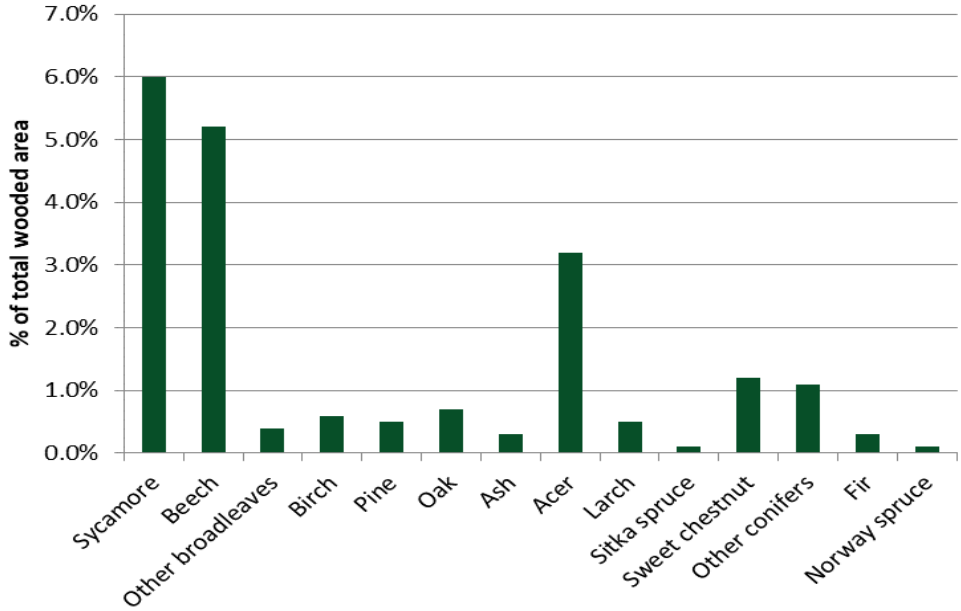


Figure 6 Tree damage attributed to squirrels as a percentage of wooded area in Britain by tree species - NFI first survey cycle data



Note: Estimates relate to individual tree components within stands observed with stripping damage above 1.8m. Values and associated standard errors are scaled up from NFI field survey data to the total woodland area using standard statistical survey methodology.

Table 9 GB trees within woodland with evidence of squirrel damage observed in NFI first cycle by age class with break down by frequency and severity of damage

Tree age class	% GB trees in woodland with squirrel damaged	Area GB trees in woodland with squirrel damaged (hectares)	Damage frequency class	Area damaged (hectares)	SE%	% area where the majority trees were recorded as likely to die
0 - 20	0.6%	8,612	<20%	2,672	*10.5*	*2%*
0 - 20	0.6%	8,612	20 to 80%	4,794	*5.3*	*8%*
0 - 20	0.6%	8,612	> 80%	1,146	*9.4*	*59%*
21 - 40	1.0%	8,760	<20%	2,954	*10.1*	*2%*
21 - 40	1.0%	8,760	20 to 80%	3,219	*7.8*	*15%*
21 - 40	1.0%	8,760	> 80%	2,587	*65.7*	*20%*
41 - 60	1.0%	4,241	<20%	1,835	*13.5*	*3%*
41 - 60	1.0%	4,241	20 to 80%	1,983	*10.4*	*6%*
41 - 60	1.0%	4,241	> 80%	424	*24.6*	*31%*
60+	0.8%	2,288	<20%	1,166	*22.1*	*6%*
60+	0.8%	2,288	20 to 80%	862	*12.0*	*5%*
60+	0.8%	2,288	> 80%	260	*13.8*	*45%*

Note: Estimates relate to individual tree components within stands observed with stripping damage above 1.8m. Values and associated standard errors are scaled up from NFI field survey data to the total woodland area using standard statistical survey methodology.

Discussion

The statistics presented should be viewed in the context of three important factors:

1. Red squirrels are native to the British Isles.
2. Grey squirrels are an introduced species and were actively encouraged to establish in Britain between 1876 and 1929.
3. From that point in time grey squirrels have spread through parts of Britain, gradually displacing the native red squirrel in most of England and Wales, and in central and south-east Scotland[8][9][10][11].

