**Protecting Oak Ecosystems.**
**Case studies on managing oak woodlands to maximize support for oak associated biodiversity.**

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Contents

## 1 Introduction

Oaks are iconic trees in Britain, there are two native species: penduncalate oak (*Quercus robur*) and sessile oak (*Q. petraea*). Over recent decades there has been a slow decline in oak health in some parts of the UK. Various diseases and pests/pathogens affecting oak have been recognised, these include Acute Oak Decline, Chronic Oak Decline, Oak Processionary Moth and a variety of powdery mildews. In some locations in the UK high levels of oak tree mortality have been reported but more typically the oak pests/pathogens within the UK cause a decline in the health of the tree rather than imminent death. However, a slow decline in health over many decades will have a cumulative impact on oak tree survival and changes in climate may also decrease oak survival rates.

Oak trees are important for biodiversity; in the UK there are at least 2300 species that use oak (oak-associated species). If oak trees decline in abundance this could have consequences for species conservation and impacts on woodland ecosystem health. Deciding how to manage oak woodlands to maximize oak associated biodiversity is an important conservation issue.

Here we document the methods applied to select and assess 30 case study sites across Britain for their biodiversity value, and to develop management recommendations to maintain oak-associated biodiversity based on current woodland conditions and the predicted change in oak health.

## 2 The sites

The sites were selected to be representative of oak dominated woodlands across the Britain, where conservation of biodiversity is a management priority. Sites are therefore primarily, but not always, nature reserves or SSSIs for which objectives and management plans have been developed, and for which records of species supported by the woodland, are available.

