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The potential ecological impact of ash dieback in the UK

Mitchell, R.J., Bailey, S., Beaton, J.K., Bellamy, P.E., Brooker, R.W., Broome, A., Chetcuti, J., Eaton, S., Ellis, C.J., Farren, J., Gimona, A., Goldberg, E., Hall, J., Harmer, R., Hester, A.J., Hewison, R.L., Hodgetts, N.G., Hooper, R.J., Howe, L., Iason, G.R., Kerr, G., Littlewood, N.A., Morgan, V., Newey, S., Potts, J.M., Pozsgai, G., Ray, D., Sim, D.A., Stockan, J.A., Taylor, A.F.S. & Woodward, S.

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Summary[1]

Introduction

1. Ash is a common woodland, hedgerow, park and garden tree throughout the UK. The arrival of the disease ash dieback within the UK may result in the death of a large proportion of British ash trees. (*Confidence: Medium*).

2. If ash dieback does lead to widespread death of ash trees within the UK, it is likely that there will be a high negative impact on populations of plant and animal species that use ash trees for feeding/breeding or as a habitat (e.g. epiphytic lichens, bryophytes, specialist invertebrates). (*Confidence: High*).

3. When assessing the potential impact of ash dieback on biodiversity, a worst case scenario (more than 95% of ash eventually dying) has been taken throughout this report. The actual impact will depend on the extent and severity of the disease in the UK (which is unknown at this time), and whether or not resistant ash populations are identified.

Objectives of the research project

4. The objectives of the research project were:
   - to collate information about the ecology of ash and species which use ash and how they do so;
   - to assess how British woodlands might change as a result of the loss of ash;
   - to define a range of management scenarios which might be applied as a result of ash dieback, and to assess how these might affect species that currently use ash and the general composition of ash-related woodland habitats.

5. The research focused on potential implications of ash dieback and did not include consideration of other pressures such as pollution or climate change that may also cause changes in woodland structure and communities.

6. The research focused on potential impacts on ash associated species and on the ecology of ash woodlands, but did not provide a detailed assessment of the potential impacts of ash dieback on the delivery of ecosystem services, which would be an important consideration in future research and management decisions.

Ecology of ash

7. Ash lies at the extreme of the range of UK tree species in that it produces nutrient-rich highly degradable litter that does not form a deep litter layer and which maintains a high soil pH. Since the litter breaks down so rapidly, little soil carbon is sequestered, and the rates of nutrient turnover around ash trees are high. The tree species that may replace ash if ash dieback-related mortality is high may not preserve these ecosystem characteristics. The nutrient cycling characteristics of ash and the high light penetration

[1] For all statements in the summary (except those that are methodological) an indication of the confidence of the statement is provided. Where the statement is based on evidence from a literature review confidence levels are provided using the LWEC reporting card method of high, medium or low http://www.lwec.org.uk/sites/default/files/attachments_report_cards/Water_report_card_web.pdf. Where evidence is based on data an indication of strength of this data is provided e.g. percentage of records in the database.

through the leaves also contribute to the diversity of the associated ground flora. (*Confidence: High*).

8. The species composition of the soil decomposer community, from bacteria through to soil macro-invertebrates, and of the associated arbuscula mycorrhizal fungi, is of considerable functional significance for ash, shaping its ecosystem functions, and the biodiversity of the other associated assemblages. (*Confidence: High*).

9. Ash is commonest in mixed woodlands, rather than as a sole canopy dominant. Its saplings are shade-tolerant, enabling it to respond well to fill any new canopy gaps. (*Confidence: High*).

10. The current structure of ash woodlands was assessed using the National Forest Inventory (NFI) which includes survey data from 15,000 one-hectare sample squares randomly located across Great Britain. The total area of ash, the area of ash as a percentage of total woodland, standing volume and number of ash trees all follow a similar pattern, being lowest in Scotland, and lower in the NFI Region of northern England than in Wales and the more southerly areas of England. Overall, from the available data, there appears to be little difference between regions in the age-structure of ash-related stands, with most ash trees being of young to moderate age (11–60 years old) and of small diameter (<20cm), with relatively few large old ash trees present in woodlands in the UK. The Northern Ireland register of woodland suggests that the area of ash as a percentage of total woodland in Northern Ireland is similar to the NFI Regions of northern England and southern Scotland.(*Confidence: High*).

11. The UK was divided for the purpose of this project into five ‘ash-relevant’ regions, based on the amount of ash present. These regions were further sub-divided on the basis of climate and soils to produce a total of nine ash-relevant sub-regions within which the impacts of ash dieback and the potential effects of different management scenarios were assessed.

Species using ash

12. In total, 1,058 species were identified as being associated with ash (ash-associated species): 12 birds, 55 mammals, 78 vascular plants, 58 bryophytes, 68 fungi, 239 invertebrates, and 548 lichens. Of the 55 mammals, 28 use the ash trees and the remainder use the ash woodland habitat; the vascular plants use the ash woodland habitat rather than the trees themselves. All other species groups have been limited to those which use the ash trees themselves for the purposes of this review. (*Confidence: High*).

13. Forty-four species have been identified as only occurring on either living or dead ash trees and were termed ‘obligate’ ash-associated species (*Confidence: High*):
    - four lichen species for which 100% of records in the British Lichen Society (BLS) database (which contains a total of 1.2 million records) occurred on ash.
    - eleven fungi for which 95% of records in the Fungal Records Database of Britain and Ireland (which contains a total of over a million records) were associated with ash (a 95% cut off rather than 100% was used due to the method of classifying associated tree species within the database).
    - Twenty-nine invertebrates for which all the available literature stated that they were obligate on ash.

14. Sixty-two species were found to be ‘highly associated’ with ash (*Confidence: High*) as follows:

- Nineteen fungi and 13 lichens, where more than 50% of records (from the above databases) were on ash.
- Six bryophytes and 24 invertebrates where all the available literature stated that the species were rarely found on tree species other than ash.

15. Assessments based on the *number* of species which are 'obligate' on, or 'highly associated with', ash identified bryophytes, fungi, invertebrates and lichens as the groups considered most at risk from ash dieback. (*Confidence: High*).

16. Using a combination of the conservation importance of the species and their level of association with ash, we classified the species that use ash trees into Red, Amber, Yellow and Green codings, indicating level of risk with respect to the likely impact of ash dieback. This gave 69 Red-coded species, 169 Amber-coded species, 383 Yellow-coded species and 330 Green-coded species. (*Confidence: Medium*).

17. Nine bryophytes (mosses, liverworts and hornworts), two Lepidoptera (butterflies and moths), 14 Diptera (flies), threee Coleoptera (beetles), and 54 lichens that are associated with ash are already of 'conservation concern' (see glossary), and may decline further as a result of ash dieback if a large proportion of ash trees die. Three bird species of conservation concern were identified (from literature and databases) as using ash more frequently than its availability, but none were highly associated with ash. Rare bat species may decline if they roost in ash trees, or if ash trees form an important component of their landscape used for commuting or foraging, but information for specific species is lacking. Eight vascular plants of conservation concern were identified as being partially associated with ash woodlands; the impact of ash dieback on these species will depend on which tree species replace ash. (*Confidence: High*).

18. Some species that are currently of 'no conservation concern' may become rare or rarer as a result of ash dieback, if a large proportion of ash trees die. Assessments were based on species' level of association with ash and published autecological information. (*Confidence: Medium due to uncertainty of ash dieback predictions*). For example:
    - Some ash-associated bryophyte species which are only now recovering from 19th and 20th century air pollution may decline due to ash dieback.
    - In oceanic areas, the loss of ash could be serious for the suite of small Atlantic liverworts that are not currently of conservation concern, because of limited habitat niches.
    - Nine of the 11 ash-obligate fungi rely on living tissue of ash and so these are likely to decline severely and rapidly due to ash dieback.
    - Seven moth species, four beetles, 14 bugs, 11 flies, four ticks/mites and five thrips that are not currently rare may become so due to their high level of association with ash.
    - Four lichen species were identified that do not currently qualify for an IUCN threat category, but have a high association with ash and may therefore be at risk from ash dieback.

Alternative tree species

19. Twenty-two tree species were assessed for their suitability as replacements for ash: field maple, Norway maple, sycamore, alder, silver birch, downy birch, hornbeam, sweet chestnut, hazel, hawthorn, beech, aspen, wild cherry, bird cherry, Douglas fir, sessile oak, pedunculate oak, goat willow, grey willow, whitebeam, yew, and small-leaved lime. These species were chosen to cover a range of management objectives and as being likely to regenerate naturally or be planted by woodland managers because of their

suitability to establish and grow on site types that support ash. Douglas fir and sweet chestnut were included on the list as examples of tree species that are currently suggested for planting for climate proofing (coping with possible climate change) and have production potential on sites currently occupied by ash. The inclusion of a tree species in the assessment does not necessarily mean that this species is being promoted as a replacement for ash if the objective is to manage for ash-associated biodiversity.

20. Ash-associated species were assessed as to whether they also used any of the 22 alternative tree species (above). Oak supported 69% of the ash-associated species but no single tree species out of those 22 would make a good overall alternative to ash. Birch, beech and oak are used by many bird species that use ash. Field maple, sycamore, alder, hazel, hawthorn, oak, aspen and the willow species are used by many bryophytes. Oaks, hazel and sycamore are important as potential substitute hosts for ash-associated lichens. Trees such as sweet chestnut, Douglas fir or yew are used by very few of the species that use ash, and were identified as the least suitable out of the 22 alternative tree species. Similarity indices between the alternative tree species and ash, based on the level of use made of the tree species by the ash-associated species showed that oak, alder, beech and aspen were most similar to ash. A mixture of tree species rather than a single tree species will support a greater variety of ash-associated species. However, it must be noted that for many ash-associated species, data on the use of these 22 alternative tree species is lacking. (Data lacking for some species: *Confidence: Low*).

21. A trait based analysis was also done to assess the similarity of these 22 tree species to ash. Nineteen traits were collated for ash and the 22 alternative tree species: bark acidity, mycorrhizal association, diaspore type, duration of flowering, floral rewards, fruit type, leaf form, leaf persistence, pollen vector, height, Ellenberg light, Ellenberg moisture, Ellenberg reaction, Ellenberg nitrogen, leaf dry matter content, leaf size, seed mass, release height, and specific leaf area. For single traits there were some matches between ash and the alternative tree species, but multi-variate analysis of all traits showed that none of the 22 tree species were very similar to ash overall. Alder and aspen were identified as the trees most similar to ash, with similarity indices of 0.7. Sweet chestnut and Douglas fir were the most dissimilar (similarity indices of 0.5). (Assessment based on published trait data and standard statistical methods. *Confidence: Medium*).

22. The two assessments of similarity of alternative tree species, i.e. use or traits (as above) were compared. The assessment of which tree alternative is most similar to ash depended on the method used to assess similarity. However, aspen was ranked relatively similar by both types of methods, and Douglas fir was ranked very dissimilar to ash by both methods.

Likely changes in woodland communities

23. Ash is dominant in eight NVC communities: W8a, W8b, W8c, W8d, W8e, W8g, W9a and W12a. (*Confidence: High*). For each community, predictions based on expert opinion and ecological information were made about the changes in vegetation following the loss of ash.

24. Regional differences in how the tree and ground flora woodland community may respond following the loss of ash were assessed. This assumed natural regeneration was unhindered and sites were not modified beyond that caused by the dying of ash trees.

25. In three quarters or more of the current ash-containing woods in Scotland, Northern England and Northern Ireland ash currently occupies less than 10% of the canopy. In these woods other tree species currently forming the main canopy cover are expected to grow and fill the spaces left by any dead ash, resulting in little new recruitment of trees or expansion of the shrub layer. Shade-tolerant shrubs already present in the understorey may grow to fill gaps in woodlands containing 10 to 20% ash in the canopy. (Assessment based on species autecological information. *Confidence: Medium*).

26. For woodlands where there is a greater component (>20%) of ash in the canopy, canopy gaps are anticipated to be larger and/or more frequent. Under these conditions, existing shrubs and particularly saplings are expected to fill the spaces in the canopy in addition to some expansion by other existing canopy tree species. Over a longer time-period, established saplings will replace shrubs and fill the canopy gaps; sycamore is predicted to become particularly dominant in many of the sub-regions in this regard. Beech and small-leaved lime may form larger components in 'former' ash woodlands in southern England. (Assessment based on species autecological information. *Confidence: Medium*).

27. Of the 22 alternative tree species, and if sites are not manipulated and conditions for natural regeneration are optimal, sycamore saplings are predicted to be most likely to replace ash in all areas except upland Scotland, upland Northern England and calcareous areas in Southern England. Birch is predicted to replace ash in upland Scotland and upland Northern England. Beech is predicted to replace ash in Wales and clay regions of Southern England on the better drained sites (approximately 10% of sites). Field maple and small-leaved lime are predicted to only replace ash in calcareous areas of southern England. (Assessment based on published species atlases and autecological information. *Confidence: Medium*).

Management scenarios

28. The six management scenarios considered most likely to occur following ash dieback are: (1) non-intervention; (2) no felling with natural regeneration promoted; (3) felling; (4) felling and replanting; (5) thinning; (6) felling with natural regeneration promoted. (*Confidence: Medium*)

29. The predicted vegetation composition of the ash woodlands following each of the management scenarios (1)–(4) above (an agreed subset) is described for two time-periods: 1–10 years, and 50–100 years. (Assessment based on NVC community composition and published species autecological information. *Confidence: Medium*).

30. The predicted change in woodland composition and structure resulting from the management scenarios will affect the other species associated with the ash woodlands. For all species that were identified as obligate or highly associated with ash, the impact of a predicted change from the current ash woodland habitat as a result of the management scenarios was assessed.

31. Overall, management scenarios (1) (non-intervention) and (2) (no felling with natural regeneration promoted) are predicted to be better for ash-associated biodiversity in the short term as they retain the ash and dead ash in the woodland for longer compared to management scenarios (3) (felling) and (4) (felling and replanting). (Assessment based on level of association with ash. *Confidence: Medium*).

32. Species that utilise deadwood (fungi and some invertebrate species) may initially increase in population in the first 1–10 years under scenarios (1) and (2) due to an increase in the availability of deadwood (*Confidence: High*). However, after 50–100

years their populations are predicted to decrease compared to current levels if all dead ash wood is lost. (*Confidence: Low*).

33. After 50–100 years there is considered to be little difference between the four scenarios in terms of their impact on obligate and highly associated species, with most species declining or becoming extinct. This is due to the assumption that in scenarios (1) and (2) all ash will be lost by 50–100 years; this may not happen, and if some ash survives then obligate species may just decline rather than becoming extinct. (*Confidence: Low*).

34. There is considered to be little regional variation in the predicted impact of the management scenarios for most species groups. (Assessment based on level of association with ash and current distribution of species. *Confidence: Low*).

Contents

List of Figures

List of Tables

Preface

Uses and Users of this Report

This report is a technical report aimed at those involved in tree and woodland management for biodiversity and nature conservation. The report will be of particular value for those considering long term options for building resilience in woodlands and encouraging adaptation to support biodiversity during the transition as and when ash dieback takes effect.

The purpose of this report is to provide supporting scientific information to help inform the policy makers, land managers and advisers involved in management of woodlands and trees so that potential impacts of ash dieback on biodiversity are appropriately understood and considered. This will help to promote management practices that will conserve and enhance biodiversity and the delivery of ecosystem services. It is one of a series of research projects being carried out to understand and inform the management of ash dieback. Further research is on-going, including the Natural England-led follow on project, to analyse the ability of ash-associated species to use another selection of tree species, as well as practical options for managing the impact of ash dieback. This will be used to produce additional guidance for policy makers and land managers. Details of this follow-on project, which will be completed in March 2014, can be found at: http://www.naturalengland.org.uk/ourwork/evidence/register/researchprojects.aspx under project RP1437.

This report may also stimulate the research community to help fill the evidence gaps and uncertainties identified, which will further our understanding of the problems and ways to deal with them. As this is a technical report, it is expected that the findings will be translated by the delivery bodies and other advisors into guidance and advice for land managers. The key findings may also be of interest to other European countries as well as stimulating media interest and public engagement in reporting ash dieback.

Scope of the research

This research focused on the ecology and function of ash, identifying ash-associated species and compiling a database of information about ash-associated species, as well as identifying likely effects of ash dieback on these species and on woodland communities dominated by ash. In addition, information was sought on the use that ash-associated species make of other tree species. The findings do not enable judgements to be made about the relative importance of ash for biodiversity compared with other tree species, but they do provide an example of methods that could be applied to other tree species to give a perspective of their relative importance for their own suite of associated species.

The report was produced in a limited time period and represents the best evidence available at the time of the potential impacts of ash dieback on ash-associated biodiversity. It did not set out to explore potential impacts on ecosystem services nor the capacity for their delivery, which would also be an important consideration, but beyond the scope of this project.

The interactions between ash dieback and the impacts of climate change and other influences that can drive changes in our woodlands and trees, such as pollution or deer browsing and possible effects on ash dieback, were beyond the remit of this project.

Epidemiology and pathology of ash dieback and Chalara infection was out of scope, and is being considered elsewhere, such as in the ObservaTREE project.

Resistance of ash to Chalara infection is a significant area for further research under the Chalara Management Plan and the effects of possible resistance in ash trees was not included in this study. This study assumes a worst case scenario (i.e. 95% to 100% of ash eventually dying) in order to explicitly examine the possible effects of this extent of loss of ash.

The results are not intended to promote replacement of ash by any particular species, although they demonstrate that a wide range of tree species can provide some of the traits and support some of the species that are dependent on, or associated with, ash.

Further information about ash dieback can be found at:
http://jncc.defra.gov.uk/page-6322
http://www.forestry.gov.uk/chalara
http://www.woodlandtrust.org.uk/learn/threats-to-our-woodland/pests-and-diseases/ash-dieback/how-to-identify-ash-dieback/?gclid=CP6k_qnakbsCFSvjwgodJA0AuQ

Policy Relevance

The report gives an analysis of information about the ecology and biodiversity of ash (*Fraxinus excelsior*) considered in the context of ash dieback, caused by a fungus, 'Chalara' (*Chalara fraxinea* or *Hymenoscyphus pseudoalbidus)*. Chalara has already affected a high proportion of ash trees in Northern Europe and is now spreading in the UK. The first record in Great Britain was in a nursery in Buckinghamshire in February 2012, and it was subsequently found in the wider environment in woodland in Norfolk. It has since been found much more widely across the country, and the current distribution can be seen at: http://www.forestry.gov.uk/pdf/UK_outbreak_map_13-12-02_Map2b.pdf/$FILE/UK_outbreak_map_13-12-02_Map2b.pdf

Current scientific advice is that it will not be possible to eradicate Chalara. The Interim Chalara Control Plan[2] , published by Defra in December 2012, set out initial targeted, science-based and proportionate action to control the disease and provide a framework for future action, as we developed our understanding of Chalara and the costs and benefits of actions. The actions announced in the Control Plan included research into natural resistance in ash to Chalara, funding to accelerate the development of ObservaTREE[3] (a tree health early warning system using volunteer groups), and advice and guidance to industry on improving their resilience to Chalara impacts. ObservaTREE is a LIFE+ project expected to get under way over 2013/ 2014.

In November 2012, Defra published the Interim Report of the independent Tree Health and Plant Biosecurity Expert Taskforce[4] convened by Defra's Chief Scientific Adviser, Professor Ian Boyd. The Task Force was set up to assess the current disease threats to the UK and has published its initial recommendations about how those threats could be addressed. This was followed by publication of the Chalara Management Plan[5] in March 2013. This plan was focused on reducing the rate of spread of the disease, increasing resilience of ash populations, encouraging engagement in monitoring and tackling the problem and building resilience in woodland and associated industries.

The Chalara Management Plan notes that the full impact of Chalara will not be seen for at least a decade, as infected mature trees will continue to survive for several years. It commits

[2] https://www.gov.uk/government/publications/interim-chalara-control-plan
[3] http://www.forestry.gov.uk/fr/observatree
[4] https://www.gov.uk/government/publications/tree-health-and-plant-biosecurity-expert-taskforce-interim-report
[5] https://www.gov.uk/government/publications/chalara-management-plan

Government to continue to work with nurseries, land owners, environmental and other groups to develop a strategic approach to understanding the economic, social and environmental impacts of the disease, secure long-term resilience of woodlands and other trees and the supply chains that support them. It made it clear that:

- Current scientific evidence shows that there is no effective cure for Chalara infection;
- Modelling gives a strong indication of continental airborne incursion and predicts continued spread over the next 20+ years;
- Socio-economic assessment indicates that the overall scale of loss of benefits from ash trees runs to billions of pounds and is significantly higher than the economic value of the timber itself[6].

The Plan signalled the importance of ash, but did not fully consider the potential impacts on biodiversity. As the potential scale of the disease in the UK became clear, the statutory nature conservation bodies recognized that ash dieback could affect biodiversity and the ability of the countries of the UK to meet commitments under the Convention of Biological Diversity[7], the EU Biodiversity Strategy[8] and individual country biodiversity strategies.

The country strategies for biodiversity[9] and the environment in each of the four countries of the UK underpin the new 'UK Post-2010 Biodiversity Framework', published in July 2012. The country strategies include further priorities and are supported by additional measures and indicators, reflecting the countries' different responsibilities, needs and views. The objectives of the strategies are generally to:

- Halt the loss of biodiversity and continue to reverse previous losses through targeted actions for species and habitats;
- Increase awareness, understanding and enjoyment of biodiversity, and engage more people in conservation and enhancement;
- Restore and enhance biodiversity in urban, rural and marine environments through better planning, design and practice;
- Develop an effective management framework that ensures biodiversity is taken into account in wider decision-making;
- Ensure that knowledge on biodiversity is available to all policy makers and practitioners.

Responding to the need to improve our understanding of the impacts of ash dieback on biodiversity in the UK, the Joint Nature Conservation Committee formed a consortium with the relevant agencies in each of the UK countries to commission this research work and subsequent peer review of the report between February and December 2013. The other funders were: Department of the Environment (Defra), Northern Ireland Environment Agency (NIEA), Forestry Commission (FC), Natural England (NE), Natural Resources Wales (NRW) and Scottish Natural Heritage (SNH).

[6] https://www.gov.uk/government/publications/chalara-in-ash-trees-a-framework-for-assessing-ecosystem-impacts-and-appraising-options
[7] http://www.cbd.int/
[8] http://ec.europa.eu/environment/nature/biodiversity/policy
[9] http://www.google.co.uk/search?hl=en&q=JNCC+country+biodiversity+strategies&meta=

1 Introduction

Chapter Summary

1. *Ash is a common woodland, hedgerow, park and garden tree throughout the UK. The arrival of the disease ash dieback within the UK may result in the death of a large proportion of British ash trees.*
2. *If ash dieback leads to widespread death of ash trees within the UK, it is likely that there will be a high negative impact on populations of plant and animal species that use ash trees for feeding/breeding or as a habitat (e.g. epiphytic lichens, bryophytes, specialist invertebrates).*
3. *The objectives of the research project were:*
    - *to collate information about the ecology of ash, species which use ash and how they do so*
    - *to assess how British woodlands might change as a result of the loss of ash*
    - *to define a range of management scenarios which might be applied as a result of ash dieback, and to assess how these might affect species that currently use ash and the general composition of ash-related woodland habitats.*

1.1 Ash trees

Ash (*Fraxinus excelsior*) is a deciduous tree with a narrow crown, smooth bark, pinnate leaves, and its roots usually have an arbuscular mycorrhizal association (Grime *et al* 2007). In optimal sites, ash may grow to 35m tall, but it typically grows less than 18m tall (Grime *et al* 2007). Individuals usually live for up to 180 years, but coppiced or pollarded specimens may survive for over 300 years (Rackham 1980) and in some waterlogged sites for 1000 years or more (Rackham 1986). When the tree is 10-20 years old it starts to produce numerous wind-dispersed fruits, with up to 100,000 seeds being produced every second year, although some seed is produced every year (Wardle 1961). Seeds may remain viable for up to six years and usually germinate in the spring of the second year after shedding (Wardle 1961). The seedlings are sensitive to shade, and dense ground flora may provide a barrier against germination/initial establishment (Wardle 1959). Once established, a sapling may survive in shaded conditions for many years until an increase in light allows it to grow to reach the canopy layer. The canopy of ash produces a relatively light shade, and the leaves, which are shed when they are still green, do not form a persistent litter (Wardle 1961).

Ash is an important woodland and non-woodland tree throughout temperate Europe. Pautasso *et al* (2013) identified that the current European distribution of ash is shaped by the following factors:

- a northern boundary due to winter cold, and a southern boundary limited by summer temperatures;
- an intermediate status between a pioneer species and a permanent forest component;
- shade tolerance as a sapling, but light-demanding as a mature tree;
- avoidance of nutrient-poor soils and very acidic soils with pH <4.2;
- low competitiveness against beech on sites with growing conditions optimal for beech.

In Great Britain, ash occurs in 88% of 10 km squares (Preston *et al* 2002). It is found in 61 of the 860 different NVC woodland sub-communities (Rodwell 1991), as well as occurring as single trees in gardens, parks and hedges. Using Countryside survey data Maskell *et al* (2013) estimated there to be 2.2 million individual ash trees (outside of woodland) in the countryside and that the length of woody linear features (hedgerows and lines of trees) composed of ash is 98.9 km. Ash is the second most common species of individual tree in Great Britain (Maskell *et al* 2013).

Although ash attains it greatest size on fertile soils, it reaches its maximum abundance and ecological impact on relatively infertile calcareous soils where most individuals form stunted trees or shrubs. Ash roots do not penetrate below the level of the permanent water-table, but the species does establish in wetland habitats provided there is a shallow zone of well-drained soil (Grime *et al* 2007).

1.2 Ash dieback

The future of ash is currently threatened by an emerging invasive fungal disease, the ascomycete *Hymenoscyphus pseudoalbidus*, commonly called 'ash dieback' or '*Chalara*' (Pautasso *et al* 2013). *Hymenoscyphus pseudoalbidus* was first scientifically described in 2006 under the name *Chalara fraxinea*. Four years later it was discovered that *Chalara fraxinea* was only the asexual (anamorphic) stage of a fungus that was subsequently named *Hymenoscyphus pseudoalbidus* (Queloz *et al* 2011). It is closely related to a fungus *Hymenoscyphus albidus*, which is saprotrophic growing on the dead leaves of ash trees and is native to Britain.

The disease first appeared in Poland in the early 1990s and has since spread through most eastern, central and northern European countries. It was first confirmed in Britain in February 2012, when it was found in a consignment of infected trees sent from a nursery in the Netherlands to a nursery in England. In October 2012, *Chalara* was confirmed in a small number of cases in Norfolk and Suffolk in ash trees at sites in the wider natural environment, including established woodland. Since then, it has been found in a number and variety of locations in the UK, including urban landscaping schemes, newly planted woodland, and more nurseries. As of 18 November 2013 *Chalara* had been confirmed at a total of 609 sites composed of 24 nursery sites, 347 recently planted sites and 238 sites in the wider environment (e.g. established woodland) (Forestry commission: http://www.forestry.gov.uk/forestry/INFD-8UDM6S#Distribution). The disease causes leaf loss and crown dieback, and usually leads to tree death. Evidence from continental Europe suggests that there could be rapid spread of the disease and a high level of tree death in the UK (Kowalski 2006; Halmschlager and Kiristis 2008; Bakys 2009; Ogris 2009; Kjaer *et al* 2012; Pautasso *et al* 2013).

1.3 Ecological impacts of ash dieback and project aims

Widespread death of ash trees within the UK has the potential to impact on populations of other plant and animal species that use ash trees for feeding/breeding or as a habitat (e.g. epiphytic lichens, bryophytes, specialist invertebrates). As well as declines in abundance of species which use ash, assessments from continental Europe suggest that there could also be some species extinctions, depending on the scale and extent of loss of ash trees across the UK (Jonsson and Thor 2012).

Although there is good knowledge about the distribution and ecology of many plant and animal species occurring in the UK, information about which species use ash (and how) has not yet been collated; this is critically important in order to assess the potential losses associated with ash dieback in the UK and guide decisions on action. Following the arrival of ash dieback in the UK, some organisations have started to assess the potential impact of the disease on the species for which they have a particular concern (e.g. the British Lichen Society). However this information has not been collated across species guilds. This disparate information needs to be brought together, to assess the magnitude of potential impacts and to make strategic decisions for all potentially affected species and habitats. The effects of ash dieback on any given species will depend on the extent to which dieback effects ash trees and their regeneration. If the dieback is severe the impact on ash-associated species will vary according to how dependent on ash the species is, which part of the ash tree it uses, the distribution of the species, its colonisation potential, and which other tree species it uses in addition to ash.

As well as the species closely associated with ash, there are concerns over the wider ‘ash woodland community’. Established ash, whether a small group of trees or as whole stands, is usually associated with a particular set of site conditions and with a suite of ground flora species which together form typical ‘ash woodland communities’. It is likely that ash trees help to perpetuate such communities, for example by influencing the intensity and seasonality of below-canopy light levels, and the type and decomposition rate of the leaf litter. Loss of ash, occupation of sites by other tree species which may replace ash, and the methods by which dying ash is managed, could all influence site conditions and the associated ‘ash woodland community’.

The responses of species associated with ash (Figure 1.1) are therefore likely to be complex and dependent upon the ecological circumstances in each locality, including the local abundance and size-class of ash, the community composition of trees, shrubs and ground vegetation as potential colonists and seed sources and, consequently, the way in which a woodland community responds (e.g. which species replace it and how rapidly this occurs). These responses are also likely to vary between regions. The response of ash, its dependent species and other tree species will also be influenced by certain management interventions, such as replanting from nursery stock with ‘ash dieback-resistant’ ash, facilitating natural spread from existing ‘ash dieback-resistant’ ash, natural regeneration of other non-ash tree species, and planting of alternative tree species. The temporal dynamics of change are also critical to assess; some wood decay species, for example, may initially increase in abundance and then decline sharply (this happened with many elm associates following Dutch elm disease).

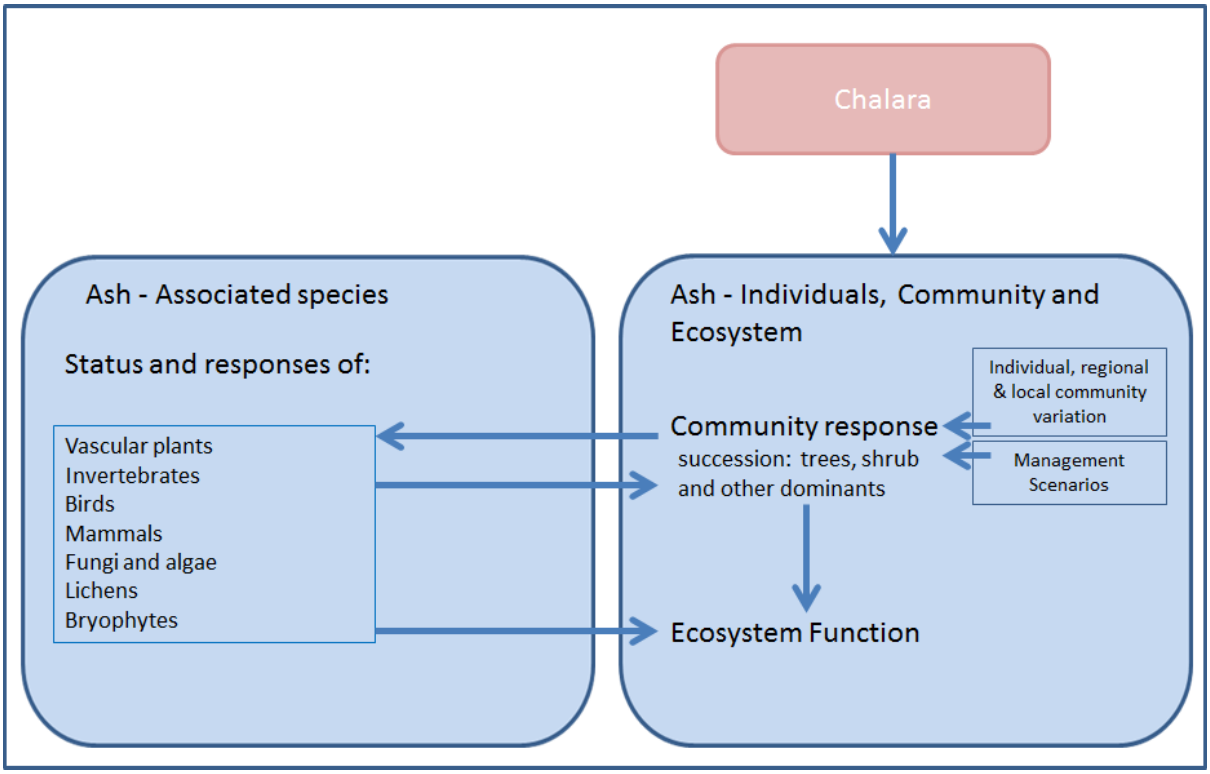


Figure 1.1. Conceptual diagram showing how the responses of the ash community and ash-associated species to *Chalara* might interact and affect ecosystem function.

This report and the associated database aim to:

- describe the ecological functioning of ash and ash woodlands;
- assess the current structure and distribution of ash woodlands;
- identify species that use ash, assess how strongly associated to ash they are, how they use ash, and which alternative plant species they will use;
- identify which tree species may replace ash;
- identify how the ground flora plant community may change following the loss of ash;
- identify how community responses in terms of replacement tree species and ground flora may differ regionally;
- compare the traits of replacement tree species to the traits of ash;
- identify a range of management scenarios that might occur following ash dieback;
- assess the impact of these management scenarios on species that are obligate or highly associated with ash;
- assess how these management impacts may vary regionally.

The outputs from this work include this Report and a searchable Microsoft Access database of the species that use ash and the impact of different management scenarios.

2 Distribution maps of ash

Chapter Summary

1. *The current structure of ash woodlands was assessed using the National Forest Inventory (NFI).*
2. *The total area of ash, the area of ash as a percentage of total woodland, standing volume and number of ash trees all follow a similar pattern, being lowest in Scotland, and lower in the NFI Region of northern England than in Wales and the more southerly areas of England.*
3. *Overall, from the available data, there appears to be little difference between regions in the age-structure of ash-related stands, with most ash trees being of young to moderate age (11–60 years old) and of small diameter (<20cm), with relatively few large old ash trees present in woodlands in the UK.*
4. *The Northern Ireland register of woodland suggests that the area of ash as a percentage of total woodland in Northern Ireland is similar to the NFI Regions of northern England and southern Scotland.*
5. *Ash is commonest in mixed woodlands, rather than as a sole canopy dominant.*
6. *The UK was divided for the purpose of this project into five 'ash-relevant' regions, based on the amount of ash present. These regions were further sub-divided on the basis of climate and soils to produce a total of nine ash-relevant sub-regions which are then used throughout the report to assess the impacts of ash dieback and the potential effects of different management scenarios.*

2.1 Chapter aims

In this Chapter we use information from the National Forest Inventory (NFI) to produce indicative information on the general structure of ash woodlands within the UK. Data are drawn from a survey of c 4,900 NFI sample squares which are allocated without preference across all woodlands, whether they be conifer or broad-leaved, in public or private ownership, urban or rural, ancient or plantation etc. These data have been used to divide the UK into five 'ash-relevant' regions, within which the impacts of ash dieback and the effects of different management scenarios are considered for this Report (Chapter 16). Other data sources could have been used, for example The Ancient Tree Hunt database (Woodland Trust, 2012) and the Countryside Survey data (Maskell *et al* 2013). Although the latter source is more comprehensive than the NFI data in that it covers ash occurring outside of woodlands e.g. in hedgerows, only figures for national estimates were readily available and these did not provide the resolution of data at the regional scale required in this analysis.

The data used are total values presented in the tables in the NFI report, which should also be consulted for details of the methodologies used in the survey and for the computation of tabulated values.

2.2 Division of the UK into regions

2.2.1 Areas of ash woodland

The areas of woodland within the different National Forest Inventory Regions (always termed 'NFI Regions' in this Report, to distinguish them from our amalgamated 'ash-relevant regions') and Northern Ireland (Figure 2.1) are shown in Table 2.1.

Figure 2.1. Five ash-relevant regions (Northern Ireland, Scotland, Wales, Northern England and Southern England) and their component National Forest Inventory Regions (labelled on map). NB The National Forest Inventory does not cover Northern Ireland.

Many woodlands comprise mixtures of species, and care needs to be taken in the interpretation of NFI data, as stocked areas indicate the proportion of total area occupied by ash rather than the area of ash woodland. There is considerable variation between the NFI Regions in the areas of conifer and broadleaved woodland: the total area of woodland is greatest in South Scotland and least in North East England. The areas of ash are lowest in Scotland, and lower in the northern NFI Regions of England and Northern Ireland than in Wales and the more southerly areas of England. The area of ash as a percentage of total woodland area follows a similar pattern, with percentages being lowest in Scotland and rising towards the south of England. Although 11% of broadleaved woodland in South Scotland comprises ash, the percentages for most of Scotland are much lower than other areas of the UK where overall amounts of ash are generally greater than 10% of broadleaved area.

Table 2.1. Areas of woodland in different National Forest Inventory (NFI) Regions.

NFI Region	**Area**				**%Ash**	
(area millions ha)	**Conifer**	**Blvs**	**Total**	**Ash**	**%Total**	**%Blvs**
North Scotland (1.9)	144.1	33.9	178.0	1.1	0.6	3.2
North East Scotland (1.2)	174.8	41.8	216.6	0.3	0.1	0.7
East Scotland (0.9)	81.6	38.1	119.7	1.8	1.5	4.7
South Scotland (2.0)	282.2	81.4	363.6	9.1	2.5	11.2
West Scotland (2.0)	223.6	69.8	293.4	1.3	0.4	1.9
North West England (1.5)	35.1	68.3	103.4	5.2	5.0	7.6
North East England (0.9)	59.3	36.2	95.5	4.4	4.6	12.2
Yorks and Humber[1] (1.6)	34.3	74.1	108.4	8.8	8.1	11.9
East Midlands (1.6)	18.1	75.8	93.9	12.0	12.8	15.8
East England (2.0)	38.0	105.6	143.6	11.3	7.9	10.7
South East England[2] (2.1)	50.8	258.3	309.1	27.7	9.0	10.7
South West (2.4)	58.8	183.3	242.1	30.5	12.6	16.6
West Midlands (1.3)	25.7	84.1	109.8	10.5	9.6	12.5
Wales (2.1)	131.1	126.2	257.3	17.6	6.8	13.9
Northern Ireland (1.4)	65.9	34.8	105.7	4.1	3.9	11.8

Data adapted from Forestry Commission (2012a,b), and the Northern Ireland register of woodland, and the Habitat Action Plan for Mixed Ash Woodlands ([1] = Yorkshire and Humberside; [2] = South East England and London; Area = thousands of hectares; Blvs = Broadleaved trees; %Ash = area of ash as a percentage of the total woodland area (%Total) or percentage of broadleaved area (%Blvs)).

The standing volume and numbers of ash trees follow similar patterns across the NFI Regions to those for area, with lowest values in Scotland and greatest values in more southerly NFI Regions of England and Wales (Table 2.2).

Table 2.2. Standing volume (m^3 overbark) and number of ash trees (thousands) (≥ than 4cm diameter at breast height) in National Forest Inventory (NFI) Regions.

NFI Region	Volume	Number of trees
North Scotland	63	620
North East Scotland	11	216
East Scotland	393	1,328
South Scotland	1,961	7,067
West Scotland	271	1,484
North West England	985	4,851
North East England	578	2,629
Yorks and Humber[1]	1,622	8,579
East Midlands	3,510	8,566
East England	2,488	12,225
South East England[2]	6,418	24,311
South West	7,408	29,453
West Midlands	3,154	8,064
Wales	4,967	16,499

([1] = Yorkshire and Humberside; [2] = South East England and London. No data available for Northern Ireland.)

2.2.2 Ash woodland communities

The National Vegetation Classification (NVC) (Rodwell 1991) identifies two main broad categories of ash woodland communities whose distribution differs across Great Britain: W8 (*Fraxinus excelsior-Acer campestre-Mercurialis perennis* woodland), which has a more southerly and easterly distribution than W9 (*Fraxinus excelsior-Sorbus aucuparia-Mercurialis perennis* woodland), which is found more in the north and west (Figure 2.2).

The frequency of W8 in Scotland is low, and W9 is the most commonly recorded community; the converse is found in southern England. Both communities are found in northern England and Wales.

NVC data for Northern Ireland are not available; instead information from the Habitats Directive habitat H9180 Tilio-Acerion forests of slopes, screes and ravines (JNCC 2013) is used (Figure 2.2c). Mixed ash woodlands are a common woodland type in Northern Ireland, comprising plant communities which are similar to W9 in character. The habitat tends to be dominated by a canopy of ash and hazel, often with frequent goat willow and a ground flora rich in spring-flowering herbs such as wood anemone, bluebell, primrose and wild garlic. Dog's mercury does not occur as a native plant in Northern Ireland, and in some stands, especially in County Antrim where the canopy is dominated by hazel, all of the 'character' species may be absent. Even here, however, the community can be readily assigned to the NVC W9 type.

Ash is also found in varying quantities in many other NVC woodland communities (Table 2.3), the distributions of which follow the same broad boundaries as W8 and W9. Some can be classified as lowland communities, and, like W8, occur in the south and east of Britain; others are upland communities which, as W9, occur in the north and west of Britain. The frequency of ash in these communities is typically low to moderate (frequency classes I and

II, where frequency is the percentage of samples in which ash occurs: classes I = 1-20% and II = 21-40%), but abundance in some can be high (Domin score 6, 26-33% abundance).

The total areas of each NVC type are poorly understood, but some, such as W2, W5, W6 and W13 are each likely to represent only a small component of the total UK woodland area including ash.

Ash may occur in broadleaved woodlands that do not fit conveniently into any of these NVC communities, for example recently planted farm woodlands. Similarly, on suitable soil types, ash often occurs at low frequencies and abundance in plantations on ancient woodland sites which are dominated by conifers. From the NFI information currently published it is not possible to identify the specific woodland communities surveyed.

The frequency and abundance categories in Table 2.3 can be used to make some inferences about the effects of ash dieback in different communities (Chapter 13) and also link to the canopy data (Chapter 14).

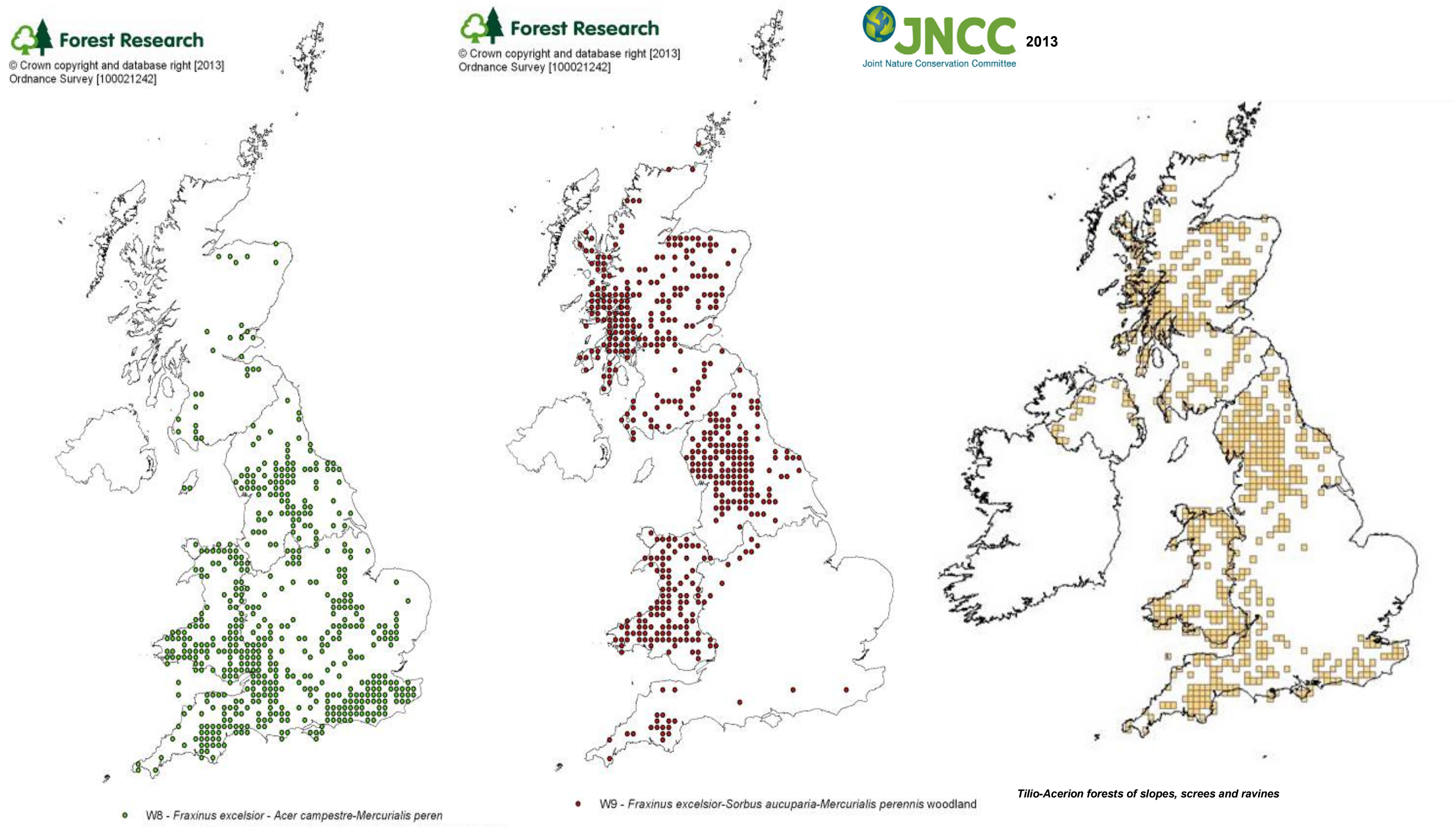


Figure 2.2. Distribution of W8 and W9 woodlands within Britain and *Tilio-Acerion forests of slopes, screes and ravines* within the UK.

Data for Great Britain adapted from JNCC (2008a) and showing boundaries of the five ash-relevant regions devised for this report. NVC data for Northern Ireland are not available; instead the map shows the distribution of the Habitats Directive habitat H9180 Tilio-Acerion forests of slopes, screes and ravines (JNCC 2013). It is likely that the map omits some ash woodland in Northern Ireland.

Table 2.3. Constancy (Frequency) and maximum abundance (Domin score) of ash in the NVC woodland communities in which it is found.

Sub-communities are shown separately where there is high variability in the ash component.

Type	Name of NVC community	Amount of Ash	
		Freq	**Domin**
Upland woodlands			
W7	*Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum*	III	8
W9	*Fraxinus excelsior-Sorbus aucuparia-Mercurialis perennis*		
- a		IV	9
- b		III	5
W11	*Quercus petraea-Betula pubescens-Oxalis acetosella*	I	7
W17	*Quercus petraea-Betula pubescens-Dicranum majus*	I	7
Lowland woodlands			
W2	*Salix cinerea-Betula pubescens-Phragmites australis*		
- a		II	6
-b		I	7
W5	*Alnus glutinosa-Carex paniculata*		
- a, b		III	4
-c		I	1
W6	*Alnus glutinosa-Urtica dioica*		
- a		II	5
-b, d, e		I	3–5
W8	*Fraxinus excelsior-Acer campestre-Mercurialis perennis*	IV	1-10
W10	*Quercus robur-Pteridium aquilinum-Rubus fruticosus*		
- a, d		I	6
-b, c, e		II - III	7–8
W12	*Fagus sylvatica-Mercurialis perennis*		
- a		IV	7
-b		I	5
- c		II	5
W13	*Taxus baccata*	I	4
W14	*Fagus sylvatica-Rubus fruticosus*	I	4

(Type = NVC classification; Freq = the percentage of samples in which ash occurs. I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80%, V = 81-100%; Domin = maximum abundance of species measured on the Domin scale (Domin10= 91-100% abundance, 9=75-90%, 8=51-75%, 7= 34-50%, 6=26-33%, 5=11-25%, 4= 4-10%, 3 to 1=<4% but with many, several or few individuals)). Adapted from the NVC floristic tables (JNCC 2008b).