Although both species can cause bark stripping damage to trees, it is generally thought that grey squirrels cause much more significant bark stripping damage than red squirrels[12]. That being so, the presence of stripping damage may broadly be equated to the presence of greys, but not exclusively. The NFI found extensive squirrel damage, with circa 166 thousand hectares of woodland stands containing some bark stripping damage above 1.8m.

The findings have shown that bark stripping damage varies across countries, regions, tree species and age classes. Bark stripping damage was highest in England, with damage found in 16% of NFI field survey squares and an estimated 11% of woodland stand area showing evidence of bark stripping damage, as seen from the ground. The second highest levels of damaged stands were found in Wales with 11% of NFI field survey squares having some damage within them and an estimated 6% of the area of woodland stands containing some bark stripping damage. This bark stripping damage pattern is consistent with the previously recorded distribution of the grey squirrel[13], with most squirrel bark stripping damage located in England and Wales and a lower rate in Scotland. At a regional level,

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[8] Shorten M (1946). A survey of the distribution of the American grey squirrel (*Sciurus carolinensis*) and the British red squirrel (*S. vulgaris leucourus*) in England and Wales in 1944-5. *Journal of Animal Ecology* **15:** 82-92.

[9] Shorten M (1957). Squirrels in England, Wales and Scotland, 1955. *Journal of Animal Ecology* **26**: 287-294.

[10] Lloyd HG (1962). The distribution of squirrels in England and Wales, 1959. *Journal of Animal Ecology* **31:** 157-165.

[11] Gurnell J, Lurz P & Bertoldi W (2014). The changing patterns in the distribution of red and grey squirrels in the North of England and Scotland between 1991 and 2010 based on volunteer surveys. *Hystrix* **25**: 83-89.

[12] Forestry Commission England (2006). *Towards a Forestry Commission England Grey Squirrel Policy.* In: *Grey squirrels and England's Woodlands* (2006). Forestry Commission England publication.

[13] Tee LA, Rowe JJ & Pepper HW (1985). *Mammal Bird Damage Questionnaire 1983*. Forestry Commission Research and Development Paper 137.

damage appears to be more prevalent in the south west and south east of England, as well as Yorkshire and the Humber.

The tree species thought to be more palatable[14] to squirrels are largely recorded in the NFI field survey as having a higher level of bark stripping damage, most notably beeches and acers. Bark stripping damage levels were highest in sycamore, with 6% of components showing signs of damage, followed by 5% for beech, acers at 3%, and again this is consistent with known squirrel preference for stripping certain tree species[15]. However, the geographic distribution of both the squirrels and the tree species should be considered with these results. As grey squirrels only occupy part of Britain, notably the southern half, any tree species predominant in the north of Britain will experience less squirrel damage, independent of its palatability. Equally, any tree species restricted geographically to the grey squirrel zone will be disproportionately exposed to damage, when compared to a species predominantly located outside the zone. To help interpret this factor, example tree species distribution maps (**Map 4**, **Map 5** & **Map 6**) have been supplied. For example, it is notable that relative tree cover for maple (sycamore) is the highest in the Humber and Yorkshire region (see **Map 4**) and that this coincides with a high level of squirrel damage and presence. Likewise, damage in beech is relatively high but we should consider equally that grey squirrels were predominately released in the lowlands within the native range of beech (**Map 5**). Also of note, is that squirrel presence and damage is low where Sitka spruce is prevalent in the far north and west of Britain (**Map 6**). Squirrel damage is low overall in Sitka spruce woodlands, however, they are also further distanced from the original release sites of the greys. This report does not conclude on these factors, as further research on such relationships is required, but the data on squirrel distribution is set alongside the tree species distribution data to aid interpretation of the estimate for damage distribution and relative damage between tree species. These factors of release location, spread, time and palatability may prove important, in targeting management action, such as conserving red squirrels through tree species planting policies.

Bark stripping damage was not highest in trees in younger pole stages (0-40 years) as may have been expected, with on average 1% damaged. Trees of the 40 to 60 years of age exhibited a similar amount of damage (~1%) as the younger classes which is inconsistent with previous findings. This could, in part, be explained by the relatively slow speed of healing of such damage and as such older trees are more likely to have signs of cumulative

[14] Tree species with high sugar content in the bark. See Shorten M (1957). Squirrels in England, Wales and Scotland, 1955. *Journal of Animal Ecology* **26**: 287-294.

[15] Mayle BA & Broome AC (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.

damage, much of which is older, simply through the passage of time and doesn't necessarily equate to the damage occurring recently, or at a higher frequency per annum.