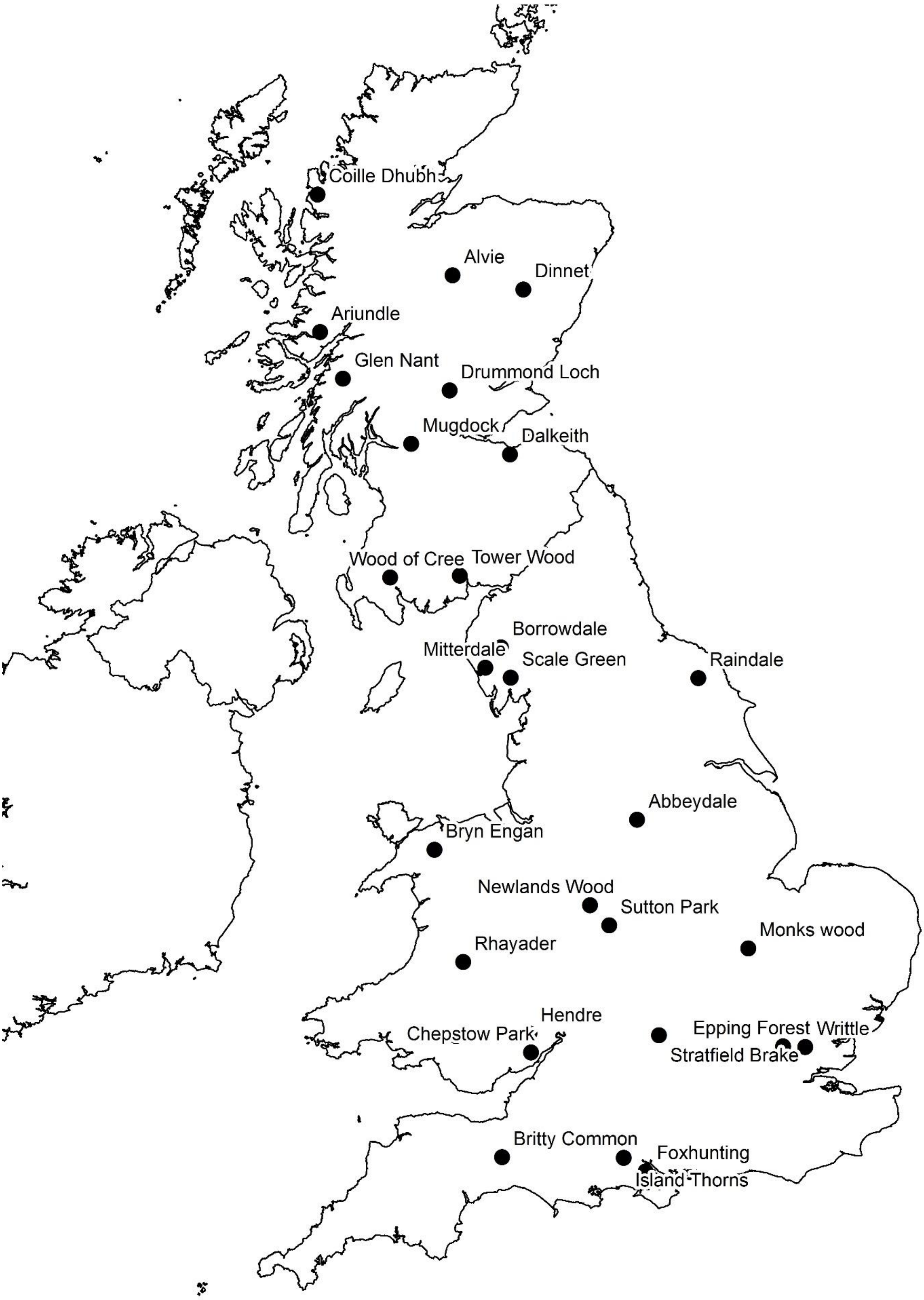


Fig. 1 Location of case study sites

## 3 Method

### 3.1 Site visit

Each site was visited in summer 2017/2018 with the aim of establishing:

- The current tree canopy composition
- The current dominance of the oak: % of oak in canopy and size of oak trees
- Current levels of regeneration of seedlings and saplings of all tree species
- A brief description of the site, its location and ground flora
- Any factors that would inhibit or influence woodland management such as grazing or lack of access

### 3.2 Identification of current management

Current and past management were identified by consulting SSSI citations and current management plans available on the web or provided directly by land managers/owners.

### 3.3 The potential change in oak

Change in site suitability for oak due to changes in climate are predicted for 2050 using climate EU climate projections. We use 2050's and 2080's projections as analogue climates for now and 2050s, respectively. This is on the basis that extreme weather events experienced in the last two decades are resulting in temperature and precipitation levels that equal the average values for the projected 2050 climate. The projected climate variables are used in the Ecological Site Classification models[1] along with the case study site's soil type to assess the impact on oak growth. Following a rule set, the predicted decline in oak health and oak productivity are extracted for each case study site location.

### 3.4 Biodiversity present

A species list for the site was obtained based on data from the NBN Atlas https://nbnatlas.org/. For most SSSIs the site boundary was defined within the atlas and there were a large number of species records making it possible to obtain a species list for the site. For other sites, particularly non-SSSIs there were very few records from the site and a search for all species records within 5km of the centre of the site was conducted. Species lists from the NBN were added to other species lists available in site documentation.

### 3.5 Identification of those species at risk from decline in oak

Species associated with oak trees were identified by comparing the species found at the site with a list of 2300 oak associated species in the OakEcol database. OakEcol is an Microsoft Excel file of 2300 oak-associated species and their level of association with oak; it is available at: https://www.hutton.ac.uk/oak-decline

Some species are only found on oak trees, called obligate species while others are found on a wider variety of tree species, how tightly associated with oak a species is, is termed its level of association, see definitions in Table 1.

[1] Site suitability (climate and soils) for different tree species was based on: Pyatt DG, Ray D, Fletcher J. 2001. An ecological site classification for forestry in Great Britain: Bulletin 124. Edinburgh: Forestry Commission

Table 1. Levels of association with oak and definitions.

| Level of association with oak | Definition |
|---|---|
| Obligate | unknown from other tree species. |
| High | rarely uses other tree species |
| Partial | uses oak more frequently than its availability |
| Uses | uses oak but the importance of oak for this species is unknown |
| Cosmopolitan | uses oak as frequently or lower than availability |

For obligate species the only way to increase/maintain their abundance is to increase/maintain the abundance of oak in the woodland; these species will be lost from the site if oak is lost. For the other species it may be possible to maintain their presence by providing other host tree species in addition to oak. High and partially associated species would receive the greatest benefit from the addition of other host tree species.