2.2.3 Regions selected

Using information in Sections 2.2.1 and 2.2.2 above and existing administrative boundaries, the following five ash-relevant regions have been identified on the basis of the amount of ash present and the woodland communities in which it is likely to occur (Table 2.4):

- Scotland – has small areas of ash both in total and as a percentage of area. Ash is most likely to occur in W9 and other upland communities.
- Northern Ireland – relatively small area of ash woodland in total, but it accounts for a moderate proportion of the broadleaved area. Ash is most likely to occur in upland communities (W9).

- Northern England – total percentage of woodland area of ash is lower than the remainder of England and Wales, but the percentage of broadleaved area which is ash-dominated is similar. Ash is found in both upland and lowland communities.
- Wales – the area of ash as a percentage of total woodland is lower than much of England but it forms a higher percentage of broadleaved area. Ash is found in both upland and lowland communities.
- Southern England – the amount of ash both as a percentage of total woodland and broadleaved cover is high. Ash is most likely to be found in lowland communities (W8).

A combination of political and ecological boundaries (sub-regions) was used to develop these regions in order to make the information more easily transferrable to forest managers (especially Forestry Commission) who often work within these 'political' boundaries.

Table 2.4. UK ash-relevant regions identified using data from the National Forest Inventory (NFI), showing indicative amounts of ash and the likely type (upland, lowland) of woodland community in which it occurs.

NFI Region	UK ash-relevant region	%Total	%Blvs	Community
North Scotland North East Scotland East Scotland South Scotland West Scotland	Scotland	Very low	Low	Upland
North West England North East England Yorkshire and Humberside	Northern England	Low	High	Upland/Lowland
Wales	Wales	Medium	High	Upland/Lowland
East Midlands East England South East England South West England West Midlands	Southern England	High	High	Lowland
***	Northern Ireland	Low	High	Upland

*** not included in the National Forest Inventory, data adapted from the Northern Ireland register of woodland and the Habitat Action Plan for Mixed Ash Woodlands. (%Total = area of ash as a percentage of total woodland area; %Blvs = area of ash as a percentage of broadleaved woodland area, where c. ≤ 3% is Very low, > 3% to ≤ 7 is Low, >7% to <10% is Medium and ≥ 10% is High.)

Aggregated data from the National Forest Inventory and Northern Ireland describing the overall areas, percentages of ash woodland, standing volumes and numbers of trees for the five ash-relevant regions are shown in Table 2.5.

Table 2.5. Overall data for the area (thousands of hectares), and percentage of ash woodland, standing volume (thousands of m^3 overbark), numbers of trees (thousands), and stand density for the five ash-relevant regions in the UK.

UK ash region	Area	%Total	%Blvs	Volume	Number of trees	Density
Scotland	13.6	1.2	5.1	2,701	10,716	788
Northern England	18.4	6.0	10.3	3,185	16,058	873
Wales	17.6	6.8	13.9	4,967	16,499	937
Southern England	92.0	10.2	13.0	22,978	82,619	898
Northern Ireland	4.1	3.9	11.8	–	–	

(%Total = area of ash as a percentage of the total woodland area; %Blvs = area of ash as percentage of broadleaved area; Density = overall estimate stocking density of stems per hectare (i.e. number/ area); Number of trees = number of trees with diameter at breast height ≥ 4cm).

2.2.4 Stand structure

Precise characteristics of the woodland stands surveyed by the National Forest Inventory are not available; the information presented in their report and the derived data below represent idealised average woodlands, and therefore over-interpretation of the data is unwise.

No information is available on how the woodlands were managed, and high forest cannot be distinguished from coppice. All stems on coppice stools were counted as separate trees which may influence estimates of tree number but not area stocked or standing volume. Estimated overall stem density may vary between regions, being greatest in Wales and least in Scotland (Table 2.5).

The published estimates of ash seedling and sapling numbers cannot be interpreted at the regional level as they are only available at the country level and none are available for Northern Ireland. As seedlings are the smallest size category observed, they typically have a patchy distribution in woodlands and numbers are likely to fluctuate greatly over time, the information currently available is likely to be of limited value in relation to the description of stand structure. Ash saplings represent more securely established plants than seedlings: in Scotland these comprise only 5% of all broadleaved saplings, but in both England and Wales they represent 20% of all broadleaved saplings, suggesting that they are a more important component of tree regeneration in these countries.

2.2.5 Overstorey cover

In some NFI sample squares the abundance of ash in the overstorey was 80–100%, but the majority of squares had less than 10% cover in all regions; the proportion of samples with more than 20% was greatest in Wales and Southern England (Table 2.6). This indicates that ash is most commonly found in mixed woodlands, and in many of these woodlands it forms a relatively minor component of the overstorey. These figures are derived from assessment of occupancy by different species in the different storeys in the NFI sample squares.

The greatest impacts of ash dieback on the general integrity of UK woodland habitats are likely to be in Southern England and Wales, where the areas of ash and the frequencies of woodlands with abundant upper canopy ash are greatest.

Table 2.6. Percentage of 1ha NFI sample squares containing ash and the breakdown of these by four classes based on %cover of ash within the upper canopy, by ash-relevant region.

UK ash region	Percentage of NFI sample squares containing ash	Percentage of the ash containing NFI sample squares in each cover class			
		≤10% cover	≥10% to ≤20% cover	≥20% to ≤60% cover	≥60% to 100% cover
Scotland	14	74	15	9	2
Northern England	45	66	16	12	6
Wales	37	49	16	24	11
Southern England	58	48	18	25	9
Northern Ireland	***	***	***	***	***

Values are frequencies as a percentage (e.g. 74% of sample squares in Scotland had <10% ash in the upper canopy). Data interpreted from NFI report map 3 (p21) (Forestry Commission 2012a). (***Not included in the National Forest Inventory.)

A supervised classification method (Richards 1993) was used for extracting quantitative information from image data of the NFI report map 3 (p21) (Forestry Commission 2012a). This provided indicative figures for the proportion of woodlands falling in to the three 'ash cover canopy categories' given in Table 2.6 for each NFI sub-region (1 to 8) (see Figure 2.3).

2.2.6 Tree size

Tree size data are available as diameter size-class distribution for the different NFI Regions. The estimated areas, numbers of trees and standing volumes of ash in nine different diameter classes are shown in Table 2.7. In all regions, a small amount of the area is occupied by trees >60cm diameter. Numbers and volumes in the larger size categories are similarly low. In all regions about half of the number of trees are 7–15cm in diameter, and 80–90% of the standing volume in all regions is found in trees between 15–60cm diameter.

2.2.7 Tree age

Information on tree age is available in seven age-classes in each NFI Region; this was generally estimated by the surveyors carrying out the NFI. The areas of trees >80 years-old are low, with greatest amounts being found in Southern England (Table 2.8). The pattern of the data is similar for numbers of trees (i.e. with relatively few old trees, the majority being 11–60 years-old in all regions). Standing volume increased with age-class, and in all regions peaked at 60–80 years-old, with very little volume occurring as old trees.

For both size-class and age-class, the most obvious differences between regions are the generally higher values for Southern England. These figures suggest that there may be relatively more small young trees in Scotland and more old trees in Wales. This is related to the amount of ash in each region; if data are expressed as percentages of the totals then overall there appears to be very little difference between the stand structures between regions (Figures 2.4 and 2.5)

2.2.8 Summary

Overall there appears to be little difference between regions in the structure of average stands, with most trees being of young to moderate age (11–60 years old) and of small diameter (<20cm), with relatively few large old trees anywhere. In addition, most ash occurs in mixed woodlands, and in many stands it comprises a small component of the overstorey canopy. Woodlands with ash in Southern England are likely to comprise NVC communities typical of lowland areas, whilst those for Scotland are most likely to be typical of upland areas; those in Wales and Northern England will comprise both.

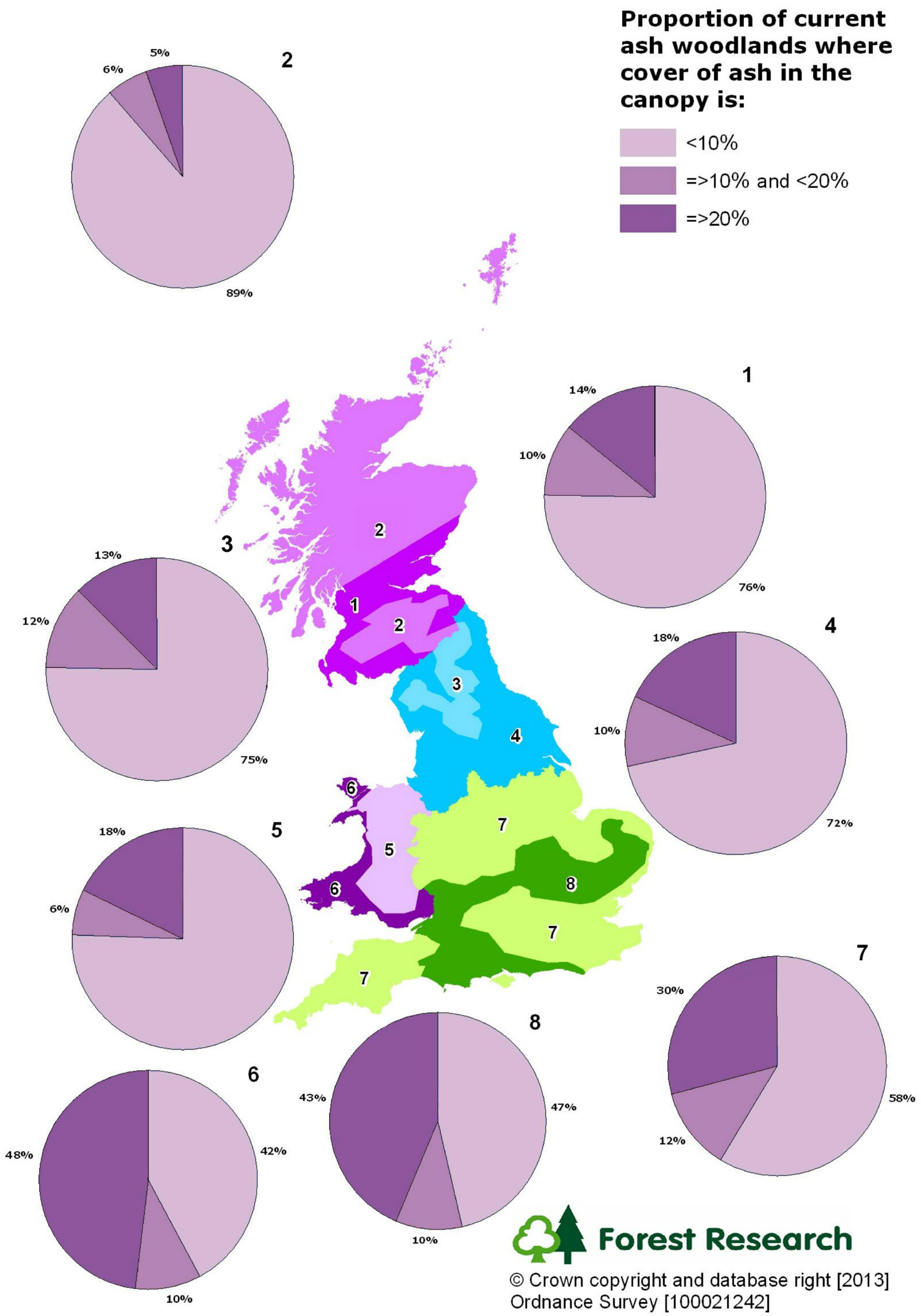


Figure 2.3. Canopy cover of current ash woodland in Britain from NFI report.
No equivalent data available for Northern Ireland (sub-regions are explained in Section 2.3).

Table 2.7. Area (thousands of hectares), number of trees (thousands), and standing volume (thousands of m^3 overbark) in the different regions by the diameter size-class of ash. Data taken from the National Forest Inventory (NFI). No equivalent data available for Northern Ireland.

	Diameter size-classes									
UK ash-relevant region	**0–7**	**7–10**	**10–15**	**15–20**	**20–30**	**30–40**	**40–60**	**60–80**	**80+**	**Total**
Area										
Scotland	3.3	2.5	1.6	1.8	1.9	1.5	0.5	0.2	0	13.3
Northern England	2.9	3.1	1.8	2.6	2.7	2.7	1.8	0.5	0.1	18.2
Wales	1.9	1.7	2.3	2.4	4.1	2.1	2.7	0.3	0	17.5
Southern England	5.9	14.1	12.9	11.1	20.8	13.8	10	2.2	1.1	91.9
Number										
Scotland	827	3,504	2,591	1,308	1,283	909	215	77	0	10,715
Northern England	291	5,190	3,647	3,178	2,246	1,072	350	78	8	16,059
Wales	707	3,119	5,273	2,873	1,730	1,554	1,125	119	0	16,499
Southern England	687	24,824	21,098	11,272	15,479	6,030	2,679	426	126	82,619
Standing volume										
Scotland	1	68	148	230	560	680	720	292	0	2,699
Northern England	3	66	187	524	761	802	539	246	57	3,185
Wales	0	34	252	586	751	1,106	1,831	405	1	4,966
Southern England	1	310	1,241	1,802	6,693	5,394	4,848	1,579	1,109	22,977

Table 2.8. Area (thousands of hectares), number of trees (thousands), and standing volume (thousands of m^3 overbark) in the different regions by the age-class of ash. Data taken from the National Forest Inventory (NFI). No equivalent data available for Northern Ireland.

	Age-Class							
UK ash-relevant region	**0–10**	**11–20**	**21–40**	**41–60**	**61–80**	**81–100**	**100+**	**Total**
Area								
Scotland	3.3	2	3	3.5	1.1	0.4	0.1	13.4
Northern England	3.1	2.5	3.9	3.3	4.3	1	0.1	18.2
Wales	2	1.8	3.1	3.8	4.1	1.9	0.8	17.5
Southern England	6.7	15.5	17	19.7	22.3	8.5	2.4	92.1
Number								
Scotland	797	1,392	4,763	2,664	681	300	118	10,715
Northern England	511	4,338	4,602	3,409	2,800	365	33	16,059
Wales	1,054	2,297	6,808	1,970	2,594	1,082	683	16,487
Southern England	1,350	22,561	24,527	16,661	12,144	4,289	1,126	82,658
Standing volume								
Scotland	1	34	604	922	1,069	48	21	2,699
Northern England	2	106	560	918	1,206	343	50	3,185
Wales	4	67	669	718	1,588	999	922	4,967
Southern England	14	627	2,828	6,091	8,144	4,094	1,180	22,978

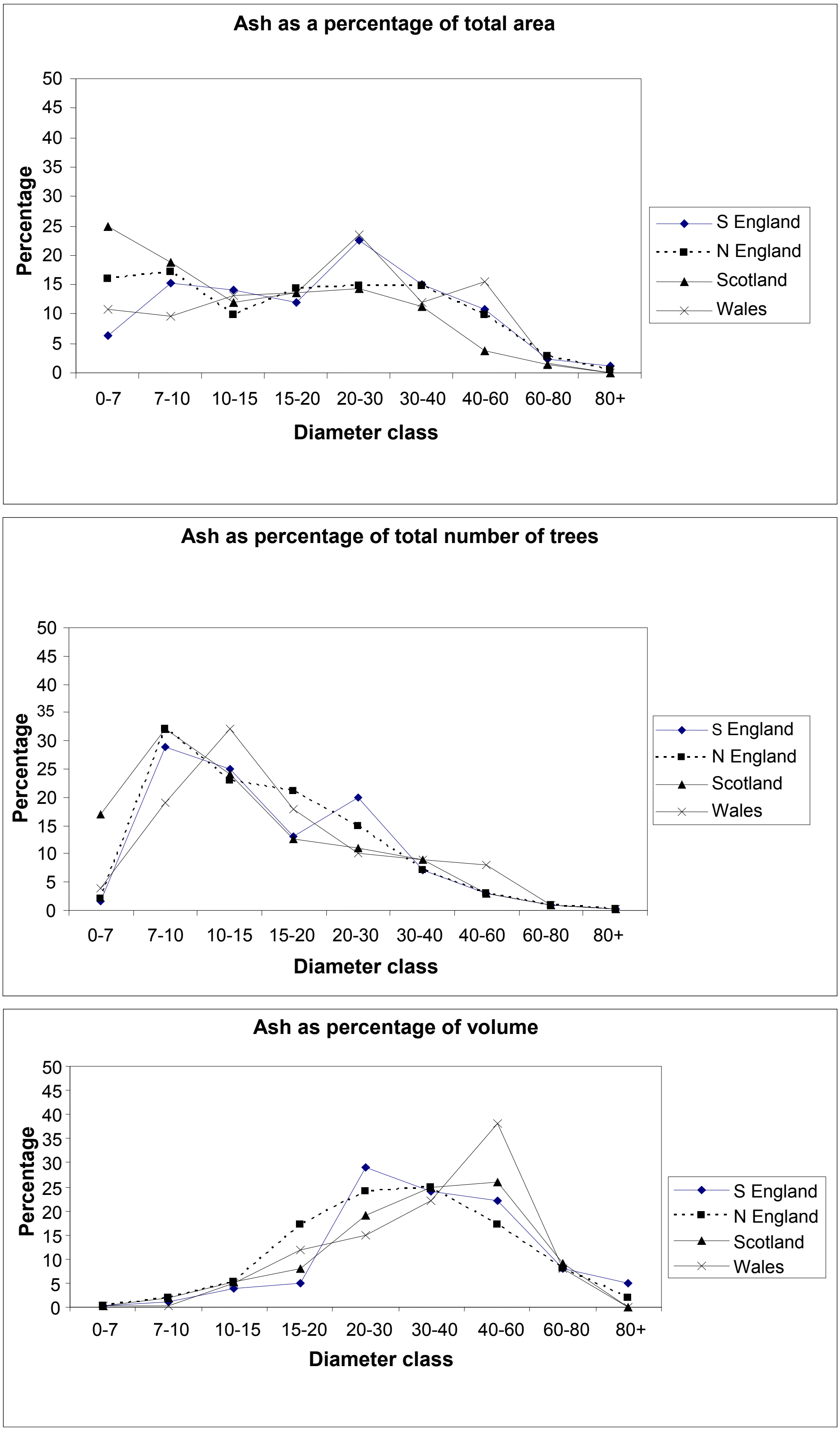
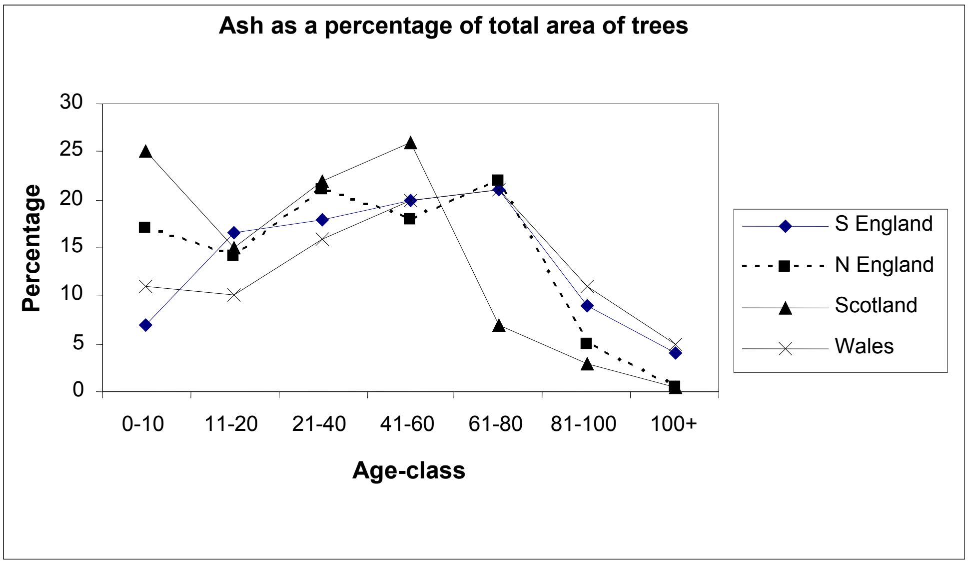
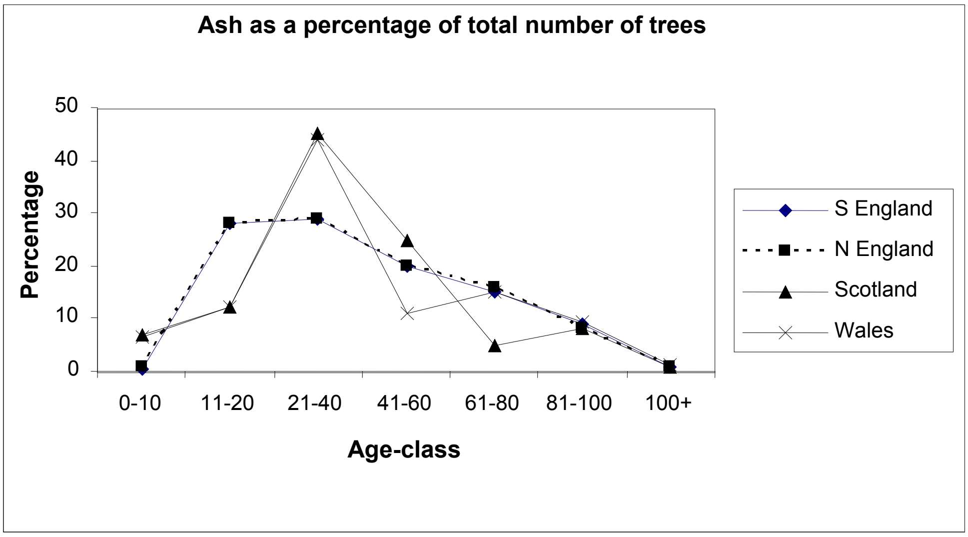


Figure 2.4. Percentages of total area of trees, number of trees and standing volume in the different regions within each diameter size-class of ash.
Data taken from the National Forest Inventory (NFI); equivalent not available for Northern Ireland.





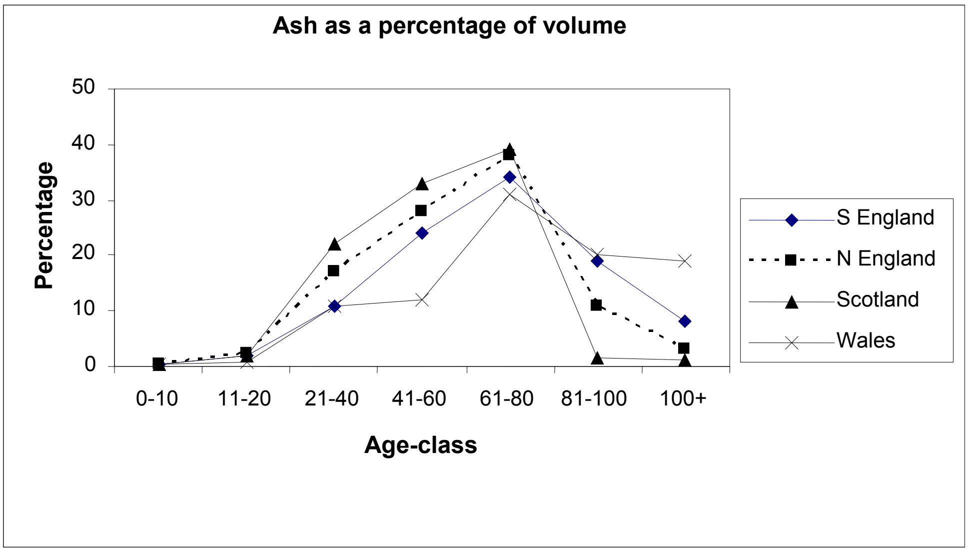


Figure 2.5. Percentages of total area of trees, number of trees and standing volume in the different regions within each age-class of ash.
Data taken from the National Forest Inventory (NFI); equivalent not available for Northern Ireland.

2.3 Sub-division of the ash regions

This further sub-division was felt necessary as the responses of woodland communities to ash dieback and subsequent management are anticipated to vary within an ash-relevant region due to differences in site type. Key site-type factors have been used to sub-divide the ash regions at a scale considered to be most appropriate for the scope of this project.

2.3.1 Use of site factors in defining sub-regions

The five top level ash-relevant regions were identified on the basis of the amount of ash present and the woodland communities in which it is likely to occur (Section 2.2.3). Some ash-relevant regions contain both upland and lowland ash-containing woodland communities (Table 2.4). Warmth of growing season, as it relates to elevation, is considered to be a key driver of woodland community compositional differences. Thresholds of accumulated temperature (day degrees above 5°C) can be used to distinguish areas suitable for supporting upland or lowland communities (Pyatt *et al* 2001). An accumulated temperature of >1200 in northern Britain and >1400 in Wales is suitable for lowland woodlands. Applying these rules resulted in two sub-regions being created in each of the ash-relevant regions 'Northern England' and 'Wales' (Figure 2.6). Application of these rules to the NFI Region 'South Scotland' distinguished the areas where there are anomalously high proportions of ash in the canopy of woodlands compared to the rest of Scotland (see Table 2.1). This resulted in a division of the ash region 'Scotland' into two sub-regions (Figure 2.6).

Ash woodlands in the Southern England ash region are known to be largely associated with either base-rich clay soils or thinner more freely draining soils over chalk and limestone outcrops. The findings by Hall (1997), linking woodland type to Natural Areas (distinctive areas based on wildlife and natural features, identified by Natural England as part of the nature conservation strategy in England), clarifies the link between the distribution of the lithologies/soils and the distribution and abundance of ash woodlands from the NFI. On this basis, the Natural Areas identified as containing primarily W8 woodlands (Table 3, p13 of Hall 1997) have been used to sub-divide the Southern England ash-relevant region into two (Figure 2.6).

The Northern Ireland region was not sub-divided, as ash woodlands are represented by predominantly upland communities, and the variations in lithology and soil type are not sufficiently marked to justify splitting the region.

In summary, Scottish, Welsh and Northern English sub-regions (i.e. the upland sub-regions) are based on climatic factors, and the southern English sub-regions are based on lithology/ soil. This sub-division gives a total of nine ash-relevant regions/sub-regions for use in Chapters 15 and 17 of the Report, as illustrated in Figure 2.6.

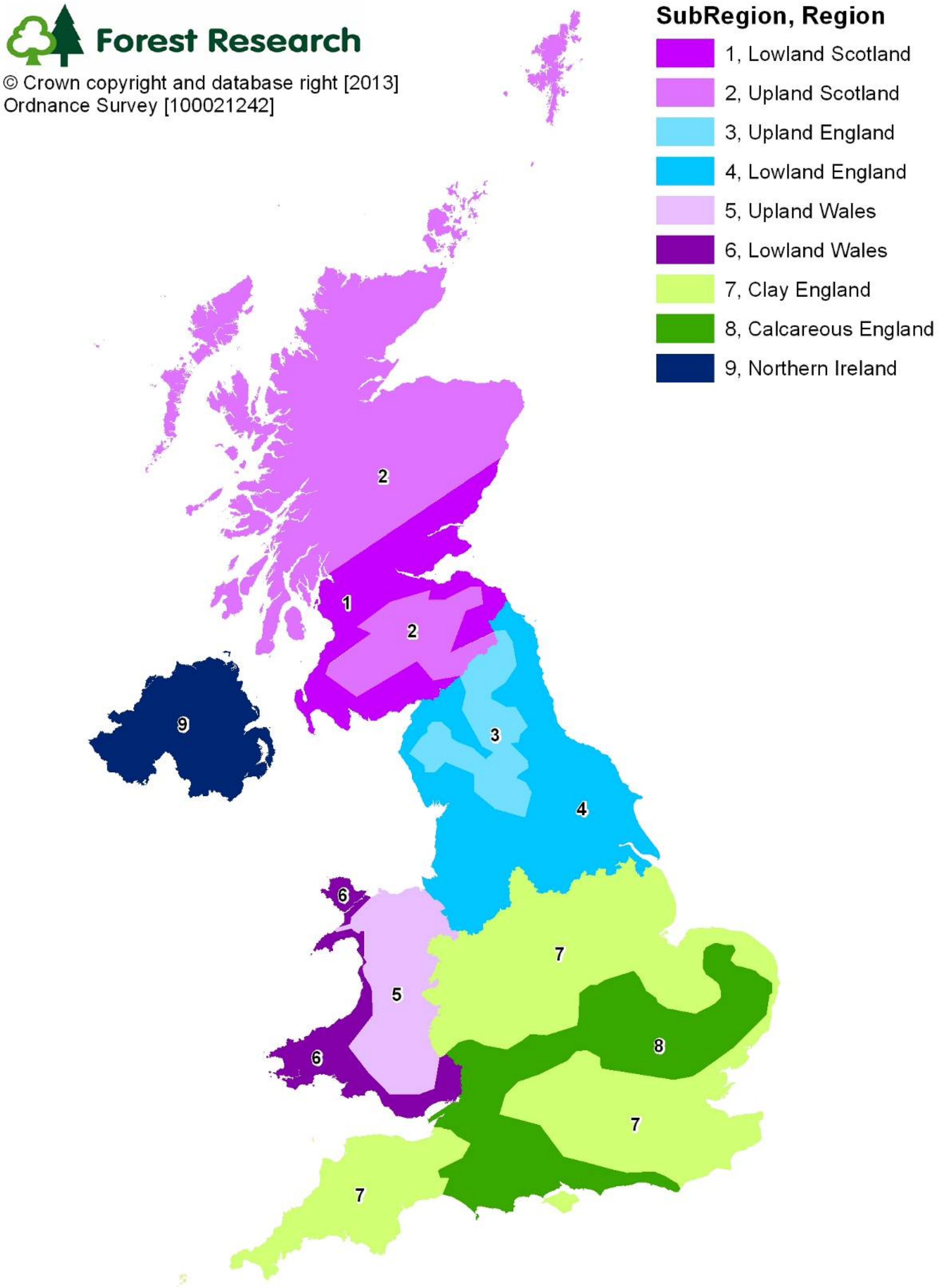


Figure 2.6. Ash-relevant regions and sub-regions used in this Report. Scotland, Wales and Northern England are divided into Upland and Lowland sub-regions (sub regions 1-6); Southern England is divided into Clay South England (7) and Calcareous South England (8). NB sub-regions are defined by general soil types however, local conditions may mean that a wood may not always be on clay when in sub-region 7 or calcareous soil when in sub-region 8.

3 The ecological function of ash

Chapter summary

1. *Established stands of ash are usually associated with a particular set of site conditions and communities, e.g. ground flora. It is likely that ash trees help to perpetuate such communities for example by influencing the intensity and seasonality of below-canopy light levels, and the type and decomposition rate of the leaf litter.*
2. *Ash lies at the extreme of the range of UK tree species in that it produces nutrient-rich highly degradable litter that does not form a deep litter layer and which maintains a high soil pH.*
3. *The nutrient cycling characteristics of ash and the high light penetration through the leaves contribute to the diversity of the associated ground flora.*
4. *The species composition of the soil decomposer community, from bacteria through to soil macro-invertebrates, and of the associated arbuscula mycorrhizal fungi, is of considerable functional significance for the ash, shaping its ecosystem functions, and the biodiversity of the other associated assemblages.*
5. *The tree species that may replace ash if ash dieback-related mortality is high may not preserve these ecosystem characteristics.*

3.1 Chapter aims

Ash trees will influence the environment around them by casting shade, adding leaves and dead twigs and roots to the woodland floor and through below-ground interactions between soil organisms and the tree roots. This in turn influences decomposition, nutrient cycling, interactions between other organisms and successional processes within the woodland. These 'ecological functions' of ash help to maintain the typical set of site conditions and communities, e.g. ground flora that are usually associated with ash.

This chapter summarizes the results of a literature review which aimed to identify the ecological function of ash and compare it with other tree species where data were available. The search (carried out in January/February 2013) focussed on use of key-word searches of Web of Knowledge (http://wok.mimas.ac.uk/), which returned both refereed scientific publications and conference proceedings. In addition to the search term 'fraxinus', keywords used were categorised as group 1: carbon, nutrient or nitrogen and cycling; group 2: litter, decomposition; group 3: succession, gaps, colonization and light; group 4: species richness, biodiversity.

3.2 Decomposition

Ash produces a labile and readily degradable litter which contrasts with most other UK tree species whose litter is slow to decompose and accumulates to a greater extent (Hagen-Thorn *et al* 2004; Table 3.1). The net result is that ash litter forms soil organic matter with a high pH. Ash and lime have been shown to have the least acidifying effect on top soils, in comparison to beech and spruce which have the most acidifying influence (Hagen-Thorn *et al* 2004). A further study has shown that ash leads to lower carbon and higher exchangeable calcium and magnesium in the upper soil layers, as well as higher pH, as compared to beech; with lime and maple being intermediate (Holzwarth *et al* 2011). A lower rate of litter accumulation on the forest floor occurs with concomitantly lower soil acidification under ash and wild cherry, which are greater in these parameters than common alder, lime or pedunculate oak (de Schrijver *et al* 2012). Ash litter is consistently among the most degradable compared to these other species, and it is generally rich in calcium and nitrogen and low in carbon and lignin; these characteristics predictability confer high rates of mass decomposition (de Schrijver *et al* 2012). Ash has been shown to have higher rates of decomposition compared to beech (Bjornlund and Christensen 2005; Lummer *et al* 2012), and, in another study, it decayed more rapidly than lime, sycamore or hornbeam, all of which in turn decayed more rapidly than beech (Jacob *et al* 2010). This hierarchy of litter decomposition rate is predicted by the litter's initial chemical composition, specifically increasing with higher concentrations of calcium and nitrogen and decreasing with lignin (Jacob *et al* 2010).

Table 3.1. Comparative information on decomposition and parameters relevant to carbon and nutrient cycling associated with ash and other tree species in the same study.

Process or parameter	Order	Ref
Litter pH, low C, high Ca Mg	Ash > Lime = Maple > Beech	a
pH 'topsoil'	Ash = Lime > Beech > Norway spruce	b
Low litter accumulation, pH Litter N, Ca, low lignin	Ash = Wild cherry > Lime = Alder = Oak	c
Leaf decomposition rate	Ash > Beech	d
Litter decomposition rate	Ash > Hazel > Oak (2 species) > Beech	e
Litter decomposition rate	Ash > Lime = Hornbeam = Sycamore > Beech	f
Root decomposition rate	Ash > Beech	g
Litterfall – concentration of: Ca Mg Mn C N C:N, Lignin:N	 Ash = Lime > Beech Ash > Lime > Beech Ash < Lime = Beech Ash < lime < Beech Ash = Lime > Beech Ash = Lime < Beech	h
Foliar C	Beech = Lime = Ash = Pedunculate oak = Maple < Norway spruce	i
Foliar Litterfall C:N	Ash = Lime = Maple < Pedunculate oak < Norway spruce < Beech	
Foliar N litterfall	Spruce = Ash = Maple =Lime = Pedunculate oak > Beech	
Foliar fractional annual C loss from forest floor	Ash = Lime = Maple > Pedunculate oak > Beech > Norway spruce	
Increasing soil C and N in organic horizon, and soil pH	Elm > Ash > Beech > Pedunculate oak > Hornbeam > Norway spruce	j
pH in organic layer and mineral soil	Elm > Ash > Hornbeam > Beech > Pedunculate oak > Norway spruce	
Soil respiration rates	Ash > Maple = Pedunculate oak = Norway spruce = Lime > Beech	k

(a – Holzwarth *et al* 2011; b – Hagen-Thorn *et al* 2004; c – de Schrejver *et al* 2011; d – Bjornlund and Christensen 2005; e – Schadler and Brandl 2004; f – Jacob *et al* 2009; g – Scheu and Schauermann 1994; h – Langenbruch *et al* 2012; i – Vesterdal *et al* 2008; j – Oostra *et al* 2006; k – Vesterdal *et al* 2012).

The higher rates of decomposition of ash litter compared to beech was also associated with greater densities of bacteria, fungal mycelia, protozoa and nematodes by factors of 4–15 (Bjornlund and Christensen 2005). Schadler and Brandl (2004) demonstrated that the decreasing gradient of decomposition of ash > hazel > oak (two species: *Q. robur and Q. rubra*) > beech litter was determined by decreasing concentrations of nitrogen and increasing carbon contents. The rapid action of soil invertebrates responded to the higher initial concentrations of litter nitrogen in ash (Schadler and Brandl 2004). However, in a comparison with decomposition of ash and oak litter, the effect of soil macrofauna enhanced decomposition in both litter substrates, but did so proportionately more in the recalcitrant oak litter than the more degradable ash litter (Riutta *et al* 2012). A larger component of the decomposition of ash litter was attributed to microbial action (Riutta *et al* 2012). Rates of decomposition of litter including ash have been shown to be affected by both earthworm abundance and the chemical characteristics of the litter, which is largely a result of the tree species (Jacob *et al* 2009). Just as ash leaf litter is considered readily degradable, it has been shown that ash root tissue also decays more rapidly than that of beech roots (Scheu and Schauermann 1994).

The highly degradable nature of the litter produced by ash is an important driver of the nutrient dynamics in the terrestrial ecosystem. However, this same characteristic is also of significance when litter is shed from ash trees in the riparian zone as allochthonous inputs to freshwater systems (Sanpera-Calbet *et al* 2009), into which it provides a rapidly mineralisable source of nutrients.

3.3 Cycling of nitrogen, carbon and other nutrient transfers

The fall of litter and its decomposition is, along with root inputs, one of the primary routes of nutrient and carbon recycling by individual trees and woodland systems (Langenbruch *et al* 2012). In this section we compare these processes for ash with other, mainly deciduous tree species (Table 3.1).

The calcium and magnesium concentrations in litterfall are greatest for ash, lime and beech in that order, with the highest C:N ratio and C:lignin ratios being found in beech, and the lowest ratios found in ash (Langenbruch *et al* 2012). In a further comparison of ash and three other species, pedunculate oak, lime, and silver birch, ash consistently had the lowest nutrient resorption efficiencies from senescent leaves, retaining relatively less N, P, K and S than any of the other species tested (Hagen-Thorn *et al* 2006). This contributed to ash's relatively large losses of K, Mg, N and S, via litterfall, all of which presented a greater transfer of nutrients to the soil than the other species tested. Furthermore, although the absolute amounts of leached throughfall were relatively small compared to other routes of nutrient transfer to the soil, in the case of ash, relatively large amounts of these elements, plus calcium, were readily lost from ash leaves via this route. These exceeded the throughfall losses of nutrients from the other tested species (Hagen-Thorn *et al* 2006). These dynamics are of considerable significance to the characteristic rapid nutrient flows and rates of recycling of nutrients through the tree-soil system for ash (Oostra *et al* 2006; Vesterdal *et al* 2008; Jacob *et al* 2009). In general, where less N and C accumulate in the organic material on the forest floor beneath certain species such as ash, then the more such elements occur in the mineral soil strata (Vesterdal *et al* 2008). A further effect of ash saplings on N cycling was found to be the reduction of soil nitrous oxide (N_2O) emissions, an effect that was greater than that attributable to beech saplings (Fender *et al* 2013). This study provides evidence of species-specific rhizosphere effects on nutrient cycling which can have a substantial influence on the emission of greenhouse gases from forest soils (Fender *et al* 2013).

Not only do ash roots decompose more rapidly than those of beech (Scheu and Shauermann 1994), but the roots of ash contain a greater concentration of nutrients, except calcium, than both lime and beech (Lang and Polle 2011), and higher soil nutrient levels around ash trees may be the result of this. This may interact positively with the overall degradability of ash leaf litter (see above), enhancing it further via microbial and invertebrate-mediated decomposition. The net effect is a more complete cycling of nutrients without accumulation in the litter layer.

The fact that ash does not accumulate an organic layer at the soil surface compared to species whose litter is more recalcitrant means that it is not considered a useful tree species if an environmental goal is the sequestration of carbon in soil. Soil organic carbon and total soil nitrogen accumulation in the O-horizon of soil declined in the order Norway spruce, hornbeam, pedunculate oak, beech, ash and elm, whereas soil pH increased in the same order (Oostra *et al* 2006). A greater degradation rate of litter is accompanied by greater release of carbon-dioxide, which was greatest for ash litter in both extent and rate (ash > silver birch > Scots pine = Norway spruce = alder = Sitka spruce > oak) and was correlated with initial calcium concentration (McTiernan *et al* 1997). Soil respiration rates under ash were also greatest compared to several other tree species (ash > maple = pedunculate oak = Norway spruce > lime > beech) and soil carbon turnover rates and decomposition rates were also highest for ash (ash = maple > lime = pedunculate oak = Norway spruce = beech) (Vesterdal *et al* 2012).

3.4 Inter-relationships among biodiversity and ecosystem function

There are multiple components to the biodiversity of a habitat type or associated with a particular species of tree such as ash. Chapters 5-12 identify the species associated with ash. Here we discuss some of the ecological connections among components of biodiversity and function related to ash trees which are not made elsewhere. Large, long-lived tree species are foundation species that provide living habitats for other smaller species, and have associated with them a range of functionally significant organisms such as the crown invertebrate assemblages and the soil microbiota that mediate the extended ecological functions of the tree (see Sections 3.1 and 3.2 above).

Naturally, no one individual ash tree will harbour all the species known to be associated with ash trees. Indeed, no single woodland is likely to contain all of the species associated with its constituent tree species. Trees of the same species in different geographical areas of Britain will have different sets of associated fauna and flora. Climatic and geographical variations, as well as the mobility of the associated species concerned will all influence which species can colonize individual trees and survive in a particular area. For example Alexander *et al* (2006) highlighted the importance of ash in the Cotswolds for supporting a large array of British Red data and nationally scarce insects.

Factors such as tree age, woodland structure, the presence of deadwood and silvicultural practices will all influence the number of species found on ash trees. As with other tree species the overall biodiversity associated with ash varies with the age of the tree. In plantations of mature ash, for example, the species richness of spiders is less in than in the younger stages, and this is attributed to the temporal decline in the habitat structure required to sustain a diverse spider fauna (Oxbrough *et al* 2005). In a comparison of ash with sycamore in an agroforestry plantation system, there were no differences between the tree species in carabid diversity, but the habitat structure of the agroforestry led to greater species richness than the unplanted agricultural grassland (Cuthbertson and McAdam 1996). The presence of deadwood in an ash woodland system also undoubtedly promotes species richness of saproxylic beetles (Franc and Aulen 2008). Silvicultural practice can successfully promote such structural diversity required to promote biodiversity, including the ground flora (French *et al* 2008).

Although the ground flora of ash woods may be relatively species-rich (see Section 3.4 below; Rodwell 1991) the overall species richness of foliage eating insects strongly associated with ash is not great in comparison with other UK tree species, ranking 12th out of 18 tree species or 12th out of 15 if only native species are considered (Southwood 1961). Southwood (1961) identified that the only native tree species with fewer insect species are lime, hornbeam and holly and that the relative species paucity was consistent across all insect taxa. This overall result was confirmed by a subsequent re-analysis (Kennedy and Southwood 1984). It is noted that Southwood (1961) only studied species specifically linked to a particular tree species and did not include those feeding on a wide range of host trees leading to a potential underestimate of the number of species using ash. Alexander *et al* (2006) lists ash of equal importance to oak for wood decaying insects and of greater importance than oak for wildlife in terms of its leaf litter. Despite the much greater insect species richness and abundance on oak compared to ash, bird species richness was similar between comparable oak and ash woodlands (Sweeney *et al* 2010).

The above- and below-ground components of woodlands are intimately connected, for example root biomass is positively correlated with the above-ground tree species diversity (Lang and Polle 2011). The nutrient acquisition by trees is strongly dependent on the mycorrhizal fungal mutualists that colonise the fine feeder roots. The fungi exchange soil-derived nutrients for sugars with the host plants. In the UK, most forest trees form ectomycorrhizas (ECM) with a wide range of soil fungi, whereas ash (and *Ulmus*, *Acer*, *Sorbus*) form arbuscular mycorrhizal (AM) associations with a more restricted group of fungi (Section 15.1.1).

The ectomycorrhizal (ECM) symbiosis is typically formed between the terminal feeder roots of woody, perennial plant species and a wide range of soil fungi. The fungi exchange soil-derived nutrients for carbohydrates from the host plant. Nutrient uptake into the host is enhanced both as a consequence of the physical geometry of the fungal mycelium and by the ability of the fungi to mobilise N and P from organic substrates through the action of extracellular catabolic enzymes. Within the root, hyphae ramify between the outer cells forming a complex structure called the Hartig net, which provides a large surface area of contact between the fungus and the host, allowing efficient transfer of metabolites. External to the root, the fungus forms a mantle or sheath, which effectively isolates the feeder roots from the soil. Since colonisation is typically >95%, this means that almost all of the absorptive root surface of the host plant is covered in fungal material and any nutrients and water must pass through the mantle in order to enter the root.

Arbuscular associations are also based on exchange of nutrients for sugars and are found in the roots of the great majority of land plants. The fungi involved are a much more restricted group than the ECM fungi, with *c*300 taxa worldwide, all within the Glomeromycota. Root morphology is usually little changed by colonisation by AM fungi. The fungi penetrate into root both within and between the outer root cells form intracellular arbuscules, which are complex branched structures and the sites of nutrient exchange. Swollen balloon-like structures called vesicles, which are storage organs, are also formed within the root. The mycelia of the AM fungi extend out into the soil scavenging for nutrients, particularly P.

Although the AM group of fungi comprises only *c*300 species worldwide, they colonise the great majority of land plants. Hence, they exhibit little host specificity and in any given area they usually form a small proportion of the total fungal diversity – 5% of fungal species in mixed woodland (Lang *et al* 2011). The lack of specificity means that ash dieback is unlikely to lead to a marked reduction in AM fungal diversity, especially as most of the understorey plants associated with ash also form AM associations.

Arbuscular mycorrhizal fungi are extremely efficient at acquiring inorganic nutrients, especially phosphorus, from immobile sources (Smith and Read 2008), whereas many ECM fungi appear to be more specialised in acquiring nutrients from a diverse range of organic nutrient sources. The mutualism between ash and AM fungi is therefore likely to have co-evolved under the mutually beneficial conditions of rapidly mineralisable litter, high pH and low litter accumulation associated with ash – characteristics which would be reinforced by the ecology of the AM fungi (Read 1991; Read and Perez-Moreno 2003). If AM and ECM fungi are adaptations to respective high and low availability of mineral nutrients, particularly P and N (Read and Perez-Moreno 2003), then association with different forms of mycorrhizal mutualists among trees may also underlie their competitive interactions for nutrients, particularly in mixed-species stands in which ash is often a component (Lang and Polle 2011). Relatively little is known about the ecology of these trophic and competitive interactions for ash and their consequences for woodland dynamics. But, as a high biomass component of a woodland ecosystem, a dominant or foundation species, ash is one of the main providers of reduced C to the AM fungal network in soil. It could therefore be predicted that loss of ash from mixed woodlands may affect the functioning of AM mycorrhizal fungal community by reducing its competitiveness due to reduced C supply. This could be exacerbated if a switch to a more ECM-dominated system was driven by colonisation of an alternative tree species that was ectomycorrhizal.

There are numerous connections between above-ground and litter and root nutrient dynamics (Sections 3.1 and 3.2 above), and these processes resulting in relatively high soil pH of ash woodlands also directly influence the species richness of the ground flora (Reusser *et al* 2010; see Section 3.5 below).