The second cycle of NFI field survey is not yet completed, however, our analysis of the preliminary data found that during this period, 2015 to 2020, circa 32% of 10km grids in Great Britain contained woodland that show some sign of squirrel presence, either damage or sightings, which is higher than assessment based on bark stripping damage alone (27%).

There has been a great deal of concern about grey squirrel damage in Great Britain over the last 100 years and some may be surprised that only circa 5% of woodland stand area is showing signs of damage. However, if we consider that half of British woodland is in Scotland, where we have few greys and correspondingly only 0.3% damage and that whereas in England, where the greys were first released and where there were more widespread releases, we have circa 11% damage, then we start to see a picture of a level of intensity of damage correlated to grey squirrel early release sites. Considering grey squirrels have only been present since the late 1800's, just 120 years ago, they have spread out and impacted on a large area of woodland – some 166 thousand hectares in a relatively short space of time. A similar pattern of spread following the release of an invasive plant species in the Victorian era can be seen in rhododendron (see NFI report on rhododendron[16]), where this invasive species has highly localised spread, mostly correlated to regions where it was first introduced. This report also only concerns the damage observable at a single point in time – whereas the number of trees that have already died due to squirrels (and rotted away), or trees that have been squirrel damaged and harvested to date is not known. There is a wider dynamic picture concerning introduction and rate of spread that should be considered when viewing this single snapshot in time of damage and presence.

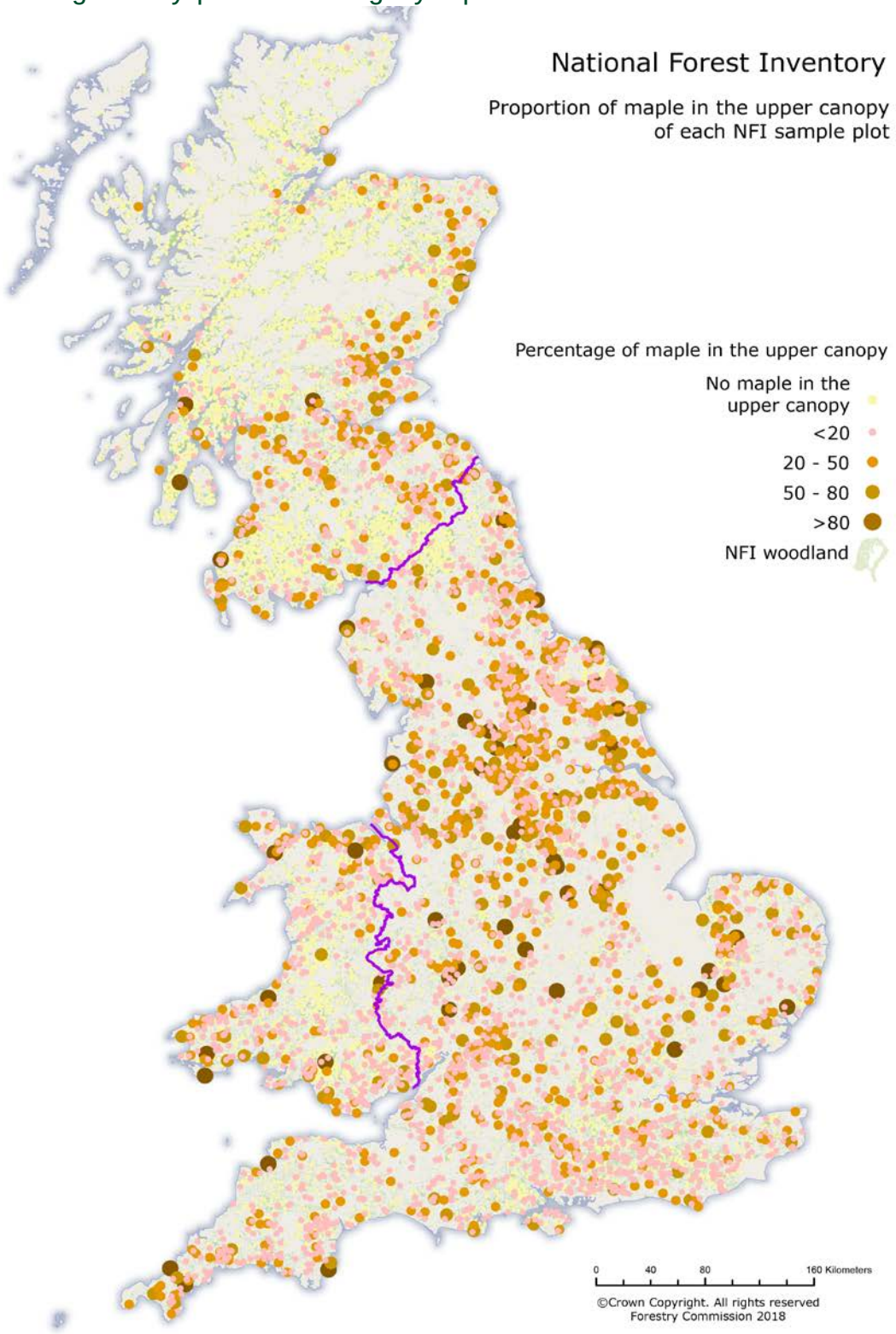
Similar analysis that NFI has undertaken for deer damage and deer presence has also found that other factors play a role in determining damage levels, with presence of preferential or palatable host tree species, woodland cover levels, the presence of alternative feedstock (such as arable crops) influencing presence and severity of grazing damage[17]. Initial analysis of the squirrel data also points to this form of relationship being at play, with woodland areas which contain high diversity of tree species and tree age classes suffering increased squirrel damage. These relationships require further study, particularly in how they change over time, as grey squirrels appear to continue to expand their range.