### 3.6 Identification of suitable silvicultural practices to promote oak abundance/health

As the analysis described in section 3.3 did not predict a major decline in oak at many of the case study sites the majority of the management recommendations focussed on ensuring oak survival into the future. These management recommendations included:

- Thinning of the overstorey to reduce competition between trees, particularly for water.
- Ground scarification to reduce competition from ground flora and establish a suitable seed bed for natural regeneration.
- Creating canopy gaps to allow enough light for natural regeneration
- Reducing grazing to enable natural regeneration to survive
- Control of vigorous ground vegetation that would compete with young oak seedlings and saplings
- Growing on locally sourced oak seed and planting out as oak seedlings/saplings

Other management recommendations included techniques to increase the tree species diversity of the wood, particularly where the wood was artificially high in oak. This often included increasing the proportion of minor species that would support oak-associated biodiversity which were already present on the site, and sometimes included introduction of other appropriate species to the site.

*For all case studies it is stressed that a) care must be taken to ensure that none of the operations planned have a negative impact on the protected or rare species present and b) the management recommendations set out in the case study scenarios do not constitute consent for any operations, which would be required from the relevant statutory nature body. In addition, it should be noted that the recommendations set out in these case studies are designed to maximise oak-associated biodiversity; other management objectives are not considered and may be equally important.*

### 3.7 Identification of other beneficial host tree species

Although a significant loss of oak is not currently predicted at many of the case study sites, this could occur with a combination of climate change and current or future diseases. If this were the case it may be desirable to encourage a greater diversity of other beneficial tree species to support oak-associated biodiversity. As the greatest diversity of oak-associated species is supported by mature and veteran trees it is important to start managing woods for the long-term and thinking now about tree species composition and age structure for 200 years time.

We have identified 30 tree species (Table 2) which could be used to diversify woodlands; these were selected as they are either currently already found in oak woods and therefore might expand to fill canopy gaps created by the loss of oak or are known to grow on site types that support oak. In particular shrubs, such as hazel may support some of the oak associated biodiversity but these are not included in our list of 30 tree species.

For each of the 2300 oak-associated species we have tried to find out if they will or will not use each of 30 other tree species. This information has been collated in the OakEcol spreadsheet (Fig. 2).

Table 2. The 30 tree species were which were assessed as to whether the oak associated species would or would not use them.

| Latin name | English name |
|---|---|
| *Acer campestre* | Field Maple |
| *Acer pseudoplatanus* | Sycamore |
| *Alnus glutinosa* | Alder |
| *Betula pendula* | Silver Birch |
| *Betula pubescens* | Downy Birch |
| *Carpinus betulus* | Hornbeam |
| *Castanea sativa* | Sweet Chestnut |
| *Fagus sylvatica* | Beech |
| *Fraxinus excelsior* | Common Ash |
| *Ilex aquifolium* | Holly |
| *Larix spp* | Larch |
| *Malus sylvestris* | Crab Apple |
| *Picea abies* | Norway Spruce |
| *Pinus nigra ssp. laricio* | Corsican Pine |
| *Pinus sylvestris* | Scots Pine |
| *Populus tremula* | Aspen |
| *Prunus avium* | Wild Cherry |
| *Pseudotsuga menziesii* | Douglas fir |
| *Quercus cerris* | Turkey oak |
| *Quercus rubra* | Red Oak |
| *Sorbus aria* | Whitebeam |
| *Sorbus aucuparia* | Rowan |
| *Sorbus torminalis* | Wild service tree |
| *Taxus baccata* | Yew |
| *Thuja plicata* | Western red cedar |
| *Tilia cordata* | Small leaved lime |
| *Tilia platyphyllos* | Large leaved lime |
| *Tilia vulgaris* | Hybrid T. cordata × T. platyphyllos |
| *Tsuga heterophylla* | Western hemlock |
| *Ulmus glabra* | Wych elm |