3.5 Successional processes

Ash is described as both an important pioneer and 'climax' forest species – it can feature as a woodland canopy tree at all forest successional stages (Wardle 1961; Dal *et al* 1991; Tapper 1996; Kompa and Schmidt 2005; Dobrowolska *et al* 2011). It produces large quantities of seed with good dispersal (up to 1.4 km) (Wardle 1961; Herault *et al* 2004; Bacles *et al* 2006) and therefore will readily colonise new areas (Bacles *et al* 2006) given appropriate conditions for germination and establishment (Wardle 1961; Kerr and Cahalan 2004; Marie-Pierre *et al* 2006).

Seedlings can regenerate in light or heavy shade (e.g. that cast by oak or beech) (Tabari *et al* 1998), requiring only a small depth of well-drained soil to establish, and they readily create a 'seedling bank' (Watt 1925; Wardle 1961). The presence of the ash 'seedling bank' gives this species a strong advantage in filling new gaps in the woodland canopy, as compared to species which do not form seedling banks, such as birch or alder spp. (Tapper 1993). Other species on our 'alternative' tree species list (see Table 4.2) with similar gap colonisation properties include beech and sycamore (Linhart and Whelan 1980; Bruciamacchi 1994; Emborg 1998; Kompa and Schmidt 2005; Ritter and Bjornlund 2005; Collet *et al* 2008; Petritan *et al* 2009). Ash seedlings were found to have greater phenotypic plasticity than beech in terms of their photosynthesis (Einhorn *et al* 2004), which might give this species an advantage in canopy gap-filling from established seedling banks (Emborg 1998). However, ash seedlings appear vulnerable to competition from dense ground vegetation/deep litter and establish more readily if the field layer is discontinuous/kept in check, for example by low light, poor, unstable, and/or dry soils or light herbivore grazing (Wardle 1961; Sukhoi 1985; Hester *et al* 1996; Bloor *et al* 2008).

The poor competitive abilities of ash seedlings in dense understorey vegetation may partly explain why it is often a co-occurring rather than dominant canopy species in many UK woodlands. Wardle (1961), for example, describes dense stands of *Mercurialis perennis* as keeping ash in check in many ash-oak woodlands; and Peltier *et al* (1997) describe a lack of ash (and beech) seedlings in areas with deep beech litter. Stands where ash is dominant have often established where there is reduced competition from other vegetation, for example on rocky screes, other unstable slopes, limestone pavements, and/or within established woodlands where heavy shade (e.g. from beech) has limited competition from other ground vegetation, allowing ash to build up a seedling bank which gradually fills canopy gaps as they appear.

In some cases ash might exert competitive dominance over other tree species such as beech, by superior competitive ability for water via its roots (Rysavy and Roloff 1994). Ash is not notable for allelopathic effects, including in its interaction with beech (Rysavy 1991) or other species, but a negative effect of ash bark extract on Scots pine and Norway spruce seed germination has been recorded (Leibundgut 1976).

3.6 Gap and colonisation processes in ash woodlands

This section considers the functional role of ash in terms of colonisation by other species, in contrast to Section 3.4 above. Ash trees cast shade, their turnover creates gaps, and their leaf litterfall has physical impacts on the vegetation growing beneath the canopy as well as influencing soil nutrient cycling (Section 3.2). All these affect the composition of the field layer vegetation within a woodland containing ash.

Dolle and Schmidt (2009) described light availability as the main factor determining the species compositional differences in vegetation diversity recorded during old field succession to either ash- or birch-dominated forest; the low relative PAR irradiance of ash compared to birch-dominated plots was associated with a more shade-tolerant range of species. Emborg (1998) found that the variation in relative light intensity (RLI) was higher under ash-dominated canopies than under beech-dominated canopies (under trees about 20m tall). This indicates that ash-dominated woodlands may allow a more spatially varied colonisation beneath the canopy than beech due to the greater within-stand variation in light.

Ash trees are usually cited as preferring soils with higher base status (pH greater than 4.5; Wardle 1961; Kerr and Cahalan 2004), and the relatively species-rich associated ground vegetation also reflects this higher base status (Rodwell 1991); however they can be found over a wide range of soil acidity. However, colonisation by ash in some circumstances such as oak woods, can occur irrespective of major expected edaphic influences such as soil N and P (Hofmeister *et al* 2004), but usually in more base-rich flushed areas. Ash leaves have high mineral ash content and decay rapidly, usually within 6 months or so (Wardle 1961), which will also facilitate growth of ground vegetation species requiring higher nutrient availability. Replacement by trees with more acidic, less readily decomposed leaf litter (such as beech and oak) could lead to reductions in cover of some of the more nutrient-demanding species due lower rates of release of nutrients back into the system. In addition smaller ground flora species may be reduced in cover if species such as beech or oak replace ash due to the physical smothering of their leaves. The rapid degradation of ash litter is associated with greater soil respiration, and these soil processes are generally sensitive to soil moisture content (Riutta *et al* 2012; Vesterdal *et al* 2012), which can influence most microbial, fungal and faunal components of the system.

The proportion of ash in the canopy of broadleaved forests in Belgium was found to be one of the most important variables in determining community composition of the ground flora (Keymeulen and Beeckman 1990). The persistence of tree litter will influence the ground flora composition with more persistent leaf litter, such as from beech, reducing the productivity of some ground flora species compared to ash (Sydes and Grime 1981b). Reusser *et al* (2010) also found that the presence of ash was correlated with a thick Ah horizon and high soil pH, which enhanced herb layer diversity, in contrast to forests with a high proportion of beech which had a negative effect on herb layer diversity.

3.7 Conclusion

Ash has a special place in the ecosystem function of woodlands, due to it lying at the extreme end of the spectrum of UK tree species with regards to the degradability of its litter. Ash withdraws relatively few nutrients from its leaves prior to abscission, its leaves and roots are readily degradable, all of these contributing to faster nutrient cycling and a higher soil pH. We might consequently expect that where ash is not replaced by functionally similar species, then localised effects of soil acidification might ensue following loss of ash. The rapid nutrient cycling in the ash-soil system is not conducive to accumulation of soil organic carbon, which may be a undesirable outcome in terms of reduction of environmental carbon dioxide. Possible replacement with soil carbon-accumulating species may be construed as an environmental advantage, but any such ecosystem consequences would have to be balanced against the atmospheric carbon fixed in the tissue of ash itself, which is not considered here. Furthermore, carbon is but one of the many differences between ash and possible replacement species, so the possible 'benefits' of any increase in carbon storage by an alternative species would need to be weighed against all the other impacts of that tree species change. This is discussed further in chapters 12 and 15 of this report.

Since ash very often grows in association with other tree species, any disappearance of ash is likely to be replaced ultimately by another tree species. The dominance and spatial distribution of dying and decaying ash will clearly impact on a wide range of above- and below-ground processes. For example, greater interspersion of ash with other species will yield more, smaller gaps, with associated effects on proportion of edge, re-colonisation and interacting nutrient dynamic and abiotic environmental changes in the gaps. Conversely if ash forms a larger proportion of the canopy and if the majority of the ash dies then larger gaps will be created with proportionally larger effects on light penetration and nutrient cycling. If ash saplings can ameliorate soil emissions of N_2O, for example, and any replacement species show a lesser effect, then this may be an additional consideration for the choice of replacement. However, the extent and the range of soil and management conditions under which N_2O emission may be an issue is not yet known.

4 Identification of species associated with ash

<u>Chapter Summary</u>

1. *A list of the plants and animals that use ash had not been collated prior to this report. This chapter describes the structure used to collate information on species associated with ash.*
2. *The information was collated into a database details of which are described in this chapter.*
3. *Information on birds, mammals, fungi, bryophytes (mosses and liverworts), vascular plants and invertebrates that use ash or ash woodlands was gathered.*
4. *For each species identified as using ash the following information was collated:*
   - *The level of association with ash*
   - *Whether the species also used any of 22 selected alternative tree species*
   - *The time of year when the ash tree was used*
   - *The part and age of ash tree that was used*
   - *Whether the ash-associated species contributed to a selected group of ecosystem services*
   - *The quality of the data used to make the above assessments*

4.1 The use of ash by other organisms

A number of animals and plants use ash as a habitat in which to live (e.g. epiphytic bryophytes and lichens), a food source (e.g. many insects and some mammals), a place to breed/nest (e.g. some birds), or a habitat in which to hunt for food (e.g. insects and birds which feed on other insects which use ash). These species may be termed ash-associated species.

Ash-associated species are associated with ash to different degrees, from obligate (unknown on other tree species) to cosmopolitan (i.e. use ash as frequently as, or less frequently than, expected from ash availability). One of the main aims of this contract was to collate information across all species groups about the use of ash. Species groups are defined as: birds, mammals, vascular plants, bryophytes, lichens, fungi, and invertebrates. Soil biodiversity is covered under the relevant species groups listed above, where such information is available. For each species group, a group of experts conducted a literature review using an extensive search of both published and grey literature from both the UK and the rest of Europe, together with unpublished information held by the participating organisations, in order to identify as comprehensively as possible those species that use ash and exactly how they use it. All data was collected under a pre-defined common structure to give a standard format for all of the data, which was then collated into a Microsoft Office Access database. (The tables from this Access database are also available as Microsoft Office Excel spreadsheets.) For individual species groups, both generic and specific approaches were developed to identify species associated with ash, these are described in the individual species group chapters (Chapters 5–11). The structure of the database is detailed in Appendix 1; below we provide a general description of the types of data collected.

4.2 The database – data collected

4.2.1 Species table

The species table in the database contains information on the species names (both Latin and English where available) and the group the species belongs to (bird, mammal, fungi, vascular plant, bryophyte, lichen, or invertebrate). The invertebrates were further sub-divided into ‘Acari’, ‘Coleoptera’, ‘Diptera’, ‘Hemiptera’, ‘Hymenoptera’, ‘Lepidoptera’, ‘Thysanoptera’, ‘Insect not in one of the previous groups’, and ‘other invertebrate’.

If the species had some level of conservation status or protection, this was recorded. Within the conservation community there are different ways of recording conservation status between different species groups. This is reflected within the database, with conservation status recorded variously as ‘Red Data Book’, ‘Birds of Conservation Concern’, or ‘IUCN’, depending on the species group; see individual species groups accounts for further details.

The level of association with ash was recorded as ‘obligate’, ‘high’, ‘partial’, ‘cosmopolitan’, and ‘uses’ (see Table 4.1 for definitions). For some species groups it was possible to define these categories based on the number of records of a species occurring on ash as opposed to other tree species; for other species groups a more subjective assessment was made based on the available literature – see individual species group reports for details. Some measure of the species mobility was recorded (‘within woodland’, ‘<2km from woodland’, and ‘>2km from woodland’) where this information was available. A complete list, and definitions of all the information collated in the species table in the database is shown in Appendix 1.

Table 4.1. Definitions of association with ash.

Value	Definition
Obligate	Unknown from other tree species
High	Rarely uses other tree species
Partial	Uses ash more frequently than its availability
Cosmopolitan	Uses ash as frequently as, or less than, its availability
Uses	Uses ash but the importance of ash for this species is unknown

4.2.2 Alternative tree species

Twenty-two alternative tree species were identified *a priori* by silviculturists and experts as potential replacements for ash (Table 4.2). The species were chosen to cover a range of situations where management objectives varied from nature conservation to timber production and the selection includes examples of species that may spread or colonise woodlands naturally following the loss of ash or may be planted by woodland mangers (Table 4.2). Douglas fir and sweet chestnut were included on the list as examples of tree species that are currently suggested for climate proofing (tree species that may cope with possible climate change) (http://www.forestry.gov.uk/fr/INFD-8CVE4D) as well as being species that have production potential and will grow in conditions where ash currently grows.

Table 4.2. The 22 selected 'alternative' tree species to ash and the ash sub-regions where alternative tree species are suitable for either conservation planting (x) or for planting for production on wet sites (†) or dry sites (*). See Figure 2.5 for sub-regions.

		Ash sub-regions								
Latin name	**English name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Acer campestre	field maple				x			x	x	
Acer platanoides	Norway maple								*	
Acer pseudoplatanus	sycamore	*	*		*	*				*
Alnus glutinosa	alder	x	x	x	x	x	x†	x	x	x
Betula pendula	silver birch	x	x	x	x	x	x	x	x	x
Betula pubescens	downy birch	x	x†	x†	x	x	x	x	x	x
Carpinus betulus	hornbeam							x*	x	
Castanea sativa	sweet chestnut						*			
Corylus avellana	hazel	x	x	x	x	x	x	x	x	x
Crataegus monogyna	hawthorn	x	x	x	x	x	x	x	x	x
Fagus sylvatica	beech							x	x	
Populus tremula	aspen	x	x	x*		x				x
Prunus avium	wild cherry	x			x		x	x	x	
Prunus padus	bird cherry	x	x	x		x	x			x
Pseudotsuga menziesii	Douglas fir	*			*	*	*	*		*
Quercus petraea	sessile oak	x	x	x	x	x	x			x
Quercus robur	pedunculate oak	x†	x	x	x†	x†	x†	x†	x	x†
Salix caprea	goat willow	x	x	x	x	x	x	x	x	x
Salix cinerea	grey willow	x	x	x	x	x	x	x	x	x
Sorbus aria	whitebeam	x					x	x	x	
Taxus baccata	yew							x	x	
Tilia cordata	small-leaved lime			x	x		x	x	x*	

The species experts searched the literature to identify whether the ash-associated species had been recorded using any of these 22 alternative tree species. The level of association of each species with each of the alternative tree species was assessed using one of ten criteria (Table 4.3). All ash-associated species were assessed against these 22 alternative tree species (N.B. both birch species and both oak species were grouped into one assessment for each genus). In addition, if the literature showed that a species that used ash also used other tree or shrub species not included in the list of 22 tree species, these additional tree or shrub species were added to the table of alternative plants for that species. (N.B. this was not done for cosmopolitan species which use so many alternative tree species that the list would be too big to be of use.)

Table 4.3. Criteria used to assess the use by ash-associated species of alternative tree species to ash.

Value	Definition
Obligate	Only uses this plant species*.
High	Rarely uses plant species other than this tree species.
Partial	Uses the alternative more frequently than its availability.
Cosmopolitan	Uses the alternative as frequently as, or lower than, its availability.
Rare	Has been recorded on the alternative but only rarely.
Uses	Uses the alternative but its importance is unknown.
Likely	It is thought likely that the species uses this tree species. This value was used for cosmopolitan invertebrates where the literature stated that the species uses a wide range of food sources but no information is available on whether it actually uses this particular tree species.
Parasitoid	The species is parasitic on a species that uses ash, but is also parasitic on a range of other species. It was beyond the scope of this project to assess all the other food plants used by all the other hosts the parasite uses.
Unknown	Not known if the species uses this alternative.
No	The species does not use this alternative tree species.

*Generally not applicable for assessment of use made of alternative plant species but was used occasionally for lichens – see Chapter 6 for explanation.

4.2.3 Tree age/growth form and parts of tree used

There are five tables within the database that further describe the specific use of ash made by the ash-associated species selected in Section 4.2.1. The 'Part' table indicates whether the ash-associated species uses the bark, canopy, roots, leaves, trunk, limbs/branches/twigs, seeds, flowers, litter, shoots, or deadwood of ash. The part of the ash tree used by a species will influence the impact that loss of ash may have on that species, for example species that use deadwood may initially increase following the arrival of ash dieback and an increase in deadwood. An additional category of 'woodland' was also included in this table; this was used to distinguish organisms (vascular plants and some mammals) that used ash woodlands but not the tree itself.

The species experts recorded the use that each species made of ash ('Use' table in database). Species were assessed as using ash for feeding directly (i.e. eating ash), feeding indirectly (eats another organism found on the ash), or using the ash as habitat in which to live (e.g. epiphytes, bird nest holes, etc.).

The time of year a species used ash ('Time' table in the database) was recorded as spring (March, April, May), summer (June, July, August), autumn (September, October, November), or winter (December, January, February). If a species used the tree all year, the 'all year' option was chosen.

Some species only use a particular age of ash; this is recorded in the 'Age' table in the database. Nine different ages of tree were identified (Table 4.4). If a species was not associated with a particular age of ash then this table was not filled in.

Table 4.4. Ash age-classes and definitions.

Age	Definition
Seed	Seed.
Seedling	1 year old or less.
Sapling	Under 2m in height.
Pole	Over 2m in height, younger than 50 years.
Mature	More than 2m in height and under 3m in girth (less than 100cm DBH).
Notable	Large girth (over 3m in girth or 100cm DBH for ash, taking into consideration environmental conditions) but with no visible 'Veteran' features (see 'Veteran' definition for list). If information is only available that the species occurs on trees >3m girth, record as 'Ancient', if you are able to be more specific about the use of 'Veteran' and 'Ancient' trees listed below, then include these ages as well.
Veteran	Large girth (over 3m in girth or 100cm DBH for ash, taking into consideration environmental conditions) with at least three 'Veteran' attributes (e.g. important habitats visible such as deadwood in the trunk; contain standing deadwood; have fallen wood around base; rot holes; water pockets; seepage lines; hollows in trunk or major limbs, etc.).
Ancient	Large girth (over 3m in girth or 100cm DBH for ash, taking into consideration environmental conditions), past biological maturity and in the final, often longest, stage of life. Usually have a retrenching crown as a key feature and numerous 'Veteran' features.
Dead	Dead tree.

If a species is associated with a particular growth form of ash this was recorded in the 'Treeform' table. The growth forms identified were: 'coppice', 'pollard', or 'natural' (i.e. not managed by coppicing or pollarding). If all growth forms were used, this was recorded as 'all growth forms'.

4.2.4 Woodland type

Ash occurs in a range of woodland types as well as in wood pasture and as single and hedgerow trees. As some species may only use ash when it occurs in a particular woodland type, this was recorded in the 'Woodland' table in the database using the criteria in Table 4.5.

Table 4.5. Definitions of woodland types.

Woodland type	Definition
Ancient woodland[1]	Any site that has always been wooded since at least 1600AD (in England and Wales), 1750 in Scotland, or 1830 in Northern Ireland, when the first maps appeared.
Recent woodland[1]	Includes woodland established since AD1600 that have regenerated and planted native woodland.
Wood pasture[1]	An ancient system of land-use in which domestic animals were grazed within woodland or under widely scattered trees. The trees were often pollarded.
Non-woodland	Single trees and hedges.

[1]Definition taken from Royal Forestry Society (2008) A glossary of tree terms http://www.rfs.org.uk/files/TreeTerms_RFS_17102011.pdf.

4.2.5 Ecosystem services

'Ecosystem services' are defined as the outputs of ecosystems from which people derive benefits (UK National Ecosystem Assessment 2011). Ecosystem services can be divided into provisioning, cultural and regulating services. It is beyond the scope of this project to assess all the ecosystem services provided by all ash-associated species. Indeed the assessment of cultural services provided by species and how this is assessed/valued is a major research topic within its own right (UK National Ecosystem Assessment 2011). Here we confine ourselves to the identification of five specific ecosystem services which may be provided by the ash-associated species (the ES table in the database):

- Provisioning – within this report we only assess whether the ash-associated species provides food for humans, such as meat, berries, nuts or fungi.
- Pollination – described by the UKNEA as a regulating service. This report identifies whether the species carries out pollination.
- Dispersal – this is an intermediate service as defined by the UKNEA. Within this report we specifically assess whether the species disperses seeds.
- Nutrient cycling – a supporting service. The UKNEA defines nutrient cycling as "The processes by which elements are extracted from their mineral, aquatic, or atmospheric sources or recycled from their organic forms, converting them to the ionic form in which biotic uptake occurs and ultimately returning them to the atmosphere, water or soil." Thus all species are involved in this process to some extent and are recorded as such in the database.
- Decomposition – this is part of nutrient cycling but as all species are involved in nutrient cycling, we assess separately whether the species carries out decomposition.

It should be noted that the provisioning of goods or services by the ash trees themselves, such as timber, was not assessed.

4.2.6 Data quality

The quality of the data used to assess the level of association with ash and alternative tree species was categorised into five classes (Table 4.7). Data was first classed as 'anecdotal', 'peer-reviewed' (PR), or 'non-peer-reviewed' (NR). 'Peer-reviewed' covered a broad range of data sources and included anything that had received some form of quality control: published text books, scientific literature and databases that were quality controlled. The 'peer-reviewed' and 'non-peer-reviewed' categories were further sub-divided depending on whether the data was based on UK information or not. This was done as there is evidence that some species use different host species in the UK than they do in continental Europe.

Table 4.6. Criteria used to assess data quality.

Data quality	Definition
Anecdotal	Information is predominantly based on anecdotal evidence – word of mouth, usually 'expert opinion'.
NR-NonUK	Information is predominantly based on literature that has an unknown review process (i.e. non-peer-reviewed) and uses data from outside the UK.
NR-UK	Information is predominantly based on literature that has an unknown review process but is based on UK data.
PR-NonUK	Information is predominantly based on peer-reviewed literature but uses data from outside the UK.
PR-UK	Information is predominantly based on peer-reviewed literature using data from the UK.

5 Vascular plants

Chapter Summary

1. *No vascular plants use ash trees as such, as there are no epiphytic vascular plants associated with ash. This chapter identifies which vascular plant species are associated with ash woodlands.*
2. *Ash is dominant in eight National Vegetation Communities: W8a, W8b, W8c, W8d, W8e, W8g, W9a and W12a.*
3. *From these 8 communities 78 vascular plants were identified that may be classed as being partially associated with ash woodlands.*
4. *Eight of these 78 vascular plants are already of conservation concern*
5. *The impact of the loss of ash on these species will depend on the extent to which ash disappears, on which tree species replaces ash, and on the environment created by these replacement tree species.*

5.1 Methods to assess which plants are most closely associated with ash woodlands

No vascular plants use ash trees as such, as there are no epiphytic vascular plants associated with ash. Here we aim to identify which vascular plant species are highly associated with ash woodlands. We used the National Vegetation Classification (NVC) types originally identified by Rodwell (1991) and the more recently updated floristic tables (http://jncc.defra.gov.uk/page-4265) to identify woodland communities and sub-communities where ash is frequently found and then to identify other plant species that are also associated with these communities. Descriptions of the NVC community distributions were based on those available at http://jncc.defra.gov.uk/page-4265.

5.1.1 Woodland communities containing ash

All woodland NVC communities containing ash were identified and are summarized in Table 5.1.

Table 5.1. Frequency of ash in all NVC woodland communities (and sub-communities).

Frequency*	Number of communities (and sub-communities)	Community or (sub-community) codes
V	0 (3)	(W8d, W8e, W8g)
IV	2 (5)	W8, W9 (W8a, W8b, W8c, W9a, W12a)
III	4 (9)	W5, W7, W12, W21 (W5a, W5b, W7a, W7c, W8f, W9b, W10e, W21b, W21d)
II	1 (9)	W10 (W2a, W6a, W7b, W10b, W10c, W11a, W12c, W21a, W21c)
I	9 (20)	W2, W4, W6, W11, W13, W14, W17, W24, W25 (not listed)
Absent	9 (24)	W1, W3, W15, W16, W18, W19, W20, W22, W23 (not listed)

*Frequency shows the percentage of samples in which ash occurs. I = 1-20%, II = 21-40%, III = 41-60%, IV = 61-80%, V = 81-100%

5.1.2 Woodland communities with a high frequency of ash

All NVC woodland communities and sub-communities where ash occurs at a frequency of IV or V (regardless of average or maximum abundance) were identified. Frequency refers to how often a plant is found, on moving from one sample of the vegetation to the next, irrespective of how much of that species is present in each sample. This identified woodland/scrub communities and sub-communities where ash occurs in at least 60% of the available samples. We have followed the usual phytosociological convention of referring to species of frequency classes IV and V in a particular community/sub-community as constants. This identified three sub-communities where ash occurred at a frequency of V (W8d, W8e, and W8g) and five sub-communities where ash occurred at a frequency of IV (W8a, W8b, W8c, W9a and W12a).

5.1.3 Common vascular plant species also occurring as constants in ash woodlands

For the eight communities identified above, all species within these communities that also occurred at a frequency of IV or V were identified (i.e. also considered as constants in the community/sub-community). This identified 19 species (Table 5.2), none of which were recorded as having any conservation designations.

The list covers species with a wide variety of life forms (after Raunkiaer 1934), and includes trees, shrubs, grasses, herbs and ferns. Of these common species that have an association with the eight ash sub-communities identified, the species that occur in nearly all of these sub-communities are *Corylus avellana* and *Mercurialis perennis* (six sub-communities, Table 5.2) and *Crataegus monogyna* and *Rubus fruticosus* agg. (four sub-communities, Table 5.2). Of the remaining species, only *Quercus robur* and *Hedera helix* are recorded as associated constants in two sub-communities, with the remaining 13 species only recorded as an associated constant in one of the eight sub-communities.

This list compares fairly favourably with the top five species identified from the Sheffield region by Grime *et al* (2007) as occurring most commonly with ash, these being *Mercurialis perennis* – 87% similarity, *Allium ursinum* – 86%, *Anemone nemorosa* – 85%, *Brachypodium sylvaticum* – 84%, and *Lamiastrum galeobodolon* – 83%.

Table 5.2. Species recorded at a frequency of IV and V in woodland sub-communities where ash is also a constant.

Taxon	Life form	IV	Sub-communities	V	Sub-communities	Total
Acer pseudoplatanus	Tree	1	W8e	0		1
Anemone nemorosa	Herb	0		1	W8b	1
Brachypodium sylvaticum	Grass	1	W8g	0		1
Corylus avellana	Tree	2	W8b, W9a	4	W8a, W8c, W8d, W8g,	6
Crataegus monogyna	Shrub	3	W8b, W8e, W8g	1	W8d	4
Deschampsia cespitosa	Grass	0		1	W8c	1
Dryopteris filix-mas sens. str.	Fern	1	W9a	0		1
Fagus sylvatica	Tree	0		1	W12a	1
Hedera helix	Shrub	2	W8d, W12a	0		2
Hyacinthoides non-scripta	Herb	1	W8b	0		1
Mercurialis perennis	Herb	4	W8a, W8e, W9a, W12a	2	W8d, W8g	6
Oxalis acetosella	Herb	1	W9a	0		1
Quercus robur	Tree	2	W8a, W8d	0		2
Ranunculus ficaria	Herb	1	W8b	0		1
Rubus fruticosus agg.	Shrub	3	W8a, W8d, W12a	1	W8c	4
Teucrium scorodonia	Herb	1	W8g	0		1
Ulmus glabra	Tree	1	W8e	0		1
Viburnum opulus	Shrub	0		1	W8g	1
Viola riviniana	Herb	1	W9a	0		1

Total = total number of communities/sub-communities where the species is present.

5.1.4 Common vascular plant species showing a preference for woodland with a constancy of ash as opposed to other woodland types

For these 19 species, all other NVC communities were searched to identify which other communities/sub-communities these species also occurred in with a frequency of IV or V. Using this high frequency enabled us to identify species which occurred in over 60% of samples. The results are listed in Table 5.3.

Table 5.3. NVC communities/sub-communities where species identified as highly associated with ash woodland also occur.

Taxon	Life form	Other NVC communities/sub-communities where the species is recorded as a constant (IV and V)		Total
		Woodland communities	**Non-woodland communities**	
Acer pseudoplatanus	Tree		OV27d	1
Anemone nemorosa	Herb	W10b, W11c, W19b		3
Brachypodium sylvaticum	Grass	W9b, W21c, W21d		3
Corylus avellana	Tree	W8f, W9b, W10c		3
Crataegus monogyna	Tree	W21a, W21b, W21c, W21d		4
Deschampsia cespitosa	Grass	W4b, W7c, W20	CG12, M26b, M31, M32a, M33, M34, MG9a, MG9b, U11b, U13a, U13b, U14, U15, U16a, U17a, U17b, U17c, U18	21
Dryopteris filix-mas sens. str.	Fern		MG2a, MG2b	2
Fagus sylvatica	Tree	W12b, W12c, W14, W15a, W15b, W15c, W15d		7
Hedera helix	Shrub	W10c, W12b, W21a, W21b, W21c, W21d		6
Hyacinthoides non-scripta	Herb	W10b, W11b, W25a	MC12a, MC12b	5
Mercurialis perennis	Herb	W8f, W12b, W13b, W21b	MG2a, MG2b	6
Oxalis acetosella	Herb	W9b, W10e, W11a, W11b, W11c, W11d, W17c, W19a, W19b	U16a, U19	11
Quercus robur	Tree	W10b, W10c, W10d, W15c		4
Ranunculus ficaria	Herb		MC12a	1
Rubus fruticosus agg.	Herb	W4a, W5b, W5c, W6d, W6e, W10a, W10b, W10c, W10d, W14, W21a, W21c, W21d, W22a, W23a, W23b, W23c, W24a, W24b, W25b	OV27c	21
Teucrium scorodonia	Herb	W23c, W25b	OV38	3
Ulmus glabra	Tree			0
Viburnum opulus	Shrub			0
Viola riviniana	Herb	W9b, W11b, W11c, W11d, W19b	CG9c, CG9d, CG9e, CG10a, CG10b, CG10c, CG11a, CG13a, CG13b, CG14, H6a, H6b, H6d, H7b, H10d, H16a, H20a, U17b	23

Of these common species that are recorded as constants in the ash woodland sub-communities, those that appear to be the most preferential to ash are *Ulmus glabra* (one ash sub-community and no other communities/sub-communities) and *Viburnum opulus* (also one versus none). The only other species which is preferential to ash is *Corylus avellana* (six versus three). *Crataegus monogyna* (four versus four), *Mercurialis perennis* (six versus six) and *Ranunculus ficaria* (one versus one) showed equal preferences to ash as opposed to other NVC communities/sub-communities. All of the other species showed a wider ecological preference (i.e. were found in a wider range of non-ash than ash-related NVC types).

5.1.5 Ancient Woodland Indicator Species associated with ash woodland

Ancient Woodland Indicator Species (AWIS) which were recorded in the NVC samples were identified using lists given in Kirby *et al* (2012) and Rose (1991), and these were also examined to assess whether they were preferential to those sub-communities where ash is a constant. Some of these species have already been listed above as they were recorded at a frequency of IV or V in ash constant communities and so are not listed again here.

This gives rise to two sets of species, which we term ‘strongly associated’ and ‘associated’; a description of how they were derived is given below.

5.1.6 Strongly associated Ancient Woodland Indicator Species from the NVC

Strongly associated species are regarded as those AWIS that occur at their maximum frequency (III, II or I) only in the ash constant communities/sub-communities described (i.e. W8a, W8b, W8c, W8d, W8e, W8g, W9a, W12a). The list (Table 5.4) covers species with a wide variety of life forms, and includes trees, shrubs, grasses, herbs and ferns. Some of the AWIS have a strong regional bias, so if the lists of ash-associated vascular plants were further developed into regional lists, this should be taken into account.

Table 5.4. Ancient Woodland Indicator Species (AWIS) strongly associated with woodlands where ash is a constant species and where the species is recorded at its highest frequency.

AWIS taxon	Life form	Preferential sub-communities[1]	Freq[2.]	Number of ash sub-communities	Conservation status
Acer campestre	Tree	W8c-e, W8g	III	4	No designation
Potentilla sterilis	Herb	W9a	III	1	No designation
Carex sylvatica	Sedge	W8a, W8g	II	2	No designation
Carpinus betulus	Tree	W8a-b	II	2	No designation
Campanula latifolia	Herb	W8g	II	1	No designation
Convallaria majalis	Herb	W8g	II	1	No designation
Galium odoratum	Herb	W12a	II	1	No designation
Melica nutans	Herb	W8g	II	1	No designation
Myosotis sylvatica	Herb	W8g	II	1	No designation
Polystichum aculeatum	Fern	W8g	II	1	No designation
Tilia cordata	Tree	W8a	II	1	No designation
Festuca gigantea	Grass	W8a-e, W8g, W9a	I	7	No designation
Polystichum setiferum	Fern	W8a-b, W8d-e	I	4	No designation
Polygonatum multiflorum	Herb	W8a-b, W8e	I	3	No designation
Daphne mezereum	Shrub	W8e, W8g	I	2	NS IUCN (2001) - Vulnerable
Platanthera chlorantha	Herb	W8a, W8c	I	2	SBL IUCN (2001) - Lower risk - Near Threatened
Viola odorata	Herb	W8d-e	I	2	No designation
Circaea x intermedia	Herb	W9a	I	1	No designation
Sorbus torminalis	Tree	W8a	I	1	No designation

[1]The ash-dominated NVC sub-communities where the species occurs at the maximum frequency.
[2]Frequency is the frequency with which the taxon is listed in the NVC tables (see Table 5.1 for definitions of frequency values); the frequency given is the highest frequency with which the species occurs in any NVC sub-community.

- NS = Nationally Scarce. Occurring in 16–100 hectads (10x10km) in Great Britain.
- IUCN (2001) - Vulnerable. A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see section V), and it is therefore considered to be facing a high risk of extinction in the wild. (Source Cheffings and Farrell 2006).
- IUCN (2001) - Lower risk - Near Threatened. A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future. (Source Cheffings and Farrell 2006)
- SBL = Scottish Biodiversity List of species of principal importance for biodiversity conservation. The Scottish Biodiversity List is a list of flora, fauna and habitats considered by the Scottish Ministers to be of principal importance for biodiversity conservation.

5.1.7 Associated Ancient Woodland Indicator Species from the NVC

Associated species are described as those AWIS that are found at their maximum frequency in a greater number of ash constant sub-communities than other communities. A list of these is given in Table 5.5. None of these species are recorded as having any conservation designations.

Table 5.5. Ancient Woodland Indicator Species (AWIS) associated with woodlands where ash is a constant species and where the indicator species is recorded at its highest frequency, and other communities where it also occurs at its highest frequency.

AWIS taxon	Life form	Preferential communities[1]	Freq[2].	Number of ash constant communities	Number of non-ash constant communities
Campanula trachelium	Herb	W8a-b, W8e, W8g, W12a-b	I	5	1
Daphne laureola	Shrub	W8d-e, W8g, W12a-b	I	4	1
Lamiastrum galeobdolon subsp. *montanum*	Herb	W8b, W10b, W12a	II	2	1

[1]The ash-dominated NVC sub-communities where the species occurs at the maximum frequency.
[2]Frequency is the frequency with which the taxon is listed in the NVC tables, the frequency given is the highest frequency with which the species occurs in any NVC sub-community.

5.1.8 Tentatively associated Ancient Woodland Indicator Species from the NVC

A third set of species may be termed 'tentatively associated' (Table 5.6), in that they are frequently found in woodland sub-communities that contain ash but not necessarily where ash is constant. For this purpose we have chosen those NVC sub-communities where ash is present in frequency class III (i.e. a common or frequent species (Rodwell 1991)), and where the maximum ash abundance is recorded as being of DOMIN scale 7 or above (up to 50% cover). This widens the ecological amplitude of the ash habitat to include some wetter *Fraxinus excelsior-Alnus glutinosa-Lysimachia nemorum* woodlands (W7a: the *Urtica dioica* and W7c: the *Deschampsia cespitosa* sub-communities), the remaining *Fraxinus excelsior-Acer campestre* type not already included (W8f: the *Allium ursinum* sub-community), the *Acer pseudoplatanus-Oxalis acetosella* sub-community of the *Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland (W10e), and the *Mercurialis* sub-community of the *Crataegus monogyna-Hedera helix* scrub community W21b. As previously, the highest frequencies in which the Ancient Woodland Indicator species (AWIS) occur in all sub-communities were inspected to assess whether there were a greater number which were found in this enlarged list of ash communities than within other communities. None of the tentatively associated species were recorded as having any conservation designations.

Table 5.6. Tentatively associated Ancient Woodland Indicator Species (AWIS): species that are frequently found in woodland sub-communities where ash is common but not necessarily where ash is constant.

AWIS taxon	Life form	Preferential communities	Freq.	Number of ash frequent or constant communities	Number of non-ash constant or frequent communities
Allium ursinum	Herb	W8f	V	1	0
Athyrium filix-femina	Fern	W7a-c, W9a-b	III	3	2
Melica uniflora	Herb	W8g, W12b	III	1	1
Phyllitis scolopendrium	Fern	W8e, W8f	II	2	0
Veronica montana	Herb	W7c, W9a	II	2	0
Prunus padus	Shrub	W8g, W9b	II	1	1
Rosa arvensis	Shrub	W21b	II	1	0
Stachys sylvatica	Herb	W7c, W9b	II	1	1
Euonymus europaeus	Shrub	W8a, W8c-g, W12a-c, W13b, W21a-d	I	8	6
Euphorbia amygdaloides	Herb	W8a-f, W10a-d, W12a-b, W14	I	7	6
Malus sylvestris sens. lat.	Tree	W8a, W8c-e, W8g, W10a-c, W10e, W21a-b	I	7	4
Crataegus laevigata	Tree	W8a-d, W10a-c, W21a	I	5	3
Equisetum sylvaticum	Herb	W7a, W7c	I	2	0
Narcissus pseudonarcissus subsp. *pseudonarcissus*	Herb	W8f-g, W10b-c	I	2	2
Ribes rubrum	Shrub	W5a-b, W8e-f	I	2	2

5.1.9 Other Ancient Woodland Indicator Species not recorded within the NVC

For those Ancient Woodland Indicator Species (AWIS) not recorded within the NVC samples (usually due to their relative rarity), it is possible to infer their general degree of association with ash from the literature, particularly from the summaries and species accounts in the *Online Atlas of the British and Irish Flora*. Table 5.7 lists the remaining Ancient Woodland Indicator Species within this group.

Table 5.7. Ancient Woodland Indicator Species (AWIS) not recorded within the NVC, but which are recorded as having an association with ash woodland.

AWIS taxon	Life form	Conservation status	British and Irish Atlas link
Paris quadrifolia	Herb	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/paris-quadrifolia
Lathraea squamaria	Herb	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/lathraea-squamaria
Viola reichenbachiana	herb	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/unmatched-species-name-235
Viola reichenbachiana x riviniana (V. x bavarica)	Herb	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/unmatched-species-name-236
Carex strigosa	Sedge	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/carex-strigosa
Dipsacus pilosus	Herb	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/dipsacus-pilosus
Elymus caninus	herb	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/elymus-caninus
Helleborus viridis	Herb	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/helleborus-viridis
Gagea lutea	Herb	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/gagea-lutea
Festuca altissima	Grass	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/festuca-altissima
Cardamine impatiens	Herb	NS SBL IUCN (2001) - Lower risk - Near Threatened	http://www.brc.ac.uk/plantatlas/index.php?q=plant/cardamine-impatiens
Bromopsis benekenii	Grass	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/bromopsis-benekenii
Carex digitata	Sedge	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/carex-digitata
Orchis purpurea	Herb	NS IUCN (2001) - Endangered	http://www.brc.ac.uk/plantatlas/index.php?q=plant/orchis-purpurea
Polygonatum odoratum	Herb	No designations found	http://www.brc.ac.uk/plantatlas/index.php?q=plant/polygonatum-odoratum
Primula elatior	Herb	NS IUCN (2001) - Lower risk - Near Threatened	http://www.brc.ac.uk/plantatlas/index.php?q=plant/primula-elatior
Hordelymus europaeus	Grass	NS The Wildlife (Northern Ireland) Order 1985 (Schedule 8 - Part 1) SBL	http://www.brc.ac.uk/plantatlas/index.php?q=plant/hordelymus-europaeus

Note: Conservation Status is summarized below.

- NS = Nationally Scarce. Occurring in 16–100 hectads in Great Britain.
- IUCN (2001) - Endangered. A taxon is endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered, and it is therefore considered to be facing a very high risk of extinction in the wild. (Source: Cheffings and Farrell 2006.)
- IUCN (2001) - Lower risk - Near Threatened. A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for, or is likely to qualify for, a threatened category in the near future. (*Source*: Cheffings and Farrell 2006.)
- SBL = Scottish Biodiversity List of species of principal importance for biodiversity conservation. The Scottish Biodiversity List is a list of flora, fauna and habitats considered by the Scottish Ministers to be of principal importance for biodiversity conservation.
- The Wildlife (Northern Ireland) Order 1985 (Schedule 8 - Part 1). Plants which are protected from intentional picking, removal or destruction and from selling (in whole or part) and from advertising for sale.

In addition there are two Northern Ireland priority species: *Melampyrum sylvaticum* and *Geranium sylvaticum* which are listed as being associated with mixed ash woodlands in the Northern Ireland Habitat Action Plan for this habitat.

5.1.10 Other rare species noted in the NVC as being associated with ash woodland

This remaining list of vascular plant species are those that are not recorded within the NVC woodland floristic tables, but are mentioned in the text as being rare species within W8 and W9 communities (Table 5.8). They include species that are not included in Kirby *et al* (2012) and Rose (1991) as possible ancient woodland indicators because rare species were generally left out of this list as there were too few occurrences to be sure there was an association with ancient woodland.

Table 5.8. Other rare species noted in the NVC as being associated with ash woodland.

Taxon	Life form	NVC	Conservation status	British and Irish Atlas link
Ribes alpinum	Shrub	W8	No designations found.	http://www.brc.ac.uk/plantatlas/index.php?q=plant/ribes-alpinum
Tilia platyphyllos	Tree	W8	No designations found.	http://www.brc.ac.uk/plantatlas/index.php?q=plant/tilia-platyphyllos
Actaea spicata	Herb	W9	No designations found.	http://www.brc.ac.uk/plantatlas/index.php?q=plant/actaea-spicata
Crepis mollis	Herb	W9	NR SBL UK BAP species IUCN (2001) - Endangered NERC s41	http://www.brc.ac.uk/plantatlas/index.php?q=plant/crepis-mollis
Polygonatum verticillatum	Herb	W9	Wildlife and Countryside Act 1981 (Schedule 8) NR SBL UK BAP species IUCN (2001) - Vulnerable	http://www.brc.ac.uk/plantatlas/index.php?q=plant/polygonatum-verticillatum

Note: Conservation Status is summarized below:

- Wildlife and Countryside Act 1981 (Schedule 8). Plants which are protected from intentional picking, uprooting or destruction (Section 13 1a); selling, offering for sale, possessing or transporting for the purpose of sale (live or dead, part or derivative) (Section 13 2a); advertising (any of these) for buying or selling (Section 13 2b).

- NR = Nationally Rare. Occurring in 15 or fewer hectads in Great Britain. Excludes rare species qualifying under the main IUCN criteria.
- SBL = Scottish Biodiversity List of species of principal importance for biodiversity conservation. The Scottish Biodiversity List is a list of flora, fauna and habitats considered by the Scottish Ministers to be of principal importance for biodiversity conservation.
- UK Biodiversity Action Plan priority species – The UK List of Priority Species and Habitats contains 1,150 species and 65 habitats that have been listed as priorities for conservation action under the UK Biodiversity Action Plan (UK BAP).
- IUCN (2001) - Vulnerable. A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see Section V), and it is therefore considered to be facing a high risk of extinction in the wild. (Source: Cheffings and Farrell 2006)
- NERC s41. Natural Environment and Rural Communities Act 2006 - Species of Principal Importance in England – Species "of principal importance for the purpose of conserving biodiversity" covered under section 41 (England) of the NERC Act (2006) and therefore need to be taken into consideration by a public body when performing any of its functions with a view to conserving biodiversity.

5.2 Completeness of data, knowledge gaps and future research needs

5.2.1 Completeness of data

As vascular plants don't use ash trees as such, but rather the habitat, some columns within the database were not relevant for vascular plants. Here we document the approach used.

The level of association with ash was recorded as partial for all species, as no vascular plants are dependent on ash in the same specific way as some invertebrates or epiphytic lichens/bryophytes. Rather the plants are associated with the ash woodland habitat. Thus in the Access database, the Table 'Part' (part of tree used) was filled in as 'woodland', to allow distinction between the epiphytic lichens and bryophytes that use the tree itself as a habitat as opposed to vascular plants that use the woodland habitat but not the tree. The tables 'Use' (use made of tree), 'Age' (age of tree used), and 'Treeform' (tree form) are not applicable to vascular plants and were therefore not filled in. For similar reasons the 'alternative tree species' table was not filled in for vascular plants. Whether any given vascular plant species would occur in a woodland containing one of the 22 alternative tree species depends on the density of the trees, the shade cast, what other species are present (competition), and other environmental factors. An assessment of how the vascular plant community of ash woodlands may change following the loss of ash is provided in Chapter 13.

Assessing the dispersal of plants and their mobility is problematic, as it can only take a few 'one-off events' for a species to colonise a new area if their seed lands in a suitable environment. In addition the time-frame over which dispersal is measured is important. Over tens, hundreds or thousands of years plants may 'move' a considerable distance as they colonise new areas. Here we define mobility as how far a seed may reasonably travel in any year. This was generally recorded as <2km, as species may move between woodlands if dispersed by animals or the wind but are unlikely to move >2km. However, if a species was recorded as largely reproducing vegetatively (Grime *et al* 2007), then the mobility was recorded as only 'within woodland'.

The plants included in this assessment are by definition associated with woodlands (Section 5.1), therefore entries of 'wood pasture' and 'non-woodland' habitat in the woodland table were not applicable. There is no indicator list of plants found in recent woodland, but there are indicator lists of ancient woodland plants (Kirby *et al* 2012). Where the species is listed as an indicator of ancient woodland, the option for 'ancient woodland' within the woodland type category in the database was chosen. However, due to the methodology used to identify the plant species associated with ash woodland (Section 5.1), this resulted in most of the plant species in the database being recorded as ancient woodland indicators.

Information on the conservation status of the vascular plants was obtained from the *Online Atlas of the British and Irish Flora*, with IUCN and Red Data Book status taken from Cheffings and Farrell (2006).

5.2.2 Knowledge gaps and future research

The vascular plant species associated with ash woodlands occur in these woodlands due to a range of environmental factors created by the ash, such as shade levels/seasonality and the chemical composition of the litter. They are also impacted by other environmental factors such as soil moisture, soil chemistry, and climate; when the requirements of the vascular plants for these conditions overlap with those in which ash can grow, the species may be found co-occurring with ash. The relative importance of the conditions provided directly by ash and those provided by general environmental conditions are generally unknown.

The impact of ash dieback on vascular plants will depend on the extent of ash dieback, mortality and regeneration, on which tree species replace ash, and how similar the traits of these tree species are to those of ash (Chapter 15), as well as any management of the woodland and control of herbivores, particularly deer and squirrels. Future research should include the monitoring of woodland vegetation following ash dieback and any associated management. Ideally this should start in woods prior to them being infected with ash dieback such as those where long-term monitoring is already happening (e.g. Wytham woods). The monitoring would enable the impact of the removal of a keystone or engineering species (ash) from within the woodland to be assessed.

5.3 Species of conservation concern that may decline further as a result of ash dieback

Of the 78 species identified as being associated with ash woodlands, only eight of them are of conservation concern: *Daphne mezereum*, *Platanthera chlorantha*, *Cardamine impatiens*, *Primula elatior*, *Hordelymus europaeus*, *Crepis mollis, Orchis purpurea* and *Polygonatum verticillatum*. The following descriptions of the habitat requirements and distribution of these species is based on information from the *Online Atlas of the British and Irish Flora* http://www.brc.ac.uk/plantatlas/.

C. mollis has the following conservation designations: UK BAP species; Red Data Book – Nationally Rare; IUCN – Endangered; and is listed under section 41of the NERC act. It occurs in 75 10km squares within Great Britain, on herb-rich grassland and wood-pasture on shallow base-rich soils. It is a light-loving plant with an Ellenberg light value of 8 (rarely found where the relative illumination in summer is less than 40%).

P. verticillatum is also a UK BAP species, and is listed as Red Data Book – Nationally Rare, and IUCN – Vulnerable. It is usually found on moist, nutrient-rich, usually basic, soils in wooded gorges and on a wooded river bank, occurring in 10 10km squares within Great Britain. It requires shadier sites than *C. mollis* (Ellenberg light value of 4, 5–10% relative illumination) and moist soils (Ellenberg moisture value of 5).

H. europaeus is listed as Nationally Scarce in the Red Data Book, and is found in 184 10km squares. It occurs in woods and copses on calcareous soils, especially in sheltered beech woodlands and along boundary banks and old hedgerows. It requires moderate light levels (Ellenberg light value of 6) and reasonably dry soils (Ellenberg moisture 4).