[16] https://www.forestresearch.gov.uk/documents/2715/Presence_of_Rhododendron_in_British_Woodlands.pdf

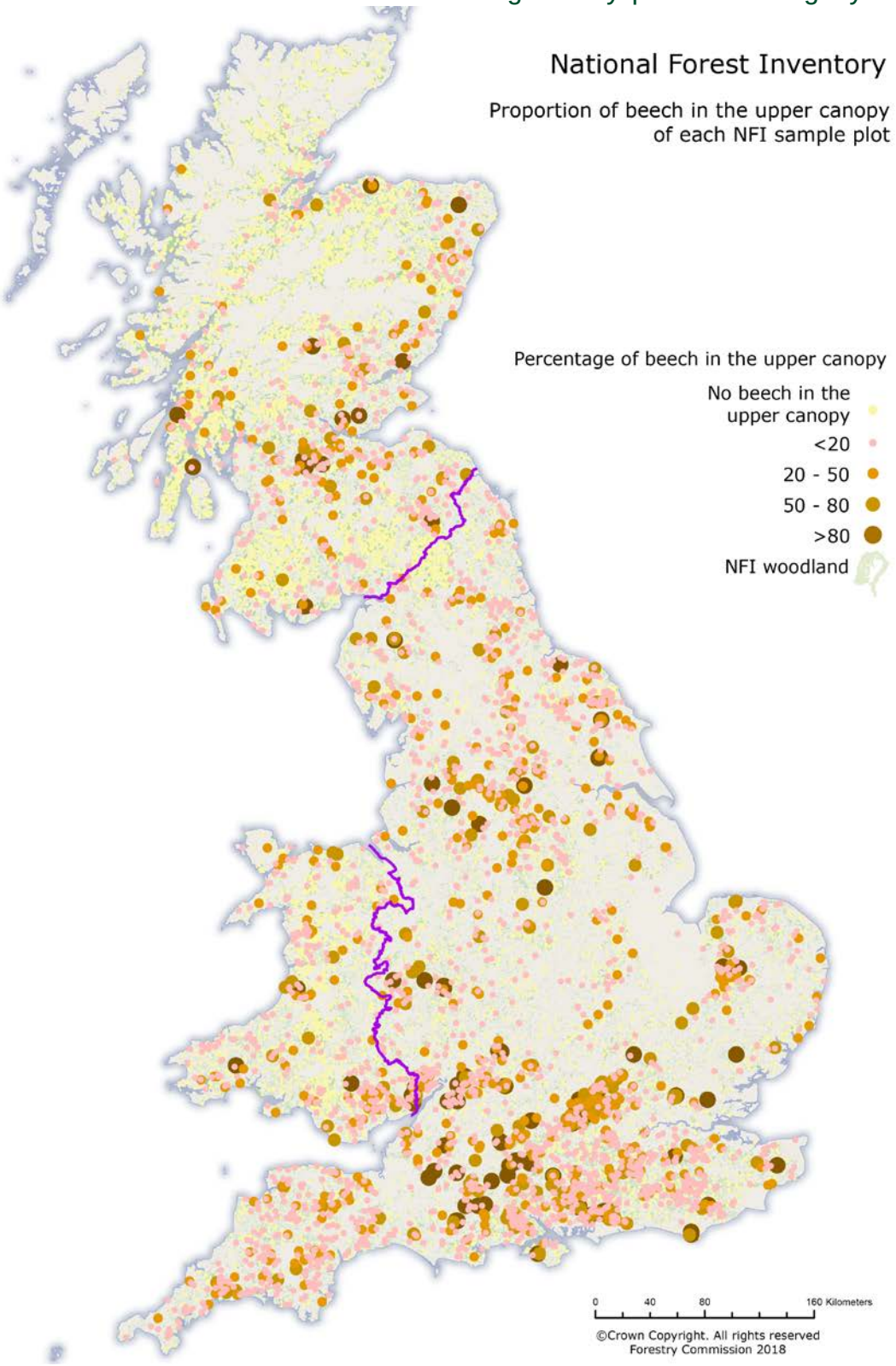
[17] See NFI Woodland Ecological Condition report: www.forestresearch.gov.uk/inventory

