Forestry Commission

NFI woodland ecological condition in Great Britain: Methodology

National Forest Inventory

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Enquiries: Ben Ditchburn, 0300 067 5561
Ben.ditchburn@forestresearch.gov.uk

Statistician: David Ross
David.ross@forestresearch.gov.uk

Website: www.forestresearch.gov.uk/inventory
www.forestresearch.gov.uk/forecast

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Introduction

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 sets out the methodology used by the NFI to assess the ecological condition of woodlands in Great Britain (GB) in terms of their likely biodiversity value. It provides information on the woodland attributes that were measured during the NFI field survey as indicators of condition and describes the rulesets used for classifying woodland stands into 'favourable', 'intermediate' or 'unfavourable' woodland ecological condition (WEC) status. The resulting statistics and classifications enable comparisons of WEC across different woodland habitat types. This information will be used for national reporting purposes and can inform the targeting of resources and woodland management, supporting the protection and enhancement of biodiverse and resilient forests and woodlands.

The WEC assessment results from the first cycle of the NFI survey (data gathered between January 2010 to January 2016), which provide a baseline against which future results can be compared. These are provided online at www.forestresearch.gov.uk/nfi. The methods and results are summarised in a series of companion reports at GB and individual country levels (Figure 1):

- *NFI woodland ecological condition in Great Britain: Executive Summary*
- *NFI woodland ecological condition in Great Britain: Methodology*
- *NFI woodland ecological condition in [country[1]]: Statistics*
- *NFI woodland ecological condition in [country[1]]: Classification Results*
- *NFI woodland ecological condition in [country]: Supporting Data*[2]

[1] There are four separate reports; Great Britain, England, Scotland and Wales
[2] Supporting/additional data are available as MS-Excel® spreadsheets

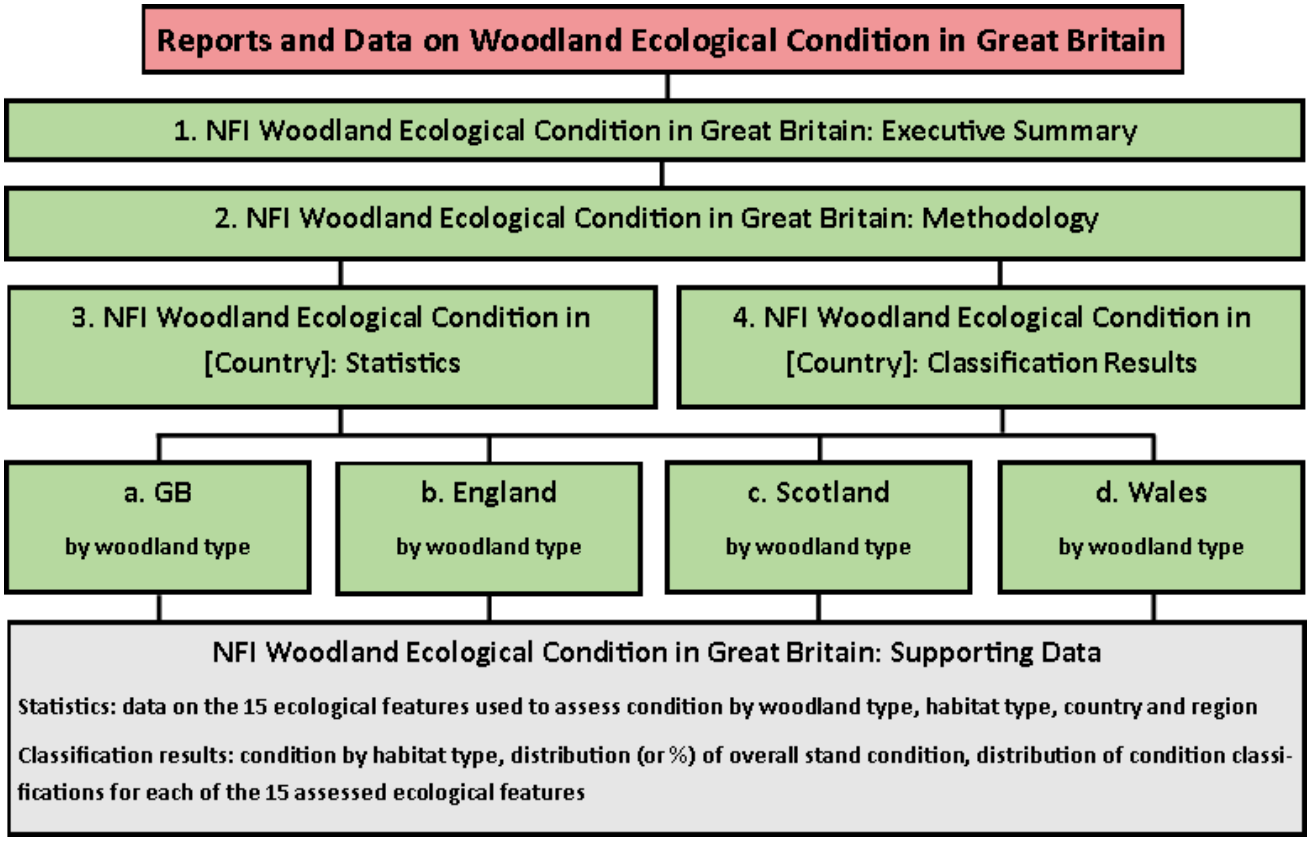


Figure 1. A schematic diagram to illustrate the link between all reports published by the NFI on the study of woodland ecological condition in Great Britain.

Ten reports have been published in relation to woodland ecological condition, namely; executive summary, methodology, statistics and classification results. [1] The Executive Summary spans all three topics presenting an overview of the methodology, key results and sign-posting to more detail; [2] this report, which describes the survey methodology and the calculation of the condition scores; [3] the statistics reports which describe the key results, one for each of the three countries and Great Britain, and; [4] the classification results describes woodland condition (as calculated by the NFI Condition Calculator) by woodland type. [green boxes] = published reports; [grey box] = detail available in supporting spreadsheets; [pink box] = over-arching theme.

The NFI

National forest inventories are carried out by the Forestry Commission (FC) to provide accurate, up-to-date information about the size, distribution, composition and condition of the forests and woodlands in Great Britain (GB). These data are essential for developing and monitoring policies and guidance to support sustainable forest management. The current NFI, which began in 2009, is a multi-purpose operation that has involved the production of a forest and woodland map for GB (1), and a continuing programme of field surveys of the mapped forest and woodland areas (2):

1. An earth observation-based programme monitors and maps the extent and location of woodlands across GB on an annual basis. The **NFI woodland map** covers all forests and woodlands over 0.5 ha with a minimum of 20% canopy cover (or the potential to achieve it), including new planting, clear-felled sites and restocked

sites. The NFI map was established in 2010 and was based upon 25 cm resolution colour aerial photography for England and Scotland, and 40 cm resolution aerial photography for Wales. It was originally validated and updated using satellite imagery (available up to 2009), which gave an independent crosscheck of woodland present. Since 2010 the map has been updated annually using 25 cm resolution colour aerial photography and satellite imagery to identify areas of recently felled forests and newly established trees. The map is stratified into Interpreted Forest Types (IFT's), including coniferous, broadleaved, mixed, and clear-fell (see the Interpreted Forest Types section of the NFI Survey Manual for more details).

2. The **NFI field survey** assesses a large, stratified-random sample of woodlands across GB on a 5-year rolling cycle using a standardised protocol. Detailed data on various attributes are collected from approximately 15,100 one-hectare sample squares that are partially or entirely covered by forest, including clear-felled areas, according to the woodland map. The first cycle ran from 2010 to 2015 inclusive, and the second cycle commenced in 2015 (to be completed in 2020). The survey provides an extensive, in-depth and spatially explicit record of our forests and woodlands.

Further details of the survey, mapping work and the derivation of forested areas can be found at www.forestresearch.gov.uk/nfi, including the NFI Survey Manual.

Why report on woodland ecological condition?

Since 2009, the Forestry Commission have worked with Natural England, Scottish Natural Heritage and Natural Resources Wales (and their antecedents) to incorporate woodland ecological condition (WEC) reporting within the NFI woodland monitoring and reporting programme. The primary purpose of this work is to provide government with evidence and statistics on the drivers and indicators of WEC, so they can make better-informed decisions concerning woodlands and their management in support of biodiversity. Secondary drivers are the United Kingdom's (UK) national and international monitoring obligations. The UK government signed the following global and pan-European (EU) agreements in 1992, which led to commitments concerning the protection of biodiversity:

- The global Convention on Biological Diversity (CBD; www.cbd.int). Contracting parties are required to develop and enforce national strategies to identify, conserve and protect existing biodiversity. Article 7 of the convention focuses on the requirement to monitor biodiversity (see Box 1).
- The EU Habitats Directive (Directive 92/43/EEC) aims to promote the maintenance of biodiversity by requiring Member States to take measures to maintain or restore natural habitats and wild species listed on its Annexes to a favourable conservation status (JNCC, 2018). Article 17 of the directive

specifically requires members to report an assessment of the conservation status of species and habitats listed on the Annexes of the Directive every 6 years.

Box 1 Convention on Biological Diversity – Article 7

> Each contracting party shall, as far as possible and appropriate, in particular for the purposes of Articles 8 to 10:
> a) Identify components of biological diversity important for its conservation and sustainable use having regard to the indicative list of categories set down in Annex 1
> b) Monitor, through sampling and other techniques, the components of biological diversity identified pursuant to subparagraph (a) above, paying particular attention to those requiring urgent conservation measures and those which offer the greatest potential for sustainable use;
> c) Identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects through sampling and other techniques; and
> d) Maintain and organise, by any mechanism data, derived from identification and monitoring activities pursuant to subparagraphs a, b and c above.

The UK was the first country to produce a national biodiversity action plan in response to these international agreements, the UK Biodiversity Action Plan (UK BAP, published in 1994). Since the creation of the UK BAP, devolution has led the four UK countries to produce individual country biodiversity groups and strategies. In 2007, however, a shared vision for UK biodiversity conservation was adopted by the devolved administrations and the UK government, which is described in 'Conserving Biodiversity – the UK Approach' (Defra 2007). At this time, an updated UK list of Priority Species and Habitats was agreed and associated Habitat Action Plans (HAPs) were renewed or developed to provide guidance on protecting and enhancing these threatened habitats (BRIG, 2011). The UK BAP was replaced by the 'UK Post-2010 Biodiversity Framework' in 2012 by the four UK countries in response to new international targets for 2020, the CBD 'Aichi Targets' and 'EU Biodiversity Strategy' (JNCC and Defra, 2012). The UK BAP priority habitat and species list remains influential, however, and formed the basis of new country-level lists (JNCC, 2019a). Of the 65 priority habitat types, nine are native woodland habitats (including the Caledonian pinewoods that fall within Scotland's native pinewood zone), which have been adopted by the NFI for WEC reporting (0, Table 22).

Development of the NFI condition monitoring approach

Assessing broad and priority woodland habitat condition

Under the UK BAP and the England Biodiversity Strategy (Mitchell et al, 2007), the aim of monitoring was to assess the condition of the broad and priority woodland habitat types against established criteria, such as those developed for Common Standards Monitoring (CSM). The CSM approach was established during the 1990s by UK conservation agencies to describe the condition of protected sites, such as Sites of Special Scientific Interest (SSSI), and to provide information with which to assess the effectiveness of conservation policies and practice (JNCC, 2003). The basic premise was to identify priority features (such as a habitat or species assemblage) that a site is expected to provide or protect, and to value or score sites by comparing the state of these features against what would be expected under successful conservation (JNCC, 2003). Protected woodland sites are assessed against five attributes (woodland extent; structure and processes; regeneration potential; tree and shrub composition; local distinctiveness (Kirby et al, 2002; JNCC, 2004)). Currently, these are assessed in the field during a whole site walking survey, although these CSM methods are currently under review with the aim of incorporating new monitoring technologies (JNCC, 2019b).

As broad and priority woodland types cover a much greater area than protected woodland sites, some form of sample survey and a new assessment approach were required to monitor their condition and biodiversity value. The FC, as lead authority on woodland habitat action and reporting, convened an expert committee, the UK Native Woodland Habitat Action Plan (UKNWHAP) Group (2002 – 2009), to coordinate this work. This group included representatives from expert organisations such as Forest Research, the Forestry and Timber Association, the Royal Society for the Protection of Birds, Scottish Natural Heritage, National Farmers Union, (former) English Nature and (former) Countryside Commission Wales. With the establishment of the NFI field survey in 2009, a UKNWHAP sub-group was created to advise on how condition could be measured and monitored via the NFI. Based on country-level strategies, legal requirements for monitoring, other suggested and established woodland indicators (e.g. CSM; the Ministerial Conferences on the Protection of Forests in Europe's 'sustainable forest management indicators'; MCPFE 2003, Geburek et al, 2010), and data collected as part of National Inventory of Woodland and Trees (NIWT; predecessor to the NFI), the group put forward 21 condition indicators to be included in the NFI survey design (Appendix A). Here we define an indicator as a quantitative or qualitative parameter that synthesises complex information and can be periodically measured to assess trends over time (Geburek et al, 2010).

In 2011, the NFI team began preparations to report on the 21 indicators suggested by the UKNWHAP sub-group. The NFI WEC working group was established to develop the approach set out in this report for assessing these WEC indicators. This group consists of

representatives from (former) FC England and Scotland, Scottish Natural Heritage, Natural England, Natural Resources Wales and the Welsh Government (Appendix B). In the absence of any existing agreed systems, it was decided to develop and implement **a** (not **the**) pioneering methodology for appraising woodland condition for national monitoring. Future updates and adjustments may be made to this initial approach according to expert feedback, emerging issues and new scientific evidence.

NFI WEC indicator selection

Although data on all the originally proposed 21 WEC indicators are collected as part of the NFI field survey, the NFI WEC working group decided to rationalise the indicators used in the ecological condition assessment. This was done on the basis that some indicators were so interdependent or highly correlated that they should be combined to avoid double counting or over representation of a factor, and that others should be evaluated separately as they do not operate at a stand level. For example, although woodland loss is an important biodiversity indicator, it is most relevant at a whole population level. Thus, total woodland area and woodland area loss across a reporting area were designated as population-level measures and are reported upon and evaluated separately to the condition classification process. This selection process resulted in a final set of 15 stand-level indicators to be taken forward to the scoring process and two population level indicators to be reported upon separately (Table 1).

Table 1: The NFI WEC indicators. Brief descriptions of the fifteen stand-level WEC indicators used in this NFI assessment (and the two population-level indicators that are reported separately, grey rows) are provided alongside information on the assumed benefits to woodland biodiversity and condition, the survey level at which assessments were made (see page 20 for survey structure information) and any relevant Common Standards Monitoring (CSM) attribute. Follow the page link for more information on an indicator. NVC = National Vegetation Classification.

Level	Indicator	Page	Brief description	Assumed benefits to biodiversity	NFI Assessment level	Relevant CSM attribute
Population	Woodland area	24	Total area of woodland by priority habitat type	Higher woodland area benefits biodiversity	Reporting region	Extent
	Woodland loss	24	Total loss in the area of woodland reported relative to the baseline (first survey cycle) and previous survey cycle	Lower woodland area loss benefits biodiversity	Reporting region	Extent
Stand	Age distribution of trees	26	The number of tree age categories (young, intermediate or old) present.	Higher tree age diversity benefits biodiversity	Component	Structure and natural processes
	Wild, domestic and feral herbivore damage	27	The presence of signs of browsing, fraying or bark stripping damage to trees by herbivores	High levels of herbivore damage are detrimental to biodiversity	Component and transect	Regeneration potential
	Invasive plant species	32	The presence and cover of invasive, non-native plant species	Invasive, non-native plant species are detrimental to biodiversity	Sub-component (vegetation assessment data)	Composition (trees and shrubs)
	Number of native tree species	34	The number of native tree and shrub species recorded (species richness)	Higher native tree species richness benefits biodiversity	Component	Composition (trees and shrubs)
	Occupancy of native trees	35	The percentage area of native tree species in the uppermost canopy relative to total uppermost canopy area	Higher native tree species occupancy benefits biodiversity	Component	Composition (trees and shrubs)

Level	Indicator	Page	Brief description	Assumed benefits to biodiversity	NFI Assessment level	Relevant CSM attribute
Stand	Open space within woodland	36	The percentage cover of internal and adjacent open space and the quality of this open space	Some open space benefits biodiversity	Section and component	Structure and natural processes
	Proportion of favourable land cover around woodland	41	The proportional cover of favourable land cover surrounding the survey square	Higher percentage of favourable landcover surrounding a woodland benefits biodiversity	Within 5.6 km radius (100 km^2 circle) of the square centre	
	Woodland regeneration (stand or component group-level)	43	The presence of seedlings, saplings and/or young trees within the component group and the number of these categories present	Regeneration benefits biodiversity	Component, sub-component, circular plots and transects within component group assessed	Regeneration potential
	Woodland regeneration (square-level)	43	The presence of seedlings, saplings and/or young trees within the square and the number of these categories present	Regeneration benefits biodiversity	Component, sub-component, circular plots and transects within square assessed	Regeneration potential
	Tree health	46	Signs of tree mortality, crown dieback, tree pests or diseases	Presence of tree pests or diseases, crown dieback or high tree mortality are detrimental to biodiversity	Component and transect	
	Vegetation and ground flora	49	The proportional cover of ground to field layer vegetation recorded	Vegetation structure matching what is expected of an NVC type benefits biodiversity	Sub-component	Local distinctiveness

Level	Indicator	Page	Brief description	Assumed benefits to biodiversity	NFI Assessment level	Relevant CSM attribute
Stand	Woodland vertical structure	53	The number of canopy storeys present	Higher vertical complexity benefits biodiversity	Section and component	Structure and natural processes
	Veteran trees	54	The number of veteran trees per unit area	Higher veteran tree occupancy benefits biodiversity	Square	Composition (trees and shrubs)
	Volume of deadwood	55	Volume of standing and lying deadwood per unit area	Higher deadwood volume benefits biodiversity	Circular plot and transect	Structure and natural processes
	Size of woodland	57	Size of the woodland parcel the component group sites within	Larger woodlands are of higher biodiversity value	Area of woodland on NFI map that a section sits within	Extent

Classifying and scoring woodlands

In most instances the NFI meets evidence requirements by supplying statistics describing current woodland states and trends, such as woodland area or timber stocks. However, reporting on woodland condition requires an element of value judgement. The NFI WEC working group therefore established a new process for using the WEC indicator data to classify and score woodlands according to their expected condition. Briefly, the process developed involves the following steps:

1. Collect data on the WEC indicators as part of the NFI field survey.
2. Supply statistics on these indicators e.g. 'x % of woodland stands showed evidence of regeneration'.
3. Using ancient semi-natural woodland (ASNW) in good condition as a benchmark (see below), define thresholds for classifying woodland stands into 'favourable', 'intermediate' or 'unfavourable' status for each WEC indicator.
4. Assign numerical scores to these categories and combine these scores for all WEC indicators to provide an overall condition status score for each woodland stand.
5. Define thresholds to apply to the combined scores in order to classify woodland stands into overall 'favourable', 'intermediate' or 'unfavourable' status.
6. Supply information on the classification and scores e.g. 'x % of woodland stands were classified as being in favourable condition status for the regeneration indicator'.
7. Use the results from the first survey cycle as a baseline against which changes in condition can be measured for monitoring purposes using data from future survey cycles.

Setting a benchmark

Conditions associated with ASNW in good condition were deemed to represent favourable condition for all woods and an achievable state that woodland managers and ecologists could aim for. These woodlands tend to have the highest biodiversity value and are particularly important for many rarer and specialist woodland associated species (Goldberg et al, 2007; Peterken, 1993). They were thus used as the benchmark against which thresholds were set.

The same condition classification thresholds are therefore applied to all woodland types. Although the approach would ideally account for the differences between woodland types and stages of development (particularly under British conditions for open space and deadwood), or for different silvicultural systems such as coppice, a 'one size fits all' approach was considered easier to implement and interpret. A paucity of scientific information on individual woodland types also precluded justifiable threshold adjustment per habitat or silvicultural system. Furthermore, all woodlands should be maximising their ecological value and biodiversity status; using the results from the first field survey

cycle as a baseline, this approach enables the condition of each woodland type to be monitored over time.

A straightforward, transparent and evidence-informed approach

The indicators and classification thresholds developed by the NFI WEC working group were based on the best available scientific evidence, expert opinion and each country's current policy needs and targets (for example, FC Scotland's 'Forestry Strategy 2019-2029'; the Defra '25 Year Environment Plan' (2018); 'A Strategy for England's Trees, Woods and Forests' (2007); the 'State of Natural Resources Report (SoNaRR)' for Wales (2016)). It is acknowledged that the thresholds may not always adequately represent real tipping points in condition, and that the indicators used are assumed to be independent of one another (thus disregarding potential interactions) and uniformly important across different woodland types and environmental conditions. However, a straightforward and consistent method was needed to distil the complex data gathered. This facilitates implementation of automated, reproducible methods, and aids interpretation by policy makers, practitioners and other end users (Marchetti, 2005). Even when particular thresholds are somewhat arbitrary because of a lack of information or consensus in the scientific literature, the results provide a reference point against which changes can be assessed over time. This is particularly true for those targets that aren't currently met, such as for the deadwood and veteran tree indicators.

Ensuring methodological transparency and providing the underpinning statistical data for individual indicators means that underlying trends or causes are not masked, and the data can be interrogated at a more detailed level or according to other rulesets. By presenting the statistics for individual indicators and woodland types, these results can inform the application of cost effective, spatially targeted management interventions and policies aimed at improving woodland condition. In this way, the NFI WEC indicator approach follows Ferris and Humphrey's (1999) recommendations that woodland biodiversity indicators should be:

- tied in to management objectives;
- easy to assess, even for non-specialists;
- repeatable (often using different observers) and subject to minimal observer bias;
- cost-effective, generating reliable data for acceptable costs;
- ecologically meaningful, providing data which are easy to interpret.

Methodology

The NFI WEC methodology works at three main levels:

- NFI woodland map: mapping all woodland area (extent, location and broad type) as per the utilising remote sensing techniques.
- NFI field sample: using a fieldwork programme to assess the nature and composition of a sample of the woodland area identified by the map.
- NFI WEC assessment: calculating the WEC statistics, scores and classes.

Categorising woodland area for reporting

The NFI defines a woodland as an area of land meeting these criteria:

1. Any area of land with an established tree canopy where the tree cover extends to at least 20% of the land and the whole area of land is greater than 0.5 ha in extent and over 20 m in width.
2. Open spaces of less than 0.5 ha or less than 20 m in width within the woodland (e.g. rides, glades, ponds).
3. Areas of clear-felled or windblown woodland for up to 10 years after the clear-fell or windblow event, if a change of land use has not been established.
4. Areas covered by young trees that are a minimum of 0.5 ha in extent, or that are adjacent to established woodland, forming a total area of at least 0.5 ha. This may have resulted from planting, natural regeneration or colonisation that has not yet established a continuous canopy.

Using this approach, woodlands are mapped as individual 'parcels' or polygons that are separated from other woodland parcels by gaps of at least 20 m in length. Within a woodland the canopy can often be further stratified into smaller units of homogeneous canopy type based on differences in features such as woodland habitat and tree species, or more subtle factors such as condition and thinning history. Such contiguous 'units' of woodland are referred to as 'stands' for the purposes of these reports.

Most British woods contain many small stands, which is largely a product of historical woodland management and land use change. For example, new woodland is often established within existing field and ownership boundaries. Homogeneous planting within these areas, if next to existing woodland, gives these stands a semi-discrete nature. A single woodland parcel can thus be subdivided into stands based on the discernible presence of discrete areas of trees. WEC assessments are made at the stand level in most instances. The stands assessed in the NFI survey samples provide the data and evidence base for the WEC results.