For the highly associated and partially associated oak-species present at each case study site we identified which other tree species they would also use in addition to oak using the information in OakEcol. We then calculated which tree species would support the greatest number of highly associated and partially associated oak species. We checked whether the site conditions at that site were predicted to be suitable to allow that tree species to establish and grow using the ESC model[2], which assesses the suitability of a site for different tree species based on its climate and soil type. Once the best beneficial tree species was selected we then calculated which tree species would support the most additional oak-associated species, not already supported by the first tree species. This process was

[2] Site suitability (climate and soils) for different tree species was based on: Pyatt DG, Ray D, Fletcher J. 2001. An ecological site classification for forestry in Great Britain: Bulletin 124. Edinburgh: Forestry Commission

repeated until the most suitable 5 or 6 tree species had been identified or until the addition of extra tree species would only support one extra oak-associated species.

It is stressed that the suggestions for alternative tree species (given in Annex A in each case study) are designed to demonstrate how OakEcol can be used to consider management for species that would be affected by a decline in oak. We have not provided a detailed assessment of the impact of these suggestions on the wider ecology of the woodland (but see section 4 below), or on other species present, nor have we considered how this fits into the wider balance of threats and risks to oak woodland. These wider issues should be considered in developing comprehensive resilience approaches to woodland management.

The establishment of beneficial tree species in addition to oak may be achieved by natural regeneration if the species are already present in the site. If the tree species are not already present then introducing the species via planting could be considered, if a severe decline in oak is predicted. If planting is considered it is important that the trees are sourced from stock grown in the UK to reduce the risk of spreading other pests/pathogens. If the establishment of non-native trees is considered this would need to be cleared with the appropriate authorities as currently planting non-native tree species in semi-natural woodlands, particularly protected areas, is not considered appropriate. However sycamore is generally tolerated, where it is already present, even within areas of the UK where it is not native.