P. elatior is listed as Nationally Scarce in the Red Data Book, and Near Threatened by IUCN criteria. It is found in woods dominated by field maple, hazel, ash and oak, on damp chalky boulder-clay soils, especially where seasonal flooding occurs. It is found in 38 10km squares in Great Britain. It is a semi-shade-tolerant plant requiring moderate moisture (Ellenberg values: light = 4, moisture = 5).

C. impatiens is listed as Nationally Scarce in the Red Data Book, and Near Threatened by IUCN criteria. It is found in woodland (particularly under ash), on moist limestone rocks (including the grykes of limestone pavement) and stable screes, by rivers and on damp roadsides. It occurs in 159 10km squares in Great Britain. It requires moderate light and moisture (Ellenberg values: light = 6, moisture = 5).

P. chlorantha is on the Scottish Biodiversity List of species of principal importance for biodiversity conservation and is classed by the IUCN as Lower risk - near threatened. It is found in a wide variety of habitats, usually on well-drained calcareous soils. Typical habitats include downland, rough pasture, hay meadows, scrub, woodland and young plantations. It is found in 1,163 10km squares in Great Britain, and requires moderate light and moisture (Ellenberg values: light = 5, moisture = 5).

O. purpurea is listed as Nationally Scarce in the Red Data Book, and Endangered by IUCN criteria. It is found on thin calcareous soils, typically over chalk but also on clay, ragstone and Carboniferous limestone. It grows in open hazel, ash or beech woodland and scrub and, more rarely, in open grassland. It is found in 36 10km squares in Great Britain. (Ellenberg values: light = 5, moisture = 4).

D. mezereum is listed as Nationally Scarce in the Red Data Book, and Vulnerable by IUCN criteria. It is a deciduous shrub of calcareous woodland, often on steep, sometimes rocky, slopes with little ground cover, but rarely in deep shade. It also grows in chalk-pits, and in wet, species-rich fens. It is found in 110 10km squares, and is a semi-shade-tolerant plant requiring moderate moisture (Ellenberg values: light = 4, moisture = 5).

The impact of the loss of ash on these species will depend on the extent to which ash disappears, on which tree species replace ash, and on the environment created by these replacement tree species. In particular, if the light received by the ground flora or soil moisture of the woodland changes, this will drive changes in populations of these species of conservation concern. If the replacement tree species cast a heavier shade than ash or if the shrub layer becomes dense this could result in a decline in *C. mollis*, *H. europaeus, O. purpurea* and *C. impatiens* which are all light-loving species. The other four species will probably survive a slight decline in light levels, but if the replacement tree species is a conifer, resulting in a large decline in light levels, then all eight species may decline. If the loss of ash results in more light reaching the ground flora and a reduction in soil moisture, this could result in a decline in *P. elatior*, *P. verticillatum* and *D. mezereum*.

5.4 Species that are not currently rare but may become so as a result of ash dieback

Ninety-one percent of the vascular plant species associated with ash woodlands are not of conservation concern. The abundance and distribution of these species within ash woodlands may change as a result of the loss of ash (Chapter 13). However, as none of these species are strongly associated with ash woodlands, or already rare, it is unlikely that a vascular plant species that is not currently rare will become so as a result of ash dieback. The main impact of ash dieback on the vascular plant community will therefore be a change in the species composition of ash woodlands and the resulting ecological functions.

6 Lichens

Chapter summary

1. *The British Lichen Society database was used to identify lichens that are associated with ash trees.*
2. *The 'level of association' for a species was considered obligate if 100% of records were from ash, high if more than 50% of records were from ash, partial if more than 11.16% of records are from ash, and cosmopolitan if the number of records from ash trees was less than 11.16%.*
3. *Eleven species were identified which are already of conservation concern (have an IUCN threat category) and are obligate or highly associated with ash. A further 43 species of conservation concern were assessed as being partially associated with ash (utilise ash to a greater extent than might be expected). These species may decline in their abundance if there is a major decline in ash abundance.*
4. *Four lichen species were identified that do not currently qualify for an IUCN threat category, but have high association with ash, and may therefore be at risk should ash undergo a major decline in its abundance.*
5. *Oak spp., hazel, aspen and sycamore were identified as potential substitute hosts for ash-associated lichen species.*

6.1 Introduction

Lichens result from the symbiotic relationship between a heterotrophic fungus, and an autotrophic partner (i.e. a green alga, or a photosynthetic cyanobacterium) (Hale 1983; Hawksworth and Hill 1984). The definition of a 'lichen species', and its scientific name apply to the lichenised-fungus only. Approximately 98% of lichen-fungi have evolved within several distinct ascomycete ('cup-fungi') clades, with the remaining *c*2% of species included within the basidiomycetes (Gargas *et al* 1995). Lichens are therefore not monophyletic, but represent an evolutionary strategy common to certain fungal lineages.

Typically the lichenised-fungi build the structural biomass of the lichen body (thallus), and within this structure they host a population of algae/cyanobacteria which they maintain (e.g. protecting the 'photobiont' from herbivory, desiccation, or UV light) and from which they sequester a source of carbon in the form of simple sugars. Most lichenised-fungi are obligate lichens, and in many cases the lichen thallus shows specialised phenotypic adaptation, having evolved a variegated structure and complex chemistry.

There are an estimated 20,000 lichen species globally (cf. Galloway 1992). Approximately 1,900 lichen species occur in the British Isles (Smith *et al* 2009), which represents *c*47% of the European lichen flora. Of the British lichen flora *c*40% of species are epiphytic, occurring on the bole and in the tree canopy (Dr R. Yahr, RBGE, pers comm). Some epiphytic lichens are broad generalists, and also occur on rocks (e.g. the yellow, foliose lichen *Xanthoria parietina*); others only occur as epiphytes (e.g. *Lecanora chlarotera*), but may be found on a range of different tree species, while some epiphytic lichens are specialists on a particular tree species (e.g. *Lecanora populicola* on aspen). Ash has a relatively high bark pH, and as a consequence its epiphytic flora is different from that of the more acid barked trees such as alder, birch, or pine (Ellis *et al* . 2013), though its flora can be similar to that of oak when growing in a more nutrient-rich soil, and also to elm and sycamore.

In terms of UK nature conservation, lichens comprised the third most speciose taxonomic group in the UK BAP revised priority list (after vascular plants and moths), with 138 species listed (http://jncc.defra.gov.uk/page-5717); and 418 species (*c*20% of the flora) designated as threatened according to IUCN's criteria (Woods and Coppins 2012). In addition to these rarities, the British flora is exceptionally diverse in biogeographic terms. The flora includes sub-Mediterranean elements in southern England through to arctic/alpine species in the Scottish mountains, and cool-temperate rainforest elements on the Atlantic fringe (Gilbert 2009). Given the restricted nature of the temperate rainforest bioclimatic zone in Europe (DellaSala 2011), many of its characteristic epiphytes fall within the designation of 'International Responsibility' – this encompasses species which may be common in Britain (e.g. in western Scotland), but are rare elsewhere in Europe, or globally (Woods and Coppins 2012).

6.2 Completeness of data, knowledge gaps and future research needs

Lichens are generally less extensively recorded than many animal groups or vascular plants. New species are regularly added to the British lichen flora, and field biologists continue to make significant advances in our knowledge of species distributions. Nevertheless, the British Lichen Society (BLS) database represents the collation of field records since about 1960, and includes more than 1.2 million individual records (Simkin 2012), the majority of which have been verified by taxonomic experts (e.g. Dr B.J. Coppins, RBGE) and lichen biogeographers (e.g. Prof. M.R.D. Seaward, University of Bradford). Many of these records are site-specific and include habitat information such as the substratum from which a specimen was recorded. Therefore, despite its limitations, the UK probably has the best known lichen flora in the world.

The lichen species we included in this assessment were those which had been confirmed as recorded from ash trees within the BLS database, using the records recently provided to the JNCC by Dr Janet Simkin (BLS Data Officer). However, when dealing specifically with the Northern Ireland region (e.g. Section 17.2), we also used the Northern Ireland Lichen Database, visualised on the NBN Gateway. Nomenclature follows Smith *et al* (2009). As a consequence of recent taxonomic revisions, a number of species could not be treated in the data analysis (e.g. *Degelia cyanoloma*, which has only recently been separated from *Degelia plumbea* (Blom and Lindblom 2010), and with most field records therefore included under the epithet *D. plumbea*).

This chapter only discusses those lichens found on ash trees and does not include those found on other substrates within the ash woodland habitat.

A conservation assessment for the lichen species associated with ash was based on IUCN criteria, which have been used to assess British lichens generally by Woods and Coppins (2012). These authors provided an unofficial assessment for the British flora (i.e. the assessed species have not been formally adopted by the IUCN, though the report has been ratified by the JNCC). This approach was preferable to the use of a Red Data Book (RDB) assessment, as the latest RDB assessment for lichens was as long ago as 1997 (Church *et al* 1997). We also made note of the additional conservation category of 'International Responsibility', which has been cautiously designated for those species where the British Isles is thought to include more than 10% of their global population (Woods and Coppins 2012).

We did not provide a score for lichen mobility. While it is self-evident that certain lichen species are widely dispersed and therefore colonise onto isolated trees remote from propagule sources, there is some evidence that other species may be dispersal-limited even within closed woodland (Walser 2004; Öckinger *et al* 2005). However, the extent to which a given species might be considered dispersal-limited appears to depend importantly on the landscape context (the spatial configuration and quality of habitat in the landscape: Ellis 2012), making it difficult to apply a generic classification.

To determine the level of a species' association with ash, we examined the number of times that a lichen had been recorded from ash, as a proportion of the total number of all records across all substrata (including corticolous, terricolous and saxicolous records, etc.). The 'level of association' for a species was considered *obligate* if 100% of records were from ash, *high* if >50% of records were from ash, *partial* if >11.16% of records are from ash, and *cosmopolitan* if the number of records from ash trees <11.16%. The 11.16% threshold was calculated by dividing the summed number of records which are from ash (for those species known to occur on ash) by the summed total number of records for the lichen species across all substratum types. This provided a rough estimate of the extent to which ash is used as a substratum across all of the associated species. Thus, the threshold of 11.16% is a tentative cut-off above which the number of records from ash was higher than might be expected on average. For species for which viable record data were unavailable, we used the default option '*uses*'.

In all cases the under-pinning data were derived from the British Lichen Society databases (Simkin 2012), and because they have been individually verified by experts, we considered these as *peer-reviewed* in terms of confidence level.

Epiphytic lichens utilise the ash tree as a habitat/substratum ('*living-space*'). Where there was relevant information in the authoritative British Lichen Flora (Smith *et al* 2009), we could also differentiate the part of the tree used (e.g. whether this may be generic as in *bark*, or more specifically as *trunk*, *limbs*/*branches/twigs* or *deadwood*). Lichens are generally long-lived perennial species, and an individual thallus may potentially occur on an ash tree over many years, so the time of year an ash tree is utilised was designated as *all year*. The age of the tree, the form of the tree used, and the woodland type were taken from the British Lichen Flora (Smith *et al* 2009) where this information was specified. Where information on the age of the tree was restricted to 'old trees', then the default option used was *notable* (Table 4.4), and in cases where there was no specific information on the form of the tree used, the default option was *mature* (Table 4.4). In the case of woodland type, we also consulted the published assessment of lichen *Indices of Ecological Continuity* (Coppins and Coppins 2002), allowing us to score *ancient* woodland indicator species.

In terms of ecosystem function, all lichens were recorded as contributing towards nutrient cycling. Lichens are able to efficiently sequester nitrogen and phosphorus especially from atmospheric wet deposition (Lang *et al* 1976; Reiners and Olson 1984). However, lichens with a cyanobacterial symbiotic partner may be especially important in nutrient cycling, as the cyanobacteria are able to fix atmospheric nitrogen (N), contributing significantly to forest N-dynamics (cf. McCune 1993; Antoine 2004). In addition to their role in nutrient cycling, lichen epiphytes provide an important node in the forest food web, providing microhabitat for (André 1985), and increasing the biomass and diversity of, invertebrates (Stubbs 1989; Gunnarson *et al* 2004).

In determining the use of alternative trees by the lichens associated with ash, we analysed data which we had previously sourced from the British Lichen Society database for the time period 1961–2010 (provided by Dr Janet Simkin, BLS Data Officer). However, data from certain tree species were not available using this approach (i.e. Norway maple and Douglas fir). In addition records in the British Lichen Society database for the use of *Salix caprea* and *S. cinera* were not available at the tree species level but were grouped under *Salix* spp., and records for *Tilia cordata* were only available for *Tilia* spp. (*T. cordata* and *T. platyphyllos* combined). Therefore these records were listed as additional species *Tilia* spp. and *Salix* spp. within the database, and the assessments for *S. caprea*, *S. cinerea* and *T. cordata* were recorded as unknown. The level of association with contrasting tree species was determined as previously described (i.e. when estimating the level of association with ash).

There were a number of minor discrepancies between the species list which had been provided to the JNCC from the BLS database, and the data for the 1961–2010 period used to examine the association with alternative tree species. These included a few rare species which appeared to be obligate on trees other than ash in the 1961–2010 data (*Agonimia opuntiella* on oak spp., *Chaenothecopsis savonica* on oak spp., and *Diplotomma pharcidium* on aspen), but which have been listed as occurring on ash in the JNCC records. These discrepancies have no substantive effect on the general assessment on the impact of ash dieback on lichens.

6.3 Species of conservation concern that may decline further as a result of ash dieback

There were 11 extant species which had been confirmed as warranting conservation concern, or which were data deficient, two of which were obligate on ash: *Lithothelium phaeosporum* (Near Threatened) and *Thelenella modesta* (Critically Endangered); or had a high level of association with ash: *Bacidia auerswaldii* (Data Deficient), *Caloplaca flavorubescens* (Endangered), *Catapyrenium psoromoides* (Critically Endangered), *Collema nigrescens* (Near Threatened), *Fuscopannaria ignobilis* (Vulnerable), *Leptogium cochleatum* (Vulnerable), *Leptogium saturninum* (Vulnerable), *Vezdaea stipitata* (Near Threatened), and *Wadeana dendrographa* (Near Threatened). The obligate species *Leptogium hildenbrandii* is now considered extinct.

A further 43 species of conservation concern were estimated to utilise ash to a greater extent than might be expected (partial association) (i.e. the number of records on ash exceeded the averaged occurrence (Table 6.1)). It is to be expected that the obligate or highly associated species would suffer a decline in their abundance with the decline in ash, and that species with a partial association would suffer a small decline, assuming that all other conditions remain equal.

Table 6.1. Lichens of conservation concern that are partially associated with ash.

Lichen	Conservation status
Acrocordia cavata	Data Deficient
Agonimia opuntiella	Data Deficient
Anaptychia ciliaris subsp. *ciliaris*	Endangered
Arthonia anglica	Endangered
Arthonia zwackhii	Near Threatened
Bacidia subincompta	Vulnerable
Biatoridium delitescens	Vulnerable
Biatoridium monasteriense	Endangered
Calicium abietinum	Data Deficient
Caloplaca herbidella	Data Deficient
Caloplaca virescens	Endangered
Chaenotheca chlorella	Near Threatened
Chaenotheca laevigata	Endangered
Collema fasciculare	Near Threatened
Collema fragrans	Endangered
Collema occultatum	Near Threatened
Collema subnigrescens	Data Deficient
Cryptolechia carneolutea	Endangered
Eopyrenula leucoplaca	Data Deficient
Fuscopannaria sampaiana	Near Threatened
Gomphillus calycioides	Near Threatened
Gyalecta flotowii	Near Threatened
Lecania chlorotiza	Near Threatened
Lecanora cinereofusca	Vulnerable
Lecanora horiza	Near Threatened
Lecanora sublivescens	Near Threatened
Lecidea erythrophaea	Vulnerable
Leptogium hibernicum	Near Threatened
Megalospora tuberculosa	Near Threatened
Pachyphiale fagicola	Near Threatened
Parmeliella testacea	Near Threatened
Parmelina carporrhizans	Vulnerable
Phlyctis agelaea	Near Threatened
Physcia clementei	Near Threatened
Physcia tribacioides	Vulnerable
Polychidium dendriscum	Vulnerable
Pseudocyphellaria intricata	Near Threatened
Pyrenula acutispora	Near Threatened
Ramonia dictyospora	Near Threatened
Rinodina biloculata	Data Deficient
Schismatomma graphidioides	Vulnerable
Teloschistes flavicans	Vulnerable
Wadeana minuta	Near Threatened

The potential relative importance of alternative tree species was examined for the obligate and high association lichens, by weighting their level of association with an alternative tree (3 = high, 2 = partial, 1 = cosmopolitan), multiplying this weighting factor by the reciprocal of the number of alternative tree species used, and calculating a summed importance score for each tree species; that is, taking into account the degree of association and range of contrasting trees used by the different lichens. This provided a tentative measure of the relative importance of the alternative tree species, in their role as substitutes for the lichens of conservation concern which are otherwise associated with ash (Figure 6.1).

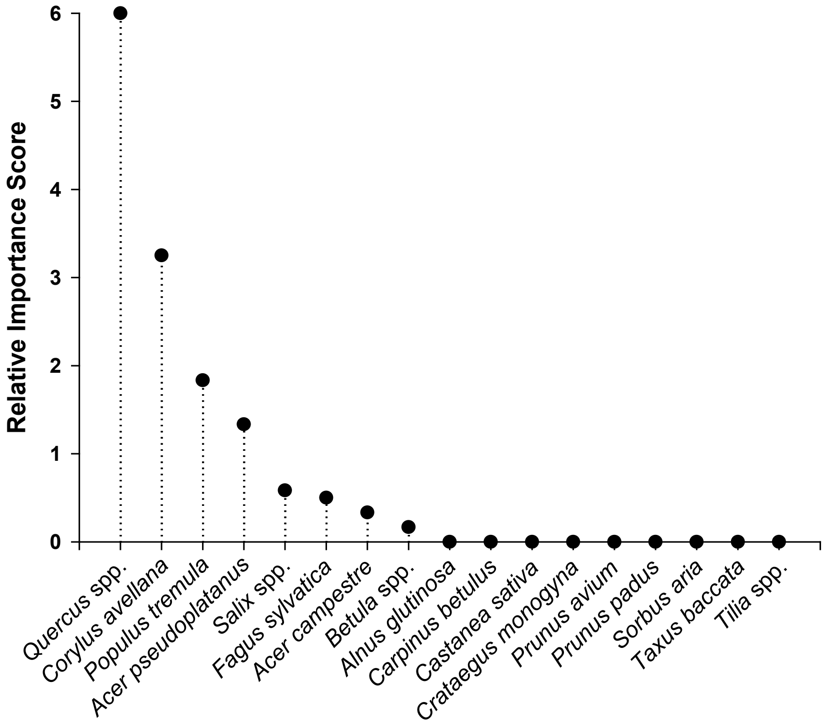


Figure 6.1. Relative importance of alternative tree species for lichens of conservation concern that are obligate or highly associated with ash.

Given that two of the 11 species are obligately associated with ash, the highest possible score for an alternative tree species would be 3 x (1/1) x 9 = 27 (i.e. if all nine lichens demonstrated high association with the same single tree species only). A low score would be 1 x (1/17) x 9 = 0.53 (i.e. if all nine lichen species had cosmopolitan associations with the 17 alternative tree species), falling to a zero value if none of nine lichen species had been recorded from a given tree. The scores for the different tree species demonstrate the potential importance of oak spp., hazel, aspen and sycamore as substitute hosts.

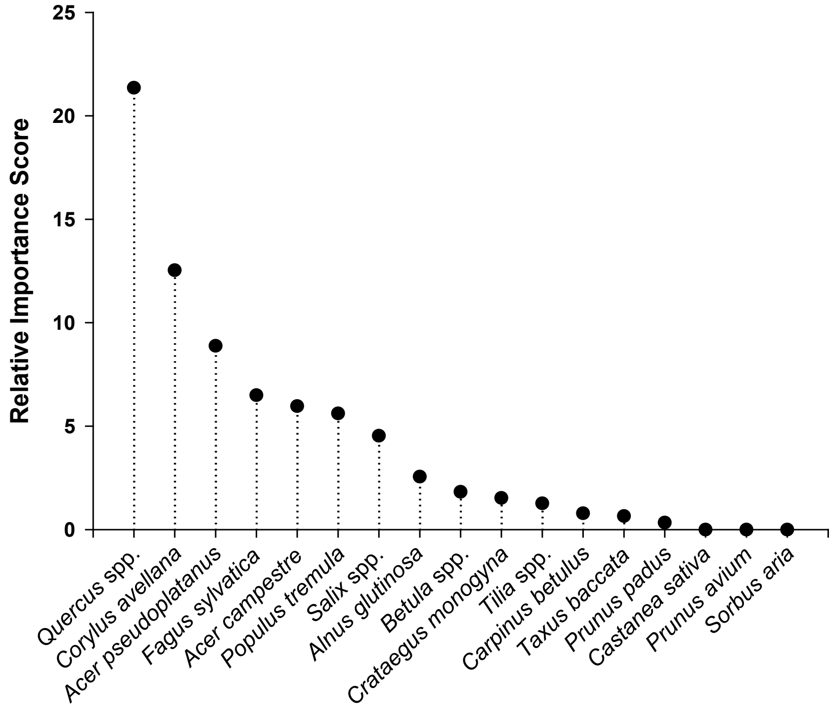


Figure 6.2. Relative importance of alternative tree species for lichens of conservation concern that are partially associated with ash.

Repeating the analysis for the 43 lichen species of conservation concern which have a partial association with ash, the analysis confirmed the relative importance of oak spp., hazel, and sycamore as potentially substitute hosts for ash-associated lichens (Figure 6.2).

6.4 Species that are not currently rare but may become so as a result of ash dieback

In addition to the species of conservation concern, the following four species do not qualify for an IUCN threat category, but have high association with ash, and may therefore be at risk should ash undergo a severe decline in its abundance: *Gyalecta derivata*, *Mycobilimbia epixanthoides*, *Pyrenula chlorospila*, and *Strigula taylorii*.

7 Bryophytes

<u>Chapter Summary</u>

1. *The British Bryological Society (BBS) database and atlases were used to identify bryophytes that are associated with ash.*
2. *No British bryophytes are obligate on ash, but six species have been identified as having a high level of association with ash.*
3. *Nine bryophytes that are already of conservation concern may decline further if the majority of ash trees die.*
4. *Some ash-associated bryophyte species which are only now recovering from 19th and 20th century air pollution may decline following ash dieback.*
5. *In oceanic areas, the loss of ash could be serious for the suite of small Atlantic liverworts that are not currently of conservation concern, because of limited habitat niches.*

7.1 Completeness of data, knowledge gaps and future research needs

In spite of their small size and difficulties in identification, distribution data for bryophytes is generally good. The British Bryological Society (BBS) has a well-organised national recording scheme, based on sending records to the Biological Records Centre, formerly at Monks Wood and now Wallingford. Individuals can submit records, or records can be sent via the network of vice-county recorders. Data validation is good: the BBS has a team of referees who check dubious or problematic records, and all new vice-county records must be supported by a specimen. Data are entered on the BBS database at BRC, where they undergo further validation checks by specialists. It is therefore unlikely that many significant erroneous records find their way onto the system these days. Of course, old records were not subjected to such a rigorous process, and work is on-going to clarify and correct these wherever possible. Systematic recording began in the 1960s, when work towards an Atlas was instigated, resulting in the publication of the Bryophyte Atlas in three volumes in the early 1990s (Hill *et al* 1991, 1992, 1994). The last 13 years have seen further fieldwork and systematic recording towards a new Atlas, due to be finalised later this year (2013). This has included deliberate targeting of under-recorded areas. All the basic distribution data on the BBS database is publically available through the NBN Gateway, with the exception of a very small number of records of extremely rare species.

A census catalogue and checklist is published about once every ten years, each one being an update of the previous one. This describes the vice-comital distribution of species and is the taxonomic and nomenclatural standard until it is superseded. The current checklist is Hill *et al* (2008). Conservation status information for British bryophytes comes from the Red List (Hodgetts 2011). The Red List for Ireland (Lockhart *et al* 2012) covers Northern Ireland.

Clearly, the distribution of large, easy-to-identify species is more well-known than that of small, critical species, but even some of the latter are becoming much more well-known. We now have at least a very good idea of the overall distribution of species in Britain, even if there are still many gaps at a more local level.

It is also becoming clear that bryophytes are sensitive to change, and that both individual populations, and distribution patterns as a whole, fluctuate much more than was realised until recently. Many species are ready colonists and able to take advantage of subtle environmental changes to increase their distribution. Others are more restricted and less mobile, and these species may be in danger of decline or extinction if the 'wrong' sort of change occurs. In general, bryophytes are very good at long-distance dispersal (Zanten and

Pocs 1981), but little is known in detail with regard to the exact dispersal potential for each species. Most species may be capable of travelling long distances (although some species deposit the huge majority of their spores close to the parent plant); this leads to low levels of endemism, and high levels of disjunction, at least in species with very specific habitat requirements.

It is likely that species behave differently in different areas within the UK, but this is poorly understood. For example, *Habrodon perpusillus* appears to be a vigorous colonist in its central Scottish heartland (Killin), but elsewhere tends to occur unpredictably on isolated trees, and does not spread much or at all.

While an increasing amount is becoming known about the ecology of bryophytes, there is still a big gap in detailed autecological studies. For example, many bryophytes are well-known as calcicoles, but the detailed nuances of the requirements of each species are largely obscure. Similarly, it is understood that bryophytes are important in the environment, especially in water retention and in providing habitat, nesting material, and to a small extent food, for other organisms, but it is not well understood in any detail exactly which other organisms are reliant on which bryophytes. Bryophytes also form associations with endophytic fungi (i.e. fungi living within the tissues of the bryophytes (e.g. Pressel *et al* 2010)). There is currently no evidence that these associations are mycorrhizal, but they do seem to have an effect on the bryophytes (e.g. the fungus *Rhizoscyphus ericae* occurs in a range of leafy liverworts, and induces rhizoid branching and septation). The implications of these associations for the environment and ecosystem functioning generally are not known.

No British bryophytes are obligate on ash, but six species have been identified as having a high level of association with ash. Epiphytic bryophytes are not usually associated exclusively with a particular species of tree, but with certain bark characteristics, climatic conditions and pollution levels; thus they may generally be found on a range of tree species. In general bryophytes are more tolerant of shade than lichens, so can dominate beneath the canopy, but some species require higher light levels and therefore grow on well-illuminated tree trunks, as in parkland and wayside trees. In the case of these six species, they favour base-rich, water-retentive and highly textured bark, so ash fulfils their needs well. However, they might also occur on other species of tree with these characteristics, such as elder (the epiphyte tree *par excellence*), elm, sycamore, maples, and willows.

7.2 Species of conservation concern that may decline further as a result of ash dieback

Ash dieback could potentially impact a number of species of conservation concern. These can be divided into two groups; those that are of conservation concern but widespread, and those that are of conservation concern and very localised:

1. Of conservation concern but widespread

- *Habrodon perpusillus* – Near Threatened. Strong preference for ash in the south, less so in the north. Sycamore is the most favoured tree in most of Scotland, and various trees are used in the Killin area, among which ash is important.
- *Myrinia pulvinata* – Near Threatened. This species occurs on ash, but its riverine habitat appears to be more important than the species of tree used as a substrate.
- *Orthotrichum obtusifolium* – Near Threatened. Historical records are mostly from ash, but recent records are mostly from other trees, aspen being the main tree in Scotland.
- *Orthotrichum pallens* – Endangered. Historical records are mostly from ash, but recent records are from various trees, including ash.
- *Orthotrichum pumilum* – Endangered. Strong preference for ash.

- *Orthotrichum speciosum* – Near Threatened. This species occurs on ash, but its main substrate in the eastern Highlands is aspen.

Orthotrichum species are sensitive to atmospheric pollution and most seem to be increasing in the UK following reduction in SO_2 levels, including very rare species such as those listed above.

2. Very localised

- *Dendrocryphaea lamyana* – Near Threatened. This species occurs on ash, but its riverine habitat appears to be more important than the species of tree used as a substrate. Restricted to a few river systems in south-west England and Wales.
- *Lejeunea mandonii* – Endangered. On rocks in England and Wales; exclusively on ash in Scotland. About four sites in Cornwall, one in South Wales and three in western Scotland.
- *Rhynchostegium rotundifolium* – Critically Endangered. At one of its two known sites, both of which are in southern England, it grows on ash, at the other on field maple and limestone.

All of these species are able to grow on other substrates to some extent. However, other substrates may not always be available, and their availability will be different in different regions. Thus, *Habrodon perpusillus* appears able to colonise quite a wide variety of trees in central Scotland, but this is not necessarily true elsewhere. It is unlikely that it would use oak, for example, if all the ash in a woodland were to die. It might use willow or some other species, but this is not guaranteed outwith central Scotland. *Orthotrichum obtusifolium* and *O. speciosum* favour aspen in semi-natural woodland in Scotland, but elsewhere aspen (often planted) does not appear to be such a valuable host tree. All the Scottish colonies of *Lejeunea mandonii* grow on ash, so it seems unlikely to be able to grow on other trees, and ash dieback in Scotland would potentially be catastrophic. In England and Wales, however, this species grows on limestone and other base-rich rock. Similarly, *Orthotrichum pumilum*, with all of its recent records on ash (except one on walnut!), has no clear alternative hosts, although there is a handful of old records from willow, elm and chestnut.

7.3 Species that are not currently rare but may become so as a result of ash dieback

Because epiphytic bryophytes are adaptable and not generally confined to a single host tree species, there are no species that are currently not rare that are likely to become rare as a result of ash dieback. However, there are many species that are likely to become rar*er*. The suite of relatively common *Orthotrichum* and *Ulota* species (about 8 *Orthotrichum* and 3 *Ulota* species), only now recovering from 19th and 20th century air pollution, would certainly become scarcer again as a result of ash dieback, although they would still occur on other trees such as elder, sycamore, maples and willow. The same would probably be true of the common liverworts *Frullania dilatata* and *Radula complanata*.

Large old ash trees in parkland or by roads or in hedges tend to support a rich flora, including mosses such as *Anomodon viticulosus*, *Homalothecium sericeum*, *Neckera* spp., and *Zygodon* spp. None of these is currently rare, but could become very much rarer in areas where there are few natural rock exposures to provide alternative substrates, such as most of south-east England and the Midlands.

In oceanic areas, the loss of ash could be serious for about a dozen small Atlantic liverworts, including *Drepanolejeunea hamatifolia*, *Harpalejeunea molleri* and *Plagochila exigua*. These plants use ash as a major substrate in ravine woodland, principally in the west of Scotland but to a lesser extent in other oceanic areas too, as well as base-rich rocks. Alternative trees may be few and far between in this habitat, often being mainly birch, oak and alder, all much less suitable substrates, so the loss of ash would be significant.

8 Fungi

Chapter Summary

1. *The Fungal Records Database of Britain and Ireland was used to identify fungi that are associated with ash trees.*
2. *Sixty-eight fungal taxa were found which matched the criteria 'more than 10 records with an associated organism of which 25% or more were with ash', or had a species epithet suggesting a strong affinity with ash'.*
3. *The degree of association with ash of these 68 taxa was defined as: obligate – 95% or more of the records were with ash (11 taxa); highly dependent – 50–95% of records were with ash (19 taxa); and the remaining 38 taxa were considered to be partially dependent on ash.*
4. *Three of the 68 taxa identified as ash-associated are already of conservation concern.*
5. *A total of six fungal taxa are reported to be obligately associated with living leaves of ash, and this group is likely to decline rapidly in areas where living ash becomes rarer. Fungi associated with dead ash may initially increase in abundance as a result of ash dieback but may then decline.*

8.1 Completeness of data, knowledge gaps and future research needs

The primary source utilised for the investigation of fungi found in association with ash in the UK was The Fungal Records Database of Britain and Ireland (FRDBI). This was supplemented with other texts, including Ellis and Ellis (1997), and a number of published studies on the ecology of taxa. In order to ensure that the current taxon name was used, and to avoid multiple entries of the same taxon, issues of synonymy were investigated using Index fungorum (http://www.indexfungorum.org/names/names.asp). In addition, the taxonomic affinity of taxa (e.g. lichen, fungus, myxomycete) was also determined using Index fungorum.

A download of the FRDBI database (from November 2012) was obtained from Paul Kirk (P.Kirk@kew.org). An initial query of the database for fungal taxa with ash as the accepted associated organism yielded 1,916 taxa. This high number of associated fungi is, however, misleading and reflects the use of the data field 'nearest associated organism', during data entry. This can result in spurious associations being made between fungi and other organisms. For example, ash forms arbuscular mycorrhizal associations not ectomycorrhizas (ECM), but 157 of the listed taxa are actually ECM fungal taxa. These taxa must have been associated with other host plant species growing near the ash tree(s) which was erroneously listed as the associated organism. In addition, it is likely that a comparable number of taxa are generalist saprotrophic fungi (e.g. many *Agaricus* spp.), which would have little direct affinity with ash. In order to distinguish taxa with close affinities to ash, the 1,916 taxa were sub-divided into three categories: those with 10 or more records with an associated organism where 25% or more were with ash; those with 10 or more records with an associated organism where fewer than 25% were with ash; and those with fewer than 10 records, at least one of which was with ash. This resulted in 63, 1,494 and 331 taxa respectively in the three categories. These totals do not add up to 1,916, as lichenised fungi were removed from the first category. An additional five taxa were moved from the third to the first category because, although they had fewer than 10 records with ash, the species epithet (fraxini, fraxinicola) suggested a strong affinity with *Fraxinus*.

The assessment of the impact of ash dieback on fungi is therefore focussed on the 68 fungal taxa which matched the criteria 'more than 10 records with an associated organism of which 25% or more were with ash', or had a species epithet suggesting a strong affinity with ash.

The alternative tree and host data for each of these 68 taxa were primarily derived from the FRDBI supplemented from Ellis and Ellis (1997). The degree of association with ash of these 68 taxa was largely determined by the data within the FRDBI. Three categories were used to distinguish between levels of association with ash: obligate – 95% or more of the records were with ash (11 taxa); highly dependent – 50–95% of records were with ash (19 taxa); and the remaining 38 taxa were considered to be partially dependent on ash.

8.1.1 Knowledge gaps

The greatest gap in our knowledge at present in relation to the fungi associated with ash in the UK is our total lack of data on the leaf endophytes of ash, and our limited knowledge of the fungi associated with ash that do not produce visible sexual or asexual structures and which are usually only detected in molecular studies. Studies on the continent (e.g. Scholtysik *et al* 2012) have found high numbers of taxa from both groups associated with ash, but so far there have been few or no studies in the UK.

In addition, from the personal experience of SW, it was apparent that the occurrence of some taxa (e.g. *Armillaria* spp.) with ash may be grossly under-represented in the FRDBI. The distribution of the data within the FRDBI is also heavily weighted to those areas which have been extensively recorded. The striking distribution of *Daldinia concentrica*, which was the commonest highly dependent taxon with 3,172 records on ash, highlights this extremely well, with both Scotland and Wales severely under-represented. This means that the distribution and abundance data from less well-studied areas is likely to under-represent actual taxon occurrence with ash. The data are also biased to taxa forming large obvious structures, such as *Daldinia concentrica*.

Very few data were found that referred to fungi associated with the below-ground portions of ash trees – the base and structural and feeder roots of the tree. Kubikova (1963) reported a range of common soil fungi associated with ash root surfaces, and Summerbell (2005) also mentioned non-specialised soil fungi associated with ash roots. As already stated, ash forms arbuscular mycorrhizal (AM) associations and since these fungi show limited host selectivity, it is unlikely that any AM fungi will be adversely affected by ash decline. We do not know whether there are any other fungi that specialise on the below-ground structures of ash.

8.2 Species of conservation concern that may decline further as a result of ash dieback

The conservation status of fungal taxa was determined using a number of sources, including the Red Data List of the UK (Evans *et al* 2006) and the JNCC UK BAP priority fungi species list (http://jncc.defra.gov.uk/). Only three taxa with a measure of conservation status occurred within the investigated 68 taxa. *Geastrum berkeleyi* is a very rare saprotrophic fungus that grows on litter and has declined post-1960 due to habitat destruction. It is reported to only appear at a single site with any regularity (http://jncc.defra.gov.uk/_speciespages/2284.pdf). The taxon has a highly dependent association with ash, with 84% of the records found with ash. However, all the records of *G. berkeleyi* with ash as the associated organism are from the single site where it still fruits. The data are therefore strongly biased in suggesting a strong association with ash. With respect to how ash dieback could affect this species, there is no reason to predict that ash decline will necessarily have a direct impact on this taxon, since it is not directly associated with ash. However, changes in canopy structure or management practices resulting from ash dieback could alter the ground-level environmental conditions and could influence the viability of this taxon.

Another litter saprotroph called *Ramariopsis pulchella* was also found to be partially associated with ash. It is listed as Near Threatened in the Red Data List of Evans *et al* (2006). There are 55 records within the FRDBI, but only 26 are with an associated organism, of which nine were ash. It is therefore categorized as only partially dependent on ash. As with *Geastrum berkeleyi*, there is no *a priori* reason to predict that ash decline will necessarily have a direct impact on this taxon.

The final taxon of conservation interest that was included in the priority 68 taxa was *Chlorencoelia versiformis*. This is listed as Endangered in Evans *et al* (2006), and is categorized as highly dependent on ash, as nearly 70% of the FRDBI records were with ash. It is an ascomycete which produces fruit bodies on deadwood, often well decomposed wood. It is therefore likely that in the short- to medium-term, the occurrence of this species may increase where ash deadwood is allowed to accumulate. Where ash deadwood is removed, a decline in abundance may be expected. Although *C. versiformis* clearly favours ash, it has also been recorded on deadwood from beech, poplar, oak and elm. Where sufficient alternative substrates are available under favourable conditions, it is likely that it will survive in the absence of ash deadwood.

A fungus with high conservation status that has been found associated with ash but which did not warrant inclusion in the top priority category is *Hericium coralloides* – a wood decay fungus. Only 16% of the 126 records in the FRDBI of *H. coralloides* were associated with ash, with the great majority of substrate recorded as beech (*Fagus sylvatica*). It is possible that a decline in ash could positively influence this species in the short- to medium-term. In the long term, negative impacts might only be expected in areas where ash had been the major substrate in the absence of beech.

8.3 Species that are not currently rare but may become so as a result of ash dieback

A total of 68 taxa were included within the high priority list derived from the FRDBI database, and for the purposes of discussing how these may be affected by ash decline it is useful to consider them on the basis of their ecology, in particular their association with ash as a substrate (Table 8.1); of these, 30 taxa were considered obligately or highly dependent on ash.

Table 8.1. Substrate choice of 68 fungal taxa recognised as being partially to obligately associated with ash in the UK.

Dependency	Living leaf	Fallen ash leaves or seeds	Causing cankers	Shoot parasite	Branches, logs, bark	Litter saprotroph	Total
Obligate	6	2	1	0	2	0	11
Highly	0	3	1	2	12	1	19
Partially	1	1	0	0	24	12	38

A total of six fungal taxa are reported to be obligately associated with living leaves of ash, and this group will decline rapidly in areas where living ash becomes rarer. Ash litter (leaves and seeds) decomposes rapidly, and without regular inputs the two taxa growing on fallen leaves or seeds will also decline rapidly. It is possible that some of these taxa may become extinct. The taxon causing cankers on shoots, *Gloeosporidiella turgida*, will also decline as living shoots become scarcer. The two decay fungi, which do not appear to have a requirement for living tissue, may increase in the short- to medium-term, as the amount of substrate suitable for colonisation (stressed and damaged ash trees) increases. These 11 taxa are obligately associated with ash, so there is little scope for providing alternative host plants to facilitate their survival. However, it may be possible that some of them may be able to also colonise other members of the Oleaceae. In addition, some of the so called obligate taxa have been rarely recorded on alternative hosts (e.g. *Cryptosphaeria eunomia* has been found on *Hedera helix* and *Laburnum anagyroides*) but whether the rare use of alternative plants would be sufficient to maintain a viable population is unknown.

The ecological groupings of the highly dependent fungal taxa are in striking contrast to the obligate group. The majority are decay fungi associated with the woody parts of ash. Many of these could therefore potentially benefit from an increase in substrate, at least in the short- to medium-term. However, they are highly dependent on ash, and as the availability of ash wood declines either through decay or management practices, the taxa are likely to decline. A similar scenario occurred with the wood decay fungus *Rhodotus palmatus*, which prior to Dutch elm disease was very rare but which increased in abundance with the death of *Ulmus* trees and subsequently declined as the substrate became scarcer with time.

The highly dependent shoot parasite, the canker former, and the taxa associated with fallen leaves and seeds are all likely to decline in the short term, as living ash and litter becomes scarcer. The one litter saprotroph in this category, *Geastrum berkeleyi*, was discussed in the previous section.

Although all the taxa in this group are highly dependent on ash, they do have alternative host plants. *Hymenoscyphus albidus*, which is closely related to the causal agent of ash dieback, *Hymenoscyphus pseudoalbidus*, has been recorded on hazel, horse chestnut, sycamore, oak, birch, and even meadowsweet. We can only hope that *H. pseudoalbidus* lacks the same ability to colonise multiple hosts. It is therefore likely that these taxa will survive the decline of ash but with reduced population sizes.

The partially dependent group are primarily taxa which colonise deadwood or grow on litter. As already mentioned, the wood decay fungi are likely to increase in abundance as more substrate becomes available. It is difficult to predict how the litter fungi will respond because we do not know whether they are directly associated with ash litter *per se* or with the conditions in which ash grows. However, as with *G. berkeleyi*, there are no *a priori* reasons to suggest they will decline in the absence of ash.

9 Invertebrates

Chapter Summary

1. *Using literature searches and the Database of Insects and their Food Plants invertebrates which are associated with ash were identified.*
2. *In total, 239 invertebrate species were identified that use ash, with 29 of them being obligate on ash, 24 highly associated with ash and 36 partially associated with ash.*
3. *Two Lepidoptera (butterflies and moths), 14 Diptera (flies), 3 Coleoptera (beetles), that are associated with ash are already of conservation concern and may decline further as a result of ash dieback if a large proportion of ash trees die.*
4. *Seven moth species, 4 beetles, 14 bugs, 11 flies, 4 ticks/mites and 5 thrips that are not currently rare may become so due to their high level of association with ash.*
5. *The most frequent alternative tree used by the ash-associated invertebrate species is oak. Other frequently used alternatives are birch, beech and willow. Further important trees for a range of phytophagous species include wild privet and elm.*

9.1 Completeness of data, knowledge gaps and future research needs

9.1.1 Information sources

Initial species selection was guided by Stubbs (2012), together with reference to the *Database of Insects and their Food Plants* maintained by the Biological Records Centre (BRC) (http://www.brc.ac.uk/DBIF/homepage.aspx). These sources primarily cover phytophagous species with Stubbs (2012) listing just species with significant, high or obligate association with ash. Some species from the BRC database were discounted where the association with ash was from old references, and this association had not been repeated in more recent and comprehensive reviews of the species. References to use of ash solely in captive rearing situations were also discounted.

The initial list of species identified was then supplemented from a wider literature search and consultation with some species-group experts. In particular, the literature search added many saproxylic and predatory species that fell outside the scope of the BRC database. For some insect species groups, there are modern publications documenting feeding association in an easily accessible manner and, where they exist, these provided the majority of information for species included in this review. Species groups with good coverage of host plant association in the literature include the Lepidoptera (especially Emmet 1992; and Crafter 2005) and Coleoptera (Bullock 1992). Standard references were then supplemented by more specialist books (e.g. Bradley *et al* 1973, 1979) and published notes where appropriate.

For some groups, comprehensive information was available from elsewhere in Europe, and, whilst there may be differences in insect-plant association in other European countries relative to within the UK, these sources nonetheless can provide a very useful starting point for further research. A good example of this is the Auchenorrhyncha for which food plant selection is far better documented for species in Germany (e.g. Nickel and Remane 2002; Nickel 2003) than in the UK, whilst feeding preferences of many Coleoptera are also better documented for continental Europe than for the UK.

9.1.2 Selection of species for inclusion

Most of the species identified in this review that are associated with ash are phytophagous (feeding on plant matter, especially foliage), xylophagous (wood eating) or saproxylic (associated with deadwood). These were all included where use of ash had been identified from the literature used. Other species, principally predators, were also included where there is a documented preference for ash (e.g. *Anthocoris simulans* which predate aphids and has been found in the UK primarily or exclusively on ash). Truly cosmopolitan predatory species, for which replacement of ash by other tree species would likely have no impact whatsoever, were not included in this analysis.

There is less comprehensive literature of the large number of parasite and parasitoid invertebrate species. We took advice that indicated that there are likely to be no such species that are dependent on ash (i.e. that are obligate on hosts that are obligate on ash (Mark Shaw pers comm; Richard Askew pers comm)). A comprehensive database is maintained for Chalcid wasps (http://www.nhm.ac.uk/research-curation/research/projects/chalcidoids/database/), which was searched for species that have invertebrate hosts that we had identified as being obligate or having a high association with ash. However, as most wasps so identified have an extensive range of alternative hosts, no attempt was made to map the alternative tree species on which these alternative hosts might occur.

In total, 239 invertebrate species were identified that use ash, with 29 of them being obligate. The Diptera had the most obligate species (12), followed by Hemiptera (6) (Table 9.1).

Table 9.1. Number of ash-associated invertebrate species and their level of association identified during the literature review. The literature was used to class the invertebrates into the different levels of classification as defined by Table 4.1.

Group	Obligate	High	Partial	Cosmopolitan	Uses	Total
Invert-Acari	3	1				4
Invert-Coleoptera		5	9	7	60	81
Invert-Diptera	12	1			27	40
Invert-Hemiptera	6	8	4	5	9	32
Invert-Hymenoptera	1	1	2	5	18	27
Invert-Lepidoptera	4	6	20	1	14	45
Invert-Thysanoptera	3	2	1	1	3	10
Total	**29**	**24**	**36**	**19**	**131**	**239**

9.1.3 Data limitations

For some less-studied groups, the degree of preference of association with different plants is little known. Examples include the scale bugs (Hemiptera), for which plant species on which these bugs have been recorded are listed by the BRC database but information is generally lacking on preference among these selections; and Symphyta (Hymenoptera) for which the plant species used are listed by Benson (1952), but with no indication of preference among these.

Information will be less complete for rare species or those that are rarely studied or documented. If there are only a small number of records of the plant species on which an invertebrate has been found, this may have the effect of making any association appear to be stronger simply through a lack of sufficient data from alternative plants. In such situations, apparent feeding preferences may be biased by the recording activity of one or a very few entomologists, or may show geographic bias according to the distribution of entomological studies. Even for the more well-studied groups, such as the Lepidoptera, there may be incomplete knowledge of plant associations for rarer species because most records are of adults and hence do not reveal information about the food plant used by the larva. The majority of records of plant-invertebrate associations are based on unsystematic observations, and undoubtedly there will be many uses made of plants by invertebrate species that are not documented at all. For the Lepidoptera, the relevant entry in the database is labelled as there being no association where none is documented, with the assumption that even if an occasional larva might be found on the respective tree species, it will be ecologically unimportant. For some other groups, and especially for xylophagous Coleoptera, undocumented potential hosts have been labelled as "likely" for species thought not to show particular discrimination between different types of deadwood. Similarly, the ecology of several saprophytic (fungus-feeding) Coleoptera is little known. Although there may be documented information on their occurrence on ash, the feeding behaviour is often not described beyond reference to larvae developing in rotting wood. In such cases there may be a general lack of knowledge about whether the species involved actually consumes wood or whether it feeds on fungi and algae growing on the wood or on other invertebrates.