As well as reporting on WEC for all woodland within a reporting area, woodlands can be classified into different categories for tailored condition reporting, such as woodland type (e.g. coniferous, broadleaved or mixed; native or non-native tree species; UK BAP priority woodland types or other habitat classifications such as EUNIS), ownership (public sector or private sector), origin (plantation woodland or semi natural woodland) or landscape type (e.g. urban or rural). Given the large volume of data gathered in this study, the complementary NFI WEC statistical reports focus on results by country and by native and non-native woodland types. Results by UK BAP priority and broad woodland habitat type and region are available via supporting data spreadsheets (Figure 1). Statistics on the woodland and habitat types reported upon arise from the field survey data, which is more accurate in identifying types compared to earth observation approaches; the NFI field survey and map are analysed together to produce the final extent statistics. The categories and definitions used for reporting according to these woodland and habitat types are set out below (see 0 for more details).

Defining the native woodland population: identifying woodland type

To measure a population, its unique characteristics or properties must first be defined so it can be distinguished from other populations. Assessing the extent of native woodland is complex because British woodlands exists on a continuum of 'native', from woodlands containing only native tree species to purely non-native woodlands, with a broad spectrum of mixtures in between (Figure 2).

Figure 2: A diagramtic representation of the continuum of native woodland composition, from purely native to purely non-native tree species composition. Blue trees symbolise native species, green trees non-native species.

A set of rules and assumptions were therefore required to categorise woodland area into native, non-native and those 'mixed' woodland stands containing native and non-native trees. This was calculated after field survey during analysis, using native tree species cover, stand size, and location to determine which class a stand fell into. The following woodland type categories and rulesets were used (for more details see 0; Figure 3):

Native woodland

Stands with 50% or more native tree species occupancy in the upper canopy that either:

- Form a discrete woodland parcel with a minimum area of 0.5 ha.
- Form a woodland stand with a minimum area of 0.1 ha that is part of a woodland that is 0.5 ha or larger.

The NFI WEC working group agreed on a fixed 50% species occupancy threshold for categorising native woodland across Great Britain, rather than altering the threshold between countries, as a this meets the NFI's requirement for a standardised and scalable methodology.

Non-native woodland
Stands with less than 40% native species occupancy sitting within a woodland of any size.

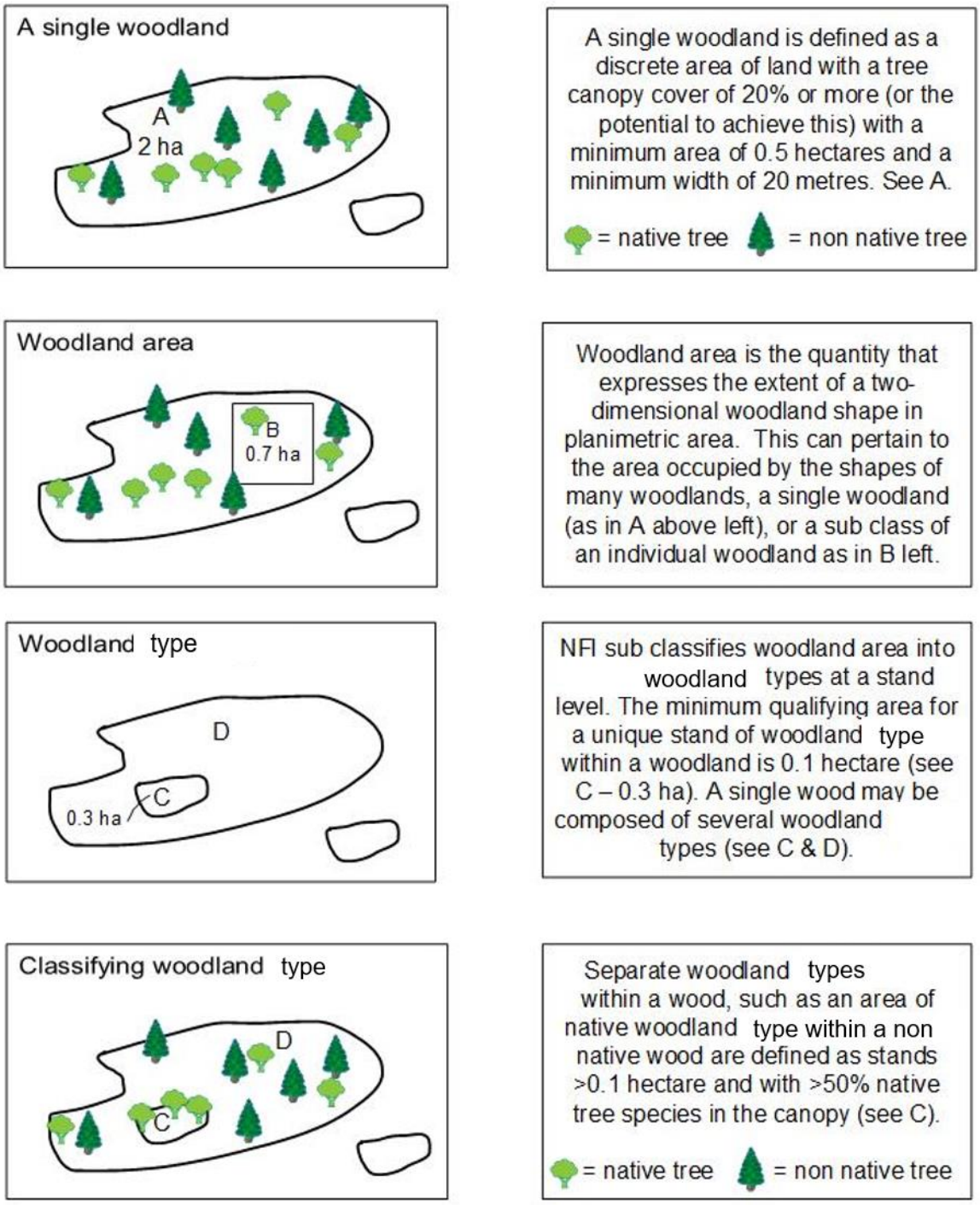
Near native and fragments
Stands that fail to meet the criteria for native or non-native woodland specified above are classified as 'near native and fragments'. Defining this category allows all woodland area to be assessed and reported on for its ecological condition status. Pinpointing these areas of woodland may help inform targeted restoration, as they may represent previously native woodland area that has been overplanted with non-natives.

The near native and fragments woodland type can be subdivided into two subclasses:

1. **Near native:** have a native canopy cover of somewhere between 40% to 49% and thus are 'nearly' native.
2. **Fragments:** have 50% or more native tree species occupancy in the upper canopy but fall under the minimum size threshold of 0.1 ha, falling in the size range 0.05 ha to 0.099 ha.

Not determinable
Areas classified as 'not determinable' apply to woodland areas that cannot be classified due to insufficient tree or other attribute information, such as areas without canopy cover and clear-fell sites with a weak vegetation layer. These form less than 0.5% of the whole woodland population.

Figure 3 Definitions of NFI woodland, woodland area and woodland types



Classifying woodland habitat types

British native woodlands contain the nine priority woodland types listed under the UK BAP (0, Table 22; including native pinewoods). The allocation of woodland area into individual priority woodland habitat types was in most instances conducted during the course of the field survey by the field surveyor. Surveyors will have taken into account factors such as tree species cover, National Vegetation Classification (NVC) type and location in these allocations. Where NFI surveyors could not identity a priority habitat type on the ground, post processing of the NFI field data collected on ground flora, NVC, tree species and location information were utilised to allocate a habitat type.

Prior to the first cycle of the NFI field survey, the NFI map was used to inform the location, broad distribution and number of NFI field survey samples to ensure the eight broadleaved priority woodland types were adequately represented in the survey. To achieve this, the three NFI map IFT categories, 'broadleaved woodland', 'coppice' and 'shrub', were combined and mapped to represent the total extent and distribution of the 'Broadleaved Mixed and Yew' UK BAP broad habitat type (which includes all eight priority broadleaved types). Sample squares were allocated to this area through a stratified random sample technique within these classes, allocated pro rata to their proportion of total woodland area. It should be noted that some of these stands will include exotic broadleaved species, such as Eucalyptus, however this and other such mapping errors will be assessed within the field work and mitigated within analysis. Native conifer woodland stands (those with an adequate upper canopy coverage of yew trees (*Taxus baccata*) or Scots pine (*Pinus sylvestris,* within Scotland's native pinewood zone)) were accounted for under the coniferous IFT type using the same approach. This method ensures that the NFI sampling is representative of these populations.

NFI survey square data structure

The NFI field survey is used to collect the stand-level WEC indicator data. Many separate observations are made within an NFI field sample in order to derive an accurate picture of condition (and for other purposes). Field samples are taken within a one-hectare square where data are mapped and recorded at several levels (see diagram in Appendix C).

Square: A one-hectare (100 m by 100 m) square, which may be entirely within woodland or may overlap the woodland edge. A stratified-random site selection design was used to provide a large (>15,000 squares) and representative sample of all types of woodland in GB, including conifer plantations and ancient semi-natural, urban, rural and upland woodlands.

Section: Within each sample square, the forest was stratified into different woodland 'sections'. Sections are defined by individual strata (homogeneous areas) at least 0.05

ha in size that are differentiated on basis of forest type (e.g. native or non-native), habitat (e.g. priority type – see above), land use, silviculture system, tree and shrub composition, age and structure. They can represent features of the natural or built environment. A section is mapped as a discrete polygon. Typically, sample squares covered parts of two or more sections (minimum number per square is one, maximum recorded in first survey cycle was 10), resulting in ~45,000 sections being assessed in the first cycle.

Component group: Homogeneous areas that are too small (<0.05 ha) to practically map as a discrete section using Geographic Information System (GIS) software in the field, but with most of the same defining characteristics as a section. They can represent features of the natural or built environment. Every section contains at least one component group and the maximum number of component groups recorded in one section was six in the first survey cycle. Component groups have no minimum size, to include very small features - those important enough to record, but too small to map (such as one-metre of railway line intruding into a sample square, a pond or small area of woodland habitat). Component groups can be subdivided into components (see below). For example, a sample square covered in upland birchwood would be listed as one section containing an upland birchwood component group; the mature birch trees within this would be a component of this group.

Component or sub-component: Individual elements (components) of the component group. For example, each tree species will be recorded under a separate component, as will each habitat type if two habitats are intimately mixed (such as upland birchwood and wet woodland). Different ground vegetation and NVC types were also recorded as sub-components below the relevant components in the first survey cycle. To extend the above example, if the upland birchwood was a mixture of W11 and W17 NVC communities, these would be recorded as sub-components.

Circular plots: Within each section, field-based computer systems were used to locate two or three randomly located 100 m^2 (0.01 ha) circular plots within which all trees of ≥4 cm diameter at breast height (DBH) were mapped, species and age identified, stocking rates assessed, tree heights and diameters measured. Three plots are generated for sections over 0.6 ha and two plots if section is less than 0.6 ha.

Transects: Within each section with tree cover, crossing the centre of the first circular plot, a 10 m length transect running north to south was established for assessing seedlings (0.5 m either side of transect line) and saplings (1 m either side of transect line). In addition, three 10 m length deadwood transects spanning from the circular plot centre were set up at 0, 120 and 240 compass degrees, where a count and diameter of all lying deadwood was taken. From the second cycle of the NFI survey (2015 onwards), two to three circular plots were used for seedling and sapling assessments instead of one

10 m long transect. Across GB, more than 610,000 trees were measured and more than 24,000 transects assessed during the first survey cycle.

Quality assurance

The FC applied rigorous and strict quality assurance processes to ensure that the field surveys capture a representative and unbiased representation of each square and woodland in turn. All measurements were subject to office-based checks and 3% were re-measured in the field by an independent quality assurance team to ensure consistency and high standards. For a more detailed discussion on the NFI survey data structure and data recording process, please see the NFI Survey Manual, available online at www.forestresearch.gov.uk/nfi.

Woodland Ecological Condition assessment units

The NFI WEC statistics, classes and scores are calculated for each woodland ecological unit in the NFI survey section. Each WEC unit will generally equate to a woodland stand surveyed. The extent of each woodland ecological unit is determined by which type of woodland classification system is utilised for the analysis and reporting. For example, in this series of reports two types of woodland classification system have been used to classify woodland area by:

- Native woodland type
- Priority habitat type

A full set of WEC records and results has been created for each classification system; firstly, breaking all woodland area by native woodland type and assigning WEC status for each native type found and, secondly, breaking all woodland area again by priority habitat type and assigning WEC status for each priority habitat type found. So, for these reports there are a series of WEC records for the native classification and separate results for the priority habitat classification.

Once the WEC unit is defined, each section or stand will be analysed to assess what proportion of it falls into individual classes of the classification type under assessment, and an individual WEC record will be created for each distinct class. For each section surveyed, one or more WEC records will therefore be created that will represent each distinct class of woodland represented.

Generally, most NFI sections are simple and will contain one type and will produce one WEC record per classification system used. However, some sections are more complex and contain more than one woodland type/class (usually one or more separate component groups) and in these instances more than one WEC record per section and classification type will be created.

If separate stands or component groups in a section are similar and meet the definition criteria for a class, such as 'native' then they will be combined into a single native WEC record. Meanwhile for the same area, although classed as 'native' area, it may be formed of two priority habitats, each meriting a separate WEC record for priority habitat assessment.

Extrapolating NFI field survey statistics to a reporting area

The field survey squares represent a 0.6% sample of all GB woodlands and this level of sample of woodland has been calculated to be representative of the wider woodland through analysing the variance within the woodland population. To calculate the WEC statistics, the areas and values reported for the samples were aggregated and scaled up to the total woodland area using standard statistical survey methodology. This multiplies the area found in the samples by the ratio of their area to total woodland area in the reporting region. The WEC statistics can thus be calculated for various geographic levels (country, region etc.) and for different woodland types within these reporting areas by extrapolating them to subsets of the NFI woodland map using the same standard statistical survey methodology.

Associated sampling standard errors are calculated and reported, giving a measure of accuracy conditional upon the underlying assumptions. This sampling standard error will account for random variation arising from sample selection, and random measurement errors. It will not account for any systematic biases in the field measurements, but these are unlikely to be an issue due to the quality assurance processes applied and the size of the sample.

The NFI Condition Calculator

To report on condition using the NFI data, an analytical tool was developed, referred to herein as the NFI 'Condition Calculator'. This tool allows the detailed data recorded in each NFI survey square to be analysed alongside the NFI woodland map and other data. It automatically produces the WEC Unit results per woodland type and aggregated statistics for the reporting area. The advantages of establishing an automated reporting tool are that results can be generated on demand using a consistent approach. The Condition Calculator will therefore allow the data from future cycles of the NFI to be analysed using the same procedures, enabling reliable comparisons for reporting on change.

The Condition Calculator results can be viewed for each stand (for individual habitats) or group of stands (for native type assessments) within a survey square using bespoke GIS software. When developing the Condition Calculator, individual results (see example in Appendix D) were exhaustively checked for a variety of locations and woodland types. Once the results were correct for each individual stand or stands checked, the tool was ready to be implemented at regional and national levels.

Individual indicator assessment details

Some indicators are best evaluated at a population level to provide an overall picture of habitat condition. Landscape extent measurements like this, such the total size of the population and whether it is expanding or contracting, do not account for differences in condition status or 'health' within individual stands, but assess the size and state of the entire habitat 'stock'. Other indicators can be considered to function at a stand level as they vary between stands and are relevant to the condition of the individual stand. The favourable landcover and woodland size indicators incorporated into the NFI WEC assessment concern the landscape surrounding the stand and therefore help to account for variation in habitat cover and configuration across space. Both the indicators that function at a stand level and those that function at a population level are pertinent to the overall, national picture of habitat condition and should be considered in tandem.

Population-level indicator methods: woodland area and loss

Estimates of woodland area are derived from the NFI woodland map, augmented by the NFI fieldwork. Broad and priority woodland habitat cover, as well as woodland type cover, are estimated through analysing the NFI field sample data and scaling it up to the NFI woodland map using standard statistical survey methodology (see page 23)[3].

Under the CSM approach, protected sites with designated woodland features are usually assessed against a target of maintaining woodland extent. For example, 'no loss of ancient woodland' or 'no net loss of semi-natural woodland' on mosaic sites is the target set. However, the woodland distribution may change over time. In the NFI methodology, recent losses or changes in distribution are detected through both the NFI site visits and through remote sensing approaches such as aerial photography and earth observation analysis. The remote sensing analysis to detect woodland loss was originally undertaken through comparing the NIWT woodland map (a predecessor to the NFI), the NFI map and ancient woodland inventories. This produced the first NFI estimates of woodland loss. From 2009 onwards, the NFI map was used in combination with sophisticated earth observation-satellite based change detection techniques to detect woodland loss. As well as providing population level measures, these techniques have provided data on *where* there has been loss of woodland and ancient woodland cover. Further analysis of these areas in combination with recent aerial photography provide information as to the cause of woodland loss, such as loss to wind farms, residential development, browsing pressure or habitat restoration. In addition, stratified samples of the NFI sites within

[3] When comparing the resulting NFI estimates of the net area of native and non-native woodland habitat area to existing gross area FC estimates, it should be noted that the NFI estimates will be lower due to the presence of open space within woodland area (which are not incorporated into the NFI measure).

apparent areas of woodland loss can be analysed to provide deeper evidence regarding the underlying causes.

Stand-level indicators

To produce the WEC statistics and classes, the NFI Condition Calculator performs 15 separate indicator calculations within a stand or group of stands[4]:

1. Age distribution of trees
2. Herbivore damage
3. Invasive plant species
4. Number of native trees
5. Occupancy of native trees
6. Open space
7. Proportion of favourable land cover
8. Woodland regeneration (stand-level) [5]
9. Woodland regeneration (square-level)
10. Tree health
11. Vegetation and ground flora
12. Woodland vertical structure
13. Veteran trees
14. Volume of deadwood
15. Total area of woodland

Although all indicators are calculated for each woodland stand or group of stands within the NFI survey squares, the measurements they are derived from are not all collected at the same spatial scale; for example, some are collected for individual components and summarised for the stand and some are collected at section, square or larger scales and attributed to the stand or stands they contain (Table 1). This is to account for differences in the spatial scale at which an indicator is relevant or detectable by the surveyor.

Thresholds were applied to each of these indicators to classify stands or component groups into three condition categories, with associated ordinal scores (unfavourable (1), intermediate (2) or favourable (3)). The scores are summed for all 15 indicators to provide each stand's overall ecological condition score, which has a maximum value of 45 and a minimum value of 16 (no unfavourable category is defined for regeneration at

[4] These 15 WEC indicators represent a consolidation of those originally identified by the UKNWHAP task group (Appendix A). A summary of each WEC indicator is provided in Table 1.
[5] Component group = Homogeneous areas that are too small (<0.05 ha) to practically map as a discrete section using Geographic Information System (GIS) software in the field, but with most of the same defining characteristics as a section. Section = within each sample square, the forest was stratified into different woodland stands or 'sections'.

the stand or component group-level). Threshold values are then applied to provide overall condition categories of unfavourable (low score), intermediate and favourable (high score).

The methodologies described below for the 15 indicator assessments and overall condition score calculation were reviewed and agreed by the NFI WEC working group. Brief scientific and expert justification for indicator selection and classification are also provided.

1. Age distribution of trees

Background

This WEC indicator relates to age structure variation within a stand. Separate Condition Calculator indicator assessments check for regeneration (8) and the presence of veteran trees (12)). Semi-natural woodlands in good condition are expected to have trees at various stages of maturity, from seedlings and saplings, to pole, mature stage and possibly also veteran trees. Tree age diversity is positively associated with structural heterogeneity and biodiversity (McRoberts et al, 2011). While older trees tend to provide more microhabitats (Tews et al, 2004; Michel and Winter, 2009; Larrieu et al, 2018), younger trees and established regeneration contribute to structural diversity and are important for maintaining woodland cover into the future (Neville, 2002). Winter et al (2008) identified age, diameter of trees and development phase as key indicators for monitoring woodland biodiversity.

Data and method used for indicator measurement

This indicator considers the age distribution of the trees recorded in the component data for each stand or group of stands assessed (habitat or native type respectively). The NFI surveyors estimate a planting or regeneration year for each tree species they observe and record for each component (see the Components section of the NFI Survey Manual for more details). The tree age is calculated by subtracting the planting year from the survey year.

Trees are grouped into classes of young, intermediate and old according to their age. Certain broadleaved trees such as birch (Betula), cherry (Prunus) or Sorbus species are typically quicker to reach maturity than other species and so were attributed a lower age threshold for the 'old' class:

If tree species is not a birch, cherry or Sorbus

- 0 – 20 years (Young)
- 21 - 150 years (Intermediate)
- >150 years (Old)

For birch, cherry or Sorbus species

- 0 - 20 years (Young)
- 21 - 60 years (Intermediate)
- >60 years (Old)

Each stand or component group can then be recorded as having one of these possible combinations of age classes:

- Young only
- Intermediate only
- Old only
- Young and Intermediate
- Young and Old
- Intermediate and Old
- Young, Intermediate and Old

Classification

The age classes found in the stand or component group are converted to scores as shown in Table 2. Only woodlands with all three age classes were deemed to be in favourable condition.

Table 2. Condition classification for tree age distribution

Value	Condition class
All three age classes present	Favourable
Two age classes present	Intermediate
No trees or only one age class present	Unfavourable

2. Wild, domestic and feral herbivore damage

Background

A low level of herbivore grazing pressure can increase woodland structural complexity and biodiversity (Kirby et al, 1994). However, in the absence of natural predators or human control, wild, domestic and feral herbivores can inflict a level of damage on woodlands that then limits woodland regenerative capacity, ecosystem functioning and biodiversity value (Fuller & Gill, 2001; SNH, 2016; SNH, 2019; Forestry Commission, 2017; Ramirez et al, 2018). Excessive browsing (feeding on buds, shoots and foliage) is a particular problem in semi-natural woodlands dependent on natural regeneration for continued woodland cover (Harmer and Gill, 2000; Fuller & Gill, 2001). As well as the impact on trees, seedlings and saplings, browsing can reduce a woodland's ground flora richness due to preferential foraging of shrubs and herbs (Gill, 2000). Herbivores can

also damage trees by fraying (rubbing) or stripping the bark, which can reduce tree health and increase their susceptibility to diseases, pests and further physical damage (Gill, 1992). Deer are of particular concern in GB because of recent and projected population level rise and range expansion for all species (Ward, 2005, Wilson 2003). However, other feral herbivores and domestic livestock, such as sheep and cattle, can pose similar problems if present in sufficient numbers. The NFI survey considers herbivore damage to negatively impact on a woodland's ecological condition based on this information.

Data and method used for indicator measurement

Herbivore damage is recorded by the NFI field surveyor for individual tree component records, under 'Browsing Damage' and 'Bark Stripping Damage', and via the transect assessments of seedling and saplings. In each case, the surveyor is prompted to enter 'None' when no damage is observed to avoid null entries. When reviewing the results for this indicator, there are important considerations to bear in mind:

- Although it is possible to report separately on assumed squirrel damage by isolating bark stripping records above 1.8 m (recorded separately), it was decided that these data may be skewed by false absences in conditions where tree type or stem density, for example, obscured the surveyor's view.
- Browsing damage to woodland vegetation other than trees is not recorded in the NFI first cycle data, which this round of reporting is based upon.
- An absence of herbivore damage within a section or stand does not mean that the woodland the section or stand sits within isn't suffering damage; herbivores may target areas within a woodland stochastically or according to factors that influence their behaviour (e.g. disturbance by people or roads; Meisinget et al, 2013), limiting damage to parts of the wood.
- It is important to consider the assessment unit size used when comparing across different herbivore damage studies, as the likelihood of damage being recorded increases with the unit area surveyed. As NFI damage data is collected at a relatively small scale (component and section levels) and analysed by the Condition Calculator at a section level, this reduces the area of woodland reported as damaged compared to surveys and assessments that record damage at larger units of area (such as county or woodland parcel). When factoring this scale issue into comparisons, herbivore damage statistics from the first NFI survey cycle appear to align with other published data (e.g. Native Woodland Survey of Scotland (Patterson et al, 2014); Ward, 2005).
- The absence of herbivore damage does not always equate with herbivore absence and/or good woodland condition:
    - The browsing damage data is dependent on the presence of seedlings, saplings and young trees on which damage can be seen. No browsing damage will be recorded in their absence. However, in severe cases, this absence might have resulted from high herbivore grazing in the recent past.