There are some caveats to the NFI squirrel extent data, most importantly that between 2010 and 2015 damage by bark stripping was the only indicator of squirrel presence recorded. Although grey squirrels can be extremely destructive in woodlands, with squirrels stripping bark from the main stem and the branches of trees, this is not always readily observable from the ground and at some sites damage high in the crown may have been missed by surveyors. This will have led to a degree of underreporting of squirrel bark stripping damage and potential underreporting of presence in the survey 2010 to 2015. However, to account for this, during the second cycle, NFI field surveyors began to identify squirrel sightings or other evidence of presence, as well as bark stripping damage. In most instances' squirrels, especially grey squirrels, make themselves evident before bark stripping damage is spotted, either through their physical presence or through other signs, their dreys, fur or hairs, scats, tracks and prints. Therefore, from 2015 onwards both sightings, other evidence and bark stripping damage have been recorded and this has led to the finding that the spread is slightly wider than that signified by observable bark stripping damage only (see **Map 1** & **Map 2**). Future analysis of the full second cycle of NFI survey will provide additional data and the planned third cycle will allow analysis of change in squirrel distribution and/or damage severity over time.

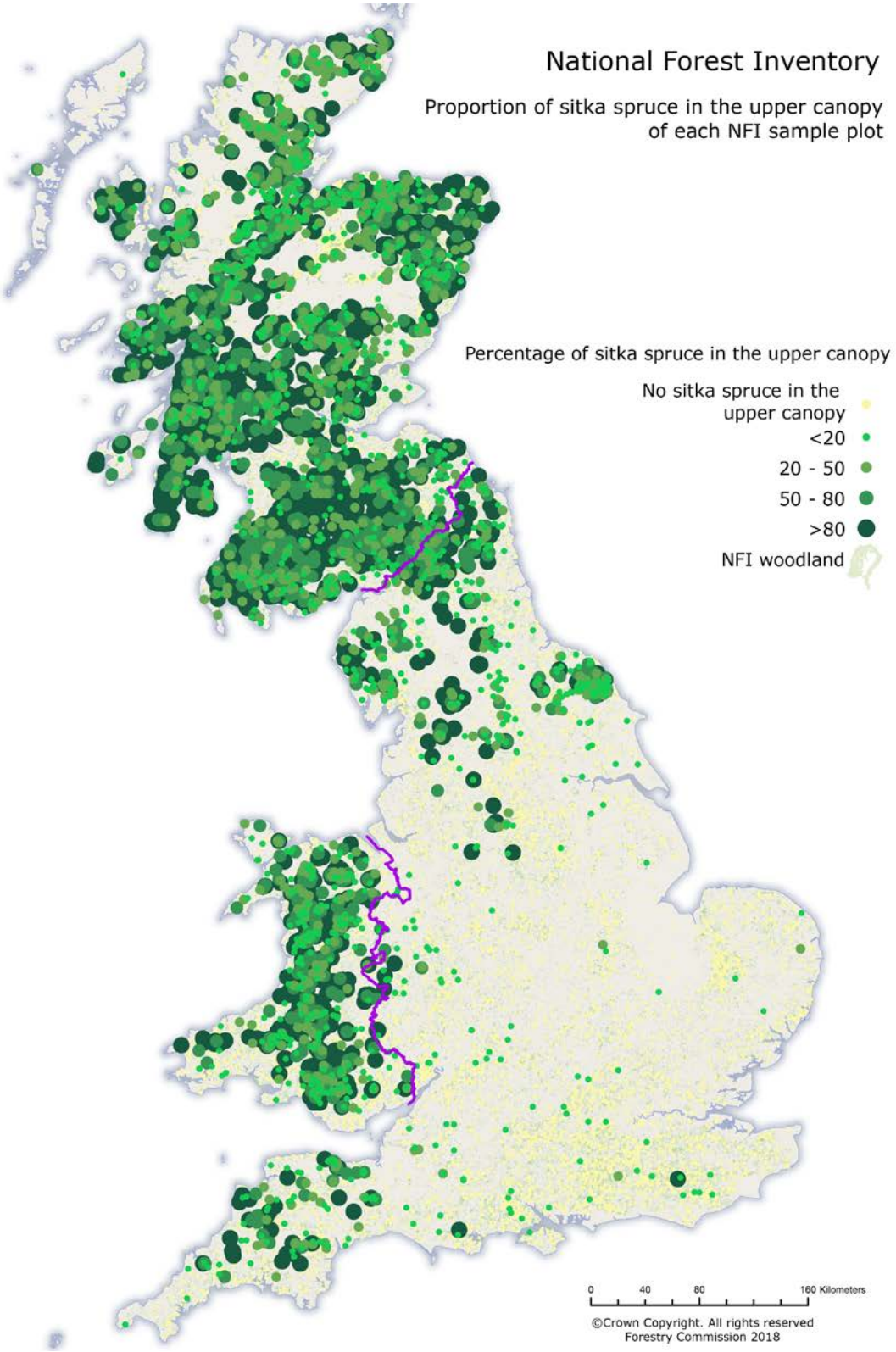
Map 4 Maple in woodlands, tree group containing acer species, most notably sycamore thought very palatable to grey squirrels



Map 5 Distribution of beech in woodland thought very palatable to grey squirrels



Map 6 Distribution of Sitka spruce within woodland, thought unpalatable to grey squirrels



Glossary

Age class	A grouping of trees into specific age ranges for classification purposes.
Area (forest/woodland)	Forest and woodland area can be defined in net or gross terms. Net area is the land actually covered by trees (in the National Forest Inventory that is to the drip line of the canopy). Gross area includes both the area covered by trees and the open spaces (<0.5 hectare) within (e.g. rides, glades, ponds).