For some groups, in particular for saproxylic species of Diptera and for Heteroptera, it is known that more species have been recorded on ash than those for which our literature search revealed documentation. For example, Rotheray *et al* (2001) record that 69 species of saproxylic Diptera were recorded on ash during their fieldwork in Scotland between 1988 and 1998, but only those with a specified conservation status are named. Similarly Bernard Nau (pers comm) reported finding 63 species of Heteroptera. Many are likely to be predatory species that show no affinity to particular tree species and those that are thought to have a particular association with ash have been identified in this work.

Information on the plant associations shown by some species is sometimes given just at the genus level. In some cases (e.g. the Lepidoptera) use of the plant genus is frequently used where it is thought that all species within the genus may be potential food plants. In other cases, where the source literature does not state that this assumption can be made and where more specific information does not indicate use of particular species within the genus, then the plant genus is simply listed as a further tree alternative.

9.1.4 Species taxonomy

Species names and taxonomy followed those used in standard references. To this end, Lepidoptera follow Bradley and Bradley (1998); Heteroptera follow Southwood and Leston (1959) together with the update provided by Ryan (2012); Auchenorrhyncha follow Biedermann and Niedringhaus (2009); Psylloidea follow Hodkinson and White (1979); Diptera follow Chandler (1988); Thysanoptera follow Strassen (2007); Hymenoptera (Symphyta) follow Benson (1952); Hymenoptera (Chalcidoidea) follow Noyes (2013); Diploploda follow Alexander (2002); Acari follow Fauna Europaea (2012); and Coleoptera follow De Jong (2012) and Duff (2012).

9.1.5 Conservation status

Macro moths (Conrad *et al* 2006) and micro moths (Davis 2012) have been classified by Red List criteria, but the assessments are regarded as preliminary and not a formal designation of Red Data Book categorisation. Nonetheless these have been used in the review as the best available assessments of these groups. Formal assessments of conservation status have been used for some groups (e.g. Kirby 1992), but for some other species no conservation assessment has been made.

9.2 Species of conservation concern that may decline further as a result of ash dieback

9.2.1 Lepidoptera

Lepidoptera species that may be particularly affected by ash dieback are inevitably those with the highest dependency on ash. Species that have a defined or provisional conservation status of at least 'Nationally Notable' and which are obligate on ash are *Atethmia centrago* (Centre-barred Sallow) and *Pammene suspectana*. The former is regarded as 'Vulnerable' due to an estimated 74% UK population decline between 1968 and 2002 (Fox *et al* 2006), whilst the latter is a rare species in the UK with few records.

Additionally, species that have just a small range of food plants including ash, and which may not qualify as obligate or highly associated under the criteria used in this report, may lose some populations as a result of ash dieback. One example is the UK BAP priority species, Barred Tooth-striped moth. Larvae of this moth feed on ash and on wild privet. A loss of ash could therefore cause the loss of a substantial proportion of the remaining UK populations of this species.

9.2.2 Diptera

Among the Diptera, most saproxylic species show little host plant specificity. However, there are a few rare or little-known species that may have a strong association with ash. *Lipsothrix nigristigma* is a crane-fly that is associated with log-jams in streams and may have a specific association with ash. The species is classed as Endangered and has suffered habitat loss through removal of woody debris from streams. *Astiosoma rufifrons*, a Dipteran classified as Vulnerable, probably feeds on ash sap, whilst the Nationally Notable *Lonchaea nitens* is a saproxylic species that may be obligate on ash.

The Endangered Diptera species *Pandivirilia melaleuca* uses only ash and oak, whilst the Nationally Rare *Tanyptera nigricornis* has been found specifically in ash but is reported to be found in other broadleaves. Both species may decline further as a result of ash dieback and their survival could depend on how well these alternative food plants can sustain the species.

A number of other Notable, Vulnerable or Endangered Diptera species, including *Eupachygaster tarsalis*, *Tachypeza fuscipennis*, *Brachyopa insensilis*, *Brachypalpus laphriformis*, *Lonchaea peregrine*, *Periscelis annulata*, *Amiota alboguttata*, *Pocota personata* and *Phaonia exoleta* have been recorded from ash but have also been recorded from alternative hosts. However, all have very specific microhabitats which are already rare, such as decaying timber, rot holes, or decaying or fermenting sap in old or ancient trees. Thus loss of ash may further endanger these species if it causes significant changes in woodland structure and, especially, if alternative tree species do not provide the appropriate microhabitats.

9.2.3 Coleoptera

Among the Coleoptera, two Nationally Notable species have a high association with ash: *Cryptophagus ruficornis* and *Hylesinus orni*. *C. rufocornis* is associated on ash with the fungus *Daldinia concentrica*, whilst *H. orni* is saproxylic.

A number of xylophagous Coleoptera species are of conservation interest and, though not highly associated with ash, could be affected by ash dieback. The Violet click-beetle

(*Limoniscus violaceus*) is an endangered species that lives among organic matter in holes within ancient trees, some of which are over 700 years old. Over a third of such trees that it is known to use in the UK are ash (Whitehead, 2003) so loss of these could have a significant impact on the tiny UK population.

9.3 Species that are not currently rare but may become so as a result of ash dieback

9.3.1 Species obligate on ash

Species that currently have no defined conservation status but which are obligate on ash will clearly be at risk of major decline should ash decline or become regionally extinct. Such species identified in this review include two Lepidoptera species, six Hemiptera, ten Diptera, three Acari, and three Thysanoptera.

9.3.2 Species highly associated with ash

There are further species highly associated with ash that could also suffer from a decline in ash. Some of these may only rarely be recorded on alternative food plants, including cultivated species, whilst it is possible that some alternative associations may be in error or represent stray individuals on plants that are not able to sustain viable populations. Thus many of these species may be equally as vulnerable to a decline or loss of ash as those documented to be truly obligate. Among the species identified in this review in this category are eight Hemiptera, five Lepidoptera, four Coleoptera, one Diptera, one Acari, and two Thysanoptera.

Notable among the above species is the genus *Psyllopsis*. All four British species of this genus of Psyllids (Hemiptera) are dependent on ash, and they represent 5% of all UK Psyllid species. Two are categorised here as obligate, whilst two have also been recorded from exotic species of *Fraxinus* (*F. ornus* and *F. angustifolia*).

9.4 Use of alternative tree species

The most frequent alternative tree used by the invertebrate species documented in this report is oak (*Quercus robur*/*petraea*, though some species are listed simply as being associated with *Quercus* and were included here). Other frequently used alternatives are birch (*Betula pubescens*/*pendula*), beech (*Fagus sylvatica*) and willow (*Salix caprea* where specified, or otherwise noted simply as *Salix* spp.). Further important trees for a range of phytophagous species include *Ligustrum* spp., especially *L. vulgare* (wild privet) and *Ulmus* spp. (elm).

10 Mammals

Chapter Summary

1. *Literature searches identified 55 mammals that are associated with ash. Twenty-four of these use the ash trees and the remainder use the ash woodland habitat.*
2. *There are no mammal species that are obligate on or highly associated with ash.*
3. *Rare bat species may decline if they roost in ash trees, or if ash trees form an important component of their landscape used for commuting or foraging, but information for specific species is lacking.*
4. *Mammals other than bats are unlikely to be greatly impacted by the loss of ash. Changes in the structure and composition of mixed woodland following the loss of ash may impact on some woodland mammal species, but information on specific species is lacking.*

10.1 Completeness of data, knowledge gaps and future research needs

10.1.1 Mammals other than bats

There are currently 38 wild living terrestrial non-chiropteran mammal species recognised in the UK (Harris and Yalden 2008). We used the handbook of British mammals as the main information source (Harris and Yalden 2008), with other sources used as necessary. Taxonomy and nomenclature follow Harris and Yalden (2008).

The ecology of UK mammals is generally rather well-known compared to many species groups; however, as no species seem to appear to be obligate or highly dependent on ash species, use of this tree is not well-documented. Many species of mammal occur in mixed broadleaved woodland and ash certainly forms part of the habitat of some mammal species. Some of these species will browse ash and others make use of ash keys, but the extent of ash use among UK mammals seems poorly documented.

Conservation designations and species distributions were taken from the NBN Gateway. In assessing the conservation status of UK mammals, the UK BAP status is likely to be the most pertinent, as this is based on population status within the UK. The IUCN designation is based on the global population status of a species, particularly within its native range. Introduced species, for example the rabbit *Oryctolagus cuniculus,* the edible dormouse *Glis glis* and Chinese water deer *Hydropotes inermis*, may be of conservation concern in their native range, but of no conservation concern, or even regarded as a pest species in the UK.

10.1.2 Bats

There are 17 species of bat in the UK that are considered resident; they are, listed alphabetically by common name: Alcathoe bat; barbastelle; Bechstein's bat; Brandt's bat; brown long-eared bat; common pipistrelle; Daubenton's bat; greater horseshoe bat; grey long-eared bat; Leisler's bat; lesser horseshoe bat; Nathusius' pipistrelle; Natterer's bat; noctule; serotine; soprano pipistrelle; and whiskered bat. These are considered individually in the assessment tables, with the exception of the Alcathoe bat which has only recently been discovered, having probably been previously confounded with the very similar whiskered and Brandt's bats. There are a further five species of bat which have been recorded very few times as vagrants; they have no systematic association with ash trees.

All of the UK bats are insectivorous and therefore none feed directly on ash, but ash is a likely contributor to the habitats used by bats in many different ways. Ash provides roosting sites in the form of tree holes, crevices and loose bark for some colonies of the tree-roosting bats. This is particularly so since it is a species that grows to a large size and old age. Ash trees also represent a source of food supply in the form of their associated insect fauna (Southwood *et al* 1982 and Chapter 9 of this report), and contribute to the overall landscape characteristics used by bats, particularly where ash forms parts of a tree-lined or tree-formed linear habitat feature such as woodland, belts of trees, or a hedgerow, either independently of, or lining another linear feature such as a road or watercourse. Such features are often used for commuting by bats, including by those that do not necessarily commonly roost in, or forage on or around, ash trees, for whom trees including ash form a part of the wider landscape characteristics (e.g. for Leisler's bats: Ruczynski and Ruczynska 1999; Natterer's bats: Smith and Racey 2008; brown long-eared bats: Murphy *et al* 2012; barbastelle bats: Zeale *et al* 2012).

Along with oak and beech, ash is considered to be a tree species favourable to roosting by bats although other tree species also provide roosting sites (http://www.bats.org.uk/pages/bat_roosts.html). Few studies reported in the modern scientific or grey literature make reference to the use of particular tree species by bats, and there are no recent studies that record the use of ash trees in the UK for roosting by bats, in relation to its availability, or that of alternative tree species in the landscape. Although such knowledge of the usage of roosts may exist (although perhaps not available), it is likely to do so in the form of early writings on natural history, anecdotal recording and bat roost data-recording. It appears, though, that this information has never been collated and published in recent literature. Most studies of the characteristics of bat roosts focus on the physical attributes of tree holes and their entrances (Kanuch 2005), their origins, and particularly their thermal characteristics (Jenkins *et al* 1998; Ruczynski 2006; Smith and Racey 2005). More such generalities regarding roost characteristics are known for different bats species, without necessarily reporting the tree species involved. The bat species with the greatest known propensity to use roosts other than in trees are the whiskered, Brandt's, serotine, brown long-eared and grey long-eared bats. In addition, the four known roosts of the Nathusius' pipistrelle in the UK are all in buildings, although the species roosts in trees elsewhere in its European range (Harris and Yalden 2008). The majority of known roosts of the common and soprano pipistrelles are also in buildings although they are also known to use tree roosts. It should be remembered that use of roost sites for a particular purpose may be in trees at one time of year and in buildings at another (e.g. summer maternity roosts, autumn roosting, and winter hibernation). Although this dilutes the overall use of trees by bats, the absolute dependence of those bats on trees would remain.

The species of bat that commonly forage by gleaning foliage, including Bechstein's, grey long-eared, brown long-eared and lesser horseshoe bats, might probably prefer not to forage in this mode on ash. The sub-divided leaf structure of ash may render this form of foraging less efficient, in comparison to foraging by gleaning on other large-leaved tree species.

10.2 Species of conservation concern that may decline further as a result of ash dieback

10.2.1 Mammals other than bats

There appear to be no non-chiropteran mammal species of conservation concern at risk of further decline due to ash dieback.

10.2.2 Bats

For the particularly rare bat species, were any of them to be known to be roosting in ash trees, or for ash trees to form an important component of their landscape used for commuting or foraging, then there may be negative consequences for the species. However, such circumstances have not yet been documented and published.

10.3 Species that are not currently rare but may become so as a result of ash dieback

10.3.1 Mammals other than bats

There are no mammal species that are obligate or highly dependent on ash. Changes in the structure and composition of mixed woodland may have detrimental effects on some woodland species, but it is not possible to speculate further.

10.3.2 Bats

Although all of the UK bat species have some form of conservation protection, the consequences of ash dieback for them resides mainly in the overall possibility that woodland cover might be reduced as a result. The consequences of the loss specifically of ash trees would not directly affect any one of the bat species as far as available data informs.

11 Birds

Chapter Summary

1. The assessment of birds associated with ash trees was primarily based on online searches of peer-reviewed literature.
2. Twelve bird species showed relatively greater use of ash compared to other tree species; other bird species may use ash trees or use the ash woodland habitat, but were not identified as preferentially using ash, so are not included in the analysis here.
3. Three bird species of conservation concern were identified as using ash more frequently than its availability, but none were highly associated with ash.
4. Four species of bird that are currently common and widespread were found to use ash more frequently than expected.

11.1 Introduction

Birds are a well-studied taxonomic group with a wide and long-established literature aimed at professional and amateur audiences. If there were strong associations with ash for any species this is likely to have been noticed and would have been remarked upon. However, for most studies of both bird communities and individual species that have looked at the effects of woodland structure and tree species composition, structure is the stronger determinant of bird abundance or species diversity (e.g. MacArthur and MacArthur 1961; Lewis *et al* 2009; Broughton *et al* 2012). There are no bird species wholly dependent on any one tree species, and this chapter therefore looks at bird species that have been shown to use ash more frequently than expected.

11.2 Completeness of data, knowledge gaps and future research needs

The assessment of birds associated with ash trees was primarily based on online searches of peer-reviewed literature. Further information was sought from RSPB research reports and unpublished reviews on the habitat associations and requirements for woodland birds.

Scientific names follow the latest British list produced by the British Ornithologists' Union (http://www.bou.org.uk/thebritishlist/British-List.pdf). However, English names are widely used, and the scientific nomenclature and taxonomy have been changed in recent years. Therefore searches were carried out using English names.

11.2.1 Peer-reviewed literature

Peer-reviewed literature was primarily searched using the Web of Science ISI search engine. Searches comprised a single bird search term plus a single habitat association term (Table 11.1). Bird search terms included English names of all Birds of Conservation Concern that are associated with woodland or trees, plus "birds" and "bird community" to identify any associations for other bird species. Searches were carried out for each bird term with each association term.

Additional searches were carried out in Google Scholar using all bird search terms with only "Ash" and "Fraxinus excelsior" as association terms to identify any important references missed by Web of Science.

Search results identified some species where tree species preferences were available but they didn't occur in habitats with ash (i.e. black grouse *Tetrao tetrix*, capercaillie *Tetrao* *urogallus* and crested tit *Lophophanes cristatus*). Other species occur in habitats with ash, but there is no information on tree selection or use (e.g. dunnock *Prunella modularis*, song thrush *Turdus philomelos* and starling *Sturnus vulgaris*). Based on known habitat use and requirements, the latter group of species are unlikely to have strong tree species associations. Therefore results presented in Sections 11.2 and 11.3 are for species where there was information on tree or woodland use for habitats that included ash.

For most species, evidence is based on one or two studies, often from single study areas. Therefore we report impacts on the best available evidence, but the generality of relationships have rarely been explored by testing in different situations.

Table 11.1. Search terms used to identify relevant peer-reviewed literature.

Bird search terms	Ash association terms
Bird	Ash
Bird community	Ash forest
Black Grouse	Ash woodland
Bullfinch	Food
Capercaillie	Foraging
Crested tit	Fraxinus excelsior
Dunnock	Nest
Hawfinch	Seed
Lesser redpoll	Tree species
Lesser spotted woodpecker	
Marsh Tit	
Pied flycatcher	
Red kite	
Song thrush	
Spotted flycatcher	
Starling	
Tree pipit	
Willow tit	
Wood warbler	

11.2.2 RSPB reviews and data-sets

In addition to peer-reviewed literature, all RSPB research reports and unpublished reports on woodland birds were checked for relevant information. Two sources of information were used: (1) an unpublished review of resource requirements for woodland birds from an on-going project; and (2) analyses of habitat associations from the *Repeat Woodland Birds Survey*.

The reviews of resource requirements included more extensive peer-reviewed literature searches than were done above, and searches of non-peer-reviewed material. This was used to identify any relevant non-peer-reviewed references to include.

The Repeat Woodland Bird Survey carried out in 2003/04 comprises woodland bird census and detailed woodland structure data from 253 sites in 15 study areas in England, Wales and Scotland. Detailed analyses of habitat associations for 32 species with adequate data, all primarily woodland species, have been carried out and published in Smart *et al* (2007) and Carpenter *et al* (2009). Of these, 14 species showed some association with woodland type based on dominant tree species. Another study identified from the literature searches compared the contribution of tree species and woodland structure to habitat associations for 26 woodland bird species (Hewson *et al* 2011). Of these, only three showed differences in occurrence across stands of different tree species and none were strongly associated with ash.

Further analysis was carried out for this project to question whether the abundance of any bird species was positively related to the proportion of canopy trees for four major tree species: ash, beech, birch and oak. This analysis was carried out using proc Genmod in SAS 9.2 using the model:

Log Bird abundance = a.easting + b.northing + c.altitude + d.%Ash + e.%Beech + f.%Birch + g.%Oak + h
(Where h=intercept, and a, b, c, d, e, f and g are regression coefficients. The values were different for each bird species.)

No birds were positively associated with ash, and only chaffinch and woodpigeon were negatively associated with ash which are considered unlikely to be the result of meaningful ecological associations. There were some regional positive and negative associations with ash dominance for other species, but there was insufficient time within the contract to determine whether these were ecologically meaningful or due to data structures. As the analysis provided no useful information, no further results are presented.

11.3 Species of conservation concern that may decline further as a result of ash dieback

Six of the 17 species of conservation concern that were considered were identified from the literature as associating with ash. Of these, only three used ash more frequently than expected from its availability, and none were highly associated.

Marsh tit (*Poecile palustris*) used holes in ash trees more often than expected, for nest sites (Broughton *et al* 2011). However, at the territory scale there was no selection for any particular canopy tree species (Broughton *et al* 2012). Although nest holes in ash are frequently used when available, due to the size and structure of rot holes, marsh tits will use a wide range of other tree species. Comparing nest sites in Polish forests of different types, it was found that although there was selection for nest holes in some tree species, including ash, the majority of nest holes were in the dominant canopy species (Wesolowski 1996). Although the association of marsh tit is not strong with ash, the loss of ash trees in mature ash-dominated woodland may have an impact at the site scale through a change in woodland structure. Marsh tits strongly select for mature closed canopy woodland (>80% canopy closure) with a good understorey cover (>40% understory) and avoid open scrub areas and young woodland (Broughton *et al* 2012). Therefore, a loss of a significant proportion of canopy trees could reduce habitat suitability.

Ash has been identified as a key food resource for **bullfinch** (*Pyrrhula pyrrhula*) during winter in southern England (Newton 1967). Bullfinches are not dependent on ash and will eat seeds of 80% of woody species and 50% of herbaceous species present; other important seeds used in winter include birch, bramble, docks and heather (Newton 1967; Marquiss 2007). Bullfinches will also move between habitats to make use of seasonally abundant seed sources (Marquiss 2007). Therefore, the impact of the loss of ash seeds will depend on the spatial scale, abundance and nutritional content of other seeds available at the time when ash would typically have been used as a food source. The initial study of bullfinch diet in the 1960’s was carried out at a time of higher population levels; bullfinch populations have since declined by 40% and abundance of ash trees has increased. It is therefore unlikely that at a national scale abundance of ash seed is limiting bullfinch populations. However, there may be localised declines or redistribution of bullfinches if ash disappears from locations where ash is currently the primary winter food supply and where there are few alternative food sources, but the extent or size of such effects is difficult to predict.

Spotted flycatchers (*Muscicapa striata*) were found to be more abundant in areas within woodland dominated by ash compared with beech, birch and oak (Smart *et al* 2007). However, at the woodland scale, ash-dominated woods were no more likely to be occupied than birch or oak woods (Smart *et al* 2007). Spotted flycatchers also occur in a wide range of habitats, including areas where ash is absent (e.g. native pine woods, gardens, farmland and oak woods). There doesn't seem to be a strong mechanistic explanation for the relationship found in the repeat woodland survey, and woodland structure or abundance of predators are more important than tree canopy composition in determining habitat suitability (Kirby *et al* 2005; Stoate and Szczur 2006). It seems unlikely that loss of ash trees will have a strong influence on spotted flycatcher populations, except in habitats and areas where ash is the dominant mature tree.

Other species of conservation concern that were found to use ash were **hawfinch** (*Coccothraustes coccothraustes*), **pied flycatcher** (*Fidecula hypoleuca*), and **lesser spotted woodpecker** (*Dendrocopus minor*). All were cosmopolitan in their use of ash, with other tree species often selected preferentially. Hawfinch selected cherry, hornbeam and yew as key food resources in winter, compared with minor use of ash seeds (Mountford 1957), and ash was used among many other tree species for nest sites (Tomialojc 2005). Czeszczewik and Walankiewicz (2003) found that pied flycatcher selected ash and alder as their nest tree in riverine forest, but in other forest types selected other tree species, depending on nest hole availability and structure. Lesser spotted woodpeckers have a strong preference for oak, both for foraging and nest sites, but will also use ash and other tree species (Smith 2007; Charman *et al* 2012).

11.4 Species that are not currently rare but may become so as a result of ash dieback

There was reference to five species that are common and widespread using ash – four of these used ash more frequently than expected.

The species with strongest evidence of using ash was **nuthatch** (*Sitta europea*). A study in Poland recorded characteristics of nest sites in different forest types. Within riverine and oak-hornbeam forest there was selection for ash trees, and the most common nest tree for the whole study was ash (Wesolowski and Rowinski 2004). Nuthatches select for type of nest holes, the most favoured being holes caused by rot from broken off branches and holes that were high up in large living trees. Within this study, ash and Norway maple provided these types of hole most frequently. Other types of hole and other tree species were also used, and it seems likely that the effect of the loss of ash trees will depend on the availability of suitable large trees of other species for nesting. In UK studies, this selection for nest sites in ash did not translate into greater occupancy in ash-dominated stands; nuthatches were most frequent in oak or chestnut dominated stands and had low occurrence in conifer dominated stands (Hewson 2011), or were most frequent in birch or oak dominated stands (Carpenter *et al* 2009).

Chiffchaff (*Phylloscopus collybita*), **blackcap** (*Sylvia atricapilla*), and **wren** (*Troglodytes troglodytes*) all showed some positive association with ash-dominated woodland within habitat associations from the repeat woodland bird survey (Carpenter *et al* 2009; Smart *et al* 2007). Chiffchaffs were most abundant at locations within woods where ash was the dominant tree species compared with beech, birch and oak. Blackcaps and wrens were most abundant in mature woods dominated by ash. Another study also showed that blackcap was more frequent in ash, hawthorn, willow or sycamore dominated stands compared with conifer or oak dominated stands (Hewson *et al* 2011). It is unlikely that ash is a direct resource for these species; all nest in bramble and other low vegetation near the ground, and feed on invertebrates in shrubs and canopy. One possible mechanism for this association is the greater density of suitable low vegetation in ash woods due to the light shade cast by an ash canopy. Dieback of canopy trees is likely to improve nesting habitat quality for these species. However, loss of canopy foliage may reduce foraging opportunities particularly for chiffchaff.

12 The importance of ash across species groups

Chapter Summary

1. *In total, 1,058 species were identified as being associated with ash (ash-associated species): 12 birds, 55 mammals, 78 vascular plants, 58 bryophytes, 68 fungi, 239 invertebrates, and 548 lichens. Of the 55 mammals, 28 use the ash trees and the remainder use the ash woodland habitat; the vascular plants use the ash woodland habitat rather than the trees themselves. Thus 953 species of the 1,058 use the ash tree as opposed to the habitat.*
2. *Forty-four species have been identified as only occurring on either living or dead ash trees and were termed 'obligate' ash-associated species: four lichens, 11 fungi and 29 invertebrates.*
3. *Sixt- two species were found to be 'highly associated' with ash: 19 fungi, 13 lichens, six bryophytes and 24 invertebrates*
4. *Using a combination of the conservation importance of the species and its level of association with ash, we classified the species that use ash trees into Red, Amber, Yellow and Green codings, indicating level of risk with respect to the likely impact of ash dieback. This gave 69 Red-coded species, 169 Amber-coded species, 383 Yellow-coded species and 330 Green-coded species.*
5. *Twenty-two tree species were assessed for their suitability as replacements for ash: field maple, Norway maple, sycamore, alder, silver birch, downy birch, hornbeam, sweet chestnut, hazel, hawthorn, beech, aspen, wild cherry, bird cherry, Douglas fir, sessile oak, pedunculate oak, goat willow, grey willow, whitebeam, yew, and small-leaved lime. The inclusion of a tree species in the assessment does not mean that this species is being promoted as a replacement for ash if the aim is to conserve ash-associated biodiversity.*
6. *Oak supported 69% of the ash-associated species but no single tree species out of those 22 would make a good overall alternative to ash. Similarity indices between the alternative tree species and ash, based on the level of use made of the tree species by the ash-associated species showed that oak, alder, beech and aspen were most similar to ash. Establishing a mixture of tree species rather than a single species to replace ash is suggested as better way of supporting ash-associated species. However, it must be noted that for many ash-associated species, data on the use of these 22 alternative tree species is lacking.*

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12.1 How important is ash for UK biodiversity?

In total, 1,058 species were identified as being associated with ash: 12 birds, 55 mammals, 78 vascular plants, 58 bryophytes, 68 fungi, 239 invertebrates, and 548 lichens. Of the 55 mammals, 28 use the ash trees and the remainder use the ash woodland habitat; the vascular plants use the ash woodland habitat not the trees themselves. All other species groups have been limited to those which use the ash trees themselves, for the purposes of this review. Thus 953 species were identified as being associated with ash trees as opposed to the ash woodland habitat. In terms of numbers of species, lichens are by far the biggest group of species associated with ash. Forty-four species have been identified as obligate on ash: 11 fungi, 29 invertebrates, and four lichens; and 62 species are highly associated with ash (Table 12.1).

Table 12.1. Number of species in different species groups with different levels of association with ash.

See Table 4.1 for definitions of levels of association.

	Level of association with ash					
Group	**Obligate**	**High**	**Partial**	**Cosmopolitan**	**Uses**	**Total**
Bird			7	5		12
Bryophyte		6	30	10	12	58
Fungi	11	19	38			68
Invertebrate	29	24	36	19	131	239
Lichen*	4	13	231	294	4	546
Mammal			1	2	52	55
Vascular plant			78			78
Total	44	62	421	330	199	

*See Chapter 6 for explanation of taxonomic differences resulting in there only being 546 lichens in this table.

12.2 Assessing the impact of ash dieback

In the individual species chapters, lists of species that are currently rare and may become rarer due to ash dieback, and species that are currently common but may become rare or rarer, have already been developed. These lists used combined information on species use of ash, conservation status, and expert knowledge. Here we aim to group species across all species groups according to the impact ash dieback may have on them, using their conservation status and association with ash. We compare two methods, with the aim of grouping all the species associated with ash into Red-, Amber-, Yellow- and Green-coded lists, according to the potential impact that ash dieback may have.

12.2.1 Method 1

Species were grouped into four categories of predicted impact of ash dieback, based on their association with ash and current conservation status. This classification is to some extent subjective and limited by the caveats already discussed within Chapters 5–11.

Red-coded species are defined as: (a) those that are obligate or highly associated with ash and already of conservation importance (UK BAP, IUCN, or Red Data Book) – these species are considered to be in danger of either going extinct or their populations severely declining due to projected impacts of ash dieback; and: (b) those species that are highly associated with ash but of unknown conservation importance, which gives us a conservative/inclusive approach as we do not currently know whether or not these species are of conservation concern. This combined categorisation identifies 73 species to be coded as Red (high risk) in relation to ash dieback.

Amber-coded species are defined as those that are highly associated with ash but currently of no conservation importance, or those that are only partially associated with ash but already are of conservation importance. These species may decline in abundance following ash dieback. We have also included those species that use ash but whose level of association is unknown and are either of conservation importance or of unknown conservation importance – this again takes a conservative/inclusive approach. This gives a total of 430 species as Amber-coded.

Yellow-coded species are defined as those of no current conservation importance which either partially use ash or their use of ash is unknown; these species may also decline but are unlikely to be as greatly impacted by the loss of ash as Amber-coded species. This gives 223 Yellow-coded species.

Green-coded species are defined as those species that are cosmopolitan in their use of ash and they are considered unlikely to be impacted by the loss of ash. There are 330 Green-coded species.

Table 12.2. Number of species classed as Red, Amber, Yellow and Green with respect to the predicted impact of ash dieback.

	Conservation importance		
Level of association with ash	**No**	**Unknown**	**Yes**
Obligate	33	3	8
High	34	7	22
Partial	149	7	264
Uses	74	25	100
Cosmopolitan	25	8	297

Table 12.3. Number of species in each species group classed as Red, Amber, Yellow and Green with respect to the impact of ash dieback. Not applicable (NA) is shown when the method used to assess the level of association with ash did not include cosmopolitan species.

	Impact of ash dieback			
Species group	**Red**	**Amber**	**Yellow**	**Green**
Bird	0	3	4	5
Bryophyte	6	42	0	10
Fungi	13	18	37	NA
Invertebrate	37	89	94	19
Lichen	17	224	11	294
Mammal	0	47	6	2
Vascular plant	0	7	71	NA

This classification (Table 12.3) clearly shows that lichens are the group most likely to be impacted by ash dieback, followed by invertebrates and bryophytes. However, it should be noted that the methods used to identify fungi and plants associated with ash will have already excluded the cosmopolitan species (Chapters 5 and 8), which is why no Green-coded species are identified for these groups.

12.2.2 Method 2

In Method 1, if the species had any conservation status (IUCN, Red Data Book, UK BAP), it was classed as being of conservation importance in Table 12.2. However, this leads to some anomalies, particularly for the mammals where some species are of international concern but are a pest in the UK. For example, rabbit is listed as IUCN 'Near Threatened', which results in it being Amber-coded in the categorisation using Method 1. Yet clearly this species is not at risk within the UK. In addition, in Method 1, species which used the ash woodland habitat as opposed to specifically using ash trees (vascular plants and some mammals) were given the same weighting as species which used ash trees. Species which are dependent on the ash woodland habitat are at lower risk than those that rely on the trees themselves; if the same habitat conditions can be created using alternative tree species then species that use the ash woodland habitat should be able to survive.

The categorisation was therefore carried out again using Method 2: measures of conservation importance, which differed between species groups (Tables 12.4 and 12.5), as follows. For mammals, if the species was a UK BAP species it was listed as of conservation importance. This reduced the number of Amber-coded mammal species from 47 to 17 and removed some anomalies such as rabbit from the list, but hedgehog was still Amber-coded by this method. For birds, if the species was listed as 'Red' or 'Amber' in the Birds of Conservation Concern, it was categorised in our list as of conservation importance. This gave the same number of bird species in each of our coded Red, Amber and Green classes as in the previous table (Table 12.3). For the fungi, invertebrates and vascular plants, if they were listed in their respective Red Data Books they were classed as species of conservation importance for our categorisation. This gave the same result for fungi and invertebrates as did Method 1, as this was the only measure of conservation importance used previously. For plants, one species was lost from the list of species of conservation importance. For lichens and bryophytes we used the IUCN criteria which were the measures used in Table 12.3, but rather than all IUCN categories being classed as 'of conservation concern', the IUCN category of 'Least Concern' was taken to mean of no conservation concern; 'Data Deficient' was classed as 'unknown'; and 'Critically Endangered', 'Endangered', 'Near Threatened' and 'Vulnerable' were all classed as of 'conservation importance'. This significantly reduced the number of lichens coded as Amber from 224 to 49, and reduced the number of Red-coded lichen species from 17 to 13. The number of Red-coded bryophyte species remains at six, but the number of Amber-coded bryophytes reduces from 42 to three.

The list was then further refined by taking into account whether it was the ash tree or the ash woodland habitat that a species used; this applied only to mammals and vascular plants, as the other species groups had only assessed species that used the ash trees. For mammals this reduced the number of Amber-coded species to seven (six bats and red squirrel). No vascular plants were included in this revised list, as they are all associated with the habitat rather than the tree.

This revised classification using Method 2 gives 69 species (a subset of the 73 species from Method 1) which are Red-coded with respect to ash dieback (Table 12.5). It reduces the number of Amber-coded species from 430 to 169, and increases the number of Yellow-coded species from 223 to 383. The number of Green-coded species remains the same at 330. The use of Method 2 in assessing the impact of ash dieback on species is our preferred and recommended method.

Based on species number Method 2 suggests that invertebrates are most at risk from ash dieback, followed by lichens and then bryophytes. A complete list of Red- and Amber-coded species classified by this method is provided in Appendix 2.

Table 12.4. Classification of species into Red, Amber, Yellow, and Green as affected by ash dieback using classification Method 2.

Only species that use ash trees as opposed to ash woodland habitat are shown.

		Conservation status		
		No	**Unknown**	**Yes**
Birds	Obligate			
	High			
	Partial	4		3
	Uses			
	Cosmopolitan	2		3
Bryophytes	Obligate			
	High			6
	Partial	28		3
	Uses	11		
	Cosmopolitan	10		
Fungi	Obligate	11		
	High	17		2
	Partial	37		1
	Uses			
	Cosmopolitan			
Invertebrates	Obligate	21	3	5
	High	16	6	2
	Partial	26	1	9
	Uses	68	13	50
	Cosmopolitan	14	4	1
Lichens	Obligate	2		2
	High	4	1	8
	Partial	188	7	36
	Uses	2	1	1
	Cosmopolitan	257	4	33
Mammals	Obligate			
	High			
	Partial	1		
	Uses	18		7
	Cosmopolitan	1		1

Table 12.5. Number of species in each species group classed as Red, Amber, Yellow and Green with respect to the impact of ash dieback using classification Method 2.

	Impact of ash dieback			
Species group	**Red**	**Amber**	**Yellow**	**Green**
Bird	0	3	4	5
Bryophyte	6	3	39	10
Fungi	13	18	37	
Invertebrate	37	89	94	19
Lichen	13	49	190	294
Mammal	0	7	19	2
Total	**69**	**169**	**383**	**330**

12.2.3 Further work

The above two methods for assessing the impact of ash dieback are fairly simplistic. Further consultation with species experts and cross checking with the lists derived in Chapters 5–11 would refine these results given a longer timescale for the work. The classification could be further developed to produce lists by the devolved countries within the UK, but this was beyond the scope of this project.

There is also a site versus landscape scale effect that should be considered when assessing the potential impact of ash dieback on ash-associated species. For species that occur at just a few sites or on a few ash trees (e.g. the round-leaved feather-moss and the violet click beetle) the conservation implications are different to species that are rare but more widespread. In the former the death of ash at few key sites will be serious even if over the country as a whole the loss of ash is marginal. The list of Red-coded species could be further prioritised based on the distribution of the ash-associated species and the number of sites at which they occur.

The actual impact of ash dieback on the species will also be influenced by the actual extent and distribution of dieback and any management undertaken, such as felling and replanting; the assessments made above should be considered together with assessments of potential management impacts (Chapter 18).

12.3 Alternative tree species

Comparison of the use made of alternative tree species by ash-associated species may be done in three ways:

- Comparison based on the level of association with the alternative tree species (Section 12.3.1).
- Comparison based on the number of ash-associated species supported (Section 12.3.2).
- Comparison of the number of ash-associated species supported by a mixture of alternative tree species (Section 12.3.3).

12.3.1 Comparison of alternative tree species based on the level of association with the ash-associated species.

Of the 22 ‘alternative’ tree species for which an assessment was made (Chapter 4), none supported a high percentage of the ash-associated species with similar levels of association as for ash (Figures 12.1, 12.2 and 12.3). Oak is used by all ash-associated bird species and birch and beech are used by most ash-associated bird species. Field maple, sycamore, alder, hazel, hawthorn, oak, aspen and the willow species are used by many ash-associated bryophytes. The majority of ash-associated fungi use very few of the alternative tree species (or at least there are no records of them using these tree species). Oak spp., hazel, aspen and sycamore are potential substitute hosts for ash-associated lichen species.

For comparison with the use made of alterative tree species (Figures 12.2 and 12.3) a similar graph for ash is shown in Figure 12.1.

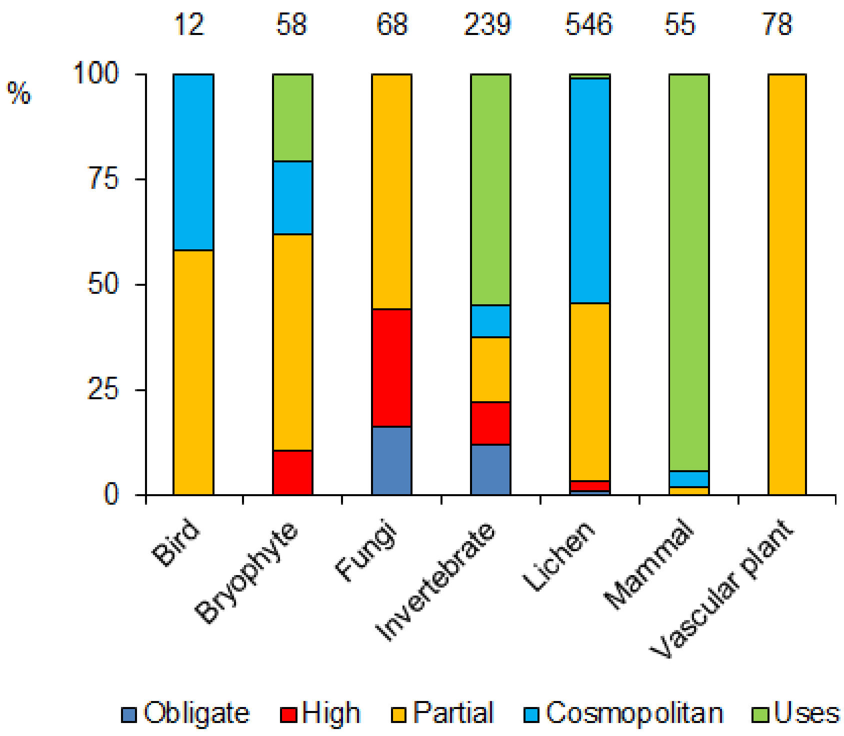

Figure 12.1. Use made of ash by different species groups.
Percentages are calculated within species groups (the total number of species in each species group is shown at the top of each bar).

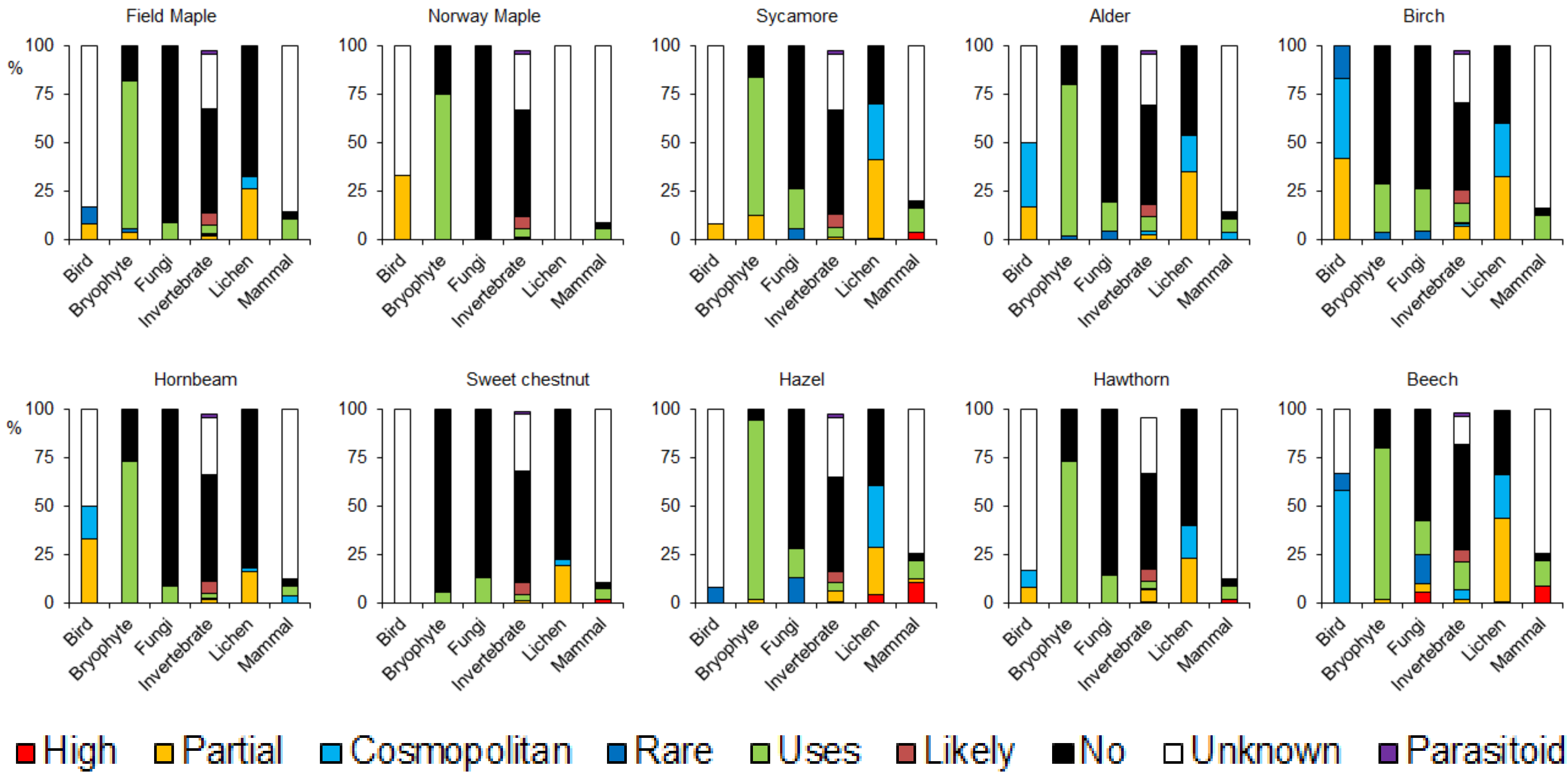

Figure 12.2. Use made of alternative tree species by species that use ash.
Percentages are calculated within species groups (total number of species in each species group are: Birds = 12, Bryophytes = 58, Fungi = 68, Invertebrates = 239, Lichens = 546, Mammals = 55). Birch species (*Betula pubescens* and *pendula*) were grouped into one assessment.

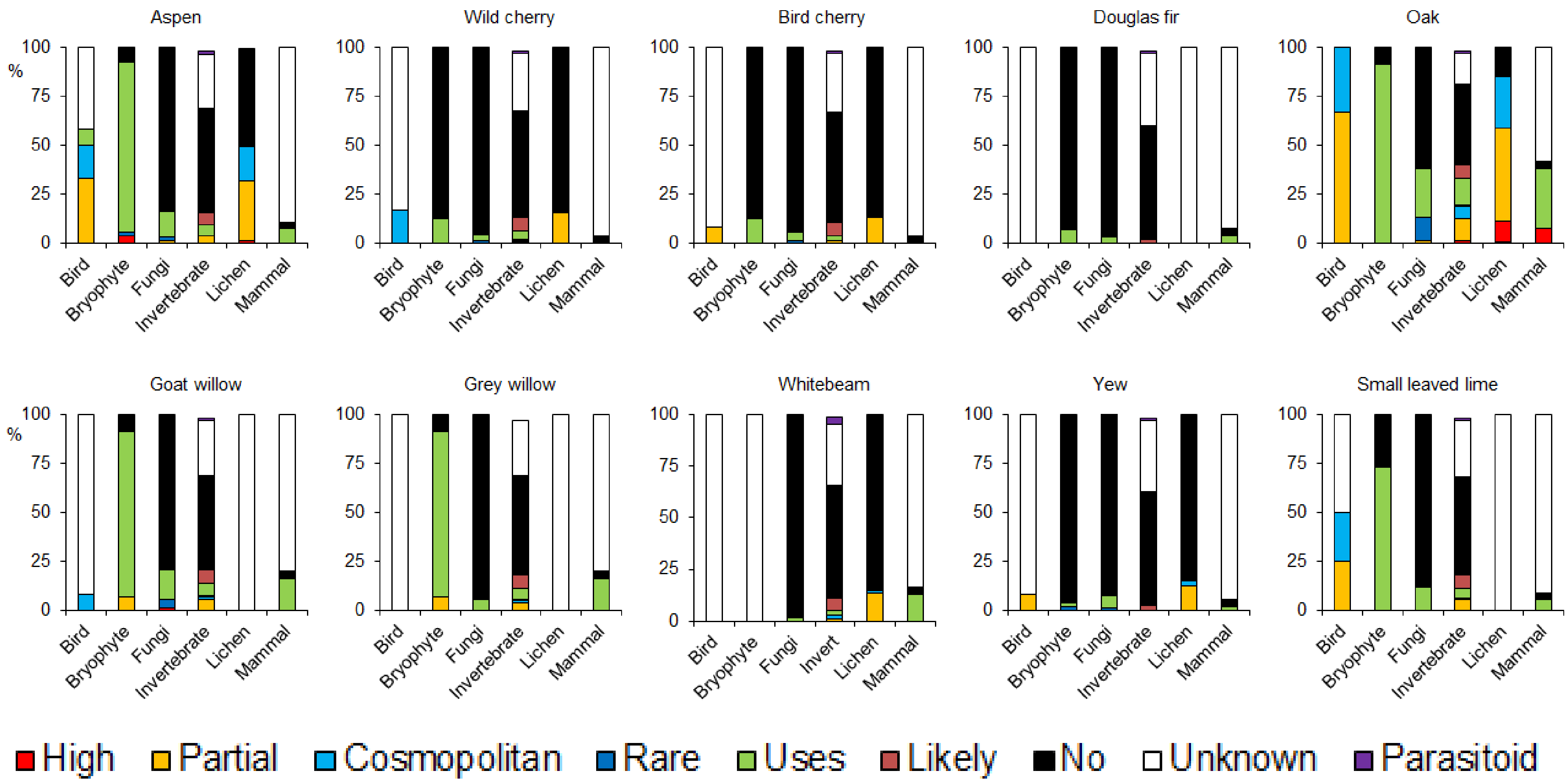

Figure 12.3. Use made of alternative tree species by species that use ash.
Percentages are calculated within species groups (total number of species in each species group are: Birds = 12, Bryophytes = 58, Fungi = 68, Invertebrates = 239, Lichens = 546, Mammals = 55). Oak species (*Quercus robur* and *Q. petraea*) were grouped into one assessment.

The data in Figures 12.1–12.3 were used to create a similarity index with respect to ash. The Euclidean distance measure of similarity was used. Each species group had 10 categorical variables ('obligate', 'high', 'partial', 'cosmopolitan', 'rare', 'uses', 'likely', 'no', 'unknown', 'parasitoid'), which within each species group totalled 100%. This index indicates that oak, alder and beech are most similar to ash based on the level of association made with the alternative tree by the species that use ash (Table 12.6). It should be noted that the similarity index for the alternative tree species was predictably low, as for ash there were no species in the 'no', 'unknown', 'parasitoid' or 'rare' categories.

Table 12.6. Similarity to ash based on the level of use made of alternative trees by species that use ash, based on Euclidian distance.
(1 = identical to ash)

Species	Similarity to ash
Bird cherry	0.34
Douglas fir	0.34
Sweat chestnut	0.35
Goat willow	0.35
Whitebeam	0.35
Yew	0.35
Wild cherry	0.36
Field maple	0.37
Norway maple	0.37
Grey willow	0.37
Small-leaved lime	0.38
Hawthorn	0.4
Hazel	0.41
Birch	0.42
Sycamore	0.43
Hornbeam	0.43
Aspen	0.45
Beech	0.47
Alder	0.48
Oak	0.49

12.3.2 Comparison of alternative tree species based on the level of association with the ash-associated species.

The use of the alternative tree species made by the species that use ash trees (953 species) was simplified from nine categories (as in Figures 12.2 and 12.3) into 'yes', 'no' and 'unknown', to give a simple way of comparing alternative tree species (Figure 12.4). 'Yes' combined species classed as 'high', 'partial', 'likely', 'uses' and 'cosmopolitan' with respect to their use of the alternative tree species. 'No' combined the 'rare' and 'no' classes; and 'unknown' combined the 'parasitoid' and 'unknown' classes. This shows that over 650 of the species that use ash also use oak to some degree, which is 69% of the ash-associated species. This suggests that oak is a good alternative to ash in this respect. In terms of the number of species that use ash that also use the alternative species, the top five alternative tree species from those studied were: oak, beech, sycamore, hazel, and birch. From the data available, Douglas fir, Norway maple, yew, small-leaved lime, grey willow, bird cherry, whitebeam, goat willow, wild cherry, sweet chestnut, hornbeam and field maple all support fewer than 300 of the 953 species that use ash. Douglas fir, yew, small-leaved lime and

Norway maple are classed as being used by very few of the species that use ash, and may therefore be classed as ecologically inappropriate tree alternatives. However, for many ash-associated species, data on their use of these tree species is completely lacking, or their use was only recorded at the level of tree species genera, and thus recorded as 'unknown' in this analysis. An alternative way of assessing the least appropriate alternative tree species is to assess which tree species have the largest number of species known not to use the tree (classed as 'No' in Figure 12.4). This approach gives hornbeam, whitebeam, sweet chestnut, wild cherry, bird cherry and yew as the most ecologically inappropriate tree alternatives to ash. These two approaches give very different lists of tree species; the only tree common to both the above 'inappropriate' lists is yew.

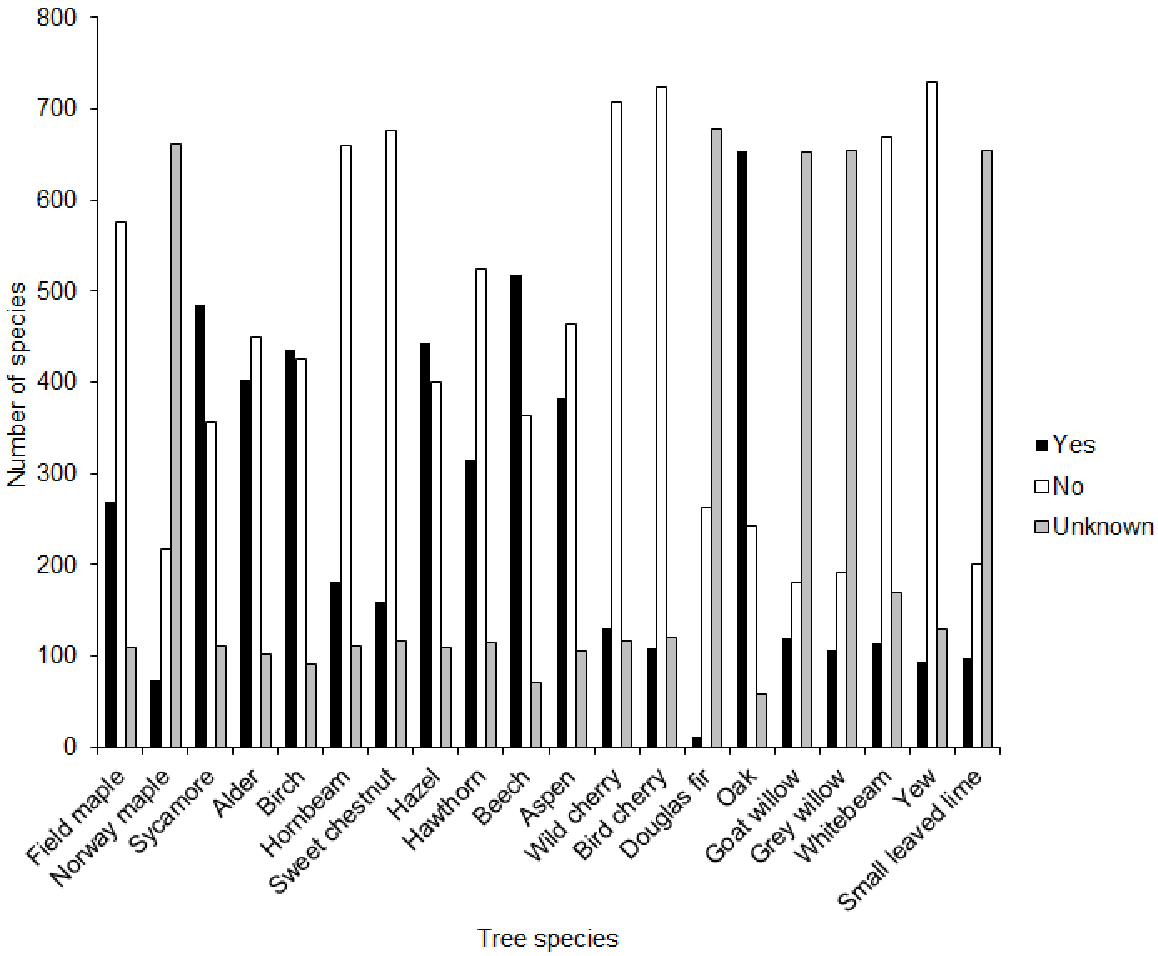

Figure 12.4. The use made of alternative tree species by ash-associated species. Yes = species uses the tree; No = species does not use the tree species; Unknown = no information on use made by species of that tree. Note that both birch species and both oak species were grouped into one assessment for each genus.

12.3.3 Tree species mixtures

The number of ash-associated species supported by mixtures of two or more alternative tree species was calculated. Establishing a mixture of alternative tree species rather than a single species of tree in place of ash would support a much greater number and variety of ash-associated species than any single alternative tree species (Table 12.7). Across all species groups, 74% of ash-associated species could be supported by planting just two tree species (oak sp. and beech). A mixture of 11 tree species would support 84% of ash-associated species – adding further tree species did not increase this percentage although it did alter the identity of the ash-associated species supported.

Table 12.7. Alternative tree species mixtures and number of ash-associated species supported. X_a shows that either of these tree species may be included in the mix and the same number of ash-associated species supported. The number of tree species that supports the maximum number of ash-associated species is shown. Note: although the number of species supported will not increase with an increase in the number of tree species different ash-associated species may be supported. Species from the list of 22 alternative trees that were not included in any of the "best mixture" of tree species groups are not shown.

		Tree species															
Species group	**No. of tree species**	**Field Maple**	**Sycamore**	**Alder**	**Birch spp.**	**Hazel**	**Hawthorn**	**Beech**	**Poplar**	**Wild Cherry**	**Bird Cherry**	**Oak spp.**	**Goat willow**	**Grey willow**	**Small-leaved lime**	**Number of species[1]**	**% of species[2]**
All species	1											x				653	69
	2							x				x				705	74
	3					x		x				x				744	78
	4		x			x		x				x				762	80
	5		x		x	x		x				x				772	81
	6		x		x	x		x	x			x				778	82
	7		x		x	x	x	x	x			x				783	82
	8		x		x	x	x	x	x			x			x	786	82
	9	x	x		x	x	x	x	x			x			x	787	83
	10	x	x		x	x	x	x	x	x		x			x	788	83
	11	x	x		x	x	x	x	x	x		x	x		x	798	84
Birds	1											x				12	100
Bryophytes	1					x										55	95
	2	x				x										57	98
Fungi	1							x								19	28
	2							x				x				30	44
	3			x_a				x				x	x_a			34	50
	4		x			x_a		x				x	x_a			36	53
	5		x			x		x				x	x			38	56
Invertebrates	1											x				86	36
	2							x				x				117	49
	3				x			x				x				130	54
	4				x	x_a		x				x			x_a	135	56
	5				x		x_a	x				x	x_a		x	140	59

		Tree species															
Species group	No. of tree species	Field Maple	Sycamore	Alder	Birch spp.	Hazel	Hawthorn	Beech	Poplar	Wild Cherry	Bird Cherry	Oak spp.	Goat willow	Grey willow	Small-leaved lime	Number of species[1]	% of species[2]
	6				x		x	x	x_a			x	x_a		x	144	60
	7				x	x	x	x	x			x			x	146	61
	8	x			x	x	x	x	x			x			x	147	62
	9	x			x	x	x	x	x	x_a	x_a	x			x	148	62
Lichen	1											x				467	85
	2		x									x				490	89
	3		x			x						x				504	92
	4		x			x			x			x				509	93
	5		x		x	x			x			x				512	93
	6		x		x	x		x	x			x				514	94
	7		x		x	x	x	x	x			x				515	94
Mammal	1											x				17	61
	2				x							x				19	68

[1]Number of ash associated species supported with this mix of trees, within species group where appropriate.
[2]Percentage of ash associated species supported with this mix of trees, within species group where appropriate.

As oak supports all the ash-associated bird species, for birds a mixture of tree species would not necessarily be more beneficial than simple replacement by oak. Two tree species (field maple and hazel) support 98% of ash–associated bryophytes (Table 12.7). Five tree species support 56% ash-associated fungi with a greater number of tree species (from the list of 22 species considered) altering the fungal species composition but not the total number of species supported (Table 12.7). Three tree species (birch, beech and oak) supported 54% of the ash-associated invertebrate species. Increasing the number of tree species to nine, with the addition of field maple, hazel, hawthorn, beech, poplar, and either bird cherry or wild cherry, supports 62% of the ash-associated invertebrates. Further increases in the number of tree species (from the list of 22 considered) does not increase the number of ash-associated invertebrates supported (Table 12.7). Sycamore and oak support 85% of ash-associated lichen species; this number could be increased to 94% by also including birch, hazel, hawthorn, beech, and poplar. A mixture of oak and birch would support 68% of the mammal species associated with ash (Table 12.7).

12.3.4 Limitations of methods to assess the suitability of alternative tree species.

The above sections (12.3.1-12.3.3) explore different methods to assess the suitability of alternative trees to ash based on the use made of these alternative trees by ash-associated species. The results illustrate the types of analyses that could be done at a finer scale or explored further. All of the methods used have a number of limitations which should be considered when using these rankings of suitability:

- The analyses assume that all ash-associated species are present (as all species were included in the analysis). Ideally the analyses should be calculated for each of the nine ash-relevant regions or at an individual site level using just the species present in that region/site. This would require information on the presence/absence of each of the 1,058 ash-associated species and this was beyond the scope of this project.
- The analyses takes no account of how highly associated the species are with ash. The analyses could be repeated for just those species identified as likely to decline (highly associated species or RED-coded and AMBER-coded species identified in Section 12.2.2) as identification of alternative trees for these species is a priority.
- The analyses assume that all the alternative tree species are equally suited to the site. Ideally the analysis should be repeated at a regional or site level only including the tree species that would be expected to colonise or be suitable for planting in each region/site.
- No account is taken of the alternative trees similarity to ash in terms of ecosystem function (see Chapter 3).
- No account is taken of the alternative trees similarity to ash in terms of plant traits, this is covered in Chapter 15.

This report uses two methods to assess the similarity of alternative tree species to ash: species use (this chapter) and plant traits (Chapter 15). These two approaches are compared in Chapter 18.2.

12.4 Other alternative species

A wide range of other plant species (254), in addition to the 22 selected alternative tree species, were identified as also being used by some of the species that use ash. (Note the 254 records of additional alternative species include some species and some genus level records where associations at the plant species level were unknown). Species of fungi that use ash have been recorded on 163 other plant species, and invertebrates on 135 other plant species (note this includes a mixture of records at the species and genus level). Obviously, obligate and highly associated species with ash will use few or no other alternative species, and will therefore by definition be more at risk from ash dieback. Across all species groups, the 'alternative' plant species that were recorded as being used by ten or more species in addition to the 22 tree species already assessed were: *Sambucus nigra*, *Ulmus* spp., *Prunus spinosa*, *Salix* spp., *Aesculus hippocastanum*, *Ligustrum vulgare*, *Ulmus glabra*, *Ulmus minor*, *Malus* spp., *Syringa vulgaris*, *Populus* spp., *Malus sylvestris*, *Hedera helix*, *Pinus sylvestris*, *Ilex aquifolium*, *Fraxinus ornus*. Note this list of alternative plant species should be treated with the appropriate caveats, because for really cosmopolitan species no other alternative species were added to the list (in addition to the 22 tree species) as the list would have been huge!

12.5 Ecosystem services

This section aimed to assess (as well as possible) whether the species associated with ash were involved in nutrient cycling, decomposition, seed dispersal, pollination and the provisioning of food for humans. This assessment was not easy to make for many species, and most species experts left these cells blank in the data spreadsheet during the literature review as the data was unknown or not readily available for that species. According to the UKNEA definition of nutrient cycling, all species are involved in this ecosystem service. The 68 fungi identified as associated with ash are all involved in decomposition, and nine invertebrates were also identified as contributing to decomposition. Thirty-two mammals were listed as being involved in seed dispersal. This ecosystem service is likely to continue if the replacement tree species for ash also produce seeds that can be used by these mammals. Only two invertebrates were recorded as pollinators. This is partly because ash itself is wind-pollinated so does not attract pollinating insects for the purposes of pollination. However many insects whose larval stage uses ash may be pollinators as adults – for example, many moths whose larva use ash may well be involved in pollination as adults, but the role of moth pollination is less well-known than that for bees. Thus, a greater number of invertebrates that use ash may be involved in pollination of other plants than suggested by this report, but within the time-frame available for this project it was not feasible to conduct a detailed literature search specifically for pollination for all of the invertebrates that use ash. Four mammals and two plants were listed as providing provisioning services – food. However, it should be noted that all tree species within the woodland potentially provide a provisioning service of timber and wood.

The assessment of ecosystem services provided by the database and this report probably represents an under-estimation, in view of the limited time available for this work. In addition, it is important to note that the species that use ash may be involved in other ecosystem services that were not assessed here. This work could be extended much further if required, by a more detailed assessment of a wider range of ecosystem services at the species level, perhaps initially just for those species identified as most at risk from ash dieback.

13 Response of woodland vascular plant community to loss of ash

Chapter Summary

1. *For each of the 12 ash woodland types identified where ash is a constant or very frequent species (W7a,c, W8a–g, W9a, W10e and W12a), broad judgements are presented on potential changes in the plant community composition and structure following possible scenarios associated with extensive ash dieback.*
2. *These are subjective assessments and the actual impact will depend strongly on the extent and rate of ash dieback, herbivory levels and management actions.*
3. *Assessments are based on NVC descriptions and an assessment of responses of key plants based on their requirements for light (Ellenberg light values), established evolutionary strategies (competitor, stress tolerator or ruderal), and observed regenerative strategies (vegetative, seed, persistent juvenile).*
4. *In the short term, there may be benefits for many field layer plant species due to the decline in canopy cover and increased light levels.*
5. *Longer-term predictions are more subjective, and local circumstances, such as past history and current management, the availability of seed parents, the vagaries of dispersal and establishment will greatly determine outcomes.*

13.1 Method

For each of the 12 ash woodland types identified where ash is a constant or very frequent species (W7a,c, W8a–g, W9a, W10e and W12a) (Chapter 5), broad judgements are presented on potential changes in the plant community composition and structure following possible scenarios associated with extensive ash dieback. These are subjective assessments whose nature and severity will obviously depend greatly on the extent and rate of ash dieback and many local factors including herbivory levels and management actions taken either directly as a result of ash dieback or otherwise. They include assessments of initial shorter-term responses to canopy reduction, some responses as a result of management to remove affected ash, and longer-term effects associated with the replacement of ash by other trees and shrubs that are already an integral part of each of the individual woodland sub-communities.

In general, in the short term, there may be positive biodiversity outcomes for many field layer species as mostly they are better adapted to periods of canopy reduction/disturbance and often only survive at present in unmanaged coppice with standards or high forest where there are glades, rides or along woodland edges (Vera 2000; Hopkins and Kirby 2007; Ainsworth *et al* 2011). This may be seen in some ways as analogous to the effects of coppicing (although with less understorey removal and ground disturbance but more deadwood remaining). However it should be pointed out that in this case there may be a slower re-establishment of the canopy.

Longer-term predictions are more subjective, and local circumstances, such as past history and current management, the availability of seed parents, the vagaries of dispersal and establishment, and once the canopy has begun to close again the interplay between certain species will greatly determine outcomes. In addition if other tree diseases establish this may alter which tree species may be expected to replace ash. A general point across the board here is that while there may be potential for replacement species, these may take longer to fill the gaps than ash which tends to have a greater number of seedlings and saplings than most species. So, in the medium term, there may be longer periods of more open conditions even though ultimately more shade-casting trees may prevail. It is clear, however, that ash does possess unique functions within British woodlands with respect to the light canopy it casts and its litter characteristics which replacement species would alter to varying degrees leading to long-term consequences for woodlands where ash is presently an important component.

Assessments of changes in species composition are based primarily on NVC descriptions and floristic tables in Rodwell (1991) and Hall *et al* (2004), other relevant literature and an assessment of responses of key plants in sub-communities by reference to their assigned Ellenberg light values (after Hill *et al* 1999), established evolutionary strategies, and observed regenerative strategies following Grime *et al* (2007). Reference to these characteristics in the text following species names is given for example as (L5, SC, V), where a species has an Ellenberg light value of 5, a stress-tolerant competitive life strategy and a primary regenerative tendency for vegetative expansion. Where Ellenberg values relate to woody species, they refer to seedlings and young saplings rather than mature specimens. A summary of these three attributes is given below. Where the frequency of *Ulmus glabra* is given in sub-community summaries, an asterisk (*) denotes that it may now be significantly lower than when many of its samples were recorded during the 1960s–1980s as a result of Dutch elm disease.

13.1.1 Ellenberg values

The requirements of a species for light summarised by Ellenberg light values are as follows:

L1	Plant in very deep shade
L2	Between 1 and 3
L3	Shade plant, mostly less than 5% relative illumination, seldom more than 30% illumination when trees are in full leaf
L4	Between 3 and 5
L5	Semi-shade plant, rarely in full light, but generally with more than 10% relative illumination when trees are in leaf
L6	Between 5 and 7
L7	Plant generally in well-lit places, but also occurring in partial shade
L8	Light-loving plant rarely found where relative illumination in summer is less than 40%
L9	Plant in full light, found mostly in full sun

13.1.2 Established evolutionary strategy (CSR model)

The CSR model originates from Ramenskii (1938) and Grime (1974) who suggested that plants have evolved primary strategies which conform to three distinct types. These are the *competitors*, exploiting conditions of low stress and low disturbance, the *stress-tolerators*, associated with high stress and low disturbance, and the *ruderals*, characteristic of low stress and high disturbance. These are the extremes of evolutionary specialization and are sub-divided into seven categories:

C	Competitor
S	Stress tolerator
R	Ruderal
C-R	Competitive-ruderal
S-R	Stress-tolerant ruderal
C-S	Stress tolerant competitor
C-S-R	‘C-S-R’ strategist

13.1.3 Regenerative strategy

The five regenerative strategies of widespread occurrence in terrestrial vegetation:

- V Vegetative expansion: new shoots vegetative in origin and remaining attached to parent plant until well-established.
- S Seasonal regeneration: independent offspring (seeds or vegetative propagules) produced in a single cohort.
- Bs Persistent seed or spore bank: viable but dormant seeds or spores present throughout the year; some persisting more than 12 months.
- W Numerous widely dispersed seeds or spores: offspring numerous and exceedingly buoyant in air; widely dispersed and often of limited persistence.
- Bj Persistent juveniles: offspring derived from an independent propagule but seedling or sporeling capable of long-term persistence in a juvenile state.

13.2 W7 *Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum* woodland

13.2.1 W7a *Urtica dioica* sub-community

Sub-community constants
Alnus glutinosa (V), *Ranunculus repens* (IV), *Chrysosplenium oppositifolium* (IV), *Urtica dioica* (IV).

Other common species (III unless otherwise stated)
Fraxinus excelsior, *Filipendula ulmaria*, *Kindbergia praelonga*, *Galium aparine*, *Angelica sylvestris*, *Brachythecium rutabulum*, *Athyrium filix-femina*, *Holcus mollis*, *Poa trivialis*, *Rubus fruticosus* agg., *Acer pseudoplatanus* (II), *Salix cinerea* (II), *Caltha palustris*.

Commonest saplings
Acer pseudoplatanus (III), *Fraxinus excelsior* (II), *Alnus glutinosa* (II).

Distribution
This community occurs on light-textured alluvial soils, on flat or gently sloping terraces of river systems and is found predominantly in Wales, northern and western England, the Weald and upland fringes of north-east Scotland.

Responses
Ash is rarely the most abundant canopy tree in this alder-dominated community, and any effects through ash dieback may be fairly limited in both the short- and longer-term. It should be mentioned that *Alnus glutinosa* is also subject to disease problems (e.g. *Phytophthora alni*), which makes it even harder to predict potential changes in community structure and composition. However, there may be some local effects in those stands where ash is more abundant, as it casts a significantly lighter shade than *Alnus glutinosa*. Some of the common bulkier light-demanding members of the community such as *Urtica dioica* (L6, C, V and Bs), *Galium aparine* (L6, C-R, S), *Caltha palustris* (L7, C-S-R, V), and *Filipendula ulmaria* (L7, C/C-S, V and Bs) may be expected to increase in cover through either vegetative expansion or increased seeding capacity. In addition, competitive-ruderals like *Poa trivialis* and particularly *Ranunculus repens* (L6, C-R) would be expected to thrive in the short term following any woodland operations to remove affected ash, as they spread on bare ground very rapidly through vigorous proliferation of stolons (*R. repens*) and creeping stems (*P. trivialis*) (Harper 1958). Short-term declines may be expected for some of the more diminutive members of the sub-community such as *Stellaria alsine* and *Chrysosplenium oppositifolium*. Gaps created may also be quickly filled with colonising *Salix*

cinerea (L7, C/C-S, W and S) whose seedlings have a capacity to outstrip the growth of accompanying woody species (Grime and Hunt 1975).

In the longer term, ash would most likely be replaced on wetter areas by *Alnus glutinosa*, providing it is not reduced severely itself by *Phytophthora*, as some recent evidence suggests (Kirby pers comm), and *Acer pseudoplatanus* on better-drained soils, especially as saplings of both species are already frequently found in most stands. If indeed *Alnus glutinosa* does become severely depleted, willow species may be the main beneficiaries, as there are few other trees that are able to thrive in such conditions.

13.2.2 W7c *Deschampsia cespitosa* sub-community

Sub-community constants
Kindbergia praelonga (V), *Deschampsia cespitosa* (IV), *Mnium hornum* (IV), *Dryopteris dilatata* (IV).

Other common species (III unless stated otherwise)
Alnus glutinosa, *Fraxinus excelsior*, *Acer pseudoplatanus*, *Quercus petraea*, *Crataegus monogyna*, *Corylus avellana*, *Sorbus aucuparia*, *Filipendula ulmaria*, *Lysimachia nemorum*, *Oxalis acetosella*, *Atrichum undulatum*, *Athyrium filix-femina*, *Holcus mollis*, *Plagiomnium undulatum*, *Juncus effusus*, *Rubus fruticosus* agg.

Commonest saplings
Acer pseudoplatanus (III), *Betula pubescens* (II), *Fraxinus excelsior* (II), *Alnus glutinosa* (I).

Distribution
The *Deschampsia cespitosa* sub-community generally occurs on brown soils that show some signs of gleying and on moderately base-rich soils kept moist by drainage impedance. It is principally found throughout Wales, in northern England, and across parts of central and northern Scotland, with a few scattered localities in southern and western England.

Responses
The canopy is usually much more mixed here, with alder sharing dominance with ash and *Betula pubescens*, often with some *Quercus petraea* and *Acer pseudoplatanus*. For these reasons a notable loss of ash would probably have a more significant effect here than in the *Urtica* sub-community. There is also a wider variety of more shrubby species, such as *Crataegus monogyna*, *Corylus avellana* and *Sorbus aucuparia*, so predicting the effects of any changes following ash dieback are even more problematic. However, sapling and pole stage individuals of *Acer pseudoplatanus* (L4, C/C-S, W and S) are generally the most frequent young trees here, and may be expected to be the most likely to benefit with the increase in canopy space created by loss of ash trees. *Betula pubescens* (L7, C/C-S, W and S) seedlings and saplings are also likely to become more abundant in gaps created. Within the field layer, a short- to medium-term increase in light levels would be likely to lead to an increased vigour and cover of some of the bulkier, light-demanding species, such as *Filipendula ulmaria* (L7, C/C-S, V and Bs) and *Lonicera periclymenum* (L5, C-S, V and S), the latter of which is dependent upon the creation of gaps in the canopy by tree-fall or woodland clearance before flowering can take place. Any disturbance caused through forestry operations to remove affected ash would be likely to favour a short- to medium-term spread of *Deschampsia cespitosa* (L6, C-S-R/C-S, S and Bs), *Holcus mollis* (L6, C/C-S-R, V), *Juncus effusus* (L7, C/C-S, V and Bs), and *Rubus fruticosus* agg. (L6, C-S, V and Bs), all of which are already common here although the latter of these may be less likely if grazing levels are high. In the longer term, as new trees develop to replace ash, the canopy may become slightly denser and we would expect the more light-demanding species to decline, with *Acer pseudoplatanus* and *Alnus glutinosa* (again depending on the effects of

Phytophthera) both probably benefitting. In the past, there may have been opportunities here for *Ulmus glabra* to develop but that is unlikely now.

Typically, both of these types of *Alnus-Fraxinus-Lysimachia* woodland occur as fairly small stands within more extensive stretches of other kinds of woodland, marking out areas where a strong influence of ground-water interrupts a vegetation pattern determined in large measure by variations in the base-richness of the soils. For these reasons, it is not likely that they would display any notable shifts to other particular sub-communities.

13.3 W8 *Fraxinus excelsior-Acer campestre-Mercurialis perennis* woodland

13.3.1 W8a *Primula vulgaris-Glechoma hederacea* sub-community

Sub-community constants
Fraxinus excelsior (IV), *Quercus robur* (IV), *Corylus avellana* (V), *Mercurialis perennis* (IV), *Kindbergia praelonga* (IV), *Rubus fruticosus* agg. (IV).

Other common species (III unless stated otherwise)
Crataegus monogyna, *Poa trivialis*, *Glechoma hederacea*, *Primula vulgaris*, *Hyacinthoides non-scripta*, *Brachythecium rutabulum*, *Mnium undulatum*, *Circaea lutetiana*, *Geum urbanum*, *Acer campestre* (II), *Carpinus betulus* (II), *Betula pendula* (II), *Tilia cordata* (II), *Ulmus carpinifolia* (II).

Commonest saplings
Acer campestre (II), *Fraxinus excelsior* (II), *Fagus sylvatica* (I), *Quercus robur* (I), *Betula pendula* (I), *Ulmus* spp. suckers (I), *Acer pseudoplatanus* (I).

Distribution
This sub-community is found on heavy base-rich mull soils predominantly in the south-east of England, but it extends well into south-west England and south Wales, and as far north as Yorkshire.

Responses
The *Primula-Glechoma* sub-community commonly forms the basis of what has been simple coppice or coppice-with-standards with a canopy dominated by *Quercus robur* and ash. Following canopy reduction, it is likely that there would be an initial increased vigour of light-demanding species such as *Rubus fruticosus* agg. (L6, C-S, V), that is able to spread rapidly vegetatively and capable of locally dominating in such situations. However, interactions with grazing are critical here – if grazing levels are heavy then *Rubus* has been shown not to increase as would otherwise be expected. Other species that may benefit include those relatively fast-growing hemicryptophytes such as *Poa trivialis* (L7, R/C-S-R, V), spreading by means of its creeping stolons. *Mercurialis* (L3, C-S, V), may be expected to decline in vigour, at least in the short term, with its noticeably higher shade preference. This may be exacerbated where woodland operations are carried out, as it is particularly sensitive to disturbance. Tree and shrub seedlings, especially those of *Quercus robur* (L7, C-S, S) but also *Acer campestre* (L5, C-S, W/S), are likely to rise with increased light levels, and, providing herbivory levels aren't too high, these species may be the beneficiaries in the longer term. Where deer numbers are high, it has been recognised by Kirby (pers comm) that both *Brachypodium sylvaticum* and *Carex pendula* have increased in cover in this type of woodland. Where present, *Crataegus monogyna* (L6, C-S, S) has been shown to be able to regenerate even in long-established woodlands, and this may be particularly so if management operations are carried out with their associated ground disturbance. In these situations, local patches of thick scrub may develop quite rapidly which cast a dense shade

and reduce the diversity of the field layer, and in the medium term, may resemble the *Mercurialis* sub-community of the *Crataegus monogyna-Hedera helix* scrub community (W21b). *Betula pendula* (L7, C/C-S, W/S), although uncommon in general, occurs here at a higher frequency than other W8 sub-communities, and would also be likely to benefit where it is present through a combination of its wind-blown seed germinating in gaps and its relatively quick growth rate. *Corylus avellana* (L4, C-S, V/S), as a frequent understory shrub, may also benefit in the short- to medium-term, as shoots are replaced more quickly and shooting becomes more prolific with increasing light levels. *Ulmus carpinifolia*, which can be locally important here, may also become increasingly invasive with a reduction in ash which might have effects on the existing trees and shrubs as *Ulmus* suckers can overtop and shade them out fairly rapidly (Rackham 1975).

Providing herbivory levels aren't high and disease levels associated with oak don't become more widespread (as they currently are in parts of the English midlands), the opening of the canopy may give *Quercus robur* seedlings/saplings a better chance of developing into mature trees, and in the longer term this would lead to the development of a denser overall canopy, a deeper, less labile litter layer and slower nutrient turnover, inferring a slight shift towards *Quercus-Pteridium-Rubus* woodland, possibly akin to the *Anemone nemorosa* sub-community (W10b), which is also found on relatively heavy soils of south-eastern Britain.

13.3.2 W8b *Anemone nemorosa* sub-community

Sub-community constants
Fraxinus excelsior (IV), *Corylus avellana* (IV), *Crataegus monogyna* (IV), *Kindbergia praelonga* (IV), *Anemone* nemorosa (V), *Ranunculus ficaria* (IV), *Hyacinthoides non-scripta* (IV).

Other common species (III unless stated otherwise)
Quercus robur, *Mercurialis perennis*, *Rubus fruticosus* agg., *Plagiomnium undulatum*, *Acer pseudoplatanus* (II), *Ulmus glabra* (II), *Carpinus betulus* (II), *Sambucus nigra* (II).

Commonest saplings
Fraxinus excelsior (II), *Acer pseudoplatanus* (II), *Ulmus glabra** (II).

Distribution
This sub-community tends to occur on soils that remain wetter for longer in spring, particularly heavy clay soils in the south-east, and locally on wet sites in the north-west.

Responses
The *Anemone nemorosa* sub-community may often be difficult to separate from W8a (Hall *et al* 2004), and would be expected for the most part to show similar responses to those described for that sub-community, as they share many attributes. One species which is particularly more frequent here is *Ranunculus ficaria* including both ssp. *ficaria* and *bulbifera* (L6, S-R, S (V)) and may be expected to benefit in the short- to medium-term. This tuber-forming herb minimizes competition with other summer-growing grasses, herbs and trees by virtue of its vernal phenology. Unshaded or lightly shaded sites have been shown to be more favourable for its growth despite the fact that it is frequent in woodland (Taylor and Markham 1978), and as such it would be likely to expand more quickly following canopy reduction than some other associates of this sub-community. Associated floristic diversity may be expected to decline where it achieves greater abundance. The other common shallow-rooted vernal species in the sub-community (e.g. *Anemone nemorosa* (L5, S-R, V and S)), would also be likely to spread rapidly in the short term at the expense of *Mercurialis perennis* for instance, particularly if management to remove dead ash was undertaken with its increased levels of disturbance to the soil (Shirreffs 1985). Such management may also lead to an increase in some of the shrubby elements such as *Crataegus monogyna* and

Sambucus nigra (L6, C, S and Bs), the latter of which tends to be more prominent here than in the other predominantly south-eastern W8 sub-communities. *Hyacinthoides non-scripta* also reaches its maximum (for W8) in this sub-community and would be unlikely to be particularly affected as it tends to be quite a persistent species where it has developed local dominance as its deep-rooted bulbs allow co-existence with other strongly competitive woodland species (Grime *et al* 2007).

The relative similarity of this and the previous sub-community would mean that they would be likely to follow similar trajectories in the light of extensive loss of ash and in the longer term, show a gradual shift towards the *Anemone* sub-community of W10. However, where *Acer pseudoplatanus* is important (as it can be here in more northern and western stands), a move towards the *Acer pseudoplatanus-Oxalis acetosella* sub-community (W10e) may be expected.

13.3.3 W8c *Deschampsia cespitosa* sub-community

Sub-community constants
Fraxinus excelsior (IV), *Corylus avellana* (V), *Rubus fruticosus* agg. (V), *Deschampsia cespitosa* (V), *Kindbergia praelonga* (IV).

Other common species (III unless stated otherwise)
Quercus robur, *Crataegus monogyna*, *Acer campestre*, *Hyacinthoides non-scripta*, *Brachythecium rutabulum*, *Circaea lutetiana*, *Fissidens taxifolius*, *Acer pseudoplatanus* (II), *Cornus sanguinea* (II), *Prunus spinosa* (II), *Juncus effusus* (II), *Filipendula ulmaria* (II), *Lysimachia nemorum* (II).

Commonest saplings
Fraxinus excelsior (IV), *Acer pseudoplatanus* (II), *Ulmus glabra** (II), *Quercus robur* (I).

Distribution
This sub-community is characteristic of heavy, wet, often trampled soils which are free from water-logging for only a short period in the summer. It is more prominent in southern Britain, but is found locally as far north as Northumbria and as far west as Pembrokeshire.

Responses
As the name suggests, *Deschampsia cespitosa* (L6, C-S-R/C-S, S and Bs) is often the most abundant plant in the ground layer here. Its survival in woodland, where flowering and seed production is often poor, may be related to the considerable longevity of established plants (>30 years), and persistence of its seed bank (Roberts 1986). Opening of the canopy through ash dieback, especially if accompanied by management operations to remove affected specimens, would be expected to result in an explosive spread of *Deschampsia* as has been demonstrated by stands subjected to coppice management (Rackham 1975; Davy 1980). Other plants typical of W8c that would also be likely to spread (at least in the short term) under these conditions on the heavy water-logged soils include *Prunus spinosa* (L6, C-S, V and S), *Rubus fruticosus* agg., and *Juncus effusus* (L7, C/C-S, V and Bs). Not surprisingly, a number of ruderal species that are also frequent here are likely to become prominent under these conditions and include species of *Rumex*, *Cirsium* and *Epilobium*. The dominance of these species will, however, usually fade and the original field layer will be restored in the longer term (Ash and Barkham 1976).

Ash saplings and pole stage trees can be particularly abundant in this sub-community, and with a gradual decline in their abundance, it is likely that *Corylus avellana*, and towards the north and the west, *Acer pseudoplatanus* may become more prominent within the shrub and canopy layers, respectively. Because the heavy soil type plays a particularly important role here in determining the community composition, it is difficult to ascertain the effects of an extensive loss of ash. However, as described above, there may be a slight shift towards the *Anemone* sub-community of W10 in more south-eastern stands and towards the *Acer pseudoplatanus-Oxalis acetosella* sub-community of W10, where *Acer pseudoplatanus* is a more important tree in the north and west.

13.3.4 W8d *Hedera helix* sub-community

Sub-community constants
Fraxinus excelsior (V), *Corylus avellana* (V), *Crataegus monogyna* (V), *Mercurialis perennis* (V), *Quercus robur* (IV), *Rubus fruticosus* agg. (IV), *Hedera helix* (IV).

Other common species (III unless stated otherwise)
Acer campestre (II), *Sambucus nigra* (II), *Brachypodium sylvaticum*, *Hyacinthoides non-scripta, Viburnum lantana* (I).

Commonest saplings
Acer campestre (III), *Fraxinus excelsior* (II), *Acer pseudoplatanus* (I).

Distribution
This sub-community becomes prominent in the more oceanic parts of central and southern Britain particularly in south-west England and south Wales but is still fairly frequent close to the English Channel and towards the north and west of England and Wales.

Responses
The *Hedera helix* sub-community is as much a product of climate (Matthews 1955) and management as it is of soil type and it is in general the most species-poor of all the *Fraxinus-Acer-Mercurialis* woodland types. It is almost invariably found with a closed dense canopy of both trees and understorey, reflecting a long period of neglect/lack of management (Rackham 1975). The most distinctive feature of the field layer is a considerable abundance of *Hedera* (L4, C-S, V and S) growing as a ground carpet. Its capacity to spread vegetatively so successfully both along the ground and vertically is unique within the British flora. The vertical stems are vital to the regenerative strategy since they alone bear flowering shoots and do so only in relatively unshaded sites. Many plants seldom escape the shade of their accompanying trees and shrubs, and so rarely flower. Thus, *Hedera* mainly sets seed in habitats which are less shaded than those in which it occurs most abundantly. It tends to be a very persistent species where it has become abundant and it is unlikely that it would be greatly affected by a significant reduction in the canopy, especially as the shrub layer, typically of *Crataegus monogyna* and *Corylus avellana*, can be quite dense here. Since the publication of the NVC, *Hedera* appears to have become more dominant, both as a ground component and a climber, and there is some evidence (Kirby pers comm) that it is also increasing in less oceanic parts of the British Isles, for instance in eastern England, and has become very prominent on dead/dying elms. We might expect something similar on ash even if they still keep some live canopy. The extra sail area of ivy on the trunks could lead to an increased risk of trees blowing down during stormy conditions. A reduction in the abundance of the shade-demanding *Mercurialis perennis* (L3) which can also be very common here may however be more likely, especially if management work is carried out to remove affected ash. Surprisingly, considering the rather dense appearance of such woods, *Brachypodium sylvaticum* (L6) can be quite prominent here and may be expected to increase its cover with rising light levels, particularly where deer numbers are high.

Not surprisingly, due to the frequently dense nature of this woodland, saplings are not recorded as being particularly common here. They could increase with some thinning of the canopy, in which case it is probably *Acer pseudoplatanus*, *Crataegus monogyna* and *Sambucus nigra* which may benefit. Where forestry operations are carried out, the associated disturbance may well encourage any of these three species and lead to the development of some dense scrub patches that resemble the *Hedera-helix-Urtica dioica* sub-community of the *Crataegus monogyna-Hedera helix* scrub community (W21a). In the long term, the loss of ash may mean that *Quercus* spp. may simply survive as the main canopy species and this would be likely to shift the woodland gradually towards its, relatively oceanic, W10 woodland counterpart, the *Hedera helix* sub-community of the *Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland (W10c).

13.3.5 W8e *Geranium robertianum* sub-community

Sub-community constants
Fraxinus excelsior (V), *Acer pseudoplatanus* (IV), *Ulmus glabra* (IV)*, *Crataegus monogyna* (IV), *Mercurialis perennis* (IV), *Kindbergia praelonga* (IV).

Other common species (III unless otherwise stated)
Corylus avellana, *Quercus petraea* (II), *Sambucus nigra*, *Rubus fruticosus* agg., *Hedera helix*, *Urtica dioica*, *Galium aparine*, *Geranium robertianum*, *Eurhynicium striatum*, *Brachythecium rutabulum*, *Plagiomnium undulatum*, *Phyllitis scolopendrium* (II), *Brachypodium sylvaticum*(II), *Ilex aquifolium* (II).

Commonest saplings
Acer campestre (III), *Fraxinus excelsior* (III), *Acer pseudoplatanus* (III), *Ulmus glabra** (II).

Distribution
The *Geranium robertianum* sub-community is typically developed on relatively eutrophic soils and is most commonly found towards the north and west of England (particularly on the limestone of the Yorkshire Dales), throughout Wales and the eastern lowlands of Scotland.

Responses
Ash tends to be the most dominant canopy tree here and is sometimes the only canopy constituent. However, in most stands *Acer pseudoplatanus* is also an important tree and it is generally more abundant here than in any other W8 woodland. Because of the relative importance of ash in this typically high-forest structure, a decline in its abundance would be likely to lead to a considerable rise in light and a concomitant reduction in humidity levels within the woodland, at least in the short- to medium-term. This would be likely to have a negative impact on the vigour of some shade-demanding plants of the sub-community, such as *Mercurialis perennis* (L4) and the ferns *Phyllitis scolopendrium* (L4) and *Polystichum setiferum* (L4), evergreen perennials typical of the sheltered, humid, moist conditions found here. The luxuriant and diverse bryophyte layer, another feature of the woodland here, would also probably decline in abundance with an opening of the canopy. Species which may take advantage of the increased light could include *Brachypodium sylvaticum* (L6, C-S-R/C-S, S and V) and *Urtica dioica* (L6, C, V and Bs), both species being typical components of more open woodland. If management to remove affected ash were to be carried out here it could lead to an increase in species associated with local disturbance like *Sambucus nigra*, *Galium aparine* (L6, C/R, S), *Geranium robertianum* (L5, R/C-S-R, Bs?) and again *Urtica dioica*, which are all frequent here, partly a reflection of the increased nutrient turnover that occurs in these better aerated soils.

In the longer term, it is likely that in this more upland landscape, *Acer pseudoplatanus* would be the main beneficiary, particularly as its seedlings and saplings are already a notable feature on the more freely drained soils encountered here. A significant shift towards such dominance within the canopy would be likely to have a significant effect on the ground layer as it casts a greater shade and produces a denser accumulation of less labile litter which tends to reduce the floristic diversity (Anderson 1979, Sydes and Grime 1981a).

13.3.6 W8f *Allium ursinum* sub-community

Sub-community constants
Corylus avellana (IV), *Mercurialis perennis* (V), *Kindbergia praelonga* (V), *Allium ursinum* (V), *Brachythecium rutabulum* (V).

Other common species (III unless otherwise stated)
Fraxinus excelsior, *Acer pseudoplatanus*, *Ulmus glabra**, *Acer campestre* (II), *Sambucus nigra* (II), *Ilex aquifolium* (II), *Crataegus monogyna*, *Rubus fruticosus* agg., *Hedera helix*, *Urtica dioica*, *Galium aparine*.

Commonest saplings
Acer campestre (II), *Acer pseudoplatanus* (II), *Ulmus glabra** (II).

Distribution
The *Allium ursinum* sub-community is typically developed on deeper, moister, enriched soils and is most commonly found towards the north and west of England (particularly in the valleys of the Yorkshire Dales), throughout Wales in south-west Scotland.

Responses
The *Allium ursinum* sub-community is often found contiguously with stands of the *Geranium robertianum* sub-community, and may replace it on concave slopes below it where colluviation has been an important process in the soil development. Ash generally has a lower abundance here than in other W8 woodlands, and the canopy is more often comprised of *Acer pseudoplatanus* and to a lesser extent *Ulmus glabra*, with *Corylus avellana* in the understorey. This factor may mediate any potential changes brought about by a decline in ash in the short term, as some of the characteristic plants here may be already better adapted to the type of habitat changes expected under an increased abundance of *Acer pseudoplatanus* in the longer term. An example is the gregarious and persistent bulb-forming perennial *Allium ursinum* (L4, S-R, S) that typically carpets the field layer here in spring and early summer. The young shoots have a strong capacity to spear through dense leaf litter, and it has been shown to be one of the most successful exploiters of beech plantations for example where litter accumulation is considerable and shade is dense. Nevertheless, it is quite sensitive to disturbance so any associated management work may reduce its vigour and cover.

13.3.7 W8g *Teucrium scorodonia* sub-community

Sub-community constants
Fraxinus excelsior (V),*Corylus avellana* (V), *Crataegus monogyna* (IV), *Mercurialis perennis* (V), *Kindbergia praelonga* (V), *Brachypodium sylvaticum* (IV), *Teucrium scorodonia* (IV).

Other common species (III unless otherwise stated)
Acer pseudoplatanus, *Ulmus glabra**, *Acer campestre*, *Ilex aquifolium* (II), *Sambucus nigra* (II), *Cornus sanguinea*, *Viburnum opulus*, *Sorbus aucuparia*, *Rhamnus catharticus*, *Prunus padus* (II), *Urtica dioica*, *Melica uniflora*, *Arrhenatherum elatius*, *Plagiomnium undulatum*, *Circaea lutetiana.*

Commonest saplings
Acer campestre (III), *Fraxinus excelsior* (III), *Acer pseudoplatanus* (I).

Distribution
This distinctive sub-community is usually restricted to steep rocky ground in relatively inaccessible locations, and is predominantly found in the Yorkshire and Derbyshire Dales as well as in southern and eastern Wales.

Responses
Although very variable, the *Teucrium scorodonia* sub-community tends to be the most species-rich of all the W8 woodlands. It appears to be a remnant type of vegetation that has survived because of the intractable character of its topography. Ash is usually the most abundant tree species in a characteristically rather open and uneven-topped canopy, but *Acer pseudoplatanus* usually plays a less prominent role (with fewer saplings present too) than it does in other 'north western types'. This is probably due as much to the less-disturbed nature of such woodland as it is to the generally drier edaphic conditions. Consequentially *Acer pseudoplatanus* may not be expected to assume such an important successional role here as in other more upland ash woodlands in a post-ash-dieback scenario. Although *Corylus avellana* is also abundant as a shrubby element, an important factor in the increased richness of the herbaceous component is the patchy shade cast by the discontinuous canopy. Loss of ash in the short term may lead to an increased vigour of *Corylus* and to an expansion of some of the light-demanding grasses *Brachypodium sylvaticum* and *Arrhenatherum elatius* (L7, C/C-S-R, S (V)) and *Teucrium scorodonia* (L6, C-S/C-S-R, V and Bs), which are all fairly frequent here already. The abundance of *Mercurialis* (L3), which is often more characteristic of shadier areas, would likely decline somewhat with increasing light levels. At present where the canopy thins out even more, fragments of vegetation more characteristic of sunny calcicolous scrub may be encountered, with species like *Geranium sanguineum* (L7) and *Rosa pimpinellifolia* (L8) which could benefit with a further canopy reduction. Similarly, the bryophyte cover in such areas contains species more adapted to rocky calcicolous grassland and these would probably be maintained. In the longer term, an enduring loss of ash from this distinctive sub-community might lead to a move towards a 'scrubbier' habitat akin to the *Mercurialis* sub-community of the *Crataegus monogyna-Hedea helix* scrub community, W21b. *Acer pseudoplatanus* is rarely very frequent here, so even a slight shift in its favour may not alter the community composition too much in its favour.

13.4 W9 *Fraxinus excelsior-Sorbus aucuparuia-Mercurialis perennis* woodland

13.4.1 W9a Typical sub-community

Sub-community constants
Fraxinus excelsior (IV), *Corylus avellana* (IV), *Thuidium tamariscinum* (IV), *Viola riviniana* (IV), *Plagiomnium undulatum* (IV), *Mercurialis perennis* (IV), *Dryopteris filix-mas sens. str*. (IV), *Eurhynchium striatum* (IV), *Kindbergia praelonga* (V).

Other common species (III unless stated otherwise)
Quercus petraea (II), *Sorbus aucuparia, Betula pubescens*, *Ulmus glabra**, *Acer pseudoplatanus*, *Crataegus monogyna*, *Sorbus aucuparia*, *Circaea lutetiana*, *Geum urbanum*, *Potentilla sterilis*, *Dryopteris dilatata*, *Mnium hornum*, *Hyacinthoides non-scripta*, *Geranium robertianum*, *Athyrium filix-femina*, *Atrichum undulatum*, *Poa trivialis*, *Rubus fruticosus* (II), *Deschampsia cespitosa* (II).

Commonest saplings
Fraxinus excelsior (II), *Ulmus glabra** (II), *Acer pseudoplatanus* (I), *Betula pubescens* (I), *Sorbus aucuparia* (I).

Distribution
The typical sub-community of the *Fraxinus-Sorbus-Mercurialis* woodland is usually found on permanently moist calcareous soils on moderately steep slopes in the sub-montane climate of north-west Britain. It is particularly frequent throughout Wales and northern England but also extends throughout Scotland and into south-west England. Northern Ireland ash woods are also considered to be part of this classification.

Responses
Ash and *Corylus avellana* are the most abundant woody species, often with a high forest structure. A number of other woody species that are also frequent in fairly equal proportions are *Sorbus aucuparia* (L6, C-S, S), *Betula pubescens* (L7, C/C-S, W and S), *Crataegus monogyna* (L6, C-S, S) and *Acer pseudoplatanus*. Any of these species could benefit from an opening up of the canopy, as they are all essentially colonists flowering freely and expanding in gaps created in the woodland habitat. Which species is the most successful in any circumstance will depend very much on local conditions, although ultimately sycamore will probably be the main beneficiary in the longer term (Waters and Savill 1992). In the short term, under a more open canopy, ferns such as *Athyrium felix-femina*, *Dryopteris dilitata*, and *D. filix-mas* (all L5), whose large spreading crowns form a distinctive part of an upper field layer may be reduced with a reduction in the humidity and shelter afforded. Similarly the more shade-demanding herbs like *Mercurialis perennis* (L3), *Geum urbanum* (L4), *Oxalis acetosella* (L4), and *Circaea lutetiana* (L4) may also decline in response to increasing vigour of some of the bulkier light-demanding species in the community such as the grasses *Brachypodium sylvaticum* (L6) and *Deschampsia cespitosa* (L6), and providing deer numbers aren't high, *Rubus fruticosus* agg.. This process may be accelerated through disturbance caused by woodland management operations undertaken to remove dead or dying ash.

Zonations to other kinds of woodland are usually related more directly and exclusively to changes in parent materials and soil conditions, so although W9a may often be associated closely with the *Dryopteris dilitata* sub-community of the *Quercus-Betula-Oxalis* woodland (W11a), it would be unlikely to replace it even if ash disappears completely. As there are few other particularly dominant canopy trees here, local circumstances are likely to be important in determining longer-term changes in community composition and structure, although *Acer pseudoplatanus* will probably ultimately be the main beneficiary.

13.5 W10 *Quercus robur-Pteridium aquilinum-rubus fruticosus* woodland

13.5.1 W10e *Acer pseudoplatanus-Oxalis acetosella* sub-community

Sub-community constants
Oxalis acetosella (IV), *Holcus mollis* (IV).

Other common species (III unless stated otherwise)
Quercus robur (II), *Quercus petraea* (II), *Acer pseudoplatanus*, *Fraxinus excelsior*, *Corylus avellana*, *Crataegus monogyna* (II), *Sambucus nigra* (II), *Rubus fruticosus* agg., *Lonicera periclymenum*, *Pteridium aquilinum*, *Dryopteris dilitata*, *Kindbergia praelonga*, *Mnium hornum*, *Hyacinthoides non-scripta*, *Deschampsia cespitosa* (II), *Viola riviniana* (II).

Commonest saplings
Acer pseudoplatanus (III), *Fraxinus excelsior* (II), *Quercus* spp. (I)

Distribution

The *Acer pseudoplatanus-Oxalis acetosella* sub-community is the most oceanic type of W10 woodland and is usually found on relatively base-poor brown soils. It is found throughout Wales, south-western and northern England in particular, with a more scattered occurrence in the Scottish lowlands.

Responses
In the short term, following a gradual loss of ash, this fairly species-rich sub-community (for W10), would be expected to show a flush of some of its commoner herbs such as *Oxalis acetosella* (L4, S/S-R, V and S), *Viola riviniana* (L6, S/C-S-R, V and S) and *Hyacinthoides non-scripta* (L5, S-R, S and V). Bulky competitive species, capable of persistent clonal spread such as *Pteridium aquilinum* (L6, C, V and W) and the grass *Holcus mollis* (L6, C/C-S-R, V) may also gradually increase in vigour and spread more rapidly than they would have otherwise. Providing herbivory levels aren't high, seedlings and saplings of woody species such as *Acer pseudoplatanus*, which can be extraordinarily abundant here in spring, and to a lesser extent, *Quercus* spp. and *Betula* spp. will increase and greater numbers are likely to survive longer in the gaps created. Similarly some of the shrubs like *Crataegus monogyna* (L6) and *Sambucus nigra* (L6) as well as *Rubus fruticosus* agg. and *Deschampsia cespitosa* may be expected to increase, especially if any forestry operations are carried out to clear dead and dying ash trees with the resultant disturbance caused to the field layer. The more shade-demanding species such as the ferns *Dryopteris dilitata* and *Athyrium felix femina*, as well as some of the typical bryophytes, may decline in vigour somewhat with the subsequent increase in light and reduction in humidity, at least in the shorter term.

In the longer term, it is likely that *Acer pseudoplatanus* would benefit at the expense of ash and would gradually become more abundant in the canopy layer alongside the existing oak. This would be likely to lead to a gradual decline in the species diversity of the field layer and a shift towards the more western and northern stands of the typical sub-community of the *Quercus-Pteridium-Rubus* woodland (W10a), or towards the *Dryopteris dilitata* sub-community of the *Quercus petraea-Betula pubescens-oxalis* woodland (W11a), albeit with a much increased prominence of *Acer pseudoplatanus*.

13.6 W12 *Fagus sylvatica-Mercurialis perennis* woodland

13.6.1 W12a *Mercurialis perennis* sub-community

Sub-community constants
Fagus sylvatica (V), *Fraxinus excelsior* (IV), *Mercurialis perennis* (IV), *Rubus fruticosus* agg. (IV), *Hedera helix* (IV).

Other common species (III unless stated otherwise)
Acer pseudoplatanus, *Corylus avellana*, *Sambucus nigra* (II), *Brachypodium sylvaticum*, *Hyacinthoides non-scripta* (II).

Commonest saplings
Acer pseudoplatanus (II), *Fraxinus excelsior* (II).

Distribution
This woodland is associated with relatively free-draining base-rich calcareous soils in the south-east lowlands of Britain and is generally most prominent on the steeper drift-free faces of chalk escarpments.

Responses

Although ash is not a constant species in this *Fagus sylvatica*-dominated woodland, locally it is the most frequent associate, and in these situations the *Mercurialis* sub-community can be the most species-rich of all the three W12 woodland types. This is probably due to a combination of the somewhat lighter shade cast where *Fraxinus* occurs, and the deeper, moister soils where the sub-community occurs. In relatively recent times, *Fraxinus* has been increasing in abundance in many of these woodlands, as seen in some of the Chiltern 'beech' woods where dense patches of pole stage individuals have developed. This may be due to the fact that *Fagus* is not encouraged at the expense of other species, as it once was when greater management intervention demanded it. Under current conditions, if ash is lost here, *Fagus* would almost definitely be the major tree to benefit in the long term, at least throughout the main locus of the sub-community, and a shift towards a noticeably species-poorer woodland field layer may be expected. However climate change may reduce the suitability of beech as a replacement. Towards the north and west, where *Acer pseudoplatanus* is also a frequent associate, it is probable that this species would also benefit. As mentioned above, ash is presently the most abundant tree in many regeneration zones here, but beech still dominates many mature stands. So while going from ash to *Acer pseudoplatanus* or *Fagus* may mean some loss of richness, overall in the future going from *Fagus* to *Acer pseudoplatanus* for example, might actually lead to local increases in the species-richness of the field layer over recent past beech dominance.

In the absence of high deer numbers, short-term changes brought about by canopy reduction through ash loss may well lead to an increase in *Rubus fruticosus* agg. and some of the meso shrub species such as *Cornus sanguinea* (L7), *Viburnum lantana* (L7), *Viburnum opulus* (L6, C-S, S), *Euonymus europaeus* (L5, C-S, S) and *Ligustrum vulgare* (L6, C-S, S), all of which can be present here on these calcareous soils and which are usually confined to gaps and margins. Some of these shrubby elements may well also be encouraged through disturbance to soils caused through potential tree operations and in these situations the community may be more akin to the *Viburnum lantana* sub-community of the *Crataegus monoguna-Hedera helix* scrub community (W21c). Where deer numbers are high, *Brachypodium sylvaticum* (L6, C-S-R/C-S, S and V) in particular, may well increase, as has been recognised in such situations over the last 20 years in some areas. *Mercurialis*, with its preference for fairly deeply shaded habitats in undisturbed areas, may decline in vigour and cover in the short term. Where the persistent *Hedera helix* is already a field layer dominant, as it can be here, short-term changes in the habitat conditions may well have little effect on its vigour, despite its preference for shadier habitats.

14 The distribution of alternative tree species and responses of ash woodland ground flora species

Chapter Summary

1. *Using information from Chapters 2, 5 and 13 this chapter assess and describes the potential regional and temporal variation in the main woodland component species in response to loss of ash from the woodland canopy and the impact of this on a selection of 20 example ash woodland ground flora species.*
2. *In three quarters or more of the current ash-containing woods in Scotland, Northern England and Northern Ireland ash currently occupies less than 10% of the canopy. In these woods other tree species currently forming the main canopy cover are expected to grow and fill the spaces left by any dead ash, resulting in little new recruitment of trees or expansion of the shrub layer. Shade-tolerant shrubs already present in the understorey may grow to fill gaps in woodlands containing 10 to 20% ash in the canopy.*
3. *For woodlands where there is a greater component (>20%) of ash in the canopy, canopy gaps are anticipated to be larger and/or more frequent. Under these conditions, existing shrubs and particularly saplings are expected to fill the spaces in the canopy in addition to some expansion by other existing canopy tree species. Over a longer time-period, established saplings will replace shrubs and fill the canopy gaps; sycamore is predicted to become particularly dominant in many of the sub-regions in this regard. Beech and small-leaved lime may form larger components in 'former' ash woodlands in southern England.*
4. *Of the 22 alternative tree species (see Chapter 4), and if sites were not manipulated and conditions for natural regeneration were optimal, sycamore saplings are predicted to be most likely to replace ash in all areas except upland Scotland, upland Northern England and calcareous areas in Southern England. Birch is predicted to replace ash in upland Scotland and upland Northern England. Beech is predicted to replace ash in Wales and clay regions of Southern England on the better drained sites (approximately 10% of sites). Field maple and small-leaved lime are predicted to only replace ash in calcareous areas of southern England.*

14.1 Chapter aims

This chapter has drawn on work carried out in Chapters 2, 5 and 13. Chapter 13 described changes that may occur in NVC communities if ash dieback causes a loss of ash; this chapter deals with fewer species than Chapter 13 but includes a spatial element in the predictions. The aim of this chapter is to assess and describe the potential regional and temporal variation in the main woodland component species in response to loss of ash from the woodland canopy and the impact of this on a selection of 20 example ash woodland ground flora species.

14.2 Methods

14.2.1 Linking NFI sample square attributes for ash with NVC woodland type

Based on the NFI, Chapter 2 identified that the majority of woodlands in Britain where ash was present (Forestry Commission 2012a), had less than 10% cover of ash in the canopy, and three classes of ash cover in the canopy were suggested as a good descriptor of the variation within ash-containing woodlands in the UK. These are defined as: woodlands with less than 10%, between 10% and 20%, and greater than 20% cover of ash in the canopy.

Using the outputs from the supervised classification of NFI report map 3 (p21) (Forestry Commission 2012a) (Section 2.2.5), and expert knowledge on the character of broadleaved woodlands in Northern Ireland, the proportions of woodlands within each ash canopy cover class were attributed to each of our ash-relevant regions/sub-regions (1–9).

Using the frequency and abundance information for ash in the floristic tables of the National Vegetation Classification (NVC) (Rodwell 1991), woodland communities or sub-communities were assigned to the three ash canopy cover classes, using the following approximate rules: **≤10**%: ash recorded at Frequency I and maximum Domin Score ≤7; **≥10% ≤20%**: ash recorded at Frequency II–III and maximum Domin Score 5–8; **≥20%**: ash recorded at Frequency IV–V and Domin Score ≥7.

14.2.2 Linking NVC woodland types with sub-regions

Using the NVC woodland community descriptions, and expert knowledge on climatic and edaphic influences on woodland type (see also Pyatt *et al* 2001) and on woodland type and distribution, the NVC communities/sub-communities identified in Section 14.2.1 were allocated to the regions/sub-regions. The most and second-most frequently occurring NVC communities/sub-communities were both identified.

14.2.3 Identifying responder trees and bushes by sub-region and time period

Frequency and abundance data for the saplings and shrub species (definitions of trees and shrubs followed Rodwell and Patterson 1994) were taken from the NVC floristic tables, and the most frequent and abundant saplings and shrubs in each woodland community/sub-community (from Section 14.2.1) were identified and ranked. The species were then re-ranked for longer time-periods post loss of ash (10–50 years and 50–100 years following loss of ash), to take account of the competitive abilities of the different species. Re-ranking followed the logic indicated by the species' primary Strategies scores (Grime *et al* 2007).

Based on the congruence between woodland types, the regions/sub-regions and the classes of woodland (based on % ash cover in the canopy), the most likely dominant responder tree/shrub for each sub-region × time period (following loss of ash) was identified. The distribution of the responder trees/shrubs suggested by this exercise was checked for consistency against data in the *New Atlas of the British and Irish Flora* (Preston *et al* 2002). For the purposes of this analysis it is assumed that no major management interventions will take place which would substantially change the tree species composition of woodlands – the key driver of change considered here was loss of ash from the canopy.

Results are displayed as the percentages of current ash woodlands for each sub-region × time period combination where changes in the main woodland component species are expected. Displays are in the form of both pie-charts and maps; in the latter, corresponding percentage of woodlands by sub-region are indicated by a random selection of 10km squares.

14.2.4 Estimating responses of ground flora species

The response of the ground flora species will be partially driven by changes in light levels, depending on the size of the canopy gaps created when ash is lost or the shade cast by the trees that replace ash. Information on the light levels under different types of ash woodlands was lacking. Thus we used Ellenberg light values which describe the realised ecological niche of the plant to characterise the different light levels found in ash woodlands.

The average Ellenberg light values for the eight NVC ash woodland communities identified in Chapter 5 as ash-dominant were calculated using the Ellenberg light values in Hill *et al* (2004). The analysis was done twice, once with unweighted scores and once with the scores weighted by the species abundances as given in the NVC floristic tables (the Domin abundances were converted to percentage covers (1 = 0.5%, 2 = 0.75%, 3 = 20%, 4 = 9.5%, 5 = 19.5%, 6 = 29.5%, 7 = 42%, 8 = 63%, 9 = 85%, 10 = 97.5%)). This gave an average Ellenberg light value for each of the ash-dominated NVC communities (Table 14.1).

Table 14.1. Weighted and unweighted mean Ellenberg light values for eight NVC communities that are dominated by ash.

NVC Community	Unweighted	Weighted
W8a	5.3	5.3
W8b	5.2	5.0
W8c	5.4	5.3
W8d	5.4	5.1
W8e	5.3	5.0
W8g	5.3	4.9
W9a	5.5	5.1
W12a	5.1	4.7

We then compared the average Ellenberg light value of ash woodlands with the Ellenberg light values for individual plant species to make predictions about their possible responses to changes in light and canopy cover. Within the time constraints of this project it was not possible to produce maps for all the 78 species identified in Chapter 5 as being associated with ash woodland. Twenty ground flora vascular plants were selected from the list of 78 ash-associated vascular plants identified in Chapter 5 for this analysis. These species were both identified as being associated with ash woodland (Chapter 5) and also selected to cover a range of growth forms and distributions (Table 14.2). For each species we attempted to predict how its abundance would change under scenarios of increased light levels (due to an opening up of the canopy following a loss of ash) or decreased light levels (due to a decline in light levels following replacement of ash with a tree species with a heavier shade than ash).

The Ellenberg light value for each of the 20 ground flora species was obtained from Hill *et al* (2004), in order to categorise each species as a potential 'increaser' or 'decreaser' under changes in canopy cover due to loss of ash (Table 14.2).

- Species with Ellenberg light value of 6 or more were predicted to increase if light increases and decrease if light decreases.
- Species with Ellenberg light values of 5 were predicted to decline if light increases and decline if light decreases (i.e. they are considered to require the same level of shade as provided by an ash-dominated canopy).
- Species with Ellenberg light values of 4 or less were predicted to decrease if light increases and stay the same or increase if light decreases.

Using the *New Atlas of the British and Irish Flora* data (Preston *et al* 2002), each of the 20 ground flora species were then allocated to the regions/sub-regions which clearly captured the species' main distribution.

Broad rules on light-level changes in response to the main component tree species changes (and inferred structural changes) in the woodland were then constructed, and the sensitivity of each of the 20 ground flora species to these changes were assessed, following the analysis of Ellenberg light values described above.

Each species was scored as potentially declining, increasing or remaining unchanged for each situation of light-level change, in each region/sub-region and for each of the three time-periods. Results are displayed as the percentage of ground flora species ((a) all species); and also by main species groups (b) grasses, (c) herbs. The results indicate where the three categories would decline, increase or remain unchanged within each sub-region and time period, and according to the proportion of woodlands the species was assumed to occupy, prior to ash dieback. Note that for simplicity, no account was taken of the possible total loss of a species if it was predicted to decline in the short term, nor was its ability to re-colonize between time-periods considered (see Section 14.4). Therefore all species have a predicted response for each of the three time-periods.

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Table 14.2. Predicted responses of the selected 20 ground flora species to an increase in light and a decrease in light. (↑ = species is predicted to survive or increase under specified canopy light-level change. ↓ = species is predicted to decline under specified canopy light-level change.) Ellenberg light values for each species are also given.

Taxon	Life form	General distribution (number of 10km squares in Great Britain)	Increase light	Decrease light	Ellenberg
Deschampsia cespitosa	Grass	Widespread in BI (2,684)	↑	↓	6
Rubus fruticosus agg.	Micro shrub	Widespread in BI (2,564)	↑	↓	6
Hedera helix	Climber/creeper	Widespread in BI (2,549)	↓	↑	4
Brachypodium sylvaticum	Grass	Fairly widespread except N and C Scotland (2,310)	↑	↓	6
Mercurialis perennis	Herb	Fairly widespread except N Scotland (2,214)	↓	↑	3
Potentilla sterilis	Herb	Fairly widespread except N Scotland (2,167)	↓	↓	5
Phyllitis scolopendrium	Fern	Fairly widespread except N Scotland (2,115)	↓	↑	4
Allium ursinum	Herb	Fairly widespread except C and N Scotland (2,034)	↓	↑	4
Festuca gigantea	Grass	Fairly widespread except N Scotland (1,885)	↓	↓	5
Galium odoratum	Herb	Fairly widespread in BI (1,836)	↓	↑	3
Polystichum setiferum	Fern	Fairly widespread but mostly C and W BI (1,249)	↓	↑	4
Platanthera chlorantha	Herb	Local but fairly widespread in BI (1,163)	↓	↓	5
Paris quadrifolia	Herb	Fairly local in England (714)	↓	↑	3
Campanula trachelium	Herb	Local in C, S and E England (555)	↓	↑	4
Melica nutans	Grass	Local in N BI (408)	↓	↑	4
Cardamine impatiens	Herb	Rare in England (159)	↑	↓	6
Daphne mezereum	Nano shrub	Very local in C and E England (110)	↓	↑	4
Crepis mollis	Herb	Rare in N England and EC Scotland (75)	↑	↓	8
Primula elatior	Herb	Restricted to Eastern England, rare (38)	↓	↑	4
Polygonatum verticillatum	Herb	Very rare in EC Scotland (10)	↓	↑	4

14.3 Results

14.3.1 Predicted changes in main woodland component species, 1 to 10 years following loss of ash from woodland canopy

For woodlands where ash occupies less than 10% of the canopy, the other tree species currently forming the main canopy cover are expected to grow and fill the spaces left by any dead ash. There is expected to be little new recruitment of trees or expansion of the shrub layer as result of the canopy filling in these woodlands with so little ash. Three quarters or more of the current ash woods in sub-regions 1, 2, 3, 4, 5 and 9 are anticipated to respond in this way. The most frequent canopy species in such woodlands are listed for each ash-relevant sub-region (Table 14.3). For woodlands where there is a greater component (>10%) of ash in the canopy, canopy gaps are anticipated to be larger and/or more frequent. Under these conditions, existing shrubs and saplings are expected to fill the spaces in the canopy in addition to some expansion by other existing canopy tree species. To give an example, for sub-region 1 (Lowland Scotland), following loss of ash we would predict as follows:

- in 76% of the current ash woods in this sub-region, ash currently forms less than 10% canopy cover, so any gaps created by ash dieback would be predicted to be filled by other canopy tree species;
- in 10% of woodlands in this sub-region, hazel is predicted to become the dominant responder species in any gap, mixed with sycamore saplings;
- in 14% of woodlands in this sub-region, sycamore saplings and to a lesser extent, grey willow are predicted to become the main responder species in gaps created by loss of ash.

The responses of ash woodlands in Northern Ireland are assumed to be similar to lowland southern Scotland (sub-region 1). The geology of Northern Ireland has much in common with central and southern Scotland: shale, greywackes, old red sandstone, carboniferous limestone and sandstone and outcrops of basalt, all occur. The regions are climatically similar, with a mainly cool moist climate in lowland and eastern areas changing to a cool wet climate at higher elevation and farther west (Pyatt *et al* 2001). Upland Mixed Ashwoods are the main woodland type in Northern Ireland on base-rich soils, particularly the Tertiary Basalts of County Antrim and the Carboniferous Limestones of County Fermanagh, with more occasional occurrences in the Sperrins, and Counties Down and Armagh. The type ranges from woods on steep limestone scarps and screes, to those on more gentle slopes with a deeper, but still base-rich, soil cover. Ash woods are most commonly found in the base-rich sedimentary areas overlain by till and alluvium.

Of the three shrubs identified as the key responder plants in this analysis, hazel appears in all sub-regions; grey willow is confined to the northern sub-regions 1, 2, 3 and 9; and hawthorn to England and Wales in sub-regions 5, 6 and 7. Of the trees identified as key responder species, sycamore saplings appear as responder species in all sub-regions except 2, 3 and 8; birch is confined to regions/sub-regions 2 and 3; beech to sub-regions 5, 6 and 7; and field maple and small-leaved lime appear in only sub-region 8. This list of tree saplings and shrubs appear in different combinations in the different sub-regions; the most dominant species being listed first in the key (Figure 14.1).

Table 14.3. Main canopy species in ash woodlands with <10% ash in canopy cover.

Sub-region	Main canopy species
1. Lowland Scotland	alder, birch, oak
2. Upland Scotland	rowan, birch, alder
3. Upland Northern England	rowan, birch, alder
4. Lowland Northern England	oak, alder
5. Upland Wales	oak, alder
6. Lowland Wales	oak, field maple, sycamore, rowan, birch
7. Clay Southern England	beech, sycamore, oak, field maple
8. Calcareous Southern England	oak, field maple, sycamore
9. Northern Ireland	alder, birch, oak

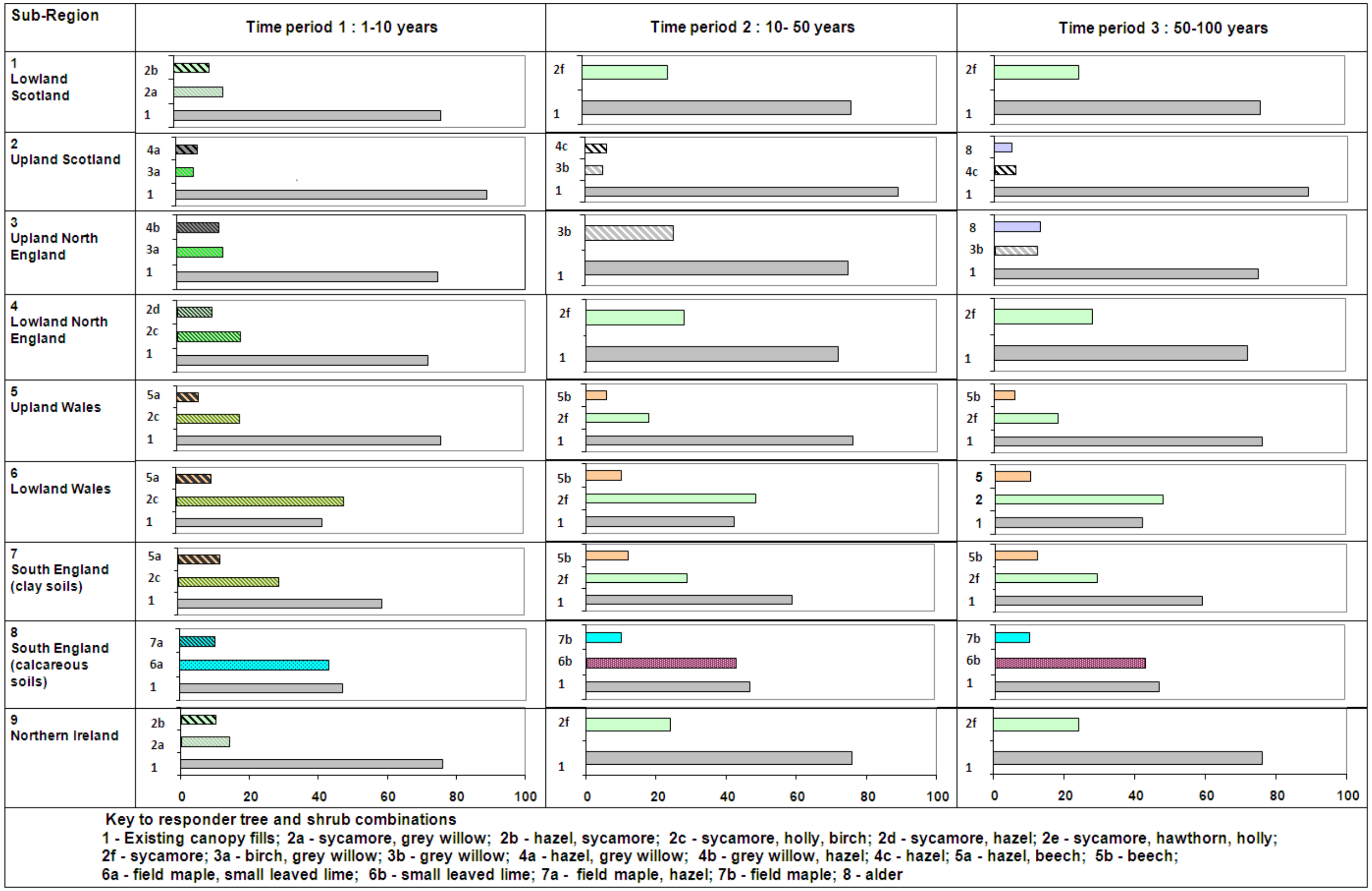

Figure 14.1. Main woodland component species by percentage of ash woodlands, in three time-periods following loss of ash from woodland canopy.
Time period 1 – trees sapling stage but older in time periods 2 and 3. In the key, species are ranked by frequency.

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14.3.2 Changes in main woodland component species, 10 to 50 years following loss of ash from woodland canopy

The proportion of ash woodlands where the main response predicted is for the existing canopy tree species to expand and fill the gaps remains the same as predicted for the first time period (1–10 years) in all the sub-regions (Figure 14.1). The canopy species composition is also predicted to be as described in Table 14.3.

Only in sub-regions 2 and 3 are shrubs (grey willow and hazel) predicted to be the main responder plants 10–50 years after loss of ash, and these are expected to be still filling the gaps previously occupied by ash trees (Figure 14.1). In sub-regions 1, 4 and 9, sycamore, now in thicket to mature tree stage, is predicted to dominate the gaps previously occupied by ash trees. Sycamore is also predicted to remain as the key responder plant in a large proportion of ash woods in sub-regions 5, 6 and 7, though in these regions beech also is predicted to form the main responder plant in up to 10% of the ash woods. Sub-region 8 differs from the rest in that small-leaved lime and field maple are expected to be main responder plants dominating the gaps previously occupied by ash trees, in collectively *c*50% of the ash woodlands of this sub-region. The responses of the trees and shrubs have been assessed in relation to available light, soil fertility and pH, and seedlings present in the understorey. So trees suitable for those sites have been predicted rather than trees that would be influenced by other factors that might impact on processes such as recruitment.

14.3.3 Predicted changes in main woodland component species, 50 to 100 years following loss of ash from woodland canopy

Although the mix of species in the original woodland canopy may have changed (e.g. through death of more short-lived trees such as birch and willow), the proportion of this canopy type in woodlands of the sub-regions is considered to remain the same as 50–100 years previously (Figure 14.1).

The dominance of the responder plant species is also predicted to have changed little compared to the previous time-period, and only in sub-regions 2 and 3 are changes in responder species dominance anticipated (Figure 14.1). In both sub-regions, alder is anticipated to replace grey willow in 5% of ash woodlands in sub-region 2, and 13% of ash woodlands in sub-region 3.

14.3.4 Anticipated light-level changes following predicted main component species changes

The likely changes in light levels in woodlands for each time-period following loss of ash were considered to be similar, regardless of whether the woodland had less than 10% ash in the canopy or between 10% and 20% ash in the first time-period. A different set of changes in light levels were anticipated to occur where there was >20% ash in the canopy and over the different time-periods (Table 14.4).

Table 14.4. Light-level changes anticipated to occur in response to the main component species changes (and inferred structural changes) in the woodlands following loss of ash from the canopy.

	<20% ash in woodland canopy	**>20% ash in woodland canopy**
1–10 years	Shadier	Lighter
10–50 years	Shadier	Shadier
50–100 years	Shadier	Shadier

14.3.5 Predicted ground flora responses, 1 to 10 years following loss of ash

The pair of tables given for each sub-region (Figure 14.2) represent the predicted response of ground flora species in woodlands where there is: currently <20% ash in the canopy (LHS table), and >20% ash in the canopy (RHS table). The percentages given above each graph indicate the proportion of the ash woods in that sub-region which currently have less or more than 20% ash in the canopy. In the woodlands where light conditions are anticipated to become shadier following loss of ash, a fairly equal proportion of all the ground flora species increase, decline or are unaffected. The three grass species *Deschampsia cespitosa*, *Brachypodium sylvaticum* and *Festuca giganteum*, found in all the eight sub-regions, however, are all predicted to decrease; only *Melica nutans*, restricted to upland sub-regions (1, 2, 3 and 5), is predicted to be unaffected. The majority of herbs (an exception being *Allium ursinum*) are predicted to be affected in some way by loss of ash in the northerly and Welsh sub-regions, with an equal proportion of the species present predicted to increase (e.g. *Galium odoratum* and *Mercurialis perennis*) or decrease (e.g. *Cardamine impatiens* and *Platanthera chlorantha*). In the southerly sub-regions (7 and 8), an equal proportion of herbs are predicted to be unaffected (e.g. *Primula elatior* and *Campanula trachelium*) as decreasing or increasing. The ferns (*Polystichum setiferum* and *Phyllitis scolopendrium*), where present, are predicted to be unaffected, as is the ubiquitous climber *Hedera helix* and the restricted (sub-regions 6, 7 and 8) shrub *Daphne mezereum*. *Rubus fruticosus*, present throughout all sub-regions, is predicted to decline.

Where canopy shade conditions are predicted to become lighter in the first 10 years, all ground flora species are predicted to be affected, with the majority of species predicted to decrease. Particular differences compared to ground flora changes predicted under increasing shade relate to *Galium odoratum*, *Allium ursinum*, *Mercurialis perennis* and the two fern species (predicted to decline), and *Deschampsia cespitosa*, *Brachypodium sylvaticum* and *Rubus fruticosus* (predicted to increase).

As the greatest proportion of woodlands containing ash in Britain have less than 20% ash in the canopy, populations of the woodland grasses *Brachypodium sylvaticum* and *Festuca giganteum*, and herbs *Platanthera chlorantha*, *Crepis mollis* and *Cardamine impatiens* could be significantly impacted on throughout their range in Britain, but other typical ash woodland herbs (e.g. *Mercurialis perennis*, *Paris quadrifolia* and *Allium ursinum*), may largely be unaffected, apart from in the south of England.

Only sub-regions 6, 7 and 8 contain large proportions of ash woods with >20% ash in the canopy. The predicted effects of loss of ash in the first 10 years could significantly affect the British populations of the ground flora species that are negatively affected by increasing light-levels and that are also restricted to these regions. Of the species tested in this exercise, *Daphne mezereum* and *Primula elatior* are identified as being of most concern. Effects of competition between species in response to changing light conditions have not been assessed, however it is likely that the growth of grasses and bramble in lighter conditions could influence the former composition of the ground flora.

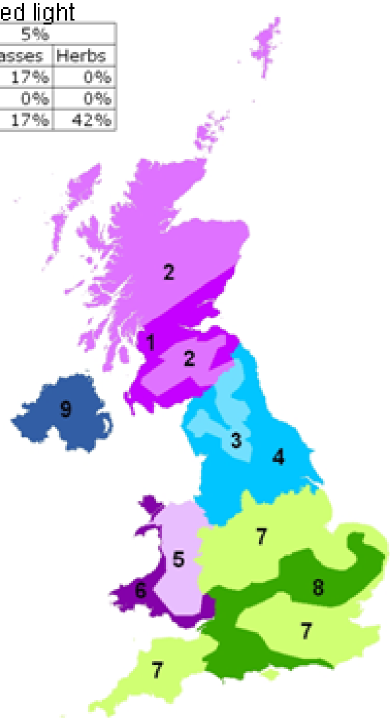
Sub region 2	Decreased light			Increased light		
% of ash woodlands	95%			5%		
	All	Grasses	Herbs	All	Grasses	Herbs
Increase	17%	0%	17%	25%	17%	0%
No change	33%	0%	17%	0%	0%	0%
Decline	50%	33%	8%	75%	17%	42%

Sub region 3	Decreased light			Increased light		
% of ash woodlands	87%			13%		
	All	Grasses	Herbs	All	Grasses	Herbs
Increase	20%	0%	20%	27%	13%	7%
No change	27%	7%	7%	7%	0%	7%
Decline	53%	20%	27%	67%	13%	40%

Sub region 9	Decreased light			Increased light		
% of ash woodlands	Unknown			Unknown		
	All	Grasses	Herbs	All	Grasses	Herbs
Increase	14%	0%	14%	21%	14%	0%
No change	43%	0%	14%	0%	0%	0%
Decline	43%	21%	14%	79%	7%	43%

Sub region 5	Decreased light			Increased light		
% of ash woodlands	82%			18%		
	All	Grasses	Herbs	All	Grasses	Herbs
Increase	20%	0%	20%	20%	13%	0%
No change	33%	7%	7%	7%	0%	7%
Decline	47%	20%	20%	73%	13%	40%

Sub region 6	Decreased light			Increased light		
% of ash woodlands	52%			48%		
	All	Grasses	Herbs	All	Grasses	Herbs
Increase	21%	0%	21%	21%	14%	0%
No change	36%	0%	7%	0%	0%	0%
Decline	43%	21%	14%	79%	7%	43%



Sub region 1	Decreased light			Increased light		
% of ash woodlands	86%			14%		
	All	Grasses	Herbs	All	Grasses	Herbs
Increase	17%	0%	17%	25%	17%	0%
No change	33%	8%	8%	0%	0%	0%
Decline	50%	25%	17%	75%	17%	42%

Sub region 4	Decreased light			Increased light		
% of ash woodlands	82%			18%		
	All	Grasses	Herbs	All	Grasses	Herbs
Increase	21%	0%	21%	21%	14%	0%
No change	36%	0%	7%	0%	0%	0%
Decline	43%	21%	14%	79%	7%	43%

Sub region 7	Decreased light			Increased light		
% of ash woodlands	71%			29%		
	All	Grasses	Herbs	All	Grasses	Herbs
Increase	19%	0%	19%	19%	13%	0%
No change	38%	0%	13%	6%	0%	6%
Decline	44%	19%	19%	75%	6%	44%

Sub region 8	Decreased light			Increased light		
% of ash woodlands	57%			43%		
	All	Grasses	Herbs	All	Grasses	Herbs
Increase	18%	0%	18%	18%	12%	0%
No change	41%	0%	18%	6%	0%	6%
Decline	41%	18%	18%	76%	6%	47%

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Figure 14.2. Predicted ground flora responses, 10 years following the loss of ash; sub-region tables show two columns representing woodlands with <20% ash cover (LHS), and >20% ash cover (RHS). (N.B. no data for Northern Ireland (sub-region 9) on the areas of ash woodland with <20% ash cover (LHS) and >20% ash cover (RHS)).

14.3.6 Predicted ground flora responses, 10 to 50 years and 50 to 100 years following loss of ash

Conditions below the woodland canopy, as it re-develops or is filled by responder trees/ shrubs, are anticipated only to get shadier over both of the next two time-periods (Figure 14.3). These two time-periods have therefore been grouped together for the analysis, as have the proportions of woods originally containing <20% and >20% ash in the canopy, as both are shadier in the second and third time-periods (Table 14.4).

Over this longer time-period, in all ash woods a fairly equal proportion of all the ground flora species are predicted to increase, decline, or be unaffected. All grass species except *Melica nutans* are predicted to decrease. In terms of the herb species, there are predicted to be a fairly equal number of winners as losers. Examples of winners are *Galium odoratum* and *Mercurialis perennis*, and losers include *Cardamine impatiens* and *Platanthera chlorantha*. The ubiquitous shrub, *Rubus fruticosus*, is expected to decline, whereas the ubiquitous climber, *Hedera helix*, is expected to increase.

Declines and increases would therefore be predicted to continue through the short- to longer-term for all the species identified as having these responses in the first 10 years in the majority of ash woods in Britain (i.e. where ash currently forms <20% of the canopy). In sub-regions 6, 7 and 8, where a greater proportion of ash woods currently have >20% ash in the canopy, conditions are expected to improve for *Mercurialis perennis*, *Galium odoratum* and *Paris quadrifolia*, stabilise for the fern species and *Primula elatior*, perhaps even leading to an increase in these species, but are expected to continue to cause declines in *Potentilla sterilis*, *Festuca gigantea* and *Platanthera chlorantha*.

Sub region 2

% of ash woodlands	100%		
	All	Grasses	Herbs
Increase	17%	0%	17%
No change	33%	0%	17%
Decline	50%	33%	8%

Sub region 3

% of ash woodlands	100%		
	All	Grasses	Herbs
Increase	20%	0%	20%
No change	27%	7%	7%
Decline	53%	20%	27%

Sub region 9

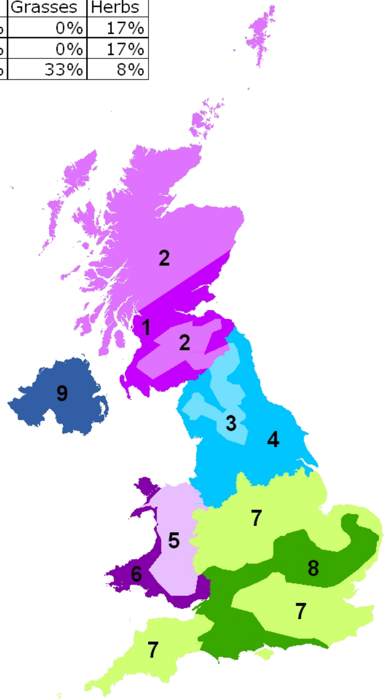
% of ash woodlands	100%		
	All	Grasses	Herbs
Increase	14%	0%	14%
No change	43%	0%	14%
Decline	43%	21%	14%

Sub region 5

% of ash woodlands	100%		
	All	Grasses	Herbs
Increase	20%	0%	20%
No change	33%	7%	7%
Decline	47%	20%	20%

Sub region 6

% of ash woodlands	100%		
	All	Grasses	Herbs
Increase	21%	0%	21%
No change	36%	0%	7%
Decline	43%	21%	14%



Sub region 8

% of ash woodlands	100%		
	All	Grasses	Herbs
Increase	18%	0%	18%
No change	41%	0%	18%
Decline	41%	18%	18%

Sub region 1

% of ash woodlands	100%		
	All	Grasses	Herbs
Increase	17%	0%	17%
No change	33%	8%	8%
Decline	50%	25%	17%

Sub region 4

% of ash woodlands	100%		
	All	Grasses	Herbs
Increase	21%	0%	21%
No change	36%	0%	7%
Decline	43%	21%	14%

Sub region 7

% of ash woodlands	100%		
	All	Grasses	Herbs
Increase	19%	0%	19%
No change	38%	0%	13%
Decline	44%	19%	19%

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Figure 14.3. The projected response of ash woodland ground flora species (up to 17 species per sub-region) from 10 years to 100 years following loss of ash.

14.4 Limitations of data and approach, and suggested improvements

The assumption that the only perturbation to woodlands over a 100-year period will be the loss of ash is probably unrealistic, but for the time available for this contract a simple approach was necessary. Other perturbations that may influence woods are climate change, changes in browsing levels, nitrogen deposition, other tree diseases and woodland management operations. Determining how these perturbations might affect woodland composition and interact with ash dieback would be very complex and difficult (and error prone) to predict. Assumptions about the longevity of shrub species, currently not included in the analysis, could be used to fine-tune the predictions for sub-regions 2 and 3 in the final (50–100 year) time-period, but are considered unlikely to have a major impact on the predicted responses.

Access to the NFI sample square data for all tree species and ground flora species would allow a far more accurate analysis of responses and succession to be modelled for all responder trees and shrubs. This would also allow fairly reliable estimates of canopy composition and the calculation of Ellenberg number for light under canopy (Hill *et al* 1999). This could broadly improve the shade-change rules used in this analysis. Furthermore, availability of the NFI sample square ground flora data would facilitate the analysis of spatial congruence between existing canopy species, likely responder plants and species of ground flora tree species, across a large sample of woodlands in Britain.

Deciding on whether ground flora species would be lost due to a change in light levels, or indeed if they would have the potential to re-colonise had they been lost, was considered to be beyond the scope of this project. Again this could be done, given more time, if considered important in the future. Neither did we consider competition between species; this might be achieved through an analysis of C-S-R classes (Grime *et al* 2007).

15 Comparison of traits in ash and alternative tree species

Chapter summary

1. *The traits of 22 alternative tree species which might be considered as replacements for ash were collected and compared with the traits of ash.*
2. *The 22 alternative tree species were: field maple, Norway maple, sycamore, alder, silver birch, downy birch, hornbeam, sweet chestnut, hazel, hawthorn, beech, aspen, wild cherry, bird cherry, Douglas fir, sessile oak, pedunculate oak, goat willow, grey willow, whitebeam, yew, and small-leaved lime.*
3. *The traits data collected were: bark acidity, mycorrhizal association, diaspore type, duration of flowering, floral rewards, fruit type, leaf form, leaf persistence, pollen vector, height, Ellenberg light, Ellenberg moisture, Ellenberg reaction, Ellenberg nitrogen, leaf dry matter content, leaf size, seed mass, release height, and specific leaf area.*
4. *For single traits there were some matches between ash and the alternative tree species*
5. *Multi-variate analysis of all traits showed that none of the 22 tree species were very similar to ash overall. Alder and aspen were identified as the trees most similar to ash, with similarity indices of 0.7. Sweet chestnut and Douglas fir were the most dissimilar (similarity indices of 0.5).*

15.1 Tree traits

Tree species differ in many characteristics, including leaf size, canopy height, and bark acidity. These traits will affect which species utilize the tree and also wider ecosystem functioning, such as nutrient cycling. Studying differences and similarities between plant traits is one way to quantify and assess how different species might impact on ecosystem functioning. If ash is lost from an ecosystem, to minimise subsequent changes, the species to replace it should have as many of the same characteristics or traits as ash as possible. This chapter compares the traits of ash with the traits of 22 alternative tree species (Table 4.2).

For the 22 alternative tree species and for ash, a range of trait characteristics were collated: bark chemistry (Barkman 1958); mycorrhizal association (Harley and Harley 1987); diaspore type; duration of flowering; floral reward; fruit type; leaf form; deciduous; pollen vector (BiolFlor database); height (Hill *et al* 2004); leaf dry matter content (LDMC); leaf size; seed mass; seed release height; and specific leaf area (LEDA database). Habitat preferences were defined using Ellenberg values for moisture, light, reaction and nitrogen (Hill *et al* 2004). See Tables 15.1 and 15.2 for details of the databases and traits/Ellenberg values used. The traits included in the analysis are those for which data were easily available, other traits which describe the ecology of ash trees such as regeneration densities, seedling viability, pollen dispersal distances were not included as information on these traits for all alternative tree species was not readily available.

Table 15.1. Databases and their sources, used to collate traits for ash and alternative tree species.

Database abbreviation	Source	Link
BiolFlor	Derived from Klotz, S., Kühn, I. & Durka, W. 2002. *BIOLFLOR – Eine Datenbank zu biologisch-ökologischen Merkmalen der Gefäßpflanzen in Deutschland*. *Schriftenreihe für Vegetationskunde 38.* Bonn: Budesamt für Naturschutz.	http://www2.ufz.de/biolflor/index.jsp
LEDA	A database on the life history traits of the Northwest European flora The LEDA Traitbase provides information on plant traits that describe three key features of plant dynamics: persistence, regeneration and dispersal.	http://www.leda-traitbase.org/LEDAportal/
PlantAtt	Derived from those published in Hill, M.O., Preston, C.D. & Roy, D.B. 2004. *PLANTATT - attributes of British and Irish Plants: status, size, life history, geography and habitats*. Abbots Ripton: Centre for Ecology and Hydrology.	PlantAtt is a publication by CEH, but does not have a dedicated website. A link to the publication can be found here: http://nora.nerc.ac.uk/9535/

Table 15.2. The traits collated for ash and alternative tree species.

Database	Trait	Possible Value	Coding*	Definitions
Barkman 1958	Bark acidity	Sub-neutral	Categorical	Sub-neutral bark
		Intermediate		Intermediate bark
		Acidic		Acidic bark
Harley and Harley 1987	Mycorrhizae association	Arbuscular	0 or 1	Arbuscular mycorrhizal fungi
		Ectomycorrhizae	0 or 1	Ectomycorrhizal fungi
Bioflora	Diaspore type	aggregate fruit (syncarpous)	Categorical	Made up of several fruitlets but formed from a single flower
		fruit with appendage		Woody endocarp of a single carpel of an aggregated fruit which contains one seed and is connected with further parts of a plant
		infructescence		The inflorescence at the time when the seeds ripen; it still forms and looks like a single functional unit but contains several fruits
		fruit		Part of the plant that developed from the ovary and contains the ripe seeds (excluding the previous two categories)
		mericarp		One segment of a fruit that breaks at maturity into units derived from the individual carpels
		seed		Embryo of a plant produced from fertilisation of the ovule by pollen, enclosed in an outer coat, contains often additional nutrients
	Duration of flowering	Number	Numeric	Number of months of flowering
	Floral rewards	nectar	0 or 1	nectar as flora reward
		pollen	0 or 1	pollen as flora reward
	Fruit type	capsule	Categorical	Dehiscent, fruit with multiple carpels; may open in various ways splitting down two sides
		drupe		Indehiscent, with fleshy epicarp and mesocarp, woody endocarp; testa not woody
		missing		Fruits are not developed as ovule are not enclosed in carpels, but are open (i.e. ferns, gymnosperms).
		nut		Indehiscent, with dry pericarp
		pome		Fleshy indehiscent; fruit (apple like) with a thin skin, not formed from the ovary but from another part of the plant (receptacle)
		schizocarp		Dry fruit that splits up into separate fruitlets due to true septae across the carpel margins
	Leaf form	acicular	Categorical	Slender, rigid, needle-shaped leaves which are equally wide across most of the length and often have a stiff tip

Database	Trait	Possible Value	Coding*	Definitions
		full		Simple leaves, either orbicular, cordate, rhombic or polygonal; width >50% of length
		lobate		Leaves with lobed divisions up to 1/4–1/3 of the leaf
		pinnate		Compound leaves with leaflets arising in opposite pairs along the midrib (rhachis)
		simple		Oval or elliptic leaves; width 25–50% of length
	Leaf persistence	summer green	0 or 1	Green leaves only in the warm season (1) Evergreen (0)
	Pollen vector	insects	0 or 1	Pollination by insects
		selfing	0 or 1	Spontaneous pollination within a flower
		wind	0 or 1	Pollination by wind
PlantAtt	Height	Number	Numeric	Height of tree
	Ellenberg light	Number	1 to 9	1 = deep shade, 9 = full light
	Ellenberg moisture	Number	1 to 12	1 = extreme dryness, 12 = submerged plant
	Ellenberg reaction	Number	1 to 9	Reaction = soil pH. 1 = extreme acidity, 9 = basic
	Ellenberg nitrogen	Number	1 to 9	1 = extreme infertile site, 9 = extremely rich situations
LEDA	LDMC	Number	Numeric	Leaf dry matter content (LDMC), a measure of tissue density, is the ratio dry leaf mass to fresh leaf mass and is expressed in mg/g
	Leaf size	Number	Numeric	Leaf size is the one-sided projected surface area of an individual leaf or lamina expressed in mm^2. For compound leaves it is the size of the leaflet
	Seed mass	Number	Numeric	seed weight in mg
	Release height	Number	Numeric	The difference between the elevation of the highest fruit or seed and the base of the plant (m)
	Specific leaf area	Number	Numeric	Specific leaf area (SLA) is the ratio of fresh leaf area to leaf dry mass: SLA = leaf area / leaf dry mass, expressed in $mm^2\ mg^{-1}$

*1 = present (the species has this trait), 0 = absent (the species does not have this trait).

15.1.1 Ecosystem function traits

Leaf dry matter content (LDMC) is a measure of tissue density. Tissue density plays a central role in the nutrient utilisation of a species, by determining the rate of biomass turnover (i.e. low tissue density is associated with high growth rate, rapid nutrient cycling and high productivity). Ash litter has a relatively low LDMC and decomposes rapidly; small-leaved lime, alder, hornbeam and goat willow all have LDMC lower than ash, whereas all of the other 22 species analysed have a higher LDMC and hence a slower rate of decomposition. If the species composition changes to one dominated by a species with a higher LDMC, decomposition rates will be slower, which will result in changes in the soil fauna community and in slower nutrient cycling within the woodland. Generally, soil communities associated with plant communities with slow decomposing litter are more fungal-dominated than bacteria-dominated (Bardgett 2005).

A mycorrhiza is a symbiotic association between a fungus and the roots of a vascular plant. In a mycorrhizal association, the fungus colonizes the host plant's roots, either intracellularly as in arbuscular mycorrhizal fungi (AMF or AM), or extracellularly as in ectomycorrhizal fungi. Mycorrhizal fungi are an important component of soil life and soil chemistry. Mycorrhizal associations enable the tree to obtain nutrients that may not otherwise be available to the tree (Section 3.3). The type of mycorrhizal association will also influence nutrient cycling (Section 3.3). Ash has arbuscular mycorrhizae, as does goat willow, grey willow, sycamore, yew, Norway maple, whitebeam, hawthorn, field maple, wild cherry, bird cherry and aspen.

15.1.2 Ecological traits

Ellenberg values (Hill *et al* 1999) for light, moisture, reaction and nitrogen describe the realised ecological niche in which the plant is found (i.e. if the plant is found in light or shady, wet or dry, acid or alkaline, fertile or nutrient poor habitats). For each of these four variables there is an ordinal scale. Comparing Ellenberg values between plants allows comparison of the type of environment in which they grow.

Ash has an Ellenberg light value of 5, described as "semi-shade plant, rarely in full light, but generally with more than 10% relative illumination when trees are in leaf" (Hill *et al* 1999). Small-leaved lime, alder, sweet chestnut, field maple and bird cherry all have the same Ellenberg light class as ash. Beech, hornbeam, hazel, sycamore, yew, Norway maple and wild cherry are all able to grow in shadier places than ash. Sessile oak, Douglas fir, whitebeam, hawthorn, aspen, silver birch, downy birch, pedunculate oak, goat willow, and grey willow all require more light.

Ash has an Ellenberg moisture level of 6, described as between a moist and a damp-site indicator (Hill *et al* 1999). Bird cherry, sessile oak and Douglas fir all occur in the same moisture class as ash. Downy birch, goat willow, alder and grey willow can grow in wetter environments than ash. All the other species require drier habitats.

Ash has an Ellenberg value of 7 for reaction, meaning it is an indicator of weakly acid to weakly basic conditions, never found on very acid soils (Hill *et al* 1999). Yew, whitebeam, Norway maple, field maple, hawthorn and goat willow also have an Ellenberg value of 7. The other tree species in the list all indicate more acidic soils.

Ash has an Ellenberg value of 6 for nitrogen (i.e. it is an indicator between intermediate fertility and richly fertile places (Hill *et al* 1999)). Hornbeam, aspen, hazel, sycamore, wild cherry, alder, field maple and hawthorn also have the same Ellenberg value as ash. Only bird cherry, Norway maple and goat willow occur on more fertile sites than ash.

15.1.3 Whole plant traits

A major difference between trees is whether they are deciduous or evergreen; this trait will influence, amongst other things, the light (and seasonality of light) which the ground flora receives, and the nutrient inputs to the soil (one fall of litter in the autumn versus continuous leaf drop; different rates of decomposition). Twenty of the 22 species considered here are deciduous, but if yew or Douglas fir replace ash this would result in a change from a deciduous- to an evergreen-dominated woodland, which would be predicted to drive big changes in ground flora, nutrient cycling and soil fauna, amongst others things.

Bark chemistry is very important for epiphytic bryophyte and lichen species, as it influences which species are able to colonise and grow on the bark (Bates 1992; Gustafsson and Eriksson 1995). Different tree species can generally be classified as having sub-neutral, intermediate or acidic bark. Ash has sub-neutral bark, thus for epiphytic species reliant on a sub-neutral bark, only the tree species with this trait are considered to be viable alternatives if ash is lost from the vicinity. From the 22 species assessed here, only grey willow, goat willow, aspen, hazel, and sycamore are considered viable alternatives in relation to their bark chemistry. Tree bark chemistry will also change with pollution levels (e.g. nitrogen and sulphur pollution make tree bark more acidic (Farmer *et al* 1991; van Herk 2001)) and soil nutrient status (Gustafsson and Eriksson 1995).

The list of replacement tree species contains a range of species, some of which may be more considered as lower growing scrub or sub-canopy species (e.g. hazel, grey willow, hawthorn) and others which when mature form tall trees (e.g. both oak species, beech and sweet chestnut). Only Douglas fir has the potential to grow considerably taller than ash, but if some of the more scrubby species establish following the loss of ash this could considerably change the woodland structure. Differences in woodland structure have been shown to influence bird communities (Amar *et al* 2010), and an increase in woodland scrub cover may be beneficial overall (Amar *et al* 2010). However, the resulting structure will be heavily driven by the herbivores present, particularly deer, through their browsing activities.

15.1.4 Leaf traits

Leaf shape and leaf size will influence the shade provided by the tree and hence the species of ground flora below the tree. Ash has a pinnate leaf shape which none of the other tree species under consideration have. This leaf shape is one reason why ash casts a relatively light shade compared to some other tree species. The data provided for leaf size gives the leaflet size for compound leaves such as ash but whole leaf size for entire leaves such as birch. Comparison between species with different leaf shapes should therefore be treated with caution. Of the deciduous trees in the list under consideration, only hawthorn, grey willow, downy birch, and have a smaller leaf area than ash leaflets. Species such as Norway maple, sycamore and sweet chestnut all have considerably larger leaves than ash and cast a much darker shade over the ground.

In many cases the specific leaf area (SLA) of a species is positively correlated with its potential relative growth rate and mass-based maximum photosynthetic rate. Lower values of SLA tend to correspond with a long leaf lifespan and species with a relatively high investment in leaf ‘defences’ (particularly structural ones). Leaf defences (structural and chemical) tend to cause the leaves to decompose more slowly. Ash has a relatively low SLA, with only grey willow and hawthorn having lower values; all other deciduous tree species in our list have higher SLA values.

15.1.5 Floral and reproductive biology

Tree flowers may be pollinated by insects, wind, or be self-fertile. Ash is wind-pollinated, along with yew, sessile oak, silver birch, alder, beech, downy birch, pedunculate oak, aspen, hazel, hornbeam, and Douglas fir. The following are pollinated by insects: grey willow, hawthorn, field maple, wild cherry, sycamore, goat willow, whitebeam, bird cherry, and Norway maple. Sweet chestnut and small-leaved lime are both wind- and insect-pollinated. Flowers attract insects by offering floral rewards of either nectar or pollen. As ash is wind-pollinated, no floral rewards are available, but if ash were replaced by an insect-pollinated tree, floral rewards would be available. Some insects will feed on the nectar but others feed on pollen itself. For example, adults of the micro-moth genus *Micropterix* such as *Micropterix tunbergella* favour feeding on pollen of oak, sycamore and hawthorn. Thus the way in which any replacement tree is pollinated may influence the invertebrate community composition (Proctor *et al* 1996).

The length of time the flowers are available will influence how long these floral rewards are available. The timing of such rewards (as food for the insect) may be critical for insect life-cycles and any organism that feeds on these insects.

15.1.6 Seed and fruit traits

Many species are dependent on seeds or fruits for food. The LEDA database classifies ash as having a diaspore type of fruit (part of the plant that developed from the ovary and contains the ripe seeds) and a fruit type as nut (inhedhiscent, with dry pericarp). Sessile oak, silver birch, alder, beech, downy birch, sweet chestnut, pedunculate oak and hazel all have the same diaspore type and fruit type as ash. However, the size of the seeds of these species varies widely, with birches and alder being considerably smaller than ash and the others being considerably larger. If a species is using the ash seeds as a food source, the size of the seed will be important; so just because the tree has the same diaspora type and fruit type as ash does not necessarily mean that the tree is a suitable replacement for ash.

15.2 Multi-variate analysis of traits

The descriptions above compare each trait of ash against the same trait for each other tree species separately. This approach would enable one to identify the 'best' replacement tree species if only one trait was of interest. However, ideally as many traits as possible of the replacement tree species should be similar to ash. Use of similarity indices allows many traits to be analysed together to assess overall which tree species are most similar to ash, so this is the approach we have taken.

A similarity measure was calculated between ash and each of the other species. The similarity between species *i* and species *j* based on *k* variables ($x_1 \ldots x_k$) was calculated as:

$$\frac{1}{k}\sum_{k} s_k(x_{ik}, x_{jk})$$

For categorical variables $s(x_i,x_j)=1$ if $x_i = x_j$ and 0 otherwise. For continuous variables $s(x_i,x_j)=1-((x_i-x_j)/\text{range}(x))^2$. The range is the difference between the maximum and minimum values of the variable. Division by the range ensures that the similarity score lies between 1 and 0.

As trait data were missing for LDMC, leaf size, seed mass, release height and SLA for Douglas fir, two analyses were run, one including Douglas fir but omitting these five variables (Analysis 1), and one omitting Douglas fir with all variables included (Analysis 2).

15.2.1 Results

None of the alternative tree species were very similar to ash, as assessed by the similarity index (Tables 15.3 and 15.4). The highest similarity index was for alder, with 0.704 in Analysis 1, and 0.765 in Analysis 2. Most of the 22 alternative tree species had a similarity to ash of between 0.51 and 0.69.

Analysis of traits for bark chemistry, mycorrhizae association, diaspora type, duration of flowering, floral reward, fruit type, leaf form, deciduous, pollen vector, height, and Ellenberg values for moisture, light, reaction and nitrogen (Analysis 1), showed that alder, aspen, hazel and yew (from most to least similar) were closest to ash in terms of these traits. Sweet chestnut, Douglas fir, small-leaved lime, and hawthorn were most dissimilar to ash. When a larger selection of traits was used but Douglas fir not included, the same four species were shown as being closest to ash, although the positioning of yew and hazel was swopped. In the analysis of a wider selection of the traits, the species most dissimilar to ash were slightly different: sweet chestnut, grey willow, hawthorn and pedunculate oak (from most to least dissimilar), although sweet chestnut and hawthorn were still in the bottom four (most dissimilar to ash) in both analyses.

In both analyses, alder and aspen are identified as being similar to ash. Like ash, both species are deciduous, wind-pollinated and have an Ellenberg nutrient score of 6. Their specific leaf areas, tree height and release height are also very similar to those of ash. In addition, alder has the same diaspora type, fruit type, Ellenberg light score and a similar leaf dry matter content to ash, and aspen has arbuscular mycorrhizae like ash. These traits explain why these two tree species were identified as similar using the multi-variate analysis. However in other respects they are very dissimilar to ash, for example alder seed is actually very different to ash seed although it is classed as the same diaspora and fruit type.

This report has used two methods to assess the similarity of alternative tree species to ash: traits (this chapter) and species use (Chapter/section 12.3). These two approaches are compared in Chapter/section 18.2.

Table 15.3. Similarity indices from Analysis 1.

Species	Similarity to ash
Alder	0.704
Aspen	0.701
Hazel	0.690
Yew	0.684
Hornbeam	0.645
Sycamore	0.642
Beech	0.629
Field maple	0.606
Wild cherry	0.601
Bird cherry	0.599
Norway maple	0.597
Pedunculate oak	0.596
Silver birch	0.593
Downy birch	0.593
Goat willow	0.583
Sessile oak	0.569
Grey willow	0.568
Whitebeam	0.567
Hawthorn	0.544
Small-leaved lime	0.542
Douglas fir	0.529
Sweet chestnut	0.518

Table 15.4. Similarity indices from Analysis 2.

Species	Similarity to ash
Alder	0.765
Aspen	0.752
Yew	0.747
Hazel	0.724
Beech	0.699
Sycamore	0.690
Hornbeam	0.690
Silver birch	0.681
Downy birch	0.679
Wild cherry	0.674
Norway maple	0.673
Field maple	0.671
Bird cherry	0.664
Goat willow	0.655
Sessile oak	0.654
Whitebeam	0.638
Small-leaved lime	0.631
Pedunculate oak	0.625
Hawthorn	0.618
Grey willow	0.610
Sweet chestnut	0.591

15.2.2 Discussion

The analysis of the traits indicates the unique combination of traits that ash has, and considers how difficult it will be to replace ash with another tree species with many similar traits. Both analyses identified the same two 'most similar' species to ash in terms of the selected traits: alder and aspen. However, neither of these species are highly similar to ash (with similarity indices of less than 0.75), and both of these tree species would produce very different woodland types to ash.

The traits used in these analyses largely describe the tree and its characteristics, not the type of woodland that these tree species will produce. This is clearly seen with the example of yew, which is assessed as having a similarity index of 0.747, yet will produce a very different woodland habitat from ash in terms of deciduous to coniferous, shade level and seasonality of shading, leaf litter, decomposition and associated ground flora. The usefulness of these similarity indices therefore depends on whether the associated species is most reliant on the specific traits of the tree species (bark pH, fruit type, etc.), in which case the similarity indices may be of some use, or if the species relies more on the habitat conditions created by the tree (shade, shelter, soil chemical properties, etc.) in which case the similarity indices are likely to be less useful as they do not capture all these variables (see Chapter 18.2 for comparison of methods to assess alternative species).

The clumping of the traits, with most tree species having a similarity index to ash of between 0.5 and 0.69, also makes it hard to separate out the tree species. The analysis was constructed such that each trait received equal weighting; if some traits are deemed to be more important then the analysis could be re-run, and this may separate out the tree species more strongly. However, this would probably need to be done on a species(/species group) by species(/species group) basis, as different traits are important for different species groups, therefore deciding which traits to weight would depend on the species/species group and the specific management aims, for example which species one wished to retain within the woodland.

16 Management scenarios and predicted impacts on vascular plant composition

Chapter Summary

1. The six management scenarios considered most likely to occur following ash dieback were: (1) non-intervention; (2) no felling with natural regeneration promoted; (3) felling; (4) felling and replanting; (5) thinning; (6) felling with natural regeneration promoted.
2. Generic habitat responses are described for each management scenario for ash woods with less than 20% ash in canopy and more than 20% ash in the canopy. Habitat responses are also considered over two time-frames: 1 to 10 years, and 50 to 100 years.
3. Detailed descriptions of the predicted vegetation composition of the ash woodlands following each of the management scenarios (1)–(4) above is described for two time-periods: 1–10 years, and 50–100 years for each of the nine ash-relevant regions. Within each ash-relevant region the ash canopy cover (<20% or >20%) most common within that region was used.

16.1 Aim

The aim of this chapter is to identify a number of management options that are representative of those likely to be taken in response to ash dieback, with comparisons made for woodlands in each of the ash-relevant regions identified in Chapter 2.
To give a realistic and achievable subset of scenarios for detailed species analysis within the time-frame of this contract, it was agreed to produce a detailed pen picture of the habitat created under selected scenarios within different regions and two time-frames against which species experts could assess whether obligate or highly associated species might be able to persist following loss of ash. The management scenarios selected, were those which aligned best with the aims of conserving ash related biodiversity rather than aims focused more on timber production. The selected scenarios are described in Section 16.4 below

16.2 Methods

The probable effects of these methods on the overstorey, understorey, shrub layer, field layer and natural regeneration within woodlands with ≤20% or >20% ash in the overstorey are described in the short term (1–10 years) and the long term (50–100 years).

16.2.1 Selected management scenarios

Five different scenarios have been identified which cover the range of different stand management options that are likely to be used in response to dieback and death of ash trees or coppice caused by *Chalara*.

(1) **Non-intervention** – stands are allowed to develop naturally with no interventions.
(2) **No felling with natural regeneration promoted** – no felling but otherwise stands initially managed for natural regeneration (e.g. fencing and vegetation management).
(3) **Felling** – all ash trees and coppice removed in one operation with, if necessary, additional trees of other species cut to make the operation at least break-even economically. The additional trees will always be less than 10% of the number of ash trees removed or canopy space created. No subsequent interventions carried out.
(4) **Felling and replanting** – all ash trees and coppice removed in one operation with, if necessary, additional trees of other species cut to make the operation at least break-even economically. This will always be less than 10% of the number of ash trees

removed or canopy space created. Then active management to replant with alternative tree and shrub species focussed on the felled areas of the stand, with subsequent management to develop overstorey species.

(5) **Thinning** – regular operations to thin stands by removing diseased and dead trees or coppicing ash, with, if necessary, additional trees of other species cut to make the operation at least break-even economically.

(6) **Felling with natural regeneration promoted** – all ash trees and coppice removed in one operation with, if necessary, additional trees of other species cut to make the operation at least break-even economically. Then active management initially to achieve natural regeneration in the stand (e.g. fencing and vegetation management), with subsequent management to develop overstorey species.

16.2.2 Assumptions

Descriptions of the changes likely to occur for each management scenario make a number of assumptions which are explained below:

- There will be a significant reduction in canopy cover of ash and some trees will probably die. However, there remains great uncertainty about how the disease will develop spatially and temporally.
- Within both the ≤20% or >20% ash in the overstorey categories of woodland the amount of ash is very variable and for those having > 20% ash the overall range is large. For this category it is assumed that the amount of ash that dies or is removed is substantial, leading to the formation of large gaps in the canopy.
- In the felling with natural regeneration promoted, and felling and replanting treatments, it is assumed that the areas without ash will be actively managed using appropriate practices (e.g. regular thinning), and that they will not be treated as non-intervention areas.
- Natural regeneration is unpredictable and will not necessarily occur even when specific management for its encouragement is carried out. The only species to regenerate will be those already at the site, consequently the range of species present will be restricted to those initially present. Few species regenerate well from seed under canopy shade, with best establishment occurring in gaps or where canopy cover has been reduced by *c*30–40%. The window of opportunity for natural regeneration of most species is often small and will take place 1–2 years after harvesting operations are carried out. The effect of specific operations to promote natural regeneration will be short-lived. Successful regeneration is most likely at sites with relatively infertile, well-drained soils that do not support good growth of competitive species; it is least likely to be successful at sites with heavy, fertile, moisture-retaining soils where competitive species can flourish: the former conditions are more likely to be met towards the north and west of the country.
- When stands are managed, it is assumed that the methods currently deemed best-practice will be used and appropriate guidelines will be followed (e.g. vegetation management, control of deer and squirrel impacts, no undue soil disturbance during harvesting).This recognises the essential need to limit the impacts of deer browsing and squirrels, not only to allow regeneration from seed but also to ensure survival of species that will regrow as coppice after felling, but also to limit adverse effects on 'desirable' field layer species which may benefit from reductions in canopy cover or protection from grazing. However, within the scenarios, outcomes are tempered by the assumption that deer browsing across the country will remain at about the same level as at present (i.e. frequently high and usually deleterious to the development of natural regeneration), and that despite following best practice guidance full stocking will be difficult to achieve. For example, mortality of seedlings and loss of recruitment will occur due to variation in micro-site and natural disturbance events, and girdling of young plants and browsing of establishing stands will result due to occasional failure in protection.
- Although it is likely that management will take place over the longer time period, it is difficult to predict what that might be. It is therefore assumed that the management intervention described happens in the first few years but is not maintained in the later (> 50 years) time-periods. Similarly, there may be some natural disturbance events, but again these are hard to predict and therefore the possible effects of these have not influenced strongly the scenario descriptions.

16.3 Generic management scenario descriptions

For the above six management scenarios, habitat responses are described in Tables 16.1 to 16.6, considering ash woods with <20% ash in canopy and >20% ash in canopy separately. Habitat responses are also considered over two time-frames: 1 to 10 years, and 50 to 100 years. The generic descriptions consider the general effects on ash woodlands throughout all sub-regions and give no specific detail on individual tree, shrub or ground flora species composition. Specific species details are given later in this Chapter, in Tables 16.7–16.15, for a subset of management scenarios.

Table 16.1. Scenario (1): Non-intervention.

Description	Response of woodland to *Chalara* infection with no consequent management			
	Woodlands where overstorey is not dominated by ash (<20%)		Woodlands where overstorey has ≥20% ash in canopy	
	After 1–10 years	After 50–100 years	After 1–10 years	After 50–100 years
Overstorey	Ash dying back but compensatory growth of other species bringing about canopy closure in all but the largest gaps. Standing deadwood will begin to increase in amount.	Relatively little change from the original state other than the loss of ash and other short-lived species which may have died (e.g. birch, willow). Deadwood will be a significant feature of the stand and much of this will now be on the ground.	Significant decline in cover of ash. Standing deadwood will start to become a dominant feature. Other species will show compensatory growth.	Species composition will reflect the original mixture but without ash and some short-lived species which may have died, but there are still likely to be some significant canopy gaps. Deadwood will be a significant feature of the stand and much of this will now be on the ground.
Understorey	Ash dying back, but little change in other species except in larger areas of dieback where there is likely to be a positive growth response.	Generally, there will be little change if initial species are shade-tolerant. Short-lived species may have died. Initial understorey may have been promoted to overstorey especially in large gaps.	Significant decline in cover of ash. Standing deadwood will start to become a dominant feature. Other species will show compensatory growth.	The understorey will be depleted as trees (not ash) will be recruited into the overstorey and there will be few, if any, replacements in the understorey due to paucity of regeneration.
Shrubs	Cover will decline generally, but localised increases in larger areas of ash dieback as existing plants show a positive growth response.	Cover will decline as the shade cast by the overstorey increases.	There will be rapid growth of individual plants of existing species in areas of the stand with substantial ash dieback.	Highly dependent on the overstorey and understorey dynamics. Unless there is a good recovery in the overstorey the shrubs will remain at a reasonable level.
Field Layer	Relatively little change except in larger areas of dieback where the abundance of existing species may initially increase.	Likely to become sparser as overstorey cover increases, predominantly shade-tolerant or vernal species that can withstand browsing (unless low browsing pressure).	Increased abundance of existing species especially those that are partially shade-tolerant such as bramble (unless kept in check by heavy browsing).	Likely to be sparser beneath areas of dense canopy with predominantly shade-tolerant or vernal species that can withstand browsing (unless low browsing pressure). In any significant gaps remaining species likely to be of open or partially shaded habitats.
Natural regeneration	Relatively little change. Only browse-tolerant species are likely to survive (unless low browsing) if there are any opportunities for regeneration.	Relatively little change. Only browse-tolerant species are likely to survive (unless low browsing) if there are any opportunities for regeneration.	Relatively little change. Only browse-tolerant species are likely to survive (unless low browsing) if there are any opportunities for regeneration.	Relatively little change. Only browse-tolerant species are likely to survive (unless low browsing) if there are any opportunities for regeneration.

Table 16.2. Scenario (2): No felling with natural regeneration promoted.

Description	Response of woodland to infection and consequent management			
	Woodlands where overstorey is not dominated by ash (<20%)		Woodlands where overstorey has ≥20% ash in canopy	
	After 1–10 years	After 50–100 years	After 1–10 years	After 50–100 years
Overstorey	Ash dying back but compensatory growth of other species bringing about canopy closure in all but the largest gaps. Standing deadwood will begin to increase in amount.	Relatively little change from the original state other than the loss of ash and other short-lived species which may have died (e.g. birch, willow). Deadwood will be a significant feature of the stand and much of this will now be on the ground.	Significant decline in cover of ash. Standing deadwood will start to become a dominant feature. Other species will show compensatory growth.	Species composition will reflect the original mixture but without ash and some short-lived species which may have died, but there are still likely to be significant canopy gaps. Deadwood will be a significant feature of the stand and much of this will now be on the ground.
Understorey	Ash dying back, but little change in other species except in larger areas of dieback where there is likely to be a positive growth response.	Generally, there will be little change if initial species are shade-tolerant. Short-lived species may have died. Initial understorey may have been promoted to overstorey especially in large gaps.	Significant decline in cover of ash. Standing deadwood will start to become a dominant feature. Other species will show compensatory growth.	The understorey will be depleted as trees will be recruited into the overstorey and there will be few, if any, replacements in the understorey due to paucity of regeneration.
Shrubs	Cover will decline generally, but localised increase in larger areas of ash dieback as existing plants show a positive growth response, which may be negated by management to promote natural regeneration.	Cover will decline as the shade cast by the overstorey increases.	There will be rapid growth of individual plants of existing species in areas of the stand with substantial dieback. But management to promote natural regeneration may reduce cover.	Highly dependent on the overstorey and understorey dynamics. Unless there is a good recovery in the overstorey the shrubs will remain at a reasonable level.
Field Layer	Relatively little change except in larger areas of dieback where the abundance of existing species may initially increase. Competitive species will be controlled in order to favour more 'desirable' species.	Likely to become sparser as overstorey cover increases, predominantly shade-tolerant or vernal species that can withstand browsing (unless low browsing pressure).	Increased abundance of existing species, but competitive species will be controlled to favour more 'desirable' species.	Likely to be sparser beneath areas of dense canopy with predominantly shade-tolerant or vernal species that can withstand browsing (unless low browsing pressure). In any significant gaps remaining species likely to be of open or partially shaded habitats.
Natural regeneration	Likely to be sparse as shaded conditions unfavourable for establishment. Only shade-tolerant species are likely to survive.	Relatively little change. Only browse-tolerant species are likely to survive (unless low browsing) if there are any opportunities for regeneration	Likely to be sparse but establishment may be better in larger areas of dieback. Only shade-tolerant species are likely to survive.	Relatively little change. Only browse-tolerant species are likely to survive (unless low browsing) if there are any opportunities for regeneration.

Table 16.3. Scenario (3): Felling (and no active management).

Description	Response of woodland to infection and consequent management			
	Woodlands where overstorey is not dominated by ash (<20%)		Woodlands where overstorey has ≥20% ash in canopy	
	After 1–10 years	After 50–100 years	After 1–10 years	After 50–100 years
Overstorey	Compensatory growth of other species that will bring about canopy closure in all but the largest gaps.	A full overstorey will be re-formed and the species composition will largely reflect the original mixture minus the ash.	The felling of ash should improve growth of other species, but if the stand has been neglected or is exposed, compensatory growth may not be as expected. Some recruitment from understorey (not ash).	Likely to be a moderate canopy of mixed species reflecting the original mixture minus the ash. Gaps in stand with few or no trees may remain, but dependent on recruitment of regeneration.
Understorey	Generally little change, but in larger gaps there is likely to be a positive growth response.	Generally, there will be little change if initial species are shade-tolerant. Short-lived species may have died. Initial understorey may have been promoted to overstorey especially in large gaps. Recruitment highly dependent on success of regeneration.	The felling of ash should improve growth of other species, but if the stand has been neglected or is exposed, compensatory growth may not be as expected. Some recruitment into overstorey.	Understorey depleted as trees are recruited into the overstorey. Replacement highly dependent on the success of natural regeneration.
Shrubs	Cover will decline generally, but localised increase in larger gaps as existing plants show a positive growth.	Cover will decline as the shade cast by the overstorey increases. More likely to persist in larger gaps.	There will be rapid growth of individual plants of existing species in parts of the stand where substantial areas of dieback are felled.	Highly dependent on the overstorey and understorey dynamics. Unless there is a good recovery in the overstorey the shrubs will remain at a reasonable level.
Field Layer	Relatively little change except in larger gaps where the initial response will be similar to that in a recently felled coppice.	Likely to become sparser as overstorey cover increases, predominantly shade-tolerant or vernal species that can withstand browsing (unless low browsing pressure). May be greater cover in gaps where tree regeneration is poor.	Early response similar to that in a recently felled coppice, but vigorous competitive species likely to persist due to slow re-development of canopy cover.	Likely to be sparser beneath areas of dense canopy with predominantly shade-tolerant or vernal species that can withstand browsing (unless low browsing pressure). In gaps with poor regeneration remaining species likely to be of open or partially shaded habitats.
Natural regeneration	The potential constrained by lack of management therefore likely to be sparse even in large gaps. Fast-growing or browse-tolerant species are likely to survive best.	Relatively little change. Only browse-tolerant species are likely to survive (unless low browsing pressure) if there are any opportunities for regeneration.	The potential constrained by lack of management therefore likely to be sparse even in large gaps. Fast-growing or browse-tolerant species are likely to survive (unless low browsing pressure).	Relatively little change. Only browse-tolerant species are likely to survive (unless low browsing pressure) if there are any opportunities for regeneration.

Table 16.4. Scenario (4): Felling and replanting.

Description	Response of woodland to infection and consequent management			
	Woodlands where overstorey is not dominated by ash (<20%)		Woodlands where overstorey has ≥20% ash in canopy	
	After 1–10 years	**After 50–100 years**	**After 1–10 years**	**After 50–100 years**
Overstorey	Compensatory growth of other species that will bring about canopy closure in all but the largest gaps. Little need for planting.	Full overstorey formed but species composition and cover will be influenced by management.	The felling of ash should improve growth of other species, including those planted in, but if the stand has been neglected or is exposed, growth may not be as expected. Some recruitment from understorey.	Full overstorey formed but species composition and cover will be influenced by management.
Understorey	Generally little change, but in larger gaps there is likely to be a positive growth response.	Potential to be better developed if planting and natural regeneration have both been successful.	The felling of ash should improve growth of other species, including those planted in, but if the stand has been neglected or is exposed, compensatory growth may not be as expected. Some recruitment into overstorey.	Potential to be better developed if planting and natural regeneration have both been successful.
Shrubs	Conditions will improve growth of existing species but this may be negated by management interventions to promote natural regeneration or plant new trees.	Potential to improve if planted in the mixture or accepted as natural regeneration.	There will be rapid growth of individual plants of existing or newly planted species in parts of the stand where substantial areas of dieback are felled.	Potential to improve if planted in the mixture or accepted as natural regeneration.
Field Layer	Initial response similar to that of coppice woodland. Competitive species will probably be controlled to favour more 'desirable' species.	Residual changes from initial interventions are possible but generally relatively little change. Dependent on canopy cover.	Initial response similar to that of coppice woodland. Competitive species will probably be controlled to favour more 'desirable' species.	Residual changes from initial interventions are possible but generally relatively little change. Dependent on canopy cover.
Natural regeneration	The potential for natural regeneration will increase as a result of management interventions and this can be accepted to increase stocking and/or diversity.	Initial management will have presumably led to successful 'regeneration' so unless there has been a change of silvicultural system, recruitment of saplings is unlikely and probably not required.	The potential for natural regeneration will increase as a result of management interventions and this can be accepted to increase stocking and/or diversity.	Initial management will have presumably led to successful 'regeneration', so unless there has been a change of silvicultural system, recruitment of saplings is unlikely and probably not required.

Table 16.5. Scenario (5): Thinning.

Description	Response of woodland to infection and consequent management			
	Woodlands where overstorey is not dominated by ash (<20%)		Woodlands where overstorey has ≥20% ash in canopy	
	After 1–10 years	**After 50–100 years**	**After 1–10 years**	**After 50–100 years**
Overstorey	Compensatory growth of other species will bring about canopy closure in all but the largest gaps.	A full overstorey will be re-formed, with the species composition reflecting loss of ash and any other species removed in the thinning.	Canopy cover and species mixture related to the amount of ash and other species removed during thinning. Recruitment from the understorey will be a major factor.	The species composition of the canopy will be altered from the original state and there are still likely to be some significant gaps.
Understorey	Ash dying back, but little change in other species except in larger areas of dieback where there is likely to be a positive growth response.	Some of initial understorey species recruited into the overstorey. Replacement depends on success of both natural regeneration and coppice	If an understorey exists it is likely to show a good response but may be depleted as it recruits into the overstorey.	The understorey will be depleted as trees will be recruited into the overstorey, with few replacements if natural regeneration fails to establish.
Shrubs	Improved light levels throughout stand leading to a positive growth response from plants of existing species.	Increased light levels due to regular thinning, resulting in increased shrub layer.	Improved light levels throughout stand leading to a positive growth response from plants of existing species.	Highly dependent on the overstorey and understorey dynamics. Unless there is a good recovery in the overstorey the shrubs will remain at a reasonable level.
Field Layer	Pulse of growth related to thinning cycle. Species which can withstand partial shade likely to thrive.	Pulse of growth related to thinning cycle. Species which can withstand partial shade and browsing likely to persist.	Increased abundance of existing species especially those that are partially shade-tolerant.	Likely to be sparser beneath areas of dense canopy with predominantly shade-tolerant or vernal species that can withstand browsing (unless low browsing pressure). In any significant gaps remaining species likely to be of open or partially shaded habitats.
Natural regeneration	Pulse of regeneration possible following thinning but unlikely to thrive, with browse-tolerant species most likely to survive (unless low browsing pressure).	Pulse of early regeneration now forming new canopy, with new regeneration unlikely except in remaining gaps. Establishment difficult in persistent canopy gaps where ground flora vigorous.	Pulse of regeneration possible following thinning but unlikely to thrive with browse-tolerant species most likely to survive. Establishment may depend on the integrity of the canopy over the whole stand.	Pulse of early regeneration now forming new canopy, with new regeneration unlikely except in remaining gaps. Establishment difficult in persistent canopy gaps where ground flora vigorous.

Table 16.6. Scenario (6): Felling with natural regeneration promoted.

Description	Response of woodland to infection and consequent management			
	Woodlands where overstorey is not dominated by ash (<20%)		Woodlands where overstorey has ≥20% ash in canopy	
	After 1–10 years	After 50–100 years	After 1–10 years	After 50–100 years
Overstorey	Compensatory growth of other species that will bring about canopy closure in all but the largest gaps.	Full overstorey formed but species composition and cover will be influenced by management.	The felling of ash should improve growth of other species, but if the stand has been neglected or is exposed, compensatory growth may not be as expected. Some recruitment from understorey.	Full overstorey formed but species composition and cover will be influenced by management.
Understorey	Generally little change, but in larger gaps there is likely to be a positive growth response.	Potential to be better developed if natural regeneration has been successful.	The felling of ash should improve growth of other species, but if the stand has been neglected or is exposed, compensatory growth may not be as expected. Some recruitment into overstorey.	Potential to be better developed if natural regeneration has been successful.
Shrubs	Conditions will improve growth of existing species but this may be negated by management interventions to promote natural regeneration.	Potential for better development but dependent on success of natural regeneration and later management.	There will be rapid growth of existing species in parts of the stand where substantial areas of dieback are felled, but this may be negated by management interventions to promote natural regeneration.	Potential for better development but dependent on success of natural regeneration and later management.
Field Layer	Initial response similar to that of coppice woodland. Competitive species will be controlled to favour more 'desirable' species.	Residual changes from initial interventions are possible but generally relatively little change. Dependent on canopy cover.	Initial response similar to that of coppice woodland. Competitive species will be controlled to favour more 'desirable' species.	Residual changes from initial interventions are possible but generally relatively little change. Dependent on canopy cover.
Natural regeneration	The potential for successful natural regeneration of both trees and shrubs will increase as a result of management interventions.	Recent past management will have led to success so unless there has been a change of silvicultural system, recruitment of further saplings is unlikely and probably not required.	The potential for successful natural regeneration of both trees and shrubs will increase as a result of management interventions. .	Recent past management will have led to successful initial recruitment so unless there has been a change of silvicultural system, further recruitment of saplings is unlikely and probably not required.

16.4 Developing detailed descriptions of habitats from the management scenarios

Only a subset of the all possible combinations of management scenarios and proportions of ash in woodlands could be considered within the scope of this project. All sub-regions had to be considered, as this would have relevance in determining effects on obligate or highly associated species, as the distribution of these species will vary across the UK. It was also considered important to consider both short and longer time-frames, as ultimately the consideration of potential persistence of different species in the longer term, not just short-term responses, is crucial for management decision-making.

The Steering Group chose the first four management scenarios and this gave a possible 144 individual habitat scenario descriptions (sub-region × ash in canopy cover class × time frame) for the species experts to consider. This number was halved by including only the ash in canopy class most representative of that region (i.e. <20% ash in canopy class for sub-regions 1, 2, 3, 4, 5 and 9, and >20% ash in canopy class for sub-regions 6, 7 and 8).

'Typical species' in the canopy/understorey and shrub layer for each scenario, time-frame and sub-region drew on work carried out in Chapter 14. Based on expert knowledge, the tree species recommended for planting for production, according to site type, was included in scenario 4. These tree species and the majority of those listed as 'typical' for each sub-region were also included on the list of trees and shrubs which the species experts were asked to consider in Chapters 4–12 (Table 4.2).

For each sub-region, the first and second most frequently occurring NVC community/sub-community was selected (see Section 14.2.2) to indicate ground flora composition prior to intervention. Changes in ground flora composition were then predicted in light of the generic responses given in Tables 16.1–16.6 and drawing on expert knowledge of woodland site conditions and management interaction impacts. Tables 16.7–16.15 give the resulting habitat pen pictures; these were the ones supplied to the species experts. The species experts then used these to assess potential impacts of each 'change' on each individual species (Chapter 17).

The two management scenarios not considered are scenario (5) – thinning; and scenario (6) – felling with natural regeneration promoted. Thinning may actually reflect what the removal of diseased ash trees from most of the current ash woods would be like. At present, ash is only a small component of most of the ash woods in Britain, with ash being scattered throughout other woodland types and typically occurring in small clumps. Further, scenario (5) differs from scenario (3) as trees are removed gradually rather than all at once. Scenario (6) encompasses enlargement of gaps, leading to the more likely success of regeneration. These scenarios will be studied in future work.

Table 16.7. Management scenario for Lowland Scotland (Region 1), where the main canopy is not dominated by ash (<20%).

Current ash dominance		**Woodlands where main canopy is not dominated by ash (<20%).**	
1. Scotland lowland		Typical canopy species: **alder**, **downy** and **silver birch**, **goat willow**, **holly**, **sessile oak**, and **sycamore**.	Typical shrub and small tree species: **hawthorn**, **hazel**, **grey willow**, **blackthorn**, and **bird cherry**. Typical ground flora species: W7, W10
Mmt. scenario		After 1–10 years	After 50–100 years
	1	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy composed of **typical** species. Canopy closes. Ground flora dominated by: **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (free draining sites).	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost) Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (dry sites).
	2	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy composed of **typical** species. Canopy closes. Shrub cover will decline. Regeneration difficult to achieve. Ground flora dominated by: **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (free draining sites).	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (dry sites).
	3	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover will decline. Ground flora dominated by: **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (free draining sites).	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** likely to remain. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (dry sites). Regeneration difficult to achieve.
	4	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover will decline. Weeding will favour development of diverse, herb-rich ground flora including **creeping buttercup**, **tufted hair-grass**, **creeping soft-grass**, **stinging nettle** and **soft rush** and some **yellow pimpernel**, **wood sorrel**, **pendulous sedge** (wet sites) and **stinging nettle**, **creeping soft-grass**, and some **bluebell**, **wood anemone**, **dog violet**, **male** and **broad buckler fern** . With trees planted in gaps: **pedunculate oak** (wetter sites); **sycamore** or **Douglas fir** (drier sites).	**No ash trees (living or dead).** Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites).

Table 16.8. Management scenario for Upland Scotland (Region 2), where the main canopy is not dominated by ash (<20%).

Current ash dominance		**Woodlands where main canopy is not dominated by ash (<20%).**	
2. Scotland upland		Typical canopy species: **alder**, **downy** and **silver birch**, **goat willow**, **holly**, **sessile oak**, and **sycamore**.	Typical shrub and small tree species: **hawthorn**, **hazel**, **grey willow**, **blackthorn**, and **bird cherry**. Typical ground flora species: W9b, W7.
Mmt. scenario		After 1–10 years	After 50–100 years
	1	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy composed of **typical** species. Canopy closes. Ground flora dominated by **wood sorrel**, **dog violet**, **meadowsweet**, **yellow pimpernel** and **pignut**.	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **lady fern**, **creeping soft-grass**, **false brome** and **wood sorrel**.
	2	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy composed of **typical** species. Canopy closes. Shrub cover will decline. Regeneration difficult to achieve. Ground flora dominated by **wood sorrel**, **dog violet**, **meadowsweet**, **yellow pimpernel**.	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** likely to remain. Ground flora sparse with some **lady fern**, **creeping soft-grass**, **false brome** and **wood sorrel**. Regeneration difficult to achieve.
	3	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover will decline. Ground flora dominated by **wood sorrel**, **dog violet**, **meadowsweet**, **yellow pimpernel**.	**No ash trees (living or dead).** Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **lady fern**, **creeping soft-grass**, **false brome** and **wood sorrel**.
	4	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover will decline. Weeding will favour development of diverse, herb rich ground flora including **wood sorrel** and **dog violet** and **creeping buttercup**. Trees planted in gaps: **downy birch** (wetter sites); **sycamore** (drier sites).	**No ash trees (living or dead).** A full canopy composed of **alder**, **holly**, **oak** and **sycamore**, with up to 20% **downy birch** (wetter sites) and possibly more **sycamore** (drier sites). Sparse vegetation cover with some **creeping soft-grass**, **wood sorrel**, **tufted hair-grass** and **dog violet**.

Table 16.9. Management scenario for Upland Northern England (Region 3), where the main canopy is not dominated by ash (<20%).

Current ash dominance		**Woodlands where main canopy is not dominated by ash (<20%).**	
3. North England upland		Typical canopy species: **alder**, **downy** and **silver birch**, **goat willow**, **holly**, **sessile oak**, and **sycamore**.	Typical shrub and small tree species: **hawthorn**, **hazel**, **grey willow**, **blackthorn**, and **bird cherry**. Typical ground flora species: W7, W9b.
Mmt. scenario		After 1–10 years	After 50–100 years
	1	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy composed of **typical** species. Canopy closes. Ground flora dominated by **meadowsweet**, **yellow pimpernel**, **broad buckler fern**, **lady fern**, **tufted hair-grass** and **soft rush**.	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush**.
	2	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy composed of **typical** species. Canopy closes. Shrub cover will decline. Regeneration difficult to achieve. Ground flora dominated by **wood sorrel**, **yellow pimpernel**, **creeping soft-grass**, **broad buckler fern**, **lady fern** and **pendulous sedge**.	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch, rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** likely to remain. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush**. Regeneration difficult to achieve.
	3	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover will decline. Ground flora dominated by **creeping soft-grass**, **tufted hair-grass**, **meadowsweet**, **yellow pimpernel** and **wood sorrel**.	**No ash trees (living or dead).** Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost) Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush**.
	4	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover will decline. Weeding will favour development of diverse, herb-rich ground flora including **creeping buttercup**, **tufted hair-grass**, **creeping soft-grass**, **stinging nettle** and **soft rush** and some **yellow pimpernel**, **wood sorrel**, **pendulous sedge**. Trees planted in gaps: **downy birch** (wetter sites) and **aspen** (drier sites).	**No ash trees (living or dead).** A full canopy composed of **alder**, **holly**, **oak** and **sycamore**, with **downy birch** (wetter sites), **aspen** (drier sites) forming up to 20% of canopy. Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Sparse vegetation cover but some **broad buckler fern**, **lady fern**, **creeping soft-grass**, **rough meadow-grass** and **wood sorrel**.

Table 16.10. Management scenario for Lowland Northern England (Region 4), where the main canopy is not dominated by ash (<20%).

Current ash dominance		**Woodlands where main canopy is not dominated by ash (<20%).**	
4. Lowland north England		Typical canopy species: **alder**, **beech**, **oak**, **downy** and **silver birch**, **field maple**, **goat willow**, **holly**, **yew**, **crab apple** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **bird cherry**, **blackthorn**, **elder** and **grey willow**. Typical ground flora species: W10, W7.
Mmt. scenario		After 1–10 years	After 50–100 years
	1	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy composed of **typical** species. Canopy closes. Shrub cover will decline. Ground flora dominated by **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (drier sites).	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **typical** species, except **birch**, **rowan** and **goat willow**. Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites).
	2	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy composed of **typical** species. Canopy closes. Shrub cover will decline. Regeneration difficult to achieve. Ground flora dominated by **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (drier sites).	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **typical** species, except **birch**, **rowan** and **goat willow**. Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites). Regeneration difficult to achieve.
	3	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover will decline. Ground flora dominated by **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (drier sites).	**No ash trees (living or dead).** Canopy composed of **typical** species, except **birch**, **rowan** and **goat willow**. Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites).
	4	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover will decline. Weeding will favour development of diverse, herb rich ground flora containing **creeping buttercup**, **tufted hair-grass**, **creeping soft-grass**, **stinging nettle** and **soft rush** and some **yellow pimpernel**, **wood sorrel**, **pendulous sedge** (wetter sites) and **stinging nettle**, **creeping soft-grass**, and some **bluebell**, **wood anemone**, **dog violet**, **male** and **broad buckler fern** (drier sites). Trees planted in gaps**: pedunculate oak** (wetter sites); **sycamore** or **Douglas fir** (drier sites).	**No ash trees (living or dead).** A full canopy composed of **typical** species, except **birch**, **rowan** and **goat willow**, with more **pedunculate oak** (wet sites); **sycamore** or **Douglas fir** (free draining sites) – up to 20% of Douglas fir but perhaps more of oak and sycamore. Sparse vegetation cover but some **broad buckler fern**, **lady fern**, **creeping soft-grass**, **rough meadow-grass** and **wood sorrel** (wetter sites) and **bramble** and **honeysuckle** (drier sites).

Table 16.11. Management scenario for Upland Wales (Region 5), where the main canopy is not dominated by ash (<20%).

Current ash dominance		**Woodlands where main canopy is not dominated by ash (<20%).**	
5. Upland Wales		Typical canopy species: **alder**, **birch**, **goat willow**, **holly**, **oak**, **rowan** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **blackthorn**, **elder**, **bird cherry** and **grey willow**. Typical ground flora species: W10, W7.
Mmt. scenario		After 1–10 years	After 50–100 years
	1	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount Existing canopy composed of **