- Herbivores may be present, but they may not have caused damage because the trees are unpalatable, protected by vegetation or impervious to damage. For example, a 150-year-old Sequoia is unlikely to be damaged because of its thick bark and high foliage.
- Tree damage by herbivores is not only driven by local characteristics of the woodland; regional herbivore densities, surrounding landscape structure and wider environmental conditions are also influential (Spake et al, In Review). For example, there may be alternative, more palatable forage available in the landscape (such as crops or heath) that distract foraging deer from the woodlands.

To gather data that may help us to better understand how conditions influence the relationship between herbivore presence and damage likelihood, surveyors have recorded sightings and other evidence of herbivore presence from the second cycle of the NFI survey (2015) onwards.

Component-level assessment of herbivore damage

A component record is created for each separate tree species of a distinct age and storey observed within a section or component group. Under each separate component, the surveyor is required to complete an assessment of Browsing Damage and Bark Stripping Damage (Table 3 & Table 4). If the trees are protected from damage (for example, if they are housed within growth tubes), surveyors recorded damage and stripping as 'Not Applicable'. If damage or stripping is recorded on trees belonging to the component, the frequency and severity of the damage is estimated by the surveyor (although this information is not used in the Condition Calculator). The process can result in more than one record of stripping per component, if stripping is recorded at different locations on a component's trees.

Table 3 Browsing damage assessment in the NFI (first survey cycle)

Data Field	Possible Values
Browsing Damage	• Yes • No • Not Applicable (protected trees)
Browsing Frequency (percentage of trees belonging to the component that show evidence of browsing)	• < 20% trees browsed • 20-80 % trees browsed • > 80% trees browsed
Browsing Severity (of the browsed trees belonging to the component, the mean proportion of the tree that has been browsed)	• < 20% browsed • 20 - 80% browsed • >80% browsed

Table 4 Bark stripping damage assessment in the NFI (first survey cycle)

Data Field	Possible Values
Stripping Location	• Up to 0.5 m • 0.5 - 1.8 m • >1.8 m • None • Not Applicable (protected trees)
Damage Frequency (percentage of trees belonging to the component that show evidence of stripping)	• < 20% trees damaged • 20-80% trees damaged • > 80% trees damaged
Stripping Severity (of the damaged trees belonging to the component, will the majority of them survive or die due to the damage?)	• Majority of damaged trees will survive • Majority of damaged trees will die

Transect assessment of herbivore damage

In the first NFI survey cycle, a transect assessment of seedlings and saplings was carried out in each section. The transect is 10 m long (1 m wide for seedlings, 2 m wide for saplings) and is randomly located within the section according to the location of the first circular plot in a north – south orientation. The 10 m transect is split into ten segments, and the surveyor must record any seedling or saplings (grouped by species) against each 1 m segment (or the surveyor records 'none' in their absence). Any instances of browsing or fraying are recorded against individual seedling or sapling records (Table 5). Further information is collected on any damage, but only the presence or absence of browsing or fraying is used by the Condition Calculator.

From the second NFI survey cycle (2015 onwards), two to three circular plots (according to section size) have been used to assess seedlings (10 m^2 plot) and saplings (20 m^2 plot) instead of a linear transect. However, the same assessment criteria are used for recording browsing and fraying.

Table 5 Young tree transect assessment in the NFI (first survey cycle)

Data Field	Possible Values
Young trees - class	• Planted Seedling (< 50 cm tall) • Planted Sapling (> 50 cm tall and < 4 cm DBH) • Regen Seedling (< 50 cm tall) • Regen Sapling (> 50 cm tall and < 4 cm DBH) • Not Valid (e.g. a metalled road within a section) • Outside Section (circular plot is partially outwith the section) • Not visually accessible • None (no seedling or saplings)
Species	*Tree species identified by surveyor*
Species quantity (the number of that species and young tree type within the meter segment)	1,2,3,4,5,>5
Browse class (for each seedling/sapling)	• None (no browsing) • < 10% Outer shoots browsed • 10 - 50% Outer shoots browsed • >50% Outer shoots browsed
Recently frayed (for each seedling/sapling)	Yes/No

Classification

The NFI Condition Calculator checks for the presence of any records of the following herbivore damage types in each component group or stand:

1. Component Browsing Damage 'Yes'
2. Component Bark Stripping Damage ≤ 1.8m
3. Transect Browsing
4. Transect Fraying
5. Component Bark Stripping Damage > 1.8m (assumed squirrel damage only)

For each component group or stand assessed, positive records of herbivore damage types one to four (listed above) are checked for. If there aren't any within the component group, all component groups within the section containing the component group are checked. And if there aren't any within the section, all component groups within the square are checked. This results in four potential categories:

- Herbivore damage in component group

- Herbivore damage in the section containing the component group
- Herbivore damage in the square containing the component group only
- No herbivore damage in square containing the component group

The same spatial assessment is carried out for squirrel damage records, resulting in these potential categories per component group:

- Squirrel damage in component group
- Squirrel damage in the section containing the component group
- Squirrel damage in the square containing the component group only
- No squirrel damage in square containing the component group

This information is combined into a condition classification (Table 6).

Table 6 Ruleset used for defining herbivore damage condition classification

Value	Condition classification
No squirrel or other herbivore damage (<1.8 m) recorded within square	Favourable
Herbivore damage recorded <1.8 m at square-level only (regardless of squirrel damage)	Intermediate
No herbivore damage recorded <1.8 m within square, but squirrel damage recorded at component group, section or square-level	Intermediate
Herbivore damage recorded <1.8 m at component group or section-level (regardless of squirrel damage)	Unfavourable

3. Invasive plant species

Background

Invasive non-native species are recognised as one of the major global causes of biodiversity loss (Duraiappah et al, 2003). It has been shown that the detrimental impact of invasive species to a woodland's native biota may occur through competition, habitat and soil alteration, disease introduction and genetic effects such as hybridisation (Manchester and Bullock, 2000). Invasive plant species such as *Rhododendron ponticum* can aggressively colonise a site, both reducing its biodiversity value and obstructing woodland regeneration (Edwards, 2006). As their deleterious effect on woodland health is clear, the presence of non-native invasive plant species negatively impacts the condition classification of the woodland.

Data and method used for indicator measurement

The NFI vegetation assessment captures information on the presence and percentage cover of vegetation types within three structural height bands (ground, field and shrub) of each stand or component group. For this WEC indicator, the Wildlife and Countryside Act (WCA, 1981), Schedule 9 (updated 2010) and other invasive species assessments (e.g. Defra's invasive species biodiversity indicator (Defra, 2019)) were used by the NFI WEC working group to identify which species should be classed as non-native and invasive in British woodlands (Table 7).

Note that the NFI survey vegetation assessment is based upon a pre-defined, abbreviated plant species list (see the NFI Survey Manual). The plant species records are thus not comprehensive of all plant species, invasive or otherwise. The invasive species list will be revised at each NFI condition assessment according to changes in invasive species presence and country-level priorities (based on a species' likelihood of arrival and establishment within a region). For example, the NFI WEC working group have suggested that American skunk cabbage (*Lysichiton americanus*) and variegated yellow archangel (*Lamiastrum galeobdolon* subsp. *Argentatum*) are recorded in future survey cycles and considered as invasive and non-native.

Table 7 Non-native invasive plant species recorded by the NFI survey

Latin name	**Common name**
Carpobrotus edulis	Hottentot-fig
Cotoneaster species	Cotoneaster
Fallopia japonica	Japanese Knotweed
Gaultheria shallon	Shallon
Gunnera tinctoria	Giant-rhubarb
Heracleum mantegazzianum	Giant Hogweed
Impatiens glandulifera	Himalayan Balsam
Lauraceae	Laurel
Rhododendron ponticum	Rhododendron
Symphoricarpos albus	Snowberry

Classification

The NFI Condition Calculator checks for the presence of invasive species within the stand, stands or component group under assessment. Any other land outside of woodland within the square is not included in this analysis.

Invasive species cover is calculated as a percentage of the total area of the stand or woodland component group. These percentages are used to assign a score for each stand or component group (Table 8). The 10% cover threshold was chosen to align with the Native Woodland Survey for Scotland (NWSS, Patterson et al, 2014) and Defra's 'invasive species biodiversity indicator' (2019). Note that because rhododendron and cherry laurel are regarded as aggressive colonisers, their presence at any amount leads to an unfavourable score.

Table 8 Ruleset used for defining the invasive species condition classification

Value	Condition classification
No invasive species recorded	Favourable
Rhododendron and cherry laurel absent, other invasive species at ≤10% cover	Intermediate
Rhododendron or cherry laurel present, or any other invasive species at >10% cover	Unfavourable

4. Number of native tree and shrub species

Background

Tree species diversity is positively associated with overall woodland ecosystem biodiversity (Van Den Meersschaut and Vandekerkhove, 2000), the abundance and diversity of particular taxa (e.g. woodland moths, Fuentes-Montemayor et al, 2012), and improved resilience in the face of rapid ecological change and threats such as tree pests (e.g. Guyot et al, 2016) and diseases (Haas et al, 2011). Woodlands with higher tree and shrub species diversity tend to be more structurally complex. They thus provide a wider variety of the microhabitats and conditions that specialist species often depend on, such as types of deadwood, shading, moisture, leaf litter composition and light levels (Larrieu et al, 2018; Broome et al, 2019).

Data and method used for indicator measurement

The NFI survey records all tree species observed within a 1 ha NFI sample square, even species represented by just one tree (see the NFI Survey Manual). For the assessment of this WEC indicator, the NFI Condition Calculator tallies the number of different native species recorded within the stand or stands to provide a good estimate of species richness at a stand or component group level. Both native tree species (recorded as components) and shrub species (recorded within vegetation types) data are used. The NFI WEC working group reviewed the full list of species recorded as part of the NFI survey and identified those that are regarded as native in each country (0, Table 23).

Although rarity could have been accounted for in this indicator by attributing stands or component groups containing rarer species (such as the wayfaring tree, *Viburnum lantana*) higher scores, the NFI WEC working group decided that this could introduce geographic bias and would impede indicator interpretation, so each tree species was given equal weighting to provide a simple sum of species present.

Classification

To determine the thresholds used for converting the continuous measures of species richness into condition categories, the distribution of this indicator data was explored at different levels (e.g. across all woodlands or according to woodland type). Data from ASNW woodlands and those with SSSI status were used to assign a threshold that categorises stands with five or more native species as in favourable condition. See Table 9 for classification rules.

Table 9 Condition classification for number of native species

Species richness (number of native species)	Condition classification
≥5	Favourable
3 - 4	Intermediate
0 - 2	Unfavourable

5. Occupancy of native species

Background

Semi natural woodlands are largely composed of trees and shrubs that are native to the site (Kirby et al, 1984). A higher proportion of native trees in the canopy of a semi-natural woodland is regarded as an indicator of good WEC because of the support the native trees provide for native woodland biodiversity. Communities in native woodlands tend to be more diverse because these relationships have had longer to develop. It's therefore recommended to maintain and plant native species in support of woodland community complexity (Forestry Commission, 2017; Bellamy et al, 2018). For example, Fuentes-Montemayor et al (2012) reported higher moth abundance and species richness in farmland woodlands with a higher proportion of native tree species. Native tree species can also provide habitat for highly specialist species; 11% of the 955 species found to be associated with ash trees (*Fraxinus excelsior*) are highly dependent or restricted to this tree species, including epiphytic lichens, bryophytes and specialist invertebrates such as *Lipsothrix nigristigma* (Mitchell et al, 2014; Broome and Mitchell, 2017). The introduction of non-native trees can also cause or facilitate the introduction and spread of tree pests and pathogens (e.g. Piotrowska et al, 2017), threatening native trees and the species that depend on them.

Data and method used for indicator measurement

The NFI Calculator first uses a lookup table to identify which tree species components are native according to the country or NFI region a square is located within and, for some species with restricted ranges, according to mapped native zone data (0, Table 23). The proportional cover of native tree species in the uppermost canopy is then calculated for a stand or component group as a percentage of the overall uppermost canopy area (all species combined).

Classification

The thresholds used for classifying the areal cover of native species data are shown in Table 10. These were adjusted for Scotland due to differences in country level targets and reporting. To achieve a favourable condition rating in the native occupancy assessment, a greater proportion of native species is required in Scotland (>90%) compared to England and Wales (>80%). By setting a higher threshold to achieve a favourable status in Scotland, this assessment provides a more conservative estimate of woodland condition when there is a relatively high proportion of non-native species in its canopy.

Table 10 Classification thresholds for each country for native tree species cover

Country	Percentage cover of native trees	Condition classification
England and Wales	> 80%	Favourable
	50 – 80%	Intermediate
	< 50%	Unfavourable
Scotland	> 90%	Favourable
	80 – 90%	Intermediate
	< 80%	Unfavourable

6. Open Space within woodland

Background

Areas of open space within and adjacent to a woodland increase structural and environmental heterogeneity; they provide the edge and other microhabitat types required by some species across various taxa, such as hoverflies (e.g. Gittings et al, 2006), spiders (e.g. Oxbrough et al, 2006), bats (e.g. Fuentes-Montemayor et al, 2013; Kirkpatrick et al, 2018) and birds (e.g. Quine et al, 2007). The associated increase in light availability provides suitable conditions for shade-intolerant species and reportedly increases vascular plant species richness (Smith et al, 2007) and epiphyte coverage (Coote et al, 2008) in plantation forests, and floristic diversity in ancient semi-natural and secondary woodlands (Peterken and Francis, 1999). Areas of clear-fell, and those

comprising young trees, have many properties common to other open habitats, such as natural glades, and can provide foraging (e.g. Kirkpatrick et al, 2018) and nesting habitats for some species.

The UK Forestry Standard (UKFS) requires for woodlands to have a minimum of 10% open ground, or ground managed for the conservation and enhancement of biodiversity as the primary objective (Forestry Commission, 2017).

Data and method used for indicator measurement

The NFI Condition Calculator scores woodland sections according to the proportional cover of open space within, and adjacent to, each section. These scores are adjusted according to the quality of the open space present.

Component level assessment of internal open space

Identifying open space

Open space areas are identified and categorised using a component's habitat type and land use information. Component tree age data is also required if the component is classified as a woodland habitat type and felled land use type:

- **Open habitat types.** Open habitat categories are listed in Appendix E.
- **Woodland habitat types.** If a component is listed as a woodland habitat type, then its land use value is checked. If a non-woodland land use value is assigned, it is categorised using the land use type and is deemed to be open space (unshaded cells, Appendix F). If it is classified as a woodland land use (green cells, Appendix F), then this woodland component does not contribute any open space unless it is defined as clear-fell ('felled' land use category) or young trees. Young trees are identified as component groups with trees <10 years old with no mature trees in a higher storey.
- **Unknown habitat types.** If the habitat is listed as 'Unknown', 'Surveyed: unknown habitat' or 'Not surveyed', then the component's land use values are used for classification. If they are attributed woodland land use types, they are only classified as open space if they are young trees or clear-fell (see above).

Classifying open space quality

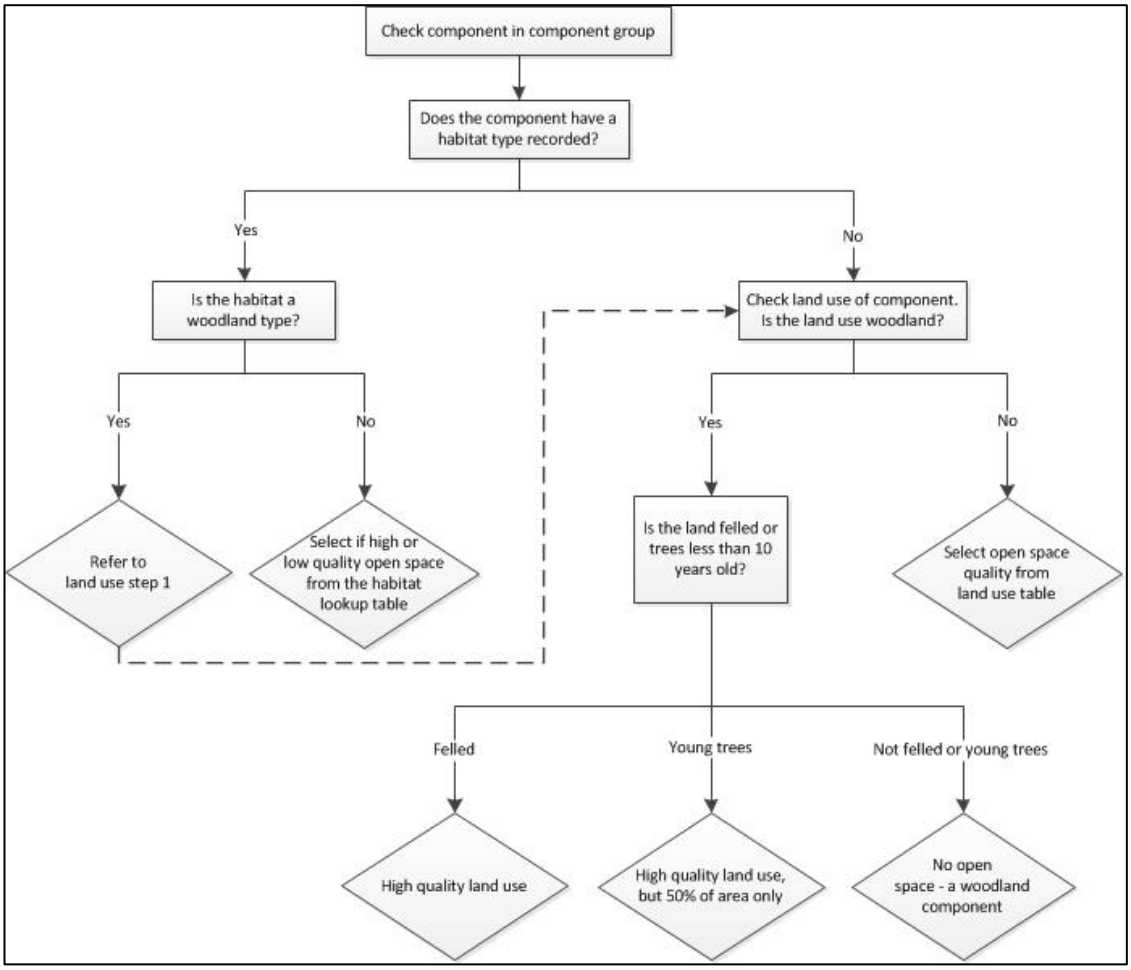
Each open space component is classified as high- or low-quality according to its habitat type (Appendix E) or land use type (unknown habitat types or woodland habitats with non-woodland land use status; Appendix F). Young trees and clear-fell are attributed high quality status, but the contribution of young trees to the total open space area is reduced by half (clear-fell area contribution remain at 100%). For example, if a stand or component group of 0.5 ha only contains trees of 7 years old, 0.25 ha (50% of 0.5 ha) is taken as the amount of internal open space for this stand or component group. This

open space identification and quality classification process is also summarised as a decision tree in Figure 4.

Section level assessment of adjacent open space

Sections are classified as either woodland or open space based on their component data. For a whole section to be classified as open space, all the component groups it contains must be classified as open space using the methods described above. If a square contains one or more open space sections, then an adjacent open space assessment is carried out within a GIS. This allocates the open space within the square to the nearest woodland sections, using a 50 m buffer around the woodland sections clipped to the square. In brief, the open space sections are mapped as a 1 m^2 point grid and each point falling within the 50 m buffer is assigned to either its nearest woodland section, or any areas of woodland outside of the square that are closer (therefore not contributing to the scores). The area of adjacent open space can then be tallied for each section by counting the number of open space points assigned. This approach therefore does not account for any open space surrounding the square. The area contribution of young tree points is halved to 0.5 m^2. More details and a series of screenshots illustrating the adjacent open space allocation is shown in Appendix G.

Figure 4 Decision Tree to determine if a section is open space



Combining internal and adjacent open space measurements

The area of internal open space calculated from a section's components is combined with the area of adjacent open space allocated to the section by summing these values. The percentage cover of open space for the section is calculated as shown in Figure 5.

Figure 5 Equation for calculating open space percentage

$$\frac{\text{(Open space area within section+adjacent open space allocated to section within 50 m buffer)}}{\text{(total section area+adjacent open space allocated to section within 50 m buffer)}} * 100$$

Classification

The percentage open space for the section is used to score open space in the NFI Condition Calculator using one of two matrices (Table 11), depending on the size of the woodland parcel within which the section is located. These thresholds were decided upon by the NFI WEC working group based on current UK forestry guidelines (e.g. UKFS; Forestry Commission, 2017) and the general consensus in the scientific literature that

some open space is good for biodiversity (but published findings on tipping points and thresholds are lacking and often context specific or scale dependent e.g. Pawson et al, 2006). Lower open space thresholds were set for smaller woodland parcels (<10 ha) for the following reasons:

- Woodland area is one of the most important drivers of biodiversity (Section 14). Open space in smaller woodlands further decreases their size, reducing the availability of internal ('core') woodland habitat required by some species.
- Smaller woods already have a higher perimeter to area ratio and thus have higher proportional edge and open space availability.
- The UKFS relaxes its 10% threshold for woodlands less than 10 ha.

Table 11 Combining woodland size, percentage open space and whether high quality open space is present into a condition classification

If woodland parcel is ≥ 10 ha:				
	<10% Total Open space	10-25% total Open space	>25 and <50% total open space	≥50% total open space
If section's open space has ≥50% high quality open space (internal or adjacent)	Intermediate	Favourable	Intermediate	Unfavourable
If section's open space has <50% high-quality open space (internal or adjacent)	Unfavourable	Intermediate	Unfavourable	Unfavourable
If the woodland parcel is < 10 ha:				
	0 – 10 % Total Open space	10 - 25% Total Open space	>25% Total Open space	
If section's open space has ≥50% high quality open space (internal or adjacent)	Favourable	Intermediate	Unfavourable	
If section's open space has <50% high-quality open space (internal or adjacent)	Intermediate	Unfavourable	Unfavourable	

7. Proportion of favourable land cover around woodland

Background

The biodiversity value of a woodland is not only determined by its local attributes - the structure of the surrounding landscape is also a critical determinant. A more permeable landscape with higher favourable habitat cover facilitates genetic exchange, species dispersal and persistence (Johnson et al, 1992; Hanski, 1999), which protects and enhances biodiversity at genetic, species and community levels (Bellamy et al, 2018). High landscape permeability can reduce the risk of inbreeding, maintain genetic diversity, improve survival and help species to recolonise sites following disturbance events, such as the loss of trees following a pest or disease outbreak (e.g. Schtickzelle and Baguette 2003; Wagner et al, 2006). At large spatial and temporal scales, it can also support species range shifts in response to rapidly changing environmental conditions and long-range dispersal events (Årevall et al, 2018).

Habitat configuration, including the availability and arrangement of trees outside woodlands and hedgerows, is also an important component in determining connectivity across heterogeneous landscapes with relatively low habitat cover, such as the highly fragmented British treescape (Fahrig, 2003, Bailey, 2007; Henry et al, 2017). However, the NFI WEC assessment does not currently incorporate an indicator of landscape woodland connectivity (see section on Future work).

Data and method used for indicator measurement

A GIS analysis is used to assess the total area of woodland from the NFI map plus specific land cover types from the Centre for Ecology and Hydrology's (CEH) Land Cover Map (LCM 2007, 25 m resolution; Morton et al, 2014) within a 5.6 km radius (100 km^2 circle) of the survey square centre point. The spatial analysis is run for each NFI survey square and the results are assumed to apply to all the woodland component groups being assessed within that square.

All areas of woodland and open land mapped by the NFI are used for this analysis, but only the LCM classes below are incorporated as 'supportive' habitats for woodland (for more details on the LCM data, consult supporting information provided by Morton et al, 2014):

- Acid grassland
- Bog
- Calcareous grassland
- Dwarf shrub heath
- Fen marsh and swamp
- Freshwater
- Inland rock

- Montane habitats
- Neutral grassland
- Rough low-productivity grassland

For each square, the applicable areas from the NFI Map and the Land Cover Map are recorded as separate values and these are summed for condition classification. This summed value is regarded as representing the total area of favourable land cover. This approach excludes the more intensively managed and highly modified arable and urban land use classes, where high levels of disturbance and low resource availability reduce species richness and specialist species occurrence (e.g. Robinson and Sutherland, 2002; Devictor et al, 2008), and exposed coastal habitats. The selection is in line with the 'broadleaf, mixed and yew woodlands' results from a Delphi review of landcover permeability for species associated with priority habitats in Britain (Eycott et al, 2011).

The spatial scale of measurement was also informed by scientific studies. The experts consulted by Eycott et al (2011) estimated that 95% of dispersal events from this woodland habitat occur within 400 m, in line with empirical evidence from studies tracking various taxa movements (e.g. gap crossing of woodland songbirds in Scotland up to 150 m, Creegan and Osborne, 2005). The reported 'scale of effect' of urban land use cover impacts is higher (e.g. up to 5 km for woodland carabids (Sadler et al, 2006) and up to at least 6 km for woodland dependent bats (Bellamy et al, 2013)), suggesting that the 5.6 km distance parameter is appropriate for assessing landscape impacts for many (not all) woodland species. However, it is acknowledged that mobility and the scale of landscape effects vary between woodland taxa, individuals and according to other regional conditions; this distance parameter does not account for the impact of landscape permeability on occasional long-distance dispersal and gene flow events.

Classification

The classification thresholds for the favourable landcover indicator are shown in Table 12. These were chosen based on expert opinion and to reflect 'critical habitat thresholds' reported in the literature. For example, a woodland within a landscape with <10% woodland cover (without even accounting for other favourable land use) is expected to be of low biodiversity value because of negative interactive effects exerting themselves between habitat amount and configuration (Andrén, 1994). However, it is acknowledged that these thresholds are unlikely to be universally appropriate across different landscape contexts and taxa.

Table 12 Condition classification for the proportion of favourable land cover assessment

Percentage cover of favourable land cover within a 5.6 km radius (100 km^2 circle)	Condition classification
>20%	Favourable
10-20%	Intermediate
<10%	Unfavourable

8. Woodland regeneration

Background

Regeneration – the establishment of seedlings, saplings and young trees - is a key indicator of woodland biodiversity and sustainable forestry (McRoberts et al, 2011). Monitoring regeneration allows predictions regarding the future health of a stand, including changes to its species composition, food web structure and biodiversity (Ellison et al, 2005).

Data and method used for indicator measurement

The presence of seedlings (<50 cm tall), saplings (≥50 cm tall and <4 cm in diameter) and other young trees of 4-7 cm DBH are assessed at the individual stand or component group level and across all component groups within the survey square. These are used to generate two separate NFI WEC indicator scores.

In the NFI survey, there are four places where a surveyor will record seedlings and saplings:

- **The component assessment:** Any storey of young trees will be recorded as a component when any trees <4 cm in diameter are present in the stand or component group. These are recorded as saplings. The young tree storey was changed to separate seedling and sapling storey categories in the second NFI survey cycle, starting in 2015. Species information is collected.
- **The vegetation assessment:** Seedlings are recorded in the ground layer and saplings are recorded in the field and shrub layers. Species information is not collected.
- **The transect assessment:** In the first cycle of the NFI, a young tree transect assessment was carried out in one plot in each woodland section. The transect is 10 m long (1 m wide for seedlings, 2 m wide for saplings) and is randomly located within the section according to the location of the first circular plot in a north – south orientation. The 10 m transect is split into ten segments, and the surveyor must record any seedling or saplings (grouped by species) against each 1 m segment (or the surveyor records 'none' in their absence).

- **Circular plots:** In the first cycle of the NFI surveys, all trees ≥4 cm DBH were also recorded in the circular plots. Trees of 4-7 cm DBH are included in this regeneration assessment and species information is collected.

These field measures are utilised within the WEC calculator to assess if:

Regeneration occurs solely within the stand, stands or component group or groups that form the WEC assessment unit

For the NFI condition assessment at stand, stands or component group-level, each woodland component group is checked for the presence or absence of native seedlings, saplings and native 4-7 cm DBH trees. If seedlings, saplings, 4-7 cm DBH trees are found in at least one component of the group then this is counted as a presence.

Regeneration occurs anywhere within the entire square

Once all the component group level assessments for regeneration are complete within a square, results for all component groups in the square are compiled. This might include component groups of different woodland types (such as native and non-native) and different woodland habitat types, if they are found in one square. If seedlings, saplings, 4-7 cm DBH trees are found in at least one component group in the square then this is counted as a presence.

The NFI canopy occupancy results indicate that native stands are in the main composed of high proportions of native species. This would imply that most regeneration in these stands is equally native. However, in some instances, non-native species may make up part of the regeneration count in native woods and that is not considered favourable in most instances. With that qualification, the vast majority of regeneration in native stands is a favourable indicator.

Classification (component group- and square-level)

Each woodland stand or component group being assessed for condition will receive both a component group-level score and a square-level score, which can be used to generate separate statistics. These scores are calculated based on the eight possible combinations of presence or absence of seedlings, saplings, 4 -7 cm trees (Table 13). To achieve a favourable score at either level, the seedlings, saplings and 4-7 cm DBH trees are all required to be present. This ensures that woodlands regarded as having favourable levels of regeneration are only those where regeneration is established, and seedlings are being recruited into saplings and saplings into small trees.

No thresholds are set for a minimum number of seedlings, saplings or smaller trees required for favourable or intermediate status because there is very little data to substantiate what level of regeneration per hectare is required to maintain woodland cover and this is likely to be dependent on woodland type and environmental conditions.

Although using the presence of young trees is perhaps a narrow or strict interpretation of regenerative capacity, a high proportion of stands were positive for young trees in the first cycle and were thus classed as in favourable or intermediate condition for this WEC indicator. Data from the first cycle of the NFI survey suggests that older native woods are stocked at a rate of around 100-200 stems per ha. Therefore, a single small tree (4-7 cm DBH) in a 0.3 ha stand (the mean size of NFI sections) is sufficient to suggest conditions are suitable for succession to be operating. However, continued recruitment of new small trees (4-7 cm DBH) from saplings will be necessary for the overstorey to be replaced in time. Furthermore, it is acknowledged that this indicator includes non-native regeneration, which doesn't necessarily indicate good ecological condition. An indicator based on increasing recruitment that excludes non-native regeneration could be used in subsequent WEC reporting (see section on Future work).

Some stands or component groups may show no evidence of regeneration for a variety of reasons related to the spatial and temporal scale of this assessment, such as localised or temporary succession, light availability or browsing. Meanwhile, young trees may be found within another, nearby component group because of increased light availability, for example. The latter component group's regeneration is a good indicator that the former component group will have the capacity to regenerate if conditions change. It is for this reason that, unlike other condition factors, there is not an unfavourable category for the component group-level regeneration score, and the square-level assessment was conceived to help factor in the presence of young trees nearby.

Table 13 Combining the presence of seedlings and saplings and 4 - 7 cm DBH trees into a condition classification at (i) component group- and (ii) square-level

Present Yes / No				
Trees 4 - 7 cm DBH	**Saplings**	**Seedlings**	**(i) Component group classification**	**(ii) Square classification**
Yes	Yes	Yes	Favourable	Favourable
No	Yes	Yes	Intermediate	Intermediate
No	No	Yes	Intermediate	Intermediate
No	Yes	No	Intermediate	Intermediate
Yes	No	No	Intermediate	Intermediate
Yes	No	Yes	Intermediate	Intermediate
Yes	Yes	No	Intermediate	Intermediate
No	No	No	Intermediate	Unfavourable

9. Tree health

Background

Rapidly changing environmental conditions and a variety of tree pests and diseases, including bacteria, fungi, oomycetes, viruses and invertebrates, can negatively impact a woodland's biodiversity, ecosystem functioning and economic value by damaging or killing trees (Boyd et al, 2013). Although the provision of deadwood has biodiversity benefits (Section 13), high levels of damage and mortality can severely limit a woodland's regenerative capacity and ecosystem functioning. The frequency and intensity of pressures on woodlands are predicted to continue rising and interactions between these pressures can magnify their negative effects (Seidl et al, 2017). For example, increasing globalisation and disturbances induced by climate and other environmental changes are driving an escalation in the emergence and impacts of tree pests and pathogens (Wainhouse and Inward, 2016; Wingfield et al, 2015; Ramsfield et al, 2016). Some specialist woodland species are particularly susceptible to the potential large-scale loss of a tree species, such as that posed by ash dieback in the UK (Clark and Webber, 2017); 11% of the 955 species found to be associated with ash trees (*Fraxinus excelsior*) in Britain are dependent on or restricted to this tree species, including some epiphytic lichens, bryophytes and invertebrates (Mitchell et al, 2014; Broome and Mitchell, 2017).

Data and method used for indicator measurement

This NFI Condition Calculator assessment is made by checking for the presence of these factors at the NFI component-level:

1. Tree mortality (alive or dead status of each plot tree and component)
Mortality has been given prominence because the presence of many dead trees in close proximity (for example in one survey section) may indicate a severe disease outbreak or an acute decline in site condition for other reasons (for example, water-logging or flooding due to changes in a drainage regime or severe weather). Furthermore, dead trees will be spotted by a surveyor, whereas symptoms of a specific disease or pest on a living tree may be difficult to observe and identify. The NFI Condition Calculator's tree mortality assessment uses the NFI Growing Stock Calculator's calculation of basal area (Brewer, unpublished; Jenkins et al, 2011), allowing a percentage of dead trees by basal area to be calculated for each section. Dead trees associated with wind blow or failed planting are not included in this assessment.

2. Tree health indicator of crown dieback
The presence or absence of several tree health indicators, such as resin bleeds, are recorded against each component. Crown dieback (the death of branches within a tree's crown) was the only poor health indicator included in this NFI WEC assessment because it is most reliably associated with poor health.

3. Tree pests and diseases

Forestry Commission's Plant Health Department classified the tree pests and diseases included in the NFI field survey recording list into expected high and low risk levels (in terms of likelihood of arrival and establishment within a region; potential rate of spread; potential severity impact; information now published as part of the UK Plant Health Risk Register (Defra, 2014)) (Table 14). For the higher risk types, surveyors were trained to a higher level in identification and expected to be highly vigilant in detecting their presence. The lower risk types were still recorded, however.

Table 14 Tree pests and diseases recorded in the first cycle of the NFI with their expected tree health risk level (high/low). NB. not all of these species are currently present in the UK.

Disease/Pest	Risk level
Acute/Chronic Oak Decline	High
Anoplophora chinensis	High
Anoplophora glabripennis	High
Ash Dieback	High
Asian Longhorn beetle	High
Bronze Birch borer	High
Canker	Low
Cryphonectria parasitica	High
Dendroctinus micans	Low
Emerald Ash borer	High
Gibrella circinata	High
Horse Chestnut Bleeding Canker	High
Horse Chestnut leaf miner	Low
Ips amitinus	High
Ips duplicatus	High
Ips typographus	High
Oak Processionary Moth	Low
Phytophthora lateralis	High
Phytophthora kernoviae	High
Phytophthora ramorum	High
Phytophthora austrocedrae	High
Phytophthora spp	High
Pine Lappet Moth	High
Pine Processionary Moth	High
Red Band Needle Blight	High
Sawyer Beetle	Low
Tomicus piniperda	Low
Weevils	High

It is important to note that some of the diseases are difficult to detect in the first phases of infection, and therefore, while positive results are a valuable indicator, negative results are not an indication of absence. Equally, positive confirmation for several of the insect pests and diseases requires destructive sampling, which was not undertaken during the field surveys. The pests and diseases recorded by the field survey changes over time according to emerging threats.

Classification

The three factors (mortality, crown dieback and pests/diseases) are combined for the classification of the condition factor as shown in Table 15. The mortality thresholds were set in recognition that while some mortality is expected as part of stand dynamics and competition (and typically benefits biodiversity by providing deadwood), high mortality signifies deterioration in stand condition. However, due to a lack of quantitative scientific evidence, the NFI data on tree mortality was analysed to specify the threshold values. The majority of stands were found to experience less than 10% mortality, with a primary cause of natural mortality. Stands with higher mortality were in the upper decile of the population (by area) and displayed more signs of other mortality causes. This information was combined with the assumption that the presence of any high-risk pests or diseases is likely to be detrimental to a woodland's ecological functioning and condition.

Table 15 Combining tree pest, diseases and mortality into a condition classification per stand or component group

	Mortality by basal area in section		
Pest/diseases present	**0 to 11% mortality**	**>11 and <25% mortality**	**≥25% mortality**
No crown dieback or pest/disease present	Favourable	Intermediate	Unfavourable
Crown dieback and/or low risk pest/disease present	Intermediate	Intermediate	Unfavourable
Any presence of high risk pest/disease	Unfavourable	Unfavourable	Unfavourable

10. Vegetation and ground flora

Background

An assessment of woodland biodiversity should incorporate information on the ground vegetation (McRoberts et al, 2011). The National Vegetation Classification (NVC) system (Rodwell, 1998) is established as the standard classification system for vegetation in Great Britain (Hall and Kirby, 2001; although it is now being replaced by the EUNIS classification system in Scotland (SNH, 2017)) and can be used as a surrogate indicator of biodiversity because there are well-established relationships between plant communities and site conditions, climatic factors and other woodland species (e.g. Ferris and Humphrey, 1999).

Data and method used for indicator measurement

This indicator score is determined for a stand or component group by assessing whether the proportions of ground and field layer vegetation recorded as part of the vegetation assessment are as expected according to its recorded NVC type. Higher than expected levels of bare ground are also penalised. Alternative methods were considered, such as assessing whether a woodland NVC type has any indicator species recorded in the vegetation assessment that would indicate favourable condition. However, given that the NFI survey does not incorporate a detailed botanical survey, it was felt that using the structural properties of the vegetation as an indicator of an NVC type's condition was a more reliable approach.

NVC data

In the NFI survey, one or more woodland NVC classes (W1 to W22) are recorded against the lowest storey components (see NFI Survey Manual). Values of 'not applicable' or 'not determinable' are used when NVC classes W1 – W22 do not apply, for example, for coniferous woodlands, open land, or if the plant community is so denuded that an assessment cannot be made. For this WEC indicator assessment, a component group is classified according to the predominant NVC type of its components.

Vegetation assessment data

The NFI vegetation assessment captures information on the presence and percentage cover of vegetation types within three structural height bands (shrub, field and ground) of each stand or component group. These data are also recorded against a component group's lowest storey and appropriate non-woodland components. Plant types are recorded, alongside leaf litter, bare soil, water and rock (see NFI Survey Manual). When accounting for the area of vegetation allocated to each layer:

- The shrub layer is independent of field and ground layers and it can be between 0% and 100% of the section area.
- The combined area for the field and ground layer vegetation must sum to 100% of the section area, with the assumption these layers are spatially discrete (Figure 6, A). However, it is acknowledged that there is likely to be some ground layer vegetation beneath the field layer. To account for this likely overlap, 25% of the field layer coverage is universally added to the ground layer coverage recorded by the surveyor (Figure 6, B). The example in Figure 6 shows a component group with 40% field layer and 60% ground layer vegetation coverage. For the purpose of this WEC indicator assessment, 25% of the field layer coverage is added to the ground layer percentage coverage as an estimate of probable overlap. Therefore, values of 40% for the field layer and 70% (60 + 10) for the ground layer are used to determine the component group's score.
- Bare soil is recorded within the ground layer but used separately in this assessment.

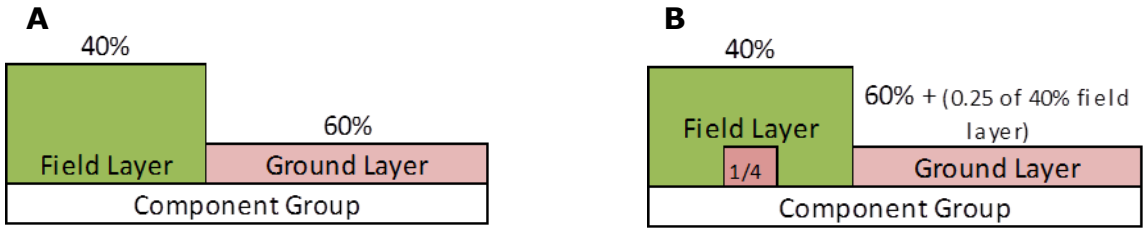


Figure 6 Recorded (A) and adjusted (B) field and ground layer percentage area cover used to calculate the vegetation and ground flora indicator in the first cycle of the NFI

Classification

This assessment checks the cover of field, ground and bare soil layers recorded for a component group against what would be expected for the NVC type. The NFI WEC working group advised on the levels expected for groups of woodland NVC types in good condition. This information was used to define the thresholds used to categorise these NVC groups into favourable, intermediate or unfavourable condition for the field layer, ground layer and bare soil data (Table 16). These three scores are combined into an overall result of favourable, intermediate or unfavourable condition for the vegetation and NVC assessment using a ruleset shown in Appendix H and Table 16. In general, the thresholds for what constitutes good condition assume that higher levels of bare or poached land is a signifier of poor condition (in most instances) and a fuller ground and field layer is favourable. The relative levels of field and ground layers which would be expected for favourable condition have been modified according to the NVC types' relative nutrient status, with higher thresholds set for richer and drier nutrient regimes.

Table 16. Ruleset used to classify component groups by comparing percentage cover of bare soil, field layer vegetation and ground layer vegetation recorded against what is expected of the NVC type. Ground layer cover is adjusted to incorproate 25% of field layer cover.

NVC type group	Field Layer %	Ground Layer %	Bare Soil %	Score
Group1 (high leaf litter and high shade) W13 Common yew woodland W14 Beech - bramble woodland W15 Beech - wavy hairgrass	≥10	>90	<20	Favourable
	<10	50-90	N/A	Intermediate
	N/A	<50	≥20	Unfavourable
Group 2 (upland rocky - nutrient poor) W11 Sessile oak - downy birch - wood sorrel W17 Sessile oak - downy birch - *Dicranum majus* W18 Scots pine - *Hylocomium splendens* woodland	>50	>80	<1	Favourable
W16 Oak - birch - wavy hairgrass woodland W9 Ash - rowan - dog's mercury woodland W19 Juniper - wood sorrel woodland W20 Downy willow - greater woodrush scrub W21 Hawthorn - ivy woodland	10-50	50-80	1-10	Intermediate
W22 Blackthorn - bramble woodland Not determinable Not applicable	<10	<50	>10	Unfavourable
Group 3 (super rich) W8 Ash - field maple - dog's mercury woodland	>80	>80	<1	Favourable
W10 Pedunculate oak - bracken - bramble	50-80	50-80	1-10	Intermediate
W12 Beech - dog's mercury woodland	<50	<50	>10	Unfavourable
Group 4 (soggy) W1 Grey willow - marsh bedstraw woodland W2 Grey willow - downy birch - common reed W3 Bay willow - bottle sedge woodland W4 Downy birch - purple moorgrass woodland	>80	≥10	<1	Favourable
W5 Common alder - great tussock sedge woodland W6 Common alder nettle woodland W7 Common alder - ash - yellow pimpernel woodland	50-80	<10	1-10	Intermediate
W18 bog Scots pine - *Hylocomium splendens* bog woodland	<50	N/A	>10	Unfavourable

11. Vertical structure

Background

Woodlands with higher structural diversity generally provide a wider range of conditions and microhabitats within a woodland, which are likely to be accompanied by a greater diversity of tree and other species (Ferris and Humphrey, 1999). For example, the vertical complexity of woodland structure has been found to be positively associated with bird species richness (e.g. Zellweger et al, 2013), in accordance with MacArthur and MacArthur's (1961) foliage height diversity-species diversity hypothesis. The existence of several storeys is also indicative of more advanced woodland stand development and is suggestive of a stand's existing capacity to regenerate over time, in line with the NFI WEC tree age distribution indicator.

Data and method used for indicator measurement

Vertical structure is defined here as the number of canopy storeys present. The NFI Condition Calculator assesses the storey structure of each stand, using the component data recorded by the surveyors for up to six different storey levels within a component group. Discrete storeys have a 4 m difference in either mean height or total height per storey (see the NFI Survey Manual for more details). In the first cycle of the NFI field survey, the possible storey values were:

- **Upper**
- **Complex**: recorded when the stand is composed of multiple tree heights that cannot easily be stratified into broad height bands (such as upper, middle or lower)
- **Middle**
- **Lower**
- **Young Trees**: in the second cycle of the NFI, the young trees storey was split into sapling and seedling storey categories
- **Shrub layer**: recorded as part of the ground vegetation assessment, rather than the tree component assessment.

Classification

If a complex storey has been recorded by the surveyor, then the stand assessed is classified as favourable for vertical structure. If a complex storey is not present, then a count is made of the number of storeys and the presence of a shrub layer and the total is used to determine the condition classification (Table 17). Having four or more storeys also leads to a favourable classification for this factor, as this represents the maximum number of storeys that can be classified by the NFI survey protocol within native woodlands. The presence of only one storey is indicative of recently established plantations or intensively managed areas and thus is assigned an 'unfavourable' classification.

Table 17 Classifying the number of storeys for the NFI Vertical Structure WEC assessment

Number of storeys recorded	Condition classification
≥4 storeys or 'complex'	Favourable
2 or 3 storeys	Intermediate
1 storey	Unfavourable

12. Veteran trees

Background

A veteran tree can be defined as 'a tree that is of interest biologically, culturally or aesthetically because of its age, size or condition' (Read, 2000). As well as their aesthetic, historic and cultural importance, veteran trees are important contributors to biodiversity. They create unique microhabitats which support a range of organisms, such as epiphytes; many of these species may be extremely specialist and only exist on veteran trees (Read, 2000; Tews et al, 2004; Gao et al, 2015). Veteran trees can be identified by their age, size, well-developed morphology, signs of damage or potential evidence of historical pollarding or coppicing. Although veteran trees can be found in woodlands, they are more frequently found outside of woodland in wood pasture, parkland and hedgerows on agricultural land (Lonsdale, 2013).

Data and method used for indicator measurement

In the NFI, veteran trees are recorded when a tree's diameter (DBH) exceeds a species-specific threshold, or by the presence of three or more characteristics such as rot holes, trunk hollowing, bark fluxes or water holes. The NFI survey protocol requires surveyors to locate and map each individual veteran tree they encounter within a survey square (records are therefore not confined to circular plot data, for example). For details on the survey methods see the NFI Survey Manual. The number of veteran trees per hectare is calculated for each section using the section area data. If there are no veteran trees in the section, then a value of 0 is recorded.

Classification

The thresholds for classifying the veteran tree WEC indicator are shown in Table 18. The favourable threshold was set to two or more veteran trees per hectare (equivalent to ≥40 per 20 ha), as an estimate of the probable occurrence of veteran trees in semi-natural woodlands in good condition. Ideally this threshold would be derived from a large sample of high quality, unmanaged woodlands across Britain, but this is unachievable given that most woodlands in Britain have been managed to some degree, or succession has been interrupted by herbivores. The thresholds used were, however, developed with consultation with experts from Forest Research and Natural England. They are also

underpinned by information derived by FC and Natural England from a Bayesian analysis of the stocking levels per hectare of mature stands, data on the probability of the survival of trees to veteran age, and assumptions around rates of recruitment, i.e. the process by which new individuals are added to an existing population, and benchmark studies in temperate continental woodlands with low levels of management (Kirby and Ditchburn, unpublished).

Table 18 Thresholds used to define the veteran tree WEC indicator classification

Number of veteran trees per 20 ha	Condition classification
≥40	Favourable
≥1 and <40	Intermediate
<1	Unfavourable

13. Volume of deadwood

Background

The volume of deadwood found in a woodland is an important element of its ecological condition and biodiversity value (Ferris and Humphrey, 1999; Humphrey et al, 2005). Around 20–25% of woodland species depend on decaying wood (Humphrey et al, 2005), as it provides important habitat and resources for small vertebrates, invertebrates, fish (wood in watercourses), cavity nesting birds, and a host of lichens and bryophytes, polypores and other saproxylic (dependent on deadwood) fungi (Humphrey et al, 2002). Obligatory saproxylic species represent one of the most diverse woodland species groups (Humphrey et al, 2005). The presence of deadwood is also an indicator of woodland that has not been extensively disturbed by human activity or that is being managed to maintain or improve its conservation value. Deadwood quantities are normally much lower in managed forests where harvestable timber is extracted (Kirby et al, 1998).

Data and method used for indicator measurement

The NFI records three types of deadwood:

1. **Standing dead trees**, recorded and measured in the circular plots.
2. **Lying deadwood**, recorded and measured along three linear transects radiating from the centre of one circular plot per section.
3. **Stumps**, measured, recorded and/or counted in the circular plots.

The NFI project has developed a Deadwood Calculator, which analyses the above three sources of field survey data and for each section derives a standing, lying and stump volume per hectare (the methodology is set out in a detailed document, which is available on request from the NFI Team).

The NFI Condition Calculator uses the deadwood volume from standing dead trees and lying deadwood only, to match the UK Forestry Standard (Forestry Commission, 2017). The deadwood volume calculations are calculated at a section-level, so if multiple woodland component groups exist within a section, each will be attributed the same per hectare values for lying and standing deadwood.

Classification

The results from other field studies and woodland management guidance were used to determine the thresholds used for this NFI WEC deadwood volume indicator. However, this evidence is limited for semi-natural woodlands in good condition in Britain. When comparing deadwood volumes between studies it is also important to consider whether lying, standing and stump deadwood, as well as dead branches on living trees, are included in the assessment.

- Green and Peterken (1997) studied 24 stands in the Lower Wye Valley and found 104 m^3 per ha in unmanaged old growth woodlands, 38 m^3 per ha in unmanaged young growth and 24 m^3 in managed semi-natural stands (all deadwood types).
- Kirby et al (1998) collated data for 63 sites and concluded a high level of deadwood in British broadleaved forests was >40 m^3 per ha of lying deadwood and/or >50 standing dead trees per ha.
- An analysis of deadwood in 86 beech (*Fagus sylvatica*) reserves in Central Europe and Southern Britain by Christensen et al (2005) found a mean volume of deadwood of 130 m^3 per ha, but volumes ranged from 0 to 550 m^3 per ha (all deadwood types).
- A review of published deadwood-biodiversity thresholds from European forests (including Britain) reported similar peaks in threshold values at 20–50 m^3 per ha of standing and lying deadwood (Müller and Bütler, 2010).
- A target of ≥20 m^3 of deadwood per ha is accepted as desirable in UK Forestry in line with the level recommended by Humphrey et al (2005), and this target has been adopted by the UKFS (Forestry Commission, 2017).

The NFI Condition assessment uses the UKFS guideline of 20 m^3 per ha to set its lower threshold between unfavourable and intermediate condition (Table 19). Although this intermediate threshold may be considered a low and perhaps unambitious level for semi-natural woodlands, it was set in consideration of the typically lower levels found within all woods in Britain and in particular productive woodlands. However, this is in contrast to the favourable threshold value of ≥80 m^3. Analysis of NFI data across all woodland types indicates that the deadwood volumes recorded (excluding stumps) ranged from 0 – 1,300 m^3 per ha, with a mean of 29 m^3 per ha and a median of 9 m^3 per ha. A literature review found that many temperate forests contain up to 50% of their biomass in deadwood. Given the right skewed distribution of deadwood volumes, a favourable

threshold of ≥80 m^3 per ha was chosen by the NFI WEC working group as a viable and appropriate upper target according to current evidence.

Table 19 Classifying volume of deadwood for the NFI condition assessment

Volume of lying and standing deadwood (m^3 per ha)	Classification
≥80	Favourable
≥20 and <80	Intermediate
0-19	Unfavourable

14. Size of woodland

Background

There is an established relationship between species richness and habitat area (MacArthur and Wilson, 1967), which is particularly well-documented for more specialist species (Tilman et al, 1994). As habitat parcel size increases so does the area to perimeter ratio, resulting in proportionally more of the internal woodland environment that is important to some species (Perrin et al, 2008) and proportionally less edge habitat that can be detrimental to some species (e.g. wrens (*Troglodytes troglodytes*; Hinsley et al, 1994) that benefit from a higher availability of woodland edge within their home range (e.g. Ries et al, 2004; Terraube et al, 2016).

For woodland biodiversity, there is evidence that woodland parcels less than 3-5 ha in size are less able to support some woodland taxa compared to larger woodlands (Humphrey et al, 2013), although different woodland species require different minimum woodland areas and this can change according to the landscape and environmental context. Specific examples include:

- **Birds:** Dolman et al (2007) found larger woodlands support more bird species, with a rapid increase in their number as woodland size increases from 0.1 to 3 ha and then a slower, but gradual increase from 3 to 10 ha. In a study in Eastern England, Hinsley et al (1994) found that rarer bird species such as jays (*Garrulus glandarius*) and treecreepers (*Certhia familiaris*) were less likely to breed in smaller woodlands of 5 – 10 ha compared to widespread species such as blackbirds (*Turdus merula*). Vanhinsbergh et al (2002) studied 50 bird species occupying farm woodlands in southern England and found species richness was positively associated with woodland area. Recent information published as part of the WrEN Project (wren-project.com; Watts et al, 2016) suggests woodland parcel size and the proportion of woodland within a 2 km radius are the strongest predictors of willow warbler (*Phylloscopus trochilus*) colonisation and settlement (Whytock et al, 2018).

- **Bats:** Murphy et al (2012) found that brown long-eared bats (*Plecotus auritus*) in south-east England primarily forage in woodlands and have a mean foraging patch size of 4.4 ha ('core' area of 2.1 ha). Other studies in Britain have also reported positive relationships between maximum woodland parcel size and the presence of some bat species (e.g. foraging bats, Bellamy et al, 2013; roosting bats, Bellamy and Altringham, 2015)

- **Invertebrates:** Usher and Keiller (1998) found that woodlands less than 1 ha in size did not support characteristic woodland moth communities, and those bigger than 5 ha were judged to be more valuable for the long-term conservation of woodland moth diversity. In a similar study in central Scotland, moth abundance and richness were higher in large woodland parcels (Fuentes-Montemayor et al, 2012).

- **Plants:** Usher et al (1992) found that many woodland herbaceous species were absent in woodlands smaller than 1.5 ha and that plant species richness increased with woodland area; on this basis they recommended new woodlands of at least 1.5 ha, ideally 5 ha. A study by Petit et al (2004) also found that the richness of ancient woodland indicator plant species was positively associated with woodland area in the British lowlands.

It should be noted that although woodland area is typically a strong indicator of many aspects of biodiversity, habitat quality and the composition and configuration of the surrounding landscape also help to shape resource availability, species dispersal and population dynamics. A woodland within an extensive, well-connected woodland network facilitates genetic exchange, species dispersal and persistence and is therefore generally better able resist or recover from local extinctions (Johnson et al, 1992; Hanski, 1999). The NFI condition assessment incorporates several local habitat quality indicators. It also assesses the 'Proportion of favourable land cover in the surrounding landscape' (Section 7), but does not currently integrate an indicator of landscape woodland connectivity (see Future work).

Data and method used for indicator measurement

Each NFI survey section is 0.05 to 1 ha in size, but the woodland sections being assessed for condition usually fall within a larger woodland parcel. In order to assess the size of the woodland parcel within which the section is located, the NFI woodland map dataset is analysed using a GIS analysis. For each NFI survey square section, NFI map woodland parcels intersecting the section are selected and their combined area is calculated and assigned. This relationship is represented in Figure 7, which shows a 0.4 ha NFI woodland survey section (purple border) within its 1 ha survey square (white border). This section would be assigned a value of 9 ha for this WEC indicator because this is the size of the NFI Map woodland parcel (red boundary) it sits within.

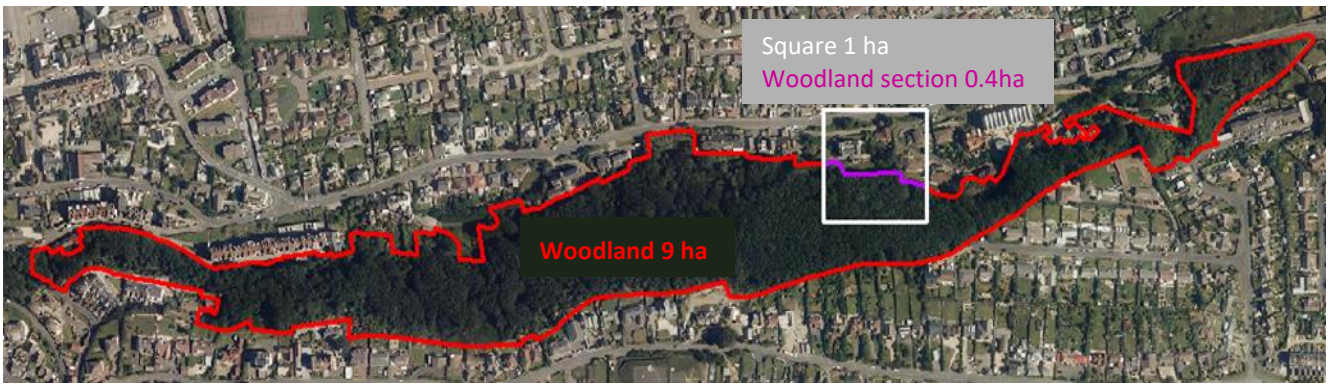


Figure 7 Example survey square and the woodland parcel it sites within

Classification

The total area of woodland is used to calculate a condition classification for the section as shown in Table 20. The NFI Condition Calculator's lower threshold of 5 ha (separating unfavourable and intermediate classes) and the upper threshold of 20 ha (separating intermediate and favourable classes) were chosen based upon the available evidence presented above. These thresholds were not adjusted according to woodland type due to a paucity of evidence that could be used to inform this decision.

Table 20 Woodland parcel area thresholds used for the NFI condition assessment

Woodland parcel area (ha)	Condition classification
>20	Favourable
≥5 and ≤20	Intermediate
<5	Unfavourable

15. Overall stand-level condition score

Background

For each stand or component group assessed, the NFI Condition Calculator generates an overall condition score and classification. The decision to do this was driven in part by the reporting requirements of Article 17 of the European Habitats Directive. Every six years, Member States of the European Union are required to report on implementation of the Habitats Directive, which includes reporting on the conservation status of individual habitats listed under Annex 1 of the Directive (JNCC, 2018). It was felt that an overall score would be a useful tool for those submitting the Article 17 reports to Europe for each woodland habitat type.

An overall ecological condition score is produced for each stand or component group by attributing a numerical score to the 'favourable', 'intermediate' and 'unfavourable'

classes and summing these scores for each of the 15 individual WEC indicators. As with all the individual indicator results, the overall scores can be reported by UK BAP Priority/Broad Habitat Type, by Annex 1 Type (as required by Article 17 reporting) and for native, near-native and non-native woodlands.

The NFI WEC working group carefully considered potential approaches for combining the 15 WEC indicator scores, including the possibility of weighting each indicator according to their assumed relative importance or strength of effect in determining overall ecological condition (e.g. Geburek et al, 2010). The consensus was that there was little evidence available at a national level for informing these weightings. For similar reasons, it was also decided not to assign individual indicators prominence as 'catastrophic' or 'red card' indicators that would guarantee an unfavourable overall score, regardless of the other indicator results. In this way the assessment does not enable current high-profile issues, policies or special interests to influence the overall score. Furthermore, it was decided that by establishing a neutral, unweighted scoring mechanism, the approach is straightforward and transparent, facilitating explanation and interpretation of the results and hopefully encouraging uptake and appropriate use by decision makers. However, individual indicator results are made available so that end users can adjust the weightings according to their own needs.

Method used for assessment

A simple ordinal scoring method was applied whereby unfavourable scores were attributed a value of one, intermediate scores a value of two and favourable scores a value of three. The resulting numerical scores were then summed across all 15 indicators to provide a total value for each individual stand or component group assessed. The component group level regeneration indicator (see Section 8) is not assigned an unfavourable score (only intermediate and favourable), so the lowest possible combined indicator score for a component group is 16 (one for all indicators, apart from the component group regeneration which has the lowest possible score of two). The highest possible score is 45 (three for each of the 15 assessments).

Classification

Table 21 shows how the overall condition classifications of favourable, intermediate and unfavourable were assigned to the summed indicator scores using bands of ten.

Table 21 Classification of summed indicator scores (using 1 for unfavourable, 2 for intermediate and 3 for favourable) into overall condition classes

Total indicator score	Overall condition score assigned
36 – 45	Favourable
26 – 35	Intermediate
16 – 25	Unfavourable

Applying the NFI WEC scores to decision making

As well as helping Britain to meet statutory obligations for reporting on woodland condition, the NFI WEC assessment can be used to inform the design and application of more strategic, cost-effective policies and management interventions aimed at improving woodland condition in support of biodiversity. The combined and individual indicator scores can be explored and compared across space and between woodland types to understand where policies and strategies are working or require change. For example, the combined scores can provide information on which woodland types are generally in better condition and which are not, and the individual indicator statistics can be interrogated to better pinpoint underlying issues. This informs policy as to what remedial or corrective action may be needed and where this should be targeted. The NFI Condition Calculator also facilitates application of the approach to future survey cycle data, providing comparable results for reliably monitoring changes in woodland condition and appraising the success of particular actions or policies.

Future work

The development of the NFI WEC indicator approach described in this document and resulting baseline statistics from the first NFI survey cycle are the result of years of data gathering, expert consultation and internal evaluation. Future changes may be implemented according to emerging issues or scientific evidence by updating the survey methods and/or recoding and rerunning the NFI Condition Calculator thresholds and approaches. For example, further evidence is required on the level at which tree mortality rates become detrimental to a woodland's functioning. The regeneration indicators could be improved by excluding non-native species and by measuring continued recruitment of new young trees.

The main area of future work will be in comparing woodland ecological condition over time through comparing two NFI survey cycles to develop woodland ecology change indicators. Additionally, the NFI survey team is working with scientists such as Forest Research's Land Use and Ecosystem Services Science Group and the WrEN project team (wren-project.com; Watts et al, 2016), to inform potential future developments such as an NFI WEC landscape woodland connectivity indicator that would reflect the impact of the composition and configuration of surrounding habitats on woodland stands at a finer resolution than the current process already achieves. Any such potential updates to the method will be back cast or integrated in a way that ensures fair and unbiased evaluation across survey cycles for monitoring changes in condition over time.

The NFI team are also collaborating on other projects to explore the NFI survey data in greater detail using statistical and machine learning approaches. An analytical framework for modelling the drivers of woodland condition across Britain has been developed and applied to the NFI data as part of the SCALEFORES project led by Southampton University in collaboration with Forest Research (Spake et al, 2019). The method is designed to enable drivers to vary according to wider environmental conditions so that we can better understand their context dependency and target management actions accordingly. It has been applied to modelling deer damage in woodlands (Spake et al, In Press), tree health (Spake et al, In Prep) and woodland recreation (Bellamy et al, In Prep). Spake et al (In Press) found that the probability of deer damage in the NFI woodlands was consistently higher in low density, broadleaved stands containing old trees, in areas with low road density. The impact of deer density on damage, however, depended on the regional climate and landscape attributes. These complex, three-way interactions are difficult to interpret and so the authors have developed an online, interactive tool[6] that enables users to better understand precited deer damage in different woodlands, landscapes and regions. Tree mortality and crown dieback in Stika Spruce (*Picea sitchensis*) plantations also appear to be driven by both

[6] https://spake.shinyapps.io/DEERDAMAGETOOL/

regional (e.g. climate; soil nitrogen) and site-level drivers (e.g. standing volume; tree age) (Spake et al, In Prep).

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Appendices

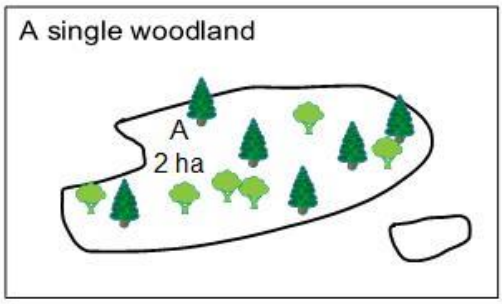
Defining native woodlands and UK BAP habitats

Given the large volume of data gathered in this study, the complementary NFI WEC statistical reports focus on results by country and by native and non-native woodland types. Results by UK BAP priority/broad woodland habitat type and region are available via supporting data spreadsheets (Figure 1). The categories and definitions used for reporting according to these woodland and habitat types are set out in the Methodology (p.16) and further details are provided below. Several key descriptors are used to discern between area of native trees, native habitats areas and native woodlands (Box 2).

UK BAP priority woodland habitats

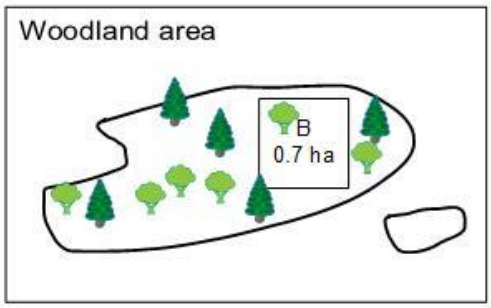
The UK BAP priority habitats were identified as the most threatened habitats requiring conservation action under the UK Biodiversity Action Plan (UK BAP). The original list of UK BAP priority habitats was created between 1995 and 1999. A Habitat Action Plan (HAP) was created for each of these habitat types (JNCC, 2019a). The priority habitat list was revised in 2007 and the number of UK BAP types was increased from 49 to 65 following publication of the Species and Habitats Review Report. The UK BAP was replaced in 2012 by the 'UK Post-2010 Biodiversity Framework', produced by the four UK countries in response to new international targets for 2020, the CBD 'Aichi Targets' and 'EU Biodiversity Strategy' (JNCC and Defra, 2012). The UK BAP priority habitat list remains influential, however, and has been used to help draw up statutory lists of priority habitats in England, Scotland, Wales and Northern Ireland, as required under Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006 (England), Section 7 of the Environment (Wales) Act 2016, Section 2(4) of the Nature Conservation (Scotland) Act 2004, and Section 3(1) of the Wildlife and Natural Environment Act (Northern Ireland) 2011. The revised list of priority woodland habitats is shown in Table 22, along with links to the definitions of these habitats and the UK BAP broad habitat type they are associated with (BRIG, 2011). Of the 65 priority habitat types, nine are native woodland habitats (including the Caledonian pinewoods that fall within Scotland's native pinewood zone), which have been adopted by the NFI for WEC reporting (Table 22).

Box 2 Definitions of NFI woodland, woodland area and woodland habitat

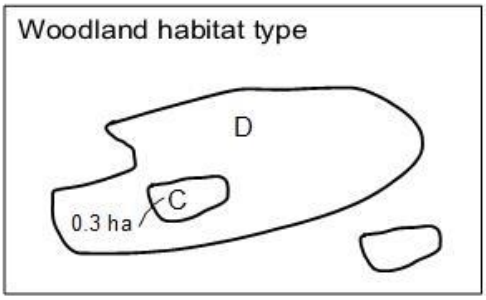


A single woodland is defined as a discrete area of land with a tree canopy cover of 20% or more (or the potential to achieve this) with a minimum area of 0.5 hectares and a minimum width of 20 metres. See A.

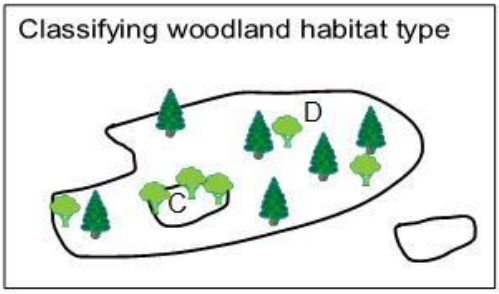
= native tree = non native tree



Woodland area is the quantity that expresses the extent of a two-dimensional woodland shape in planimetric area. This can pertain to the area occupied by the shapes of many woodlands, a single woodland (as in A above left), or a sub class of an individual woodland as in B left.

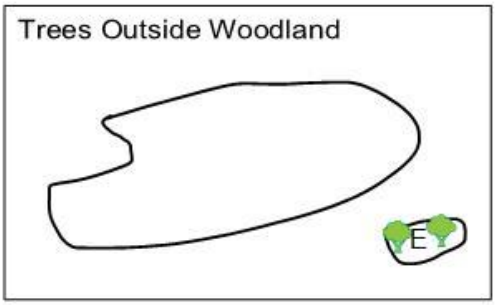


NFI sub classifies woodland area into woodland habitat types at a stand level. The minimum qualifying area for a unique stand of woodland habitat within a woodland is 0.1 hectare (see C – 0.3 ha). A single wood may be composed of several woodland habitat types (see C & D).



Separate woodland habitat types within a wood, such as an area of native woodland habitat within a non native wood are defined as stands >0.1 hectare and with >50% native tree species in the canopy (see C).

= native tree = non native tree



Trees outside of woodland (TOW) are defined as discrete areas of tree canopy <0.5 hectare in extent (see E). They are not included in NFI woodland area estimates or area of woodland habitat estimates and are accounted for separately as TOW. These may be composed of either native or non native trees.

Table 22 UK BAP priority woodland habitats with links to relevant JNCC webpages.

UK BAP broad habitat	UK BAP priority habitat	Changes agreed in the UK BAP 2007 review
Broadleaved mixed and yew woodland	Traditional Orchards Word document PDF (80kb)	New priority habitat
	Wood-Pasture and Parkland (updated December 2011) Word document PDF (34kb)	Revised name (previously 'Lowland Wood-Pasture and Parkland'); scope expanded
	Upland Oakwood Word document PDF (26kb)	No change
	Lowland Beech and Yew Woodland Word document PDF (29kb)	No change
	Upland Mixed Ashwoods Word document PDF (29kb)	No change
	Wet Woodland Word document PDF (29kb)	No change
	Lowland Mixed Deciduous Woodland Word document PDF (27kb)	Formally adopted as priority habitat
	Upland Birchwoods Word document PDF (33kb)	Formally adopted as priority habitat
Coniferous woodland	Native Pine Woodlands PDF (78kb)	No change

Defining the native woodland population

Native tree species

The NFI WEC working group helped to determine which tree species should be identified as native in each country using expert knowledge and information from sources such as Forest Research's Tree Species Database, the NWSS methodology for Scotland (Patterson et al, 2014, Annex 1) and NRW guidance for Wales (NRW, 2015) (Table 23). In Wales, a native zone dataset was used to indicate where beech (*Fagus sylvatica*), hornbeam (*Carpinus betulus*) and large-leaved lime (*Tilia platyphyllos*) are considered native. These three species were considered native in England and non-native in Scotland. In Scotland, a native pine zone dataset was used to indicate where Scots pine (*Pinus sylvestris*) is considered native, following the NWSS methodology (Patterson et al, 2014). Sycamore (*Acer pseudoplatanus*) was classed as naturalised and thus not native in all countries. However, this list will be revisited at each NFI condition assessment in consideration of emerging understanding and consensus (changes to the classification of some species has been highlighted as potential areas of improvement by the working group (Table 23)).

Table 23 Tree species and species groups classified as native (1), non-native (0) or native only within a restricted zone (Zone) within each country. *classifications to be re-visited.

Species	*Latin name*	England	Wales	Scotland
Alder (species unidentified)	*Alnus* spp.	1*	1*	1*
Armand's pine	*Pinus armandii*	0	0	0
Ash	*Fraxinus excelsior*	1	1	1
Aspen	*Populus tremula*	1	1	1
Atlas cedar	*Cedrus atlantica*	0	0	0
Austrian pine	*Pinus nigra var nigra*	0	0	0
Beech	*Fagus sylvatica*	1	Zone	0
Bhutan pine	*Pinus wallichiana*	0	0	0
Big leaf maple	*Acer macrophyllum*	0	0	0
Birch (downy/silver)	*Betula pubescens/pendula*	1	1	1
Bird cherry	*Prunus padus*	1	1	1
Bishop pine	*Pinus muricata*	0	0	0
Black poplar	*Populus nigra*	1	1	1
Black walnut	*Juglans nigra*	0	0	0
Blackthorn	*Prunus spinosa*	1	1	1
Bornmullers/Turkish fir	*Abies bornmuelleriana*	0	0	0
Box (species unidentified)	*Buxus* spp.	1*	1*	1
Calabrian pine	*Pinus brutia*	0	0	0
Cedar of Lebanon	*Cedrus libani*	0	0	0
Cider gum	*Eucalyptus gunnii*	0	0	0

Species	*Latin name*	England	Wales	Scotland
Coast redwood	*Sequoia sempervirens*	0	0	0
Common alder	*Alnus gultinosa*	1	1	1
Common lime	*Tilia europaea*	1	1	0
Common walnut	*Juglans regia*	0	0	0
Corsican pine	*Pinus nigra var maritima*	0	0	0
Crab apple	*Malus sylvestris*	1	1	1
Crack willow	*Salix fragilis*	1	1	0
Douglas fir	*Pseudotsuga menziesii*	0	0	0
Downy birch	*Betula pubescens*	1	1	1
Downy oak	*Quercus pubescens*	0	0	0
Elm	*Ulmus spp*	1*	1*	1*
English elm	*Ulmus procera*	1	1	0
European larch	*Larix decidua*	0	0	0
European silver fir	*Abies alba*	0	0	0
Field maple	*Acer campestre*	1	1	0
Goat willow	*Salix caprea*	1	1	1
Grand Fir	*Abies grandis*	0	0	0
Grecian fir	*Abies cephalonica*	0	0	0
Green alder	*Alnus viridis*	0	0	0
Grey alder	*Alnus incana*	0	0	0
Grey poplar	*Populus canescens*	0	0	0
Grey willow	*Salix cinerea*	1	1	1
Hawthorn (species unidentified)	*Crataegus* spp.	1	1	1
Hazel	*Corylus avellana*	1	1	1
Holly (species unidentified)	*Ilex* spp.	1	1	1
Holm oak	*Quercus ilex*	0	0	0
Hornbeam	*Carpinus betulus*	1	Zone	0
Horse chestnut	*Aesculus hippocastanum*	Zone*	0*	0*
Hungarian oak	*Quercus frainetto*	0	0	0
Hybrid larch	*Larix x eurolepis*	0	0	0
Hybrid poplar	*Populus serotina/trichocarpa*	1*	1*	1
Italian alder	*Alnus cordata*	0	0	0
Japanese cedar	*Cryptomeria japonica*	0	0	0
Japanese larch	*Larix kaempferi*	0	0	0
Korean pine	*Pinus koreana*	0	0	0
Large-leaved lime	*Tilia platyphyllos*	1	Zone	0
Lawsons cypress	*Chamaecyparis lawsoniana*	0	0	0
Lenga	*Nothofagus pumilio*	0	0	0
Leyland cypress	*Cupressocyparis leylandii*	0	0	0
Lime (species unidentified)	*Tilia* spp.	1	0	0
Loblolly pine	*Pinus taeda*	0	0	0
Lodgepole pine	*Pinus contorta*	0	0	0

Species	*Latin name*	England	Wales	Scotland
London plane	*Platanus x acerifolia*	0	0	0
Macedonian pine	*Pinus peuce*	0	0	0
Maritime pine	*Pinus pinaster*	0	0	0
Mexican white pine	*Pinus ayacahuite*	0	0	0
Mixed broadleaves		1*	1*	1*
Mixed conifers		0	0	0
Monterey pine	*Pinus radiata*	0	0	0
Mountain pine	*Pinus uncinata*	0	0	0
Narrow-leafed ash	*Fraxinus angustifolia*	0	0	0
Noble fir	*Abies procera*	0	0	0
Nordmann fir	*Abies nordmanniana*	0	0	0
Norway maple	*Acer platanoides*	0	0	0
Norway spruce	*Picea abies*	0	0	0
Oak (robur/petraea)	*Quercus* spp.	1	1	1
Oriental beech	*Fagus orientalis*	0	0	0
Oriental spruce	*Picea orientalis*	0	0	0
Paper-bark birch	*Betula papyrifera*	0	0	0
Pedunculate/common oak	*Quercus robur*	1	1	1
Plane (species unidentified)	*Platanus* spp.	0	0	0
Ponderosa pine	*Pinus ponderosa*	0	0	0
Pyrenean oak	*Quercus pyrenaica*	0	0	0
Raoul/rauli	*Nothofagus nervosa*	0	0	0
Red alder	*Alnus rubra*	0	0	0
Red ash	*Fraxinus pennsylvanica*	0	0	0
Red oak	*Quercus borealis*	0	0	0
Red (pacific silver) fir	*Abies amabilis*	0	0	0
Roble	*Nothofagus obliqua*	0	0	0
Rowan	*Sorbus aucuparia*	1	1	1
Scots pine	*Pinus sylvestris*	0	0	Zone
Serbian spruce	*Picea omorika*	0	0	0
Sessile oak	*Quercus petraea*	1	1	1
Shagbark hickory	*Carya ovata*	0	0	0
Shining gum	*Eucalyptus nitens*	0	0	0
Silver birch	*Betula pendula*	1	1	1
Silver maple	*Acer saccharinum*	0	0	0
Sitka spruce	*Picea sitchensis*	0	0	0
Slash pine	*Pinus ellottii*	0	0	0
Small-leaved lime	*Tilia cordata*	1	1	1
Smooth-leaved elm	*Ulmus carpinifolia*	1	1	0
Sweet chestnut	*Castanea sativa*	1*	1*	0*
Sycamore	*Acer pseudoplatanus*	0	0	0
Tulip tree	*Liriodendron tulipifera*	0	0	0

Species	*Latin name*	England	Wales	Scotland
Turkey oak	*Quercus cerris*	0	0	0
Wellingtonia	*Sequoiadendron giganteum*	0	0	0
Western hemlock	*Tsuga heterophylla*	0	0	0
Western red cedar	*Thuja plicata*	0	0	0
Western white pine	*Pinus monticola*	0	0	0
Weymouth pine	*Pinus strobus*	0	0	0
White ash	*Fraxinus americana*	0	0	0
White oak	*Quercus alba*	0	0	0
White poplar	*Populus alba*	0	0	0
White willow	*Salix alba*	1	1	0
Whitebeam	*Sorbus aria*	1	1	0
Wild cherry/gean	*Prunus avium*	1	1	1
Wild service tree	*Sorbus torminalis*	1	1	0
Wych elm	*Ulmus glabra*	1	1	1
Yew	*Taxus baccata*	1	1	1
Yunnan pine	*Pinus yunnanensis*	0	0	0
Other birches	*Betula* spp.	0*	0*	0*
Other broadleaves		0*	0*	0*
Other Cedar	*Cedrus* spp.	0	0	0
Other cherry species	*Prunus* spp.	0*	0*	0*
Other conifer species		0	0	0
Other Eucalyptus species	*Eucalyptus* spp.	0	0	0
Other fir (Abies) species	*Abies* spp.	0	0	0
Other larch species	*Larix* spp.	0	0	0
Other Nothofagus species	*Nothofagus* spp.	0	0	0
Other oak species	*Quercus* spp.	0	0	0
Other pine species	*Pinus* spp.	0	0	0
Other poplar species	*Populus* spp.	0	0	0
Other spruce species	*Picea* spp.	0	0	0
Other walnut species	*Juglans* spp.	0	0	0
Other willow species	*Salix* spp.	1	1	0

Categorising native woodland

Due to various historical drivers, a large proportion of British woodland comprises non-native species, or mixtures of native and non-natives. Mixtures are more common at a woodland parcel scale, rather than a stand scale, because stands of different species can be planted adjacent to one another. These mixed parcels and stands complicate identification and isolation of Britain's native woodland population. Furthermore, the spatial dispersion and clumping of native and non-native stands appears to vary regionally. In lowland Britain, for example, circumstances led to a high proportion of non-native tree species being established adjacent to or within existing native woodlands. In upland Britain, non-native woodland was often established far from existing woodlands, facilitating identification and measurement of native woodlands in these areas.

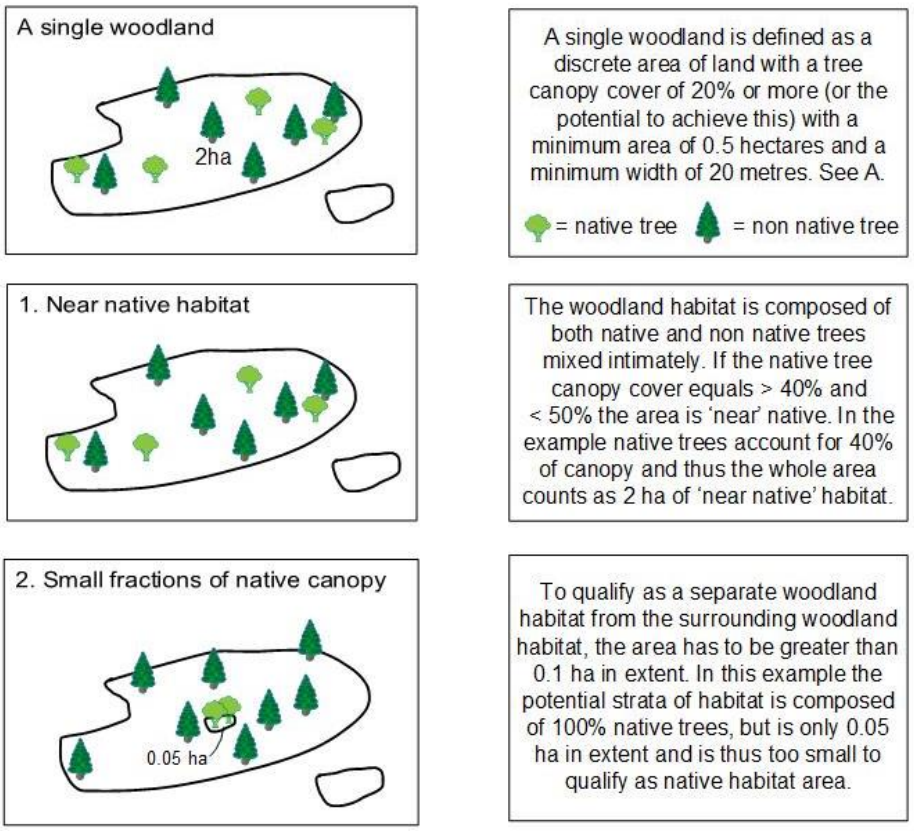
A set of rules and assumptions were required to categorise these mixed woodlands. Where these lines are drawn and at what scale they are applied (e.g. at a woodland stand or parcel level) impact the size and characteristics of the tree population that is identified as native, thus influencing the apportioning of condition scores. The thresholds used to define the NFI WEC woodland type categories of 'native', 'non-native', 'near native and fragments' (see Box 3) and 'not determinable' are provided in the Methodology (p.17). The unit of measurement at which these are measured are set out and justified below.

The resulting estimated area of these woodland types per country and region (including a break out of the 'near native and fragments' types) are provided in Table 24. When comparing the resulting NFI estimates of the net area of native and non-native woodland habitat area to existing gross area FC estimates, it should be noted that the NFI estimates will be lower due to the presence of open space within woodland area (which are not incorporated into the NFI measure).

Table 24 Area of woodland by woodland type for each GB country and region, with a breakout of near native and fragments

Region	Native	Fragments	Near native	Non native	Not determinable	Total
	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)	Area (ha)
GB	**1,507,105**	**4,290**	**52,486**	**1,461,267**	**19,629**	**3,044,777**
ENGLAND	**914,095**	**1,123**	**28,337**	**398,186**	**1,706**	**1,343,446**
North West England	73,932	116	2,213	45,152	421	**121,834**
North East England	36,201	267	2,738	77,982	149	**117,338**
Yorkshire and the Humber	68,954	105	3,678	46,837	271	**119,845**
East Midlands	73,964	42	2,262	26,272	37	**102,577**
East England	107,595	70	3,253	43,206	181	**154,306**
South East England	280,796	142	6,353	57,302	308	**344,901**
South West England	186,732	253	4,400	70,192	205	**261,782**
West Midlands	85,920	127	3,439	31,243	134	**120,863**
SCOTLAND	**442,611**	**2,491**	**17,822**	**908,259**	**17,205**	**1,388,388**
North Scotland	94,541	422	2,880	119,908	5,751	**223,503**
North East Scotland	111,260	364	3,418	115,197	2,248	**232,485**
East Scotland	48,860	175	2,472	80,049	2,171	**133,728**
South Scotland	78,739	874	6,152	336,526	2,709	**425,000**
West Scotland	109,211	656	2,900	256,579	4,327	**373,672**
WALES	**150,399**	**676**	**6,328**	**154,822**	**718**	**312,943**

Box 3 Definitions of the woodland habitat types in the NFI 'near native and fragments' category



Unit of measurement

Unfortunately, a unit of measurement was not defined when the definitions of native woodland were set. For example, the percentage occupancy of native tree species over all woodlands across a geographic area such as a county or river catchment could be measured to derive a single percentage, or native tree occupancy could be measured for each individual woodland parcel. This would have obvious implications for native woodland classification – in the first case the threshold would be applied to categorise all woodlands in that area based on the combined percentage, in the second case each woodland would be assessed individually to identify native parcels. As British woodland cover is fragmented and doesn't form one contiguous parcel, it is more meaningful and practical to take the second approach and to assess individual woodlands. However, when attempting to identify an entire sub population, spatial scale becomes an issue because woodland parcels differ in size. Discrete woodland parcels range in size from 0.5 hectares to 50,000 hectares across Britain. A small woodland containing a small stand of native tree species is more likely to be classified as native compared to a larger woodland with the same area of native trees. This approach therefore has the

disadvantage of excluding native woodland stands that sit within or adjacent to non-native woodlands that are more than twice their size.

Instead of categorising woodlands at the parcel scale, discernible homogeneous strata (stands) can be assessed individually, irrespective of any adjacent woodland. This approach is 'blind' as to whether a stand sits within a large or small wood, or as to whether that wood is predominantly native or non-native. This method is less sensitive to scale; as woodlands are partitioned into stands with relatively homogeneous structure, a discernible area of native trees (>0.1 ha) within a non-native woodland will be assessed separately to the surrounding woodland. Although it could be argued the landscape adjacent and surrounding a native stand should not be disregarded when classifying native woodland, the inclusion of an adjacency or similar measurement would be complicated and somewhat arbitrary. Furthermore, any impacts of the surroundings on the condition of that native stand are likely to be reflected in the resulting WEC indicator scores.

In summary, assessing percentage occupancy of native species at a stand or component group level as opposed to a discrete woodland parcel was chosen because:

- No upper size threshold has ever been set or agreed on the area over which to assess canopy occupancy. If a parcel approach was taken, a 1 ha parcel with 100% native species occupancy would count towards UK BAP targets, whilst a 20 ha native species stand within a 100 ha non-native woodland parcel would not.
- If the purpose of condition monitoring is to identify native woodland under threat and to encourage management action to improve the condition of that wood, discounting stands of native woodland within a larger conifer woodland, would run counter to that purpose.
- The NFI enables all native species to be measured from individual trees, to groups below the 0.5 ha threshold and to larger groupings. This allows woodland that is 'near' native to be extracted and studied within the NFI. Also, if the definitions of what constitutes native change over time, these can be applied in query form to the NFI database and their associated areas estimated.

Figure 7 and

Table 25 illustrate the scale issues discussed by demonstrating the impact of applying the canopy occupancy threshold different levels.

Figure 8. A visual summary of how the NFI determine strata on the basis of the relative configurations of native and non-native species

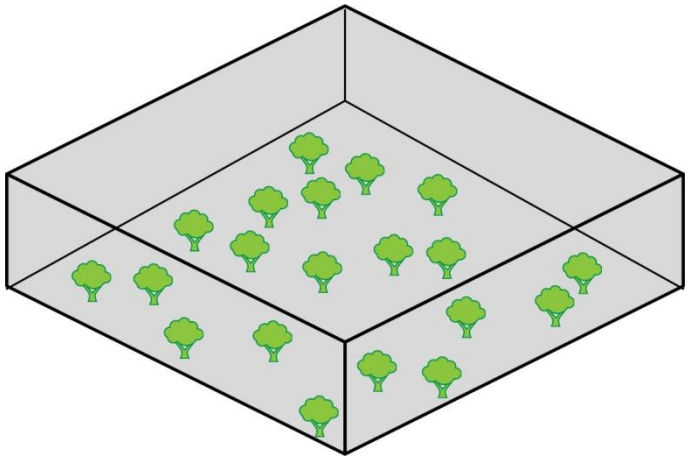


Figure 7.i. A 100% native sample. In this example the entire area of 1 ha is composed of native species and the entire area is classified as native woodland and will contribute to the national estimate of native area.

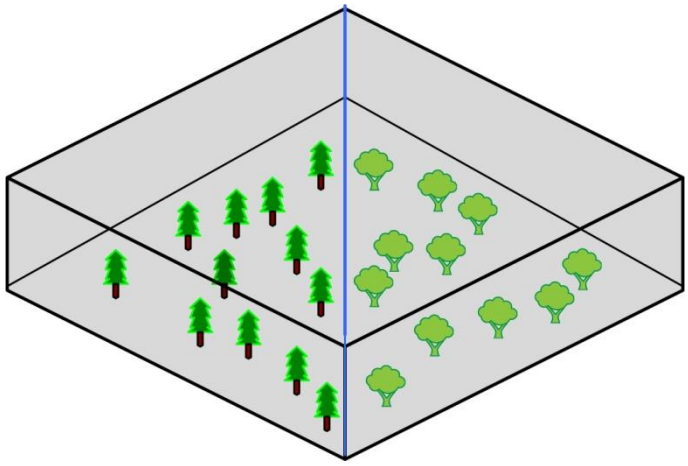


Figure 7.ii A sample with two stands, one native and one non-native. In this example half the area (0.5 ha) is composed of native species and that half of the square is separated out as a section (as denoted by the blue line) and is classified as native type and will contribute to the national estimate of native area. The remaining half is classified as non-native.

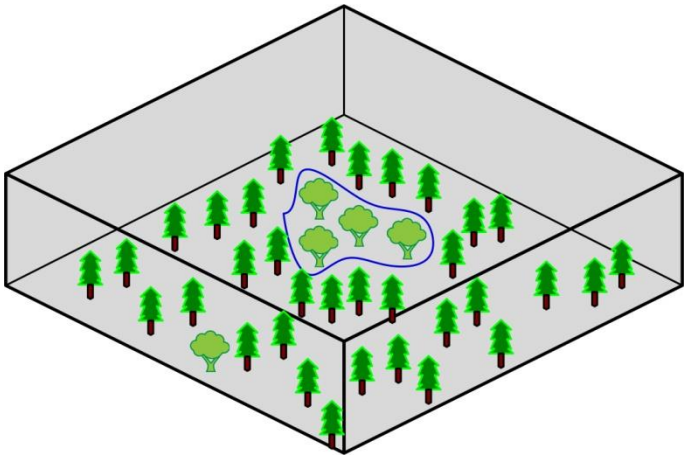


Figure 7.iii. A small area of natives within a conifer matrix. In this example a small isolated area (0.2 ha) is composed of native species and that area of the square is separated out as a section (as denoted by the blue line) and is classified as native woodland habitat. As it is greater than 0.1 ha and is located in a woodland greater than 0.5 ha it will contribute to the national estimate of native area. The remaining area is classified as non-native.

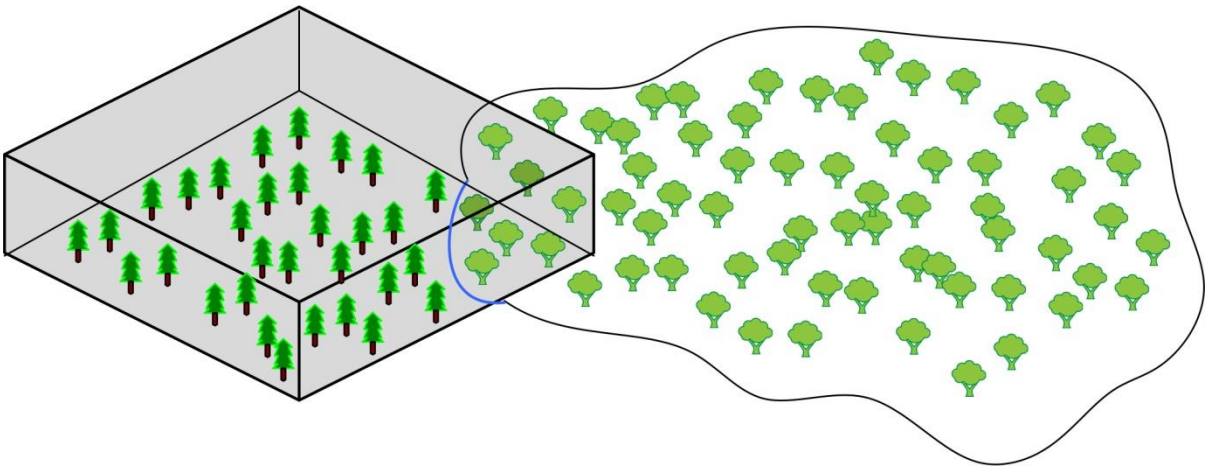


Figure 7.iv: A small sample of native within a 'Relevant Adjacent Stand'. Where an area of native woodland habitat within the sample square is less than 0.1 hectares, but the stand continues out with the sample square, If the entire stand area is greater than 0.1 ha then the area of native within the sample square will contribute to the national native estimate, as it is a sample fraction of an area greater than 0.1 ha (the native woodland threshold) and part of a wood greater than 0.5 ha (the woodland area threshold).

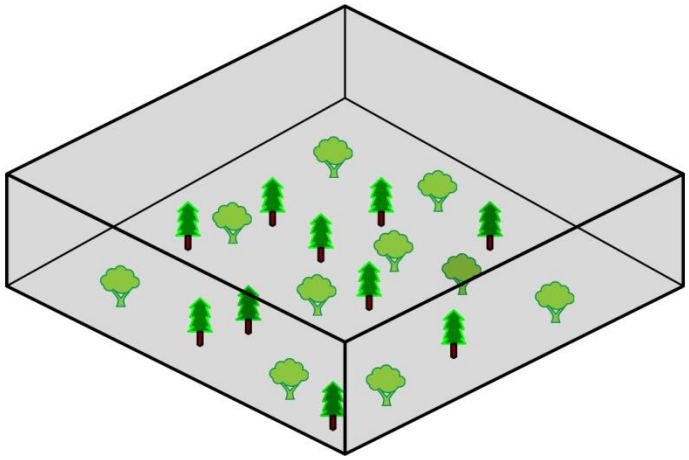


Figure 7.v A native intimate mixture. A central definition of a native area is that at least 50% of the area is of the native species that constitutes that as native. In this example the woodland within the sample square is an intimate mixture of native broadleaves and non-native conifers, at a 50:50 mix. The entire area therefore is classified as native, whilst the species proportions discern the site as in poorer condition than a site with a higher proportion of natives.

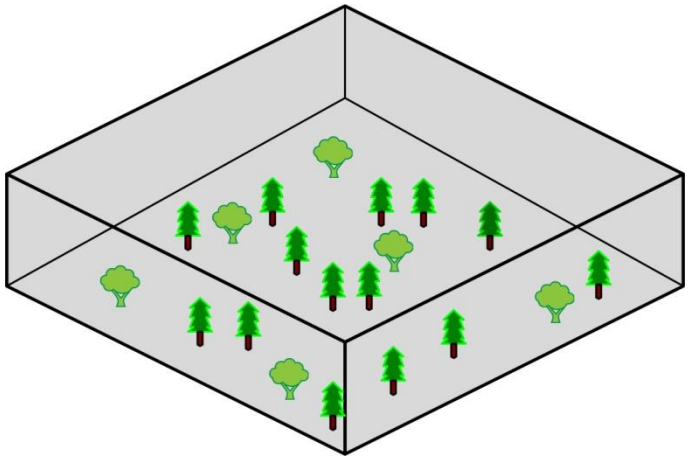
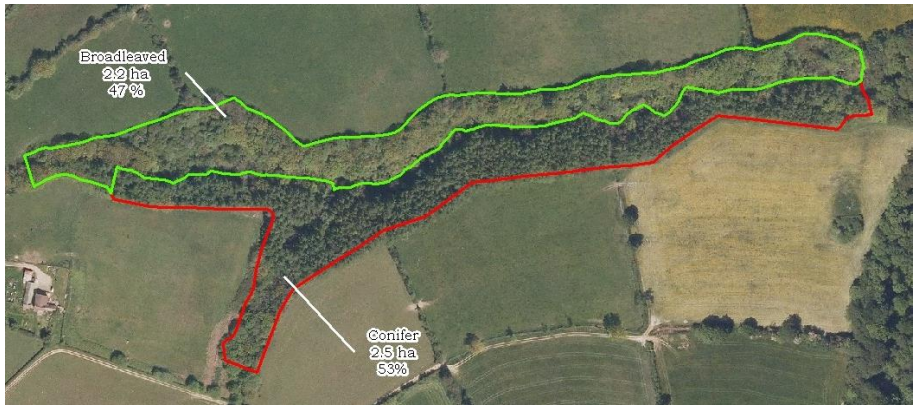


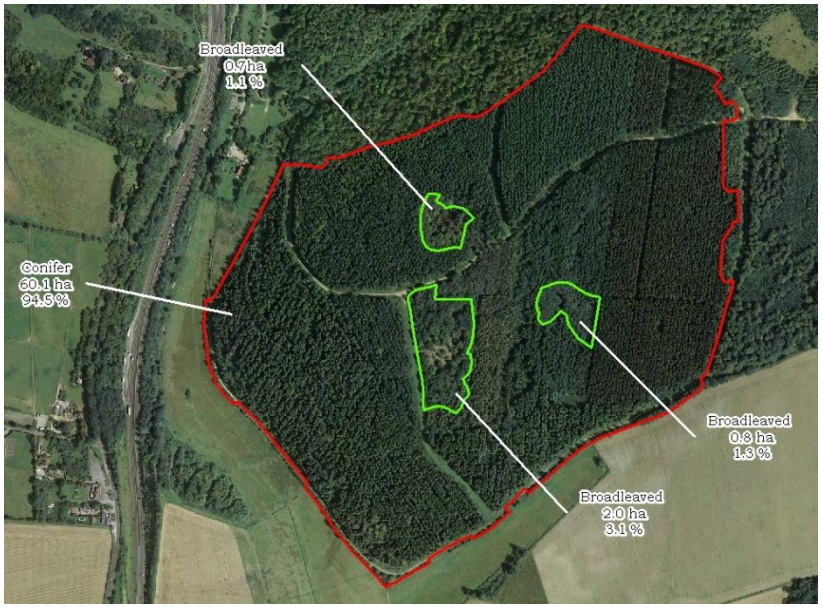
Figure 7.vi A non-native intimate mixture. In this example the woodland within the sample square is an intimate mixture of native broadleaves and non-native conifers, at a 30:70 mix respectively. The entire area therefore is classified as non-native, whilst the species mixture measured within the survey identifies that the non-native area has native species within it.

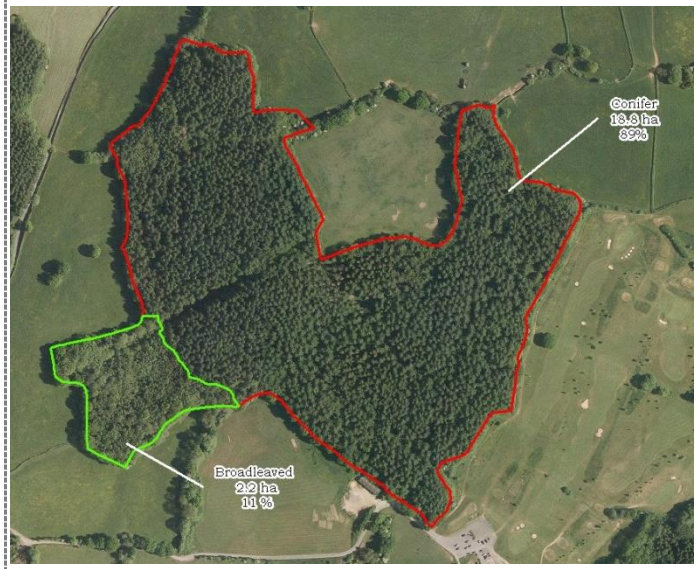
Table 25 Examples of how classifying woodlands into native, other or non-native can change according to whether canopy occupancy is measured at a parcel or stand scale. A relatively constant stand size was chosen to demonstrate how choosing the wrong unit over which to assess % native occupancy can create a non-linear inclusion or exclusion of a relatively fixed unit of 2 ha of native woodland. This stand size was chosen as it is the average distinct native woodland size.

Example	Parcel classification	Stand classification	Comment
100% native tree occupancy 	Native	Native	
 Stand A: 100% native tree occupancy, 52% of woodland parcel area Stand B: 100% non-native tree occupancy, 48% of woodland parcel area	Native	Stand A: native Stand B: non-native	If native occupancy was assessed at the discrete woodland parcel scale, the whole woodland parcel would be included in a native woodland assessment as native occupancy is 52%.

Example	Parcel classification	Stand classification	Comment
Stand A: 100% native tree occupancy, 50% of woodland parcel area Stand B: 100% non-native tree occupancy, 40% of woodland parcel area 	Native	Stand A: native Stand B: non-native	If native occupancy was assessed at the discrete woodland parcel scale, the whole woodland parcel would be included in a native woodland assessment as native occupancy is 50%.

Example	Parcel classification	Stand classification	Comment
Stand A: 100% native tree occupancy, 47% of woodland parcel area Stand B: 100% non-native tree occupancy, 53% of woodland parcel area 	Non-native	Stand A: native Stand B: non-native	The native canopy in the stand north of the brook forms only 47% of the discrete woodland canopy and would therefore by definition be excluded from the assessment of native area if the assessment were made at the discrete woodland parcel level. However, if the assessment were made at the stand level, the area of the stand to the north would be included in the native assessment, as the area is over 0.5 hectares and is 100% native in canopy.

Example	Parcel classification	Stand classification	Comment
Stand A: 100% native tree occupancy, 1.1% of woodland parcel area Stand B: 100% native tree occupancy, 3.1% of woodland parcel area Stand C: 100% native tree occupancy, 1.3% of woodland parcel area Stand D: 100% non-native tree occupancy, 94.5% of woodland parcel area 	Non-native	Stand A: native Stand B: native Stand C: native Stand D: non-native	It has been argued that native woodland areas such as stand A-C should not be included because they sit within a parcel of predominantly young conifers, which may put them at a condition 'disadvantage' as compared to a wholly discreet 2 ha broadleaved woodland stand.

Example		Parcel classification	Stand classification	Comment
	Stand A: 100% native tree occupancy, 11% of woodland parcel area Stand B: 100% non-native tree occupancy, 89% of woodland parcel area	Non-native	Stand A: native Stand B: non-native	Only one side of a square parcel of native woodland is in contact with the conifer element of the discrete woodland parcel.
		Near native?	Near native?	An intimate mixture of natives and non-natives. Photography interpretation has shown this to be mainly broadleaved, but only assessment on the ground could establish if this were above the 50% threshold.

Example	Parcel classification	Stand classification	Comment
	Near native?	Near native?	An intimate mixture of natives and non-natives. Photography interpretation has shown this to be mainly conifer but only assessment on the ground could establish if this were above the 50% threshold.

Appendix A 21 indicators proposed by UKNWHAP group

	Indicator suggested in 2008 and measured in NFI	Final condition Indicators used to produce an NFI WEC Assessment	Comment
Woodland Area	Woodland area by prioirty habitat type	**Toal woodland area by Habitat**	Reported seperately. Not included in the WEC assessment as in most instances an individual stands health is not correlated to the total area of that habitat in Britain
	NVC	**Vegetation and Ground Flora**	Merged into vegetation assessment and included in WEC assessment of stand ecological value
	Woodland loss	**Woodland loss**	Reported seperately. Not included in the WEC assessment as in most instances an individual stands health is not correlated to the total area of that habitat in Britain
Diversity of woodland structure	Number of vertical layers	**Number of vertical storeys**	Merged to one total value and included in WEC assessment of stand ecological condition
	Cover of shrub layer		
	Index of horizontal diversity	**Multiple Indicators**	Accounted for in **Number of native species, open space, the area of woodland that the stand is situated in** and **how unique stands were identifed** and assessed
	Young growth	**Age distribution of trees**	Merged to one total value and included in WEC assessment of stand ecological condition
	Old Growth		
	Volume of Deadwood	**Volume of Deadwood**	Merged to one total value and included in WEC assessment of stand ecological condition
	Woodland Edge	**Proportion of Favourable Land Cover and Open Space**	Included in the WEC assessment as part of both the **Open Space and Favourable Land cover indicators**
	Open Areas	**Open space**	Included in WEC assessment of stand ecological condition as part of **open space** and in part as part of the overall asessment of **age distribution** and number of **unique stands identified**
Regeneration potential	Regeneration present where expected	**Woodland Regeneration**	Primarily formulated into two indicators; **Woodland Regneration at stand level and Woodland Renegeration at square level.** Native or planted factored into these. Naturalness of canopy accounted for in **Occupancy of Native, Age Distribution and Vertical Structure**
	Nativeness of regeneration		
	Naturalness of regen and canopy		
	Level of browsing	**Grazing and herbivore damage**	Included in WEC assessment of stand ecological condition
Tree and shrub composition	Number of tree and shrub species per section (stand)	**No of native species per section (stand)**	Included in WEC assessment of stand ecological condition
	Canopy Cover	**Open Space**	Included in WEC assessment of stand ecological condition as part of the accounting of gaps in the canopy
	Canopy share of native/ non-native species	**Occupancy of native**	Included in WEC assessment of stand ecological condition
	Presence of veteran trees	**Veteran trees**	Included in WEC assessment of stand ecological condition
Quality indicator	Presence of invasive non-native species	**Invasive Plant Species**	Included in WEC assessment of stand ecological condition
	Threats and damages	**Tree Health**	Included in WEC assessment of stand ecological condition

Appendix B NFI WEC working group

Members

- Ben Ditchburn (Forest Research)
- Chris Tucker (Natural Resources Wales)
- Colin Edwards (Scottish Forestry)
- Emma Goldberg (Natural England)
- Fiona McFarlane (Welsh Government)
- Jeanette Hall (Scottish Natural Heritage)
- Neil Riddle (Forestry Commission)
- Rebecca Isted (Forestry Commission)

Other contributors

- Chloe Bellamy (Forest Research)
- David O'Brien (Scottish Natural Heritage)
- Keith Kirby (formally Natural England)
- Laura Henderson (formally Forest Research)
- Penny Steel (Forest Research)
- Tom McKenna (Scottish Natural Heritage)
- Tom Wilson (formally Forest Research)

Appendix C NFI Survey Square Structure

NFI Data Model:

- **Square**
  - **Sections**
    - **Component Group**
      - **Components**

The land below stratified by the NFI Data Model =

- One Square
  - Two Sections
    - Two Component Groups
      - Four tree components
      - One open component

Each section represents a homogenous strata of unique habitat. Sections must be greater than 0.05 ha within the square and are physically mapped in GIS. Sections are also referred to as 'patches' of woodland.

Component groups (CG) also represent a homogenous strata of unique habitat and are equal to sections with the exception that they are too small to map within GIS. They cannot exceed 0.05 ha within the square. They are also referred to as 'patches' of woodland.

Sections and component groups are stratified into components. Components represent individual elements or 'parts' of land cover within the section or CG. In woodland they are characterised by trees of different species, height and age intimately mixed within the same area. Each component is assessed individually for tree health, browsing, etc.

Sum of % component areas within a section / CG must = 100%

Each Storey must = 100% of the section / CG – 2 storeys = 200%, 3, 300% etc

Relevant Adjacent Stand. To discriminate between native, 'near native' and non native woodland, the total area of any patch of native woodland habitat both inside and outside of the square must be assessed (if contiguous).

Section 1 – 0.26 ha
1 component - 100% open

Section 2 – 0.74 ha
2 component groups (CG)
Component group 1

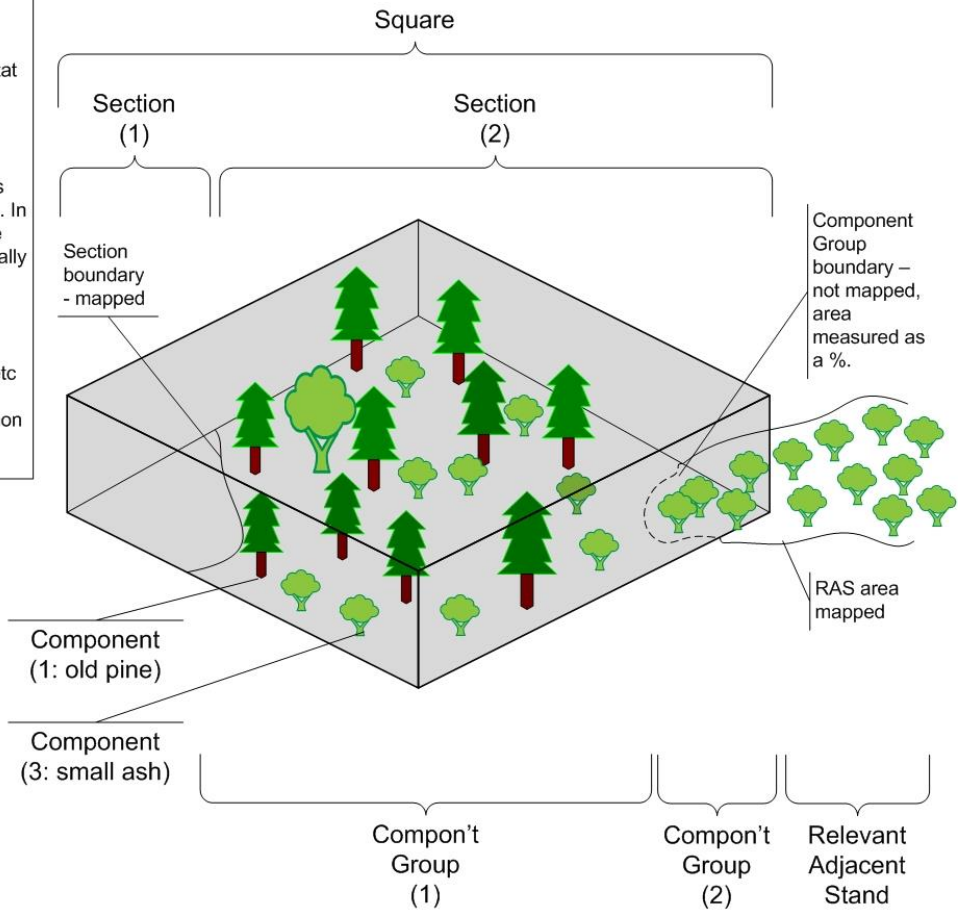
Component 1: upper storey, large pine - 90 % of area / storey

Component 2 upper storey large ash – 5 % of area / storey

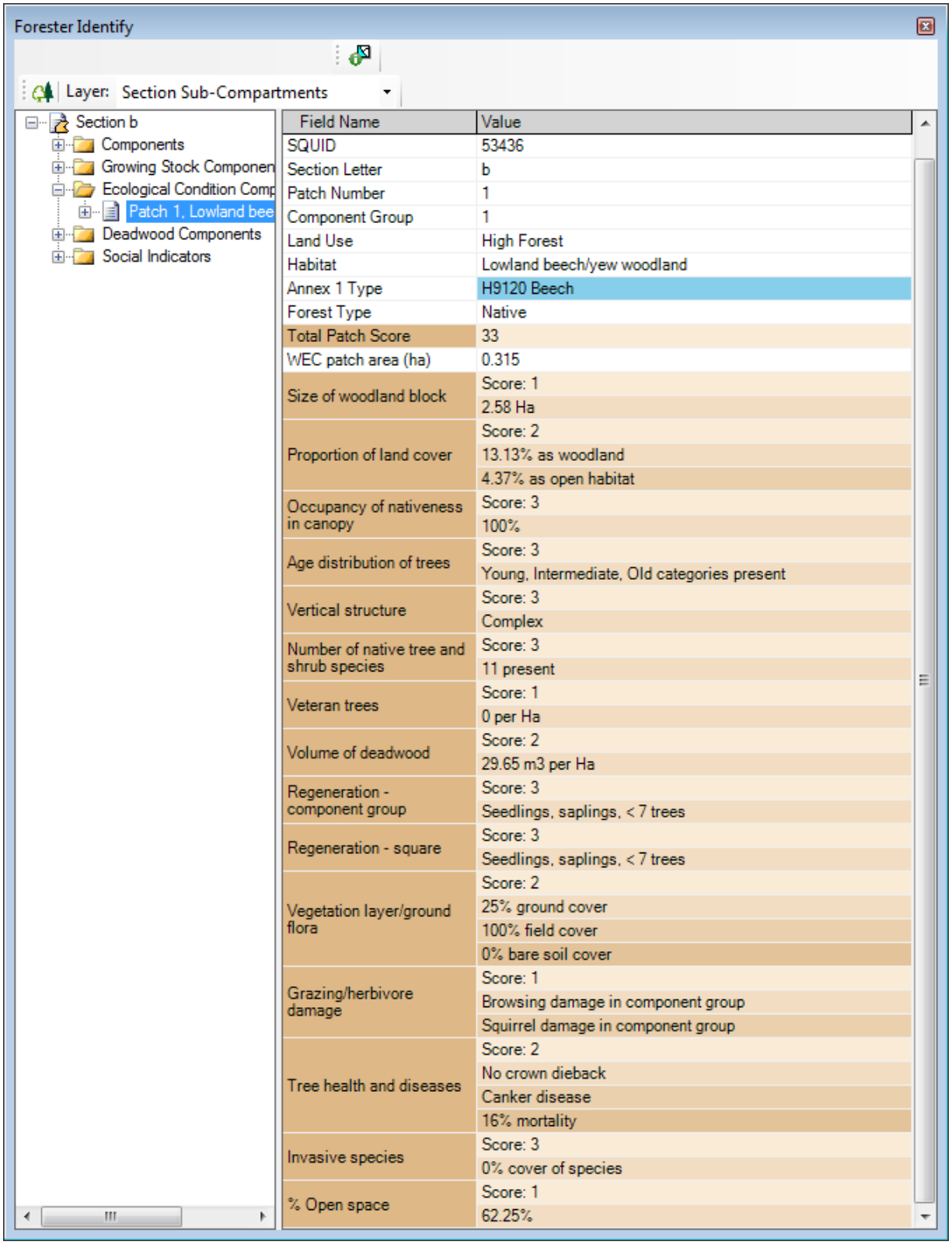
Component 3 lower storey small ash - 95% of area

Component group 2

Component 1 – upper story young Ash, 5% of section, 100% of CG area



Appendix D Condition Calculator Result example



Field Name	Value
SQUID	53436
Section Letter	b
Patch Number	1
Component Group	1
Land Use	High Forest
Habitat	Lowland beech/yew woodland
Annex 1 Type	H9120 Beech
Forest Type	Native
Total Patch Score	33
WEC patch area (ha)	0.315
Size of woodland block	Score: 1
	2.58 Ha
Proportion of land cover	Score: 2
	13.13% as woodland
	4.37% as open habitat
Occupancy of nativeness in canopy	Score: 3
	100%
Age distribution of trees	Score: 3
	Young, Intermediate, Old categories present
Vertical structure	Score: 3
	Complex
Number of native tree and shrub species	Score: 3
	11 present
Veteran trees	Score: 1
	0 per Ha
Volume of deadwood	Score: 2
	29.65 m3 per Ha
Regeneration - component group	Score: 3
	Seedlings, saplings, < 7 trees
Regeneration - square	Score: 3
	Seedlings, saplings, < 7 trees
Vegetation layer/ground flora	Score: 2
	25% ground cover
	100% field cover
	0% bare soil cover
Grazing/herbivore damage	Score: 1
	Browsing damage in component group
	Squirrel damage in component group
Tree health and diseases	Score: 2
	No crown dieback
	Canker disease
	16% mortality
Invasive species	Score: 3
	0% cover of species
% Open space	Score: 1
	62.25%

Appendix E Habitat types and open space quality rating

Habitat type	Open habitat?	Quality rating for open space
Unknown	Check land use	N/A
Surveyed: unknown habitat	Check land use	N/A
Not surveyed	Check land use	N/A
Broadleaved;mixed/yew woodlands	Check land use	High
Coniferous woodlands	Check land use	High
Lowland beech/yew woodlands	Check land use	High
Lowland mixed deciduous woodland	Check land use	High
Native pine woodlands	Check land use	High
Non-hap native pine	Check land use	High
Upland birchwoods	Check land use	High
Upland mixed ashwoods	Check land use	High
Upland oakwoods	Check land use	High
Wet woodland	Check land use	High
Woodpasture & parkland	Check land use	High
Arable/horticulture	Yes	Low
Built up areas & gardens	Yes	Low
Improved grassland	Yes	Low
Neutral grassland	Yes	High
Urban	Yes	Low
Bogs	Yes	High
Boundary & linear features	Yes	High
Bracken	Yes	High
Calcareous grassland	Yes	High
Continental shelf slope	Yes	High
Dwarf shrub heath	Yes	High
Fen; marsh/swamp	Yes	High
Inland rock	Yes	High
Inshore sublittoral rock	Yes	High
Inshore sublittoral sediment	Yes	High
Littoral rock	Yes	High
Littoral sediment	Yes	High
Montane habitats	Yes	High
Oceanic seas	Yes	High
Offshore shelf rock	Yes	High
Offshore shelf sediment	Yes	High
Rivers & streams	Yes	High

Habitat type	Open habitat?	Quality rating for open space
Standing open water/canals	Yes	High
Supralittoral rock	Yes	High
Supralittoral sediment	Yes	High
Aquifer fed naturally fluctuating water	Yes	High
Arable field margins	Yes	High
Blanket bog	Yes	High
Blue mussel beds on sediment	Yes	High
Calaminarian grasslands	Yes	High
Carbonate mounds	Yes	High
Coastal & floodplain grazing marsh	Yes	High
Coastal saltmarsh	Yes	High
Coastal sand dunes	Yes	High
Coastal vegetated shingle	Yes	High
Cold-water coral reefs	Yes	High
Deep sea sponge communities	Yes	High
Estuarine rocky habitats	Yes	High
Eutrophic standing waters	Yes	High
File shell beds	Yes	High
Fragile sponge and anthozoan communities on subtidal rocky habitats	Yes	High
Hedgerows	Yes	High
Horse mussel beds	Yes	High
Inland rock outcrop and scree habitats	Yes	High
Intertidal chalk	Yes	High
Intertidal mudflats	Yes	High
Intertidal underboulder communities	Yes	High
Limestone pavements	Yes	High
Lowland calcareous grassland	Yes	High
Lowland dry acid grassland	Yes	High
Lowland fens	Yes	High
Lowland heathland	Yes	High
Lowland meadows	Yes	High
Lowland raised bog	Yes	High
Machair	Yes	High
Maerl beds	Yes	High
Maritime cliff/slopes	Yes	High
Mesotrophic lakes	Yes	High
Mountain heaths & willow scrubs	Yes	High
Mud habitats in deep water	Yes	High

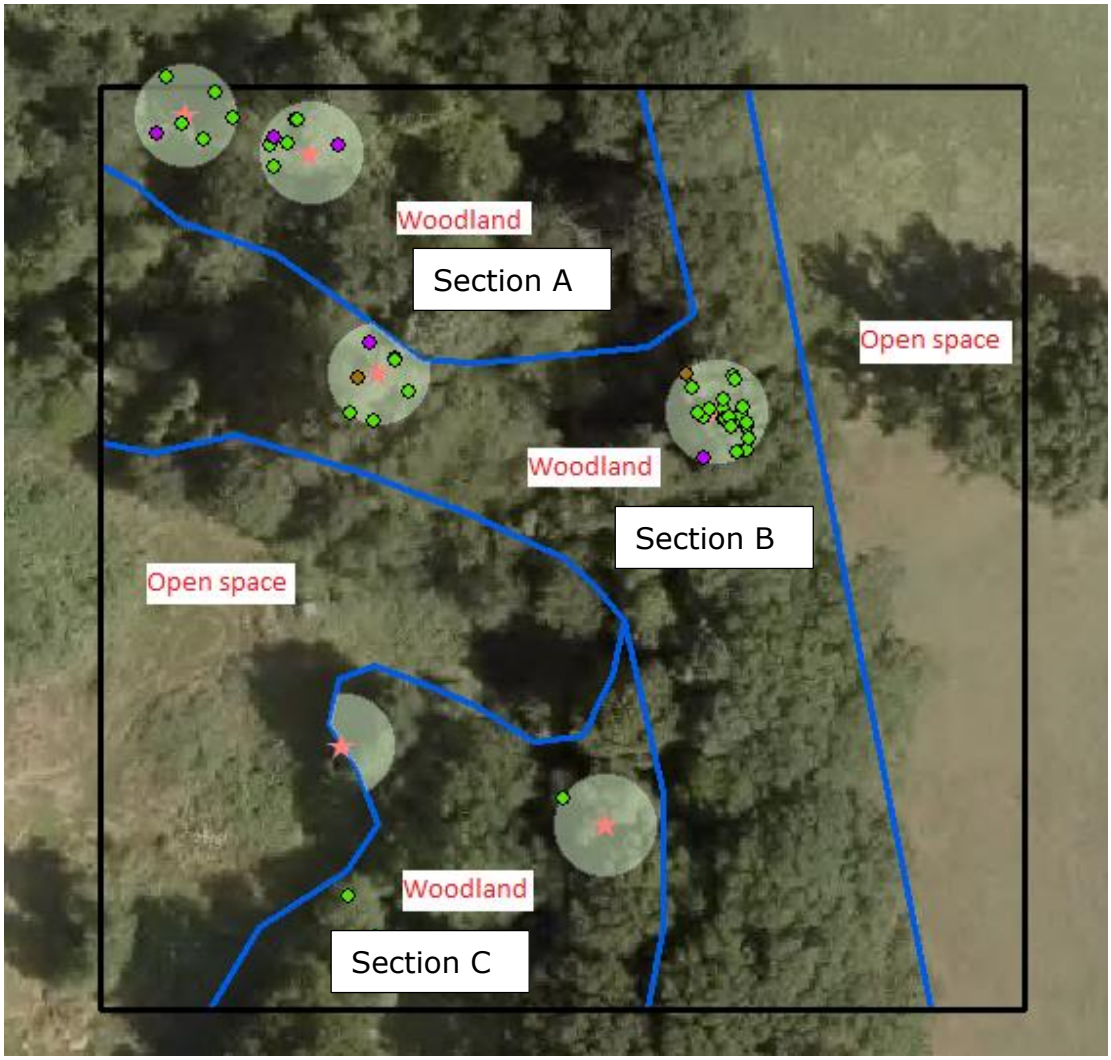
Habitat type	Open habitat?	Quality rating for open space
Oligotrophic and dystrophic lakes	Yes	High
Open mosaic habitats on previously developed land	Yes	High
Peat & clay exposures with piddocks	Yes	High
Ponds	Yes	High
Purple moor grass/rush pastures	Yes	High
Reedbeds	Yes	High
Rivers	Yes	High
Sabellaria alveolata reefs	Yes	High
Sabellaria spinulosa reefs	Yes	High
Saline lagoons	Yes	High
Seagrass beds	Yes	High
Seamount communities	Yes	High
Serpulid reefs	Yes	High
Sheltered muddy gravels	Yes	High
Sublittoral sands/gravels	Yes	High
Tide swept channels	Yes	High
Traditional orchards	Yes	High
Upland calcareous grassland	Yes	High
Upland flushes, fens & swamps	Yes	High
Upland hay meadows	Yes	High
Upland heathland	Yes	High

Appendix F Land use and open space quality rating

Land use (Green = woodland)	Quality Rating for open space
High Forest PHF	High (if clear-fell or young trees)
Agricultural land AGR	Low
Open OPN	High
Ancient and Ornamental NAO	High (if clear-fell or young trees)
Arboreta NAR	High (if clear-fell or young trees)
Archaeological sites MAS	High
Burnt PBU	High
Cabins / Holiday House CRH	Low
Campsite CRC	Low
Car Parks/Picnic Areas FRC	Low
Christmas Trees FMC	Low (if clear-fell or young trees)
Deer glades FMD	High
Failed PFA	High
Felled PFE	High
Information Centre FRE	Low
Linear feature & open space assoc. linear feature LIF	High
Mineral Working EMM	Low
Non-plantation research FMR	Low
Nursery FMN	Low
Open Water MOW	High
Other Built Facility EMO	Low
Other Recreation FRO	Low
Partially Intruded Broadleaf PIB	High (if clear-fell or young trees)
Perm. Open Space assoc. with Linear Feat. POS	High
Plantable land LHP	Low
Quarries FMQ	Low
Research Plantation PRP	High (if clear-fell or young trees)
Residential EMR	Low
Seed Orchard FMS	High (if clear-fell or young trees)
Seed Stand PSS	High (if clear-fell or young trees)
Unplantable or bare UNP	High
Unplanted streamsides FMW	High
Windblow - Alive WBA	High (if clear-fell or young trees)
Windblow - Dead WBD	High (if clear-fell or young trees)
Worked Coppice PWC	High (if clear-fell or young trees)

Appendix G Method for adjacent open space assessment

1. The NFI WEC calculator first classifies sections into woodland or open space using their habitat, land use and tree planting age data. In the example below, woodland Section A does not have open space directly adjacent to it. Section B has open space adjacent to both its western and eastern boundaries, and Section C has open space available to its western boundary only. Section B and Section C share their open space to the west. The WEC calculator accounts for this through first calculating which space is available to the woodland stands and then allocating the open space proportionally to each stand where appropriate.



2. The woodland sections in the square are combined in the calculator and a 50 m buffer is created.
3. The area of the 50 m buffer (green, purple and blue) comprises open space outside of the woodland sections **and** falling within the survey square boundary. For analysis purposes, this open space buffer is converted to a 1 m^2 point grid (green, purple and blue points).
4. The 1 m^2 open space points are allocated to the nearest woodland section (or woodland outside the square). Each 1 m^2 of open space area can only be allocated to one woodland section to avoid double counting. In this way, the green open space points are allocated to Section B and purple to Section C.
5. The NFI Woodland Map is used to represent and account for the existence of woodland outside of the survey square boundary. If woodland outside of the square boundary is nearer to a given 1 m^2 of open space than the woodland sections within the square, then the 1 m^2 is not allocated to a woodland section. This is represented by the blue open space points.

Appendix H Rules for vegetation & ground flora indicator overall score

F = Favourable, I = Intermediate, U = Unfavourable. (Grey = Not currently a possible combination)

Group 1 (W13, W14, W15)				Group 2 (W9, W11, W16, W17, W18, W19, W20, W21, W22, N/A)				Group 3 (W8, W10, W12)				Group 4 (W1, W2, W3, W4, W5, W6, W7, W18 bog)			
Field layer	Ground layer	Bare soil	Overall Score	Field layer	Ground layer	Bare soil	Overall Score	Field layer	Ground layer	Bare soil	Overall Score	Field layer	Ground layer	Bare soil	Overall Score
F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
F	F	I	F	F	F	I	F	F	F	I	F	F	F	I	F
F	F	U	U	F	F	U	U	F	F	U	U	F	F	U	U
F	I	F	I	F	I	F	I	F	I	F	F	F	I	F	F
F	I	I	I	F	I	I	I	F	I	I	F	F	I	I	F
F	I	U	U	F	I	U	U	F	I	U	U	F	I	U	U
F	U	F	I	F	U	F	I	F	U	F	I	F	U	F	I
F	U	I	I	F	U	I	I	F	U	I	I	F	U	I	I
F	U	U	U	F	U	U	U	F	U	U	U	F	U	U	U
I	F	F	F	I	F	F	F	I	F	F	F	I	F	F	I
I	F	I	F	I	F	I	F	I	F	I	F	I	F	I	I
I	F	U	U	I	F	U	U	I	F	U	U	I	F	U	U
I	I	F	I	I	I	F	I	I	I	F	I	I	I	F	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	U	U	I	I	U	U	I	I	U	U	I	I	U	U
I	U	F	I	I	U	F	I	I	U	F	I	I	U	F	I
I	U	I	I	I	U	I	I	I	U	I	I	I	U	I	I
I	U	U	U	I	U	U	U	I	U	U	U	I	U	U	U
U	F	F	I	U	F	F	I	U	F	F	I	U	F	F	I
U	F	I	I	U	F	I	I	U	F	I	I	U	F	I	I
U	F	U	U	U	F	U	U	U	F	U	U	U	F	U	U
U	I	F	I	U	I	F	I	U	I	F	I	U	I	F	I
U	I	I	I	U	I	I	I	U	I	I	I	U	I	I	I
U	I	U	U	U	I	U	U	U	I	U	U	U	I	U	U
U	U	F	U	U	U	F	U	U	U	F	U	U	U	F	U
U	U	I	U	U	U	I	U	U	U	I	U	U	U	I	U
U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U

Glossary

Word/phrase	Definition
Age class	A grouping of trees into specific age ranges for classification purposes. For the purposes of the "age distribution of trees" NFI WEC indicator, trees are grouped into three age classes: 0 – 20 years (Young); 21 - 150 years (Intermediate); >150 years (Old). For birch, cherry or Sorbus species: 0 - 20 years (Young); 21 - 60 years (Intermediate) >60 years (Old). Not applicable is used for stands without trees.
Ancient semi-natural woodland (ASNW)	Woodland which has been in continuous existence since 1600 (1750 in Scotland).
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).
Bark stripping	The removal of bark from trees by herbivores.
Biodiversity	Biodiversity represents 'all heritability-based variation at all levels of organisation, from the genes within a single local population, to the species composing all or part of a local community, and finally to the communities themselves that compose the living parts of the multifarious ecosystems of the world' (Wilson, 1997, p.1)
Broadleaves	Trees and shrubs that belong to the angiosperms (flowering plants) (as distinct from the gymnosperms that includes conifers). Most in the UK are deciduous and have laminar leaves (they do not have needles or cones) and a few, such as alder, have cone-like structures for their seeds which are not true cones. Sometimes referred to as 'hardwoods'.
Browsing	Herbivores feeding on tree buds, shoots and foliage.
Canopy	The mass of foliage and branches formed collectively by the crowns of trees.
Canopy cover	The percentage cover of the canopy across a defined area (e.g. NFI survey section or square).
Clear-felling	Cutting down of an area of woodland (if it is within a larger area of woodland it is typically a felling greater than 0.25 hectare). Sometimes a scatter or small clumps of trees may be left standing within the felled area.
Common Standards Monitoring (CSM)	The CSM approach was established during the 1990s by UK conservation agencies to describe the condition of protected sites, such as Sites of Special Scientific Interest (SSSI), in order to assess the effectiveness of conservation policies and practice.
Component (or sub-component)	Individual elements of the NFI survey component group. For example, each tree species will be recorded under a separate component, as will each habitat type if two habitats are intimately mixed (such as upland birchwood and wet woodland).
Component group	Homogeneous areas of the NFI survey that are too small (<0.05 ha) to practically map using Geographic Information System (GIS) software in the field, but with most of the same defining characteristics as a section. Component groups can be subdivided into components.
Condition	Shorthand for Woodland Ecological Condition.

Word/phrase	Definition
Conifers	Trees and shrubs that belong to the gymnosperms, as distinct from the angiosperms that include broadleaves). Conifers mostly have needles or scale-like leaves and are usually evergreen. Sometimes referred to as 'softwoods'.
Convention on Biological Diversity (CBD)	A multilateral treaty to develop national strategies for the conservation and sustainable use of biological diversity.
Crown dieback	The death of branches within a tree's crown.
Deadwood	Non-living woody biomass not contained in the litter, either standing or lying on the ground (the NFI 'volume of deadwood' indicator does not include data on stumps).
Diameter at breast height (DBH)	The diameter on the stem of a tree at 'breast height', defined as 1.3 m from ground level.
Drip line	The drip line is the furthest tip of the widest branch in the crown; the last point from which the tree can drip if wet. If two treed sections have drip lines that cross over each other use the centre line of the cross over.
Earth observation	The collection of information about the physical, chemical, and biological systems of the planet via remote-sensing technologies.
Ecology	The relations of organisms to one another and to their physical surroundings.
Establishment	The formative period that ends once young trees are of sufficient size that, given adequate protection, they are likely to survive at the required stocking. This varies for species and according to environmental condition, but is typically from around five to twenty years.
EU Habitats Directive	The EU Habitats Directive (Directive 92/43/EEC) aims to promote the maintenance of biodiversity by requiring Member States to take measures to maintain or restore natural habitats and wild species listed on its Annexes to a favourable conservation status (JNCC, 2018).
(Vegetation) field layer	Vegetation 10 cm to 2 m tall measured as part of the NFI vegetation assessment.
Flora	The plants of a particular region, habitat, or geological period.
Forest (or woodland)	See woodland
Forestry Commission (FC)	The government department responsible for regulating forestry, implementing forestry policy and managing state forests in England. It was formerly also responsible for Forestry in Wales and Scotland, however on 1 April 2013 the Forestry Commission's functions in Wales transferred to a new organisation, Natural Resources Wales. From 1 April 2019, forestry was fully devolved, except for common issues addressed on a GB or UK basis, such as international forestry, plant health and forestry standards. Following devolution, two new Scottish Government agencies were created, Scottish Forestry and Forest & Land Scotland.
Forestry and Land Scotland (FLS)	The Scottish Government agency responsible for managing Scotland's national forests and land.
Fragments	Small areas of woodland with 50% or more native tree species occupancy in the upper canopy, but that fall in the size range 0.05 ha to 0.099 ha.

Word/phrase	Definition
Geographic Information System (GIS)	A system designed to capture, store, manipulate, analyse, manage, and present spatial or geographic data.
Global Positioning System (GPS)	A satellite-based global navigation satellite system that provides geolocation and time information to a GPS receiver.
Great Britain (GB)	England, Scotland and Wales.
(Vegetation) ground layer	Vegetation 0 – 10 cm tall measured as part of the NFI vegetation assessment.
Habitat Action Plan (HAP)	For all UK BAP priority habitats classified between 1995 and 1999, a Habitat Action Plan (HAP) was created (45 in total). For the habitats added to the priority habitats list in 2007, no UK action plans have been, or will be, produced, as conservation action is now primarily carried out at a country-level, rather than a UK-level, in response to the generation of country-level biodiversity strategies and aims (JNCC, 2019a).
Herbivore	An animal that is adapted to eating plant material for the main component of its diet.
Hectare (ha)	Unit of area defined as 10,000 square metres (100 m by 100 m), approximately equivalent to 2.47 acres.
Indicator	A quantitative or qualitative parameter that synthesises complex information and can be periodically measured to assess trends over time. 15 stand level indicators were selected to assess the condition of woodlands as part of the NFI WEC approach.
Invasive species	A species that is not native to a location, where it is likely to cause ecological or economic harm.
Invertebrate	A cold-blooded animal that does not have a backbone.
Lichen	A composite organism that arises from algae or cyanobacteria living among filaments of multiple fungi species in a mutualistic relationship.
National Forest Inventory (NFI)	National forest inventories are carried out in GB by the FC to provide accurate, up-to-date information about the size, distribution, composition and condition of the forests and woodlands. The current NFI, which began in 2009, is a multi-purpose operation that has involved the production of a forest and woodland map for GB and a continuing programme of field surveys of the mapped forest and woodland areas.
National Forest Inventory map	An earth observation-based programme that monitors and maps the extent and location of woodlands across GB on an annual basis.
National Forest Inventory field survey	A field survey of a large, stratified-random sample (15,100 sites) of woodlands across GB on a 5-year rolling cycle using a standardised protocol.
Native species	Species that have arrived and inhabited an area naturally, without deliberate assistance by man. For trees and shrubs in the United Kingdom usually taken to mean those present after post-glacial re-colonisation (around 11,000 years ago) and before historic times. Some species are only native in particular regions - hence locally native.
Natural England (NE)	The government's adviser for the natural environment in England. Natural England is an executive non-departmental public body, sponsored by Defra.
Naturalised species	A species that, once it is introduced outside its native distributional range, establishes self-sustaining populations.

Word/phrase	Definition
Natural Resources Wales (NRW)	The organisation responsible for advising the Welsh Government on the environment, created on 1 April 2013. NRW is responsible for the functions previously carried out by the Environment Agency in Wales, the Countryside Council for Wales and Forestry Commission Wales.
National Vegetation Classification (NVC)	Vegetation classification system commonly used in Great Britain.
Native woodland	Woodland with 50% or more native tree species occupancy in the upper canopy that either: - Forms a discrete woodland parcel with a minimum area of 0.5 ha. - Forms a woodland stand with a minimum area of 0.1 ha that is part of a woodland that is 0.5 ha or larger.
Native Woodland Survey of Scotland (NWSS)	A survey of all native woodlands, nearly native woodlands and non-native plantations on ancient woodland sites in Scotland.
Near native woodland	'Nearly' native woodland with 40% to 49% native species canopy cover.
NFI Condition Calculator	An analytical GIS tool developed to automatically produces the component group-level NFI WEC indicator results per woodland type and aggregated statistics for the reporting area.
NFI WEC working group	The expert committee that was established to develop the NFI WEC indicator approach. This group consists of representatives from (former) FC England and Scotland, Scottish Natural Heritage, Natural England, Natural Resources Wales and the Welsh Government.
Non-native woodland	Woodland with less than 40% native species occupancy.
(Woodland) parcel	Discrete blocks of woodland that are separated from other woodland parcels by gaps of at least 20 m in length.
Private sector estate	Forests and woodlands in the UK not managed by the Forestry Commission, Natural Resources Wales or Forest Service. In the context of the National Forest Inventory, 'Private sector' is used for convenience although it includes land owned or managed by bodies such as local authorities and charities.
(Natural) Regeneration	The regeneration of existing woodland by natural means, i.e. without sowing or planting.
(Ecological) resilience	The ecological resilience of woodland ecosystems refers to their ability to absorb disturbance while maintaining the major habitat-forming species that define their structure and ecosystem functioning. Resilience incorporates both the woodland ecosystem's ability to resist changes in response to disturbance or, failing this, its capacity to recover functioning via adaptation.
(NFI) sample square	The one-hectare (100 m by 100 m) square plots, which may be entirely within woodland or may overlap the woodland edge, used for the NFI field survey.
Sapling	Young tree ≥50 cm tall and <4 cm in diameter.
Saproxylic	Dependent on deadwood.
(NFI WEC) score	An ordinal score is assigned to the individual indicator classes of 'unfavourable' (1), 'intermediate' (2) and 'favourable' (3). The scores are summed for all 15 indicators to provide each stand's overall ecological condition score, which has a maximum value of 45.
Scottish Natural Heritage (SNH)	The public body responsible for protecting and promoting Scotland's natural heritage, especially its natural, genetic and scenic diversity. To be renamed 'NatureScot' from May 2020.

Word/phrase	Definition
Section	Within each NFI sample square, the forest was stratified into different woodland 'sections'. Sections are defined by individual strata at least 0.05 ha in size that are differentiated on basis of forest type, habitat, land use, silviculture system, tree and shrub composition, age and structure.
Seedling	Young tree <50 cm tall.
Shrub	Woody plants often (but not always) branching abundantly from the base that are between 2-5 m tall.
(Vegetation) shrub layer	Vegetation 2-5 m tall measured as part of the NFI vegetation assessment.
Site of Special Scientific Interest (SSSI)	A formal conservation designation that is applied to areas of particular interest to science because of the geology/geomorphology features or species it contains or supports.
(Woodland) Stand	A distinct area of woodland (from either planting or natural regeneration), 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). In this report, any standard error greater than 25% is reported in amber italics and represents a lower degree of assurance in the estimates.
Stocking	The density of trees within a woodland.
Stump	The above-ground base part of a tree that would usually remain after felling.
Transect	A path along which a survey is carried out.
Transition woodland	Land classified as woodland area that is in transition between no tree cover and tree cover. Examples include clear-fell sites, restock sites, new planting sites and land with natural regeneration.
UK Biodiversity Action Plan (UK BAP)	The UK government's national biodiversity action plan that was developed in response to the Convention on Biological Diversity and replaced by the 'UK Post-2010 Biodiversity Framework' in 2012 following new international targets. It described the biological resources of the UK and provided detailed plans for conservation of these resources (JNCC, 2019a). The UK BAP priority habitats were identified as the most threatened habitats requiring conservation action under the UK BAP.
UK Forestry Standard (UKFS)	The reference standard for sustainable forest management across the UK that applies to all woodland to ensure that international agreements and conventions on areas such as sustainable forest management, climate change, biodiversity and the protection of water resources are applied in the UK.
United Kingdom (UK)	Great Britain and Northern Ireland.
Woodland (or forest)	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).

Word/phrase	Definition
(NFI) Woodland Ecological Condition (WEC)	The approach used by the NFI to assess the ecological condition of woodlands in GB in terms of their likely biodiversity value.
(Woodland) storey	A woodland's trees and shrubs can often be stratified into distinct layers, or storeys, according to their height.
Vertical (woodland) structure	The number of canopy storeys present.
Veteran trees	A tree that is of interest biologically, culturally or aesthetically because of its age, size or condition (Read, 2000)

NFI national reports

This inventory report is one of a series of publications reporting the outputs of the Forestry Commission National Forest Inventory.

These and NFI data can be found on the NFI website: www.forestresearch.gov.uk/inventory.

Authors

B. Ditchburn, C. Bellamy, T. Wilson, P. Steel, L. Henderson and K. Kirkby

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Survey design

B. Ditchburn and A. Brewer

Publication support

D. Ross, L. Halsall, W. Peden, H Stephenson and V. Burton

Reviewers

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