Broadleaves	Trees and shrubs that belong to the angiosperm division of the plant kingdom (as distinct from the gymnosperm division that includes conifers). Most in the UK have laminar leaves and are deciduous. Sometimes referred to as 'hardwoods'.
Canopy	The mass of foliage and branches formed collectively by the crowns of trees.
Conifers	Trees and shrubs that belong to the gymnosperm division of the plant kingdom (as distinct from the angiosperm division that includes broadleaves). Conifers mostly have needles or scale-like leaves and are usually evergreen. Sometimes referred to as 'softwoods'.
Drey	The nest of a squirrel, built of twigs, dry leaves, and grass, and typically assembled in the forks of a tall tree.
Dripline	The dripline of a tree is the outermost extent of its canopy, literally the furthest point at which water will drip off the tree.
Forest (or woodland)	Land predominately covered in trees (defined as land under stands of trees with a canopy cover of at least 20%, or the ability to achieve this, and with a minimum area of 0.5 hectare and minimum width of 20 m), whether in large tracts (generally called forests) or smaller areas known by a variety of terms (including woods, copses, spinneys or shelterbelts).
Great Britain (GB)	England, Scotland and Wales.
Grey Squirrel	Sciurus carolinensis
Palatable	Pleasant to taste, trees with a high sugar content are more palatable to squirrels.
Pole	A tree between the size of a sapling and a mature tree.
Red Squirrel	Sciurus vulgaris
Scat	An animal faecal dropping.
Stand	A distinct area of woodland, generally composed of a uniform group of trees in terms of species composition and spatial distribution, and age and size class distribution.
Standard error (SE)	The measure of the margin of error associated with an estimate as a result of sampling from a population with statistical variability. Larger standard errors indicate less precision in the estimate. Standard errors in this report are quoted in relative terms (i.e. as percentages of the value of the estimate).
Woodland	see Forest.