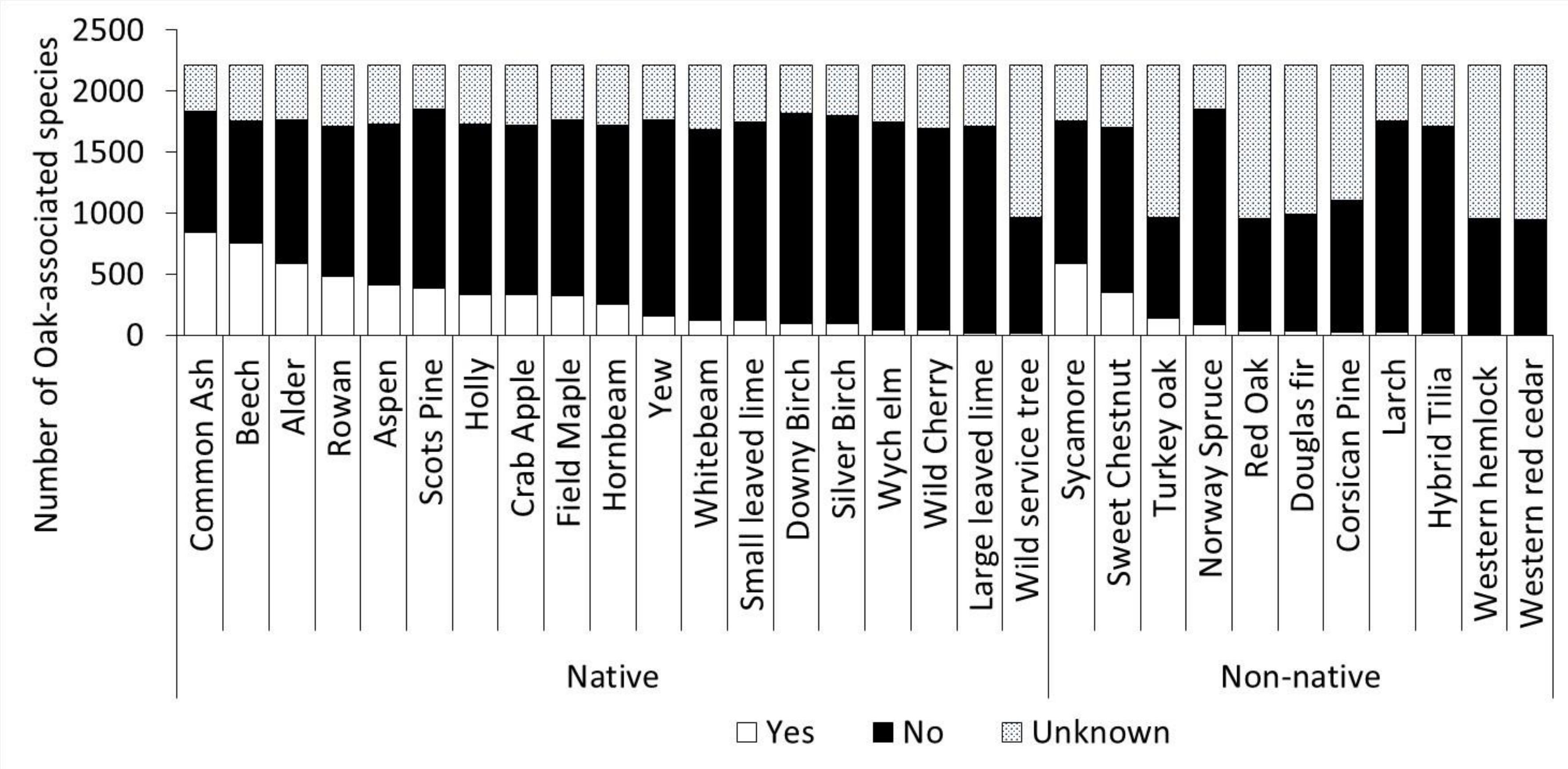


Figure 2. Use by oak associated species of 30 alternative tree species. Yes = oak associated species known to use that tree species, No = oak associated species known not to use that tree species, Unknown = data lacking to assess if the species will or will not use that tree species.

## 4 Impacts of beneficial tree species on functioning

While we have concentrated on identifying trees to support oak-associated biodiversity it should be noted that a change in tree canopy composition due to loss of oak and increased abundance of the beneficial tree species, will drive changes in ground flora composition (due to changes in shading) and in ecosystem functioning such as litter decomposition, soil chemistry and carbon storage. When deciding which beneficial tree species to encourage a trade-off may have to be made between supporting oak-associated species and changes in these other woodland functions.

**Table 2.** Likely impact on selected ecosystem functions and shading of ground flora of selected beneficial tree species compared to oak.

| | Functioning[1] | Shade[2] |
|---|---|---|
| Field Maple | Data lacking | Lighter shade |
| Sycamore | Faster litter decomposition. Litter and soil have a higher nitrogen concentration and lower carbon concentration | Similar |
| Alder | Faster litter decomposition. Litter and soil have a higher nitrogen concentration and lower carbon concentration | Lighter shade |
| Birch (Silver and downy) | Faster litter decomposition. Litter and soil have a higher nitrogen concentration and lower carbon concentration | Lighter shade |
| Hornbeam | Faster litter decomposition. Litter and soil have a higher nitrogen concentration and lower carbon concentration | Slightly lighter shade |
| Sweet Chestnut | Similar to oak but with slightly slower litter decomposition. Litter and soil have a slightly higher carbon concentration and slightly lower nitrogen concentration | Similar |
| Beech | Similar to oak but with slightly slower litter decomposition. Litter and soil have a slightly higher carbon concentration and slightly lower nitrogen concentration | Darker shade |
| Holly | Data lacking | Darker shade as all year round |
| Larch | Slower litter decomposition. Litter and soil have a high carbon concentration and lower nitrogen concentration. | Similar? |
| Crab Apple | Data lacking | Lighter shade |
| Norway Spruce | Slower litter decomposition. Litter and soil have a high carbon concentration and lower nitrogen concentration. | Darker as all year round shading. |
| Corsican Pine | Slower litter decomposition. Litter and soil have a high carbon concentration and lower nitrogen concentration. | Darker as all year round shading. |
| Scots Pine | Slower litter decomposition. Litter and soil have a high carbon concentration and lower nitrogen concentration. | Darker shade in winter as evergreen, but |

| | | |
|---|---|---|
| | | may be lighter in summer? |
| Aspen | Faster litter decomposition. Litter and soil have a higher nitrogen concentration and lower carbon concentration | Lighter shade |
| Wild Cherry | Data lacking | Lighter shade |
| Douglas fir | Slower litter decomposition. Litter and soil have a high carbon concentration and lower nitrogen concentration. | Darker as all year round shading. |
| Turkey oak | Data lacking | Similar? |
| Red Oak | Slightly slower litter decomposition. Litter and soil have a slightly higher carbon concentration and lower nitrogen concentration | Similar? |
| Whitebeam | Data lacking | Lighter shade |
| Rowan | Data lacking | Lighter shade |
| Wild service tree | Data lacking | Lighter shade |
| Yew | Data lacking | |
| Western red cedar | Slower litter decomposition. Litter and soil have a high carbon concentration and lower nitrogen concentration. | Darker as all year round shading. |
| Small leaved lime | Faster litter decomposition. Litter and soil have a higher nitrogen concentration and lower carbon concentration | Lighter shade |
| Large leaved lime | Data lacking | Lighter shade |
| Hybrid T. cordata × T. platyphyllos | Data lacking | Lighter shade |
| Western hemlock | Slower litter decomposition. Litter and soil have a high carbon concentration and lower nitrogen concentration. | Darker as all year round shading. |
| Wych elm | Data lacking | |

[1]Functioning information based on extensive literature reviews of comparative data and analysed in Mitchell et al (2019) Collapsing foundations: the ecology of the British oak, implications of its decline and mitigation options. Biological Conservation on line early DOI 10.1016/j.biocon.2019.03.040.

[2]Shading information based on expert judgement. The above provides a broad comparison of individual tree species compared to oak; the overall shade cast will depend on the mix of species in the canopy and the density of trees. If the shade cast by the tree species is lighter than oak then light demanding ground flora species may increase in abundance. If the shade cast by the tree is darker than oak then light demanding ground flora species may decrease in abundance.

## 5 Confidence in data

### 5.1 Level of association with oak

In total 610 different data sources were consulted to collate the list of oak-associated species. There was a high level of confidence in the level of association of the species with oak (Fig. 3), particularly for obligate species where 94% of data came from peer reviewed literature using UK data and for highly associated species where 99% came from peer reviewed literature using UK data.

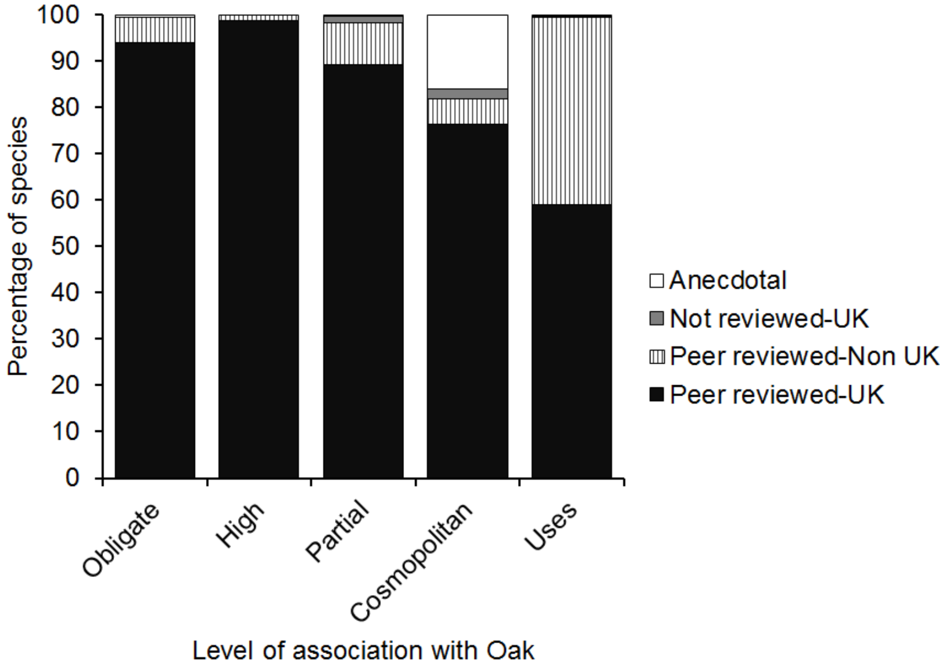


Figure 3. Quality of data sources from which an assessment of the species level of association with oak was assessed. Definitions of levels of association with oak are provided in Table 1. Anecdotal = Information on the use the species makes of oak is predominantly based on anecdotal evidence. Not reviewed-Non UK = Information on the use the species makes of oak is predominantly based on literature that has an unknown review process and uses data from outside the UK. Not reviewed-UK = Information on the use the species makes of oak is predominantly based on literature that has an unknown review process but is based on UK data. Peer reviewed-Non UK = The species is known to occur in the UK, but the information used to assess the level of association of the species with oak is predominantly based on peer reviewed literature from outside the UK. Peer reviewed-UK = Information on the use the species makes of oak is predominantly based on peer reviewed literature using data from the UK. This includes published books and quality-controlled databases.

### 5.2 Species present at site

It is acknowledged that the species list for the case study sites will be incomplete, and as such will impact on the management options chosen. However, current management decisions made at the sites are also based on incomplete species list.

## 5.3 Information on alternative trees

Information on the use of other tree species was not available for all species for all trees. For all native tree-alternatives, except wild service tree, information on use was available for over 75% of oak-associated species, thus allowing an informed decision to be made about the suitability of the tree as a replacement. This level of information was available for five of the non-native tree species, but for the remaining six species, including the two non-native oak species, information was not available for over 50% of associated species, giving low confidence in their suitability. This distinction in the confidence of the data is critical; for example Turkey oak and sweet chestnut are known to support similar numbers of oak associated species (130 and 101 respectively, Fig. 2). However, we have data for over 75% of species for sweet chestnut (Fig. 4) and we know that 1266 species (57% of species) will not use this tree species; this compares with Turkey oak where we only have data for 43% of species and we know that 350 species (16%) will not use this tree species. This highlights important knowledge gaps about the potential use made of many non-native trees by our native fauna. Generally, there was more information available for tree species that had been naturalized in the UK or widely planted. For the non-native trees there was more information for those species whose range includes parts of Europe (i.e. overlaps with a high proportion of oak-associated species), compared to American tree species, for example.

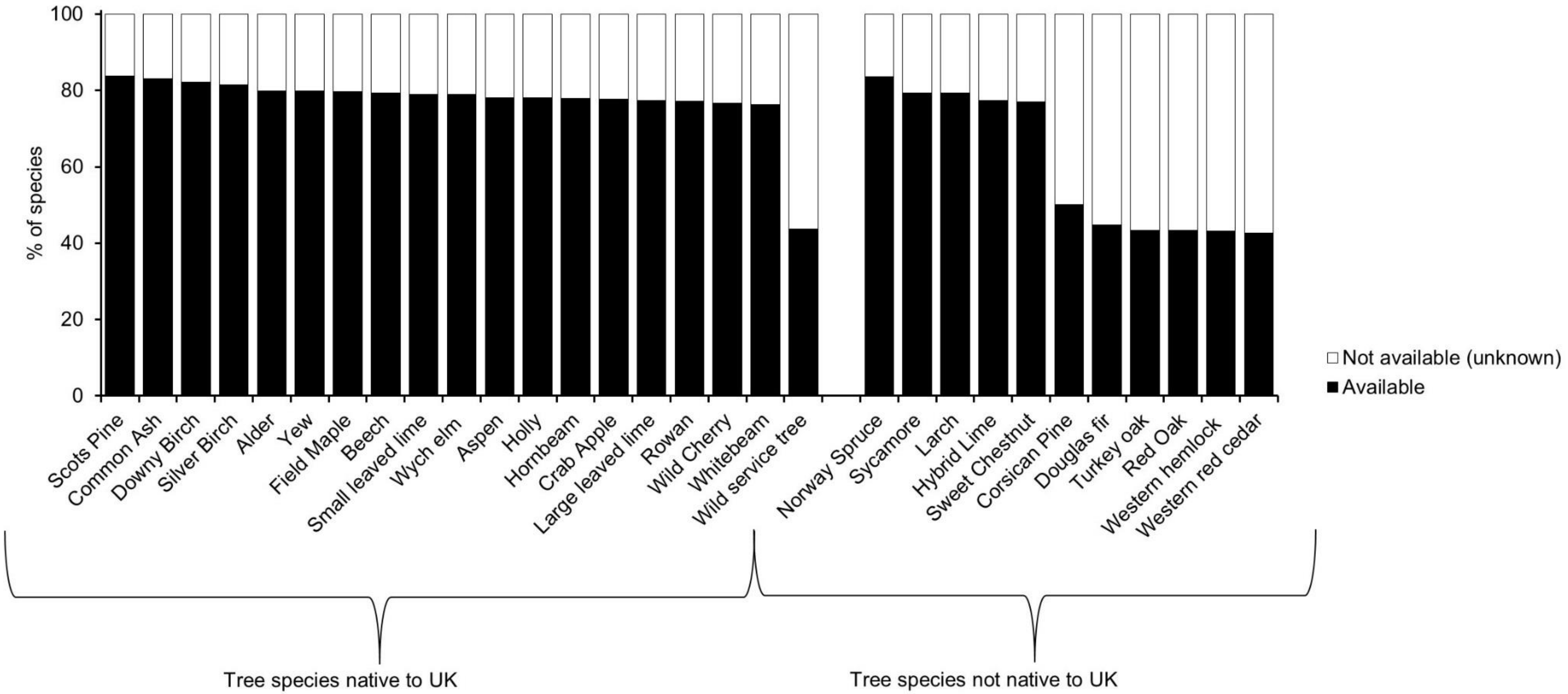


Figure 4. Percentage of oak associated species for which data were available on whether they would or would not use 30 alternative tree species

## 6 A 6 step approach to do similar work at other sites

The approach taken here was designed to follow a simple 6 step procedure that could be followed at any site, where the management was aimed at supporting oak associated biodiversity.

Step 1: Produce a species list for the site across as many taxa as possible based on available information.

Step 2: Identify oak-associated species present on the site and short-list those for site management to target – it is suggested to target those species with a high level of association with oak and/or those species that already have a high level of conservation protection (use the OakEcol excel file to do this).

Step 3: Assess the site to determine the amount and distribution of oak and other tree species present and identify factors limiting current or future oak health/abundance – e.g. lack of new saplings/young trees.

Step 4: Identify management to maintain oak abundance into the future; this could include some of the following:

- Thinning to reduce competition
- Ground scarification to establish suitable seed bed for natural regeneration and to reduce competition from ground flora.
- Growing on local oak seed and planting out as oak seedlings/saplings
- Reducing grazing to enable natural regeneration to survive
- Control of competing ground vegetation
- Creating canopy gaps to allow enough light for natural regeneration

Step 5: Identify tree species that could act as alternatives to oak to provide habitat for the oak-associated species (use the OakEcol excel file to do this) and replicate, as far as possible, ecosystem function at the site (Table 2). Cross reference this list with the list of tree species already on the site and select those which should be encouraged by natural regeneration or planting. If considering planting the soil type and current and future climates will need to be taken into account to assess if the tree species is suitable to be grown at the site. However, if the aim is to conserve biodiversity rather than timber production, the site conditions will only need to be suitable for tree survival, not necessarily for the tree to grow productively.

Step 6: Select the appropriate management interventions according to the site's objectives and potential for management and aim to maximise the oak-associated biodiversity. This should take into account the balance between maintaining a healthy and viable oak population (Step 4) with diversification of tree species composition to increase resilience of the woodland to future climates and diseases and a potential decline in oak (Step 5)

## 7 Acknowledgements

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