Appendices

Appendix 1 - Area of broadleaved woodland in GB with evidence of squirrel bark stripping damage observed in NFI first cycle by species and age class

Species	Age Class	(000 ha)	% of total species/age class wooded area	SE%
Acer	0-20	0.2	3.1%	25.0
Acer	21-40	0.2	4.2%	19.6
Acer	41-80	0.1	1.9%	32.7
Acer	80+	0.0	3.7%	95.7
Ash	0-20	0.4	0.4%	17.2
Ash	21-40	0.1	0.1%	27.0
Ash	41-80	0.1	0.2%	35.4
Ash	80+	0.0	0.4%	79.1
Beech	0-20	1.3	4.2%	8.9
Beech	21-40	1.7	5.3%	10.5
Beech	41-80	2.2	7.9%	13.3
Beech	80+	0.3	1.9%	18.9
Birch	0-20	0.9	0.5%	13.7
Birch	21-40	0.7	0.9%	14.4
Birch	41-80	0.4	0.6%	25.5
Birch	80+	0.0	0.3%	41.7
Oak	0-20	0.6	1.3%	17.3
Oak	21-40	0.2	0.9%	18.2
Oak	41-80	0.2	0.3%	22.9
Oak	80+	0.1	0.3%	30.5
Sweet chestnut	0-20	0.2	1.7%	67.4
Sweet chestnut	21-40	0.1	2.6%	39.6
Sweet chestnut	41-80	0.0	0.1%	54.8
Sweet chestnut	80+	0.0	0.2%	56.2
Sycamore	0-20	3.2	4.8%	6.4
Sycamore	21-40	3.9	12.1%	44.1
Sycamore	41-80	1.4	3.6%	11.2
Sycamore	80+	0.1	2.8%	28.0
Other broadleaves	0-20	1.5	0.3%	15.0
Other broadleaves	21-40	0.5	0.4%	27.9
Other broadleaves	41-80	0.3	0.4%	21.3
Other broadleaves	80+	0.1	0.6%	28.3

Note:

- Estimates relate to individual tree components within stands observed with stripping damage above 1.8m. Values and associated standard errors are scaled up from NFI field survey data to the total woodland area using standard statistical survey methodology.
- Acer includes all maple species other than sycamore which is given separately.

Appendix 2 - Area of conifer woodland in GB with evidence of squirrel bark stripping damage observed in NFI first cycle by species and age class

Species	Age Class	(000 ha)	% of total species/age class wooded area	SE%
Fir	0-20	0.1	0.4%	22.3
Fir	21-40	0.0	0.1%	37.5
Fir	41-80	0.1	0.3%	100.9
Fir	80+	0.0	0.0%	0.0
Larch	0-20	0.1	0.5%	31.5
Larch	21-40	0.2	0.6%	38.9
Larch	41-80	0.1	0.4%	60.6
Larch	80+	0.0	0.0%	0.0
Norway spruce	0-20	0.0	0.0%	45.5
Norway spruce	21-40	0.0	0.1%	74.9
Norway spruce	41-80	0.0	0.3%	52.8
Norway spruce	80+	0.0	0.0%	0.0
Pine	0-20	0.1	0.1%	58.8
Pine	21-40	0.8	0.6%	27.7
Pine	41-80	0.6	0.7%	26.7
Pine	80+	0.0	0.0%	0.0
Sitka spruce	0-20	0.0	0.0%	42.2
Sitka spruce	21-40	0.2	0.1%	29.7
Sitka spruce	41-80	0.1	0.1%	72.2
Sitka spruce	80+	0.0	0.0%	0.0
Other conifers	0-20	0.0	0.2%	72.0
Other conifers	21-40	0.0	0.4%	74.6
Other conifers	41-80	0.2	3.1%	80.0
Other conifers	80+	0.0	0.1%	97.4

Note:

- Estimates relate to individual tree components within stands observed with stripping damage above 1.8m. Values and associated standard errors are scaled up from NFI field survey data to the total woodland area using standard statistical survey methodology.

Further information

This report is one of a series of publications reporting the outputs of the Forest Research National Forest Inventory.
For further information on the NFI, including contact details, please visit: www.forestresearch.gov.uk/inventory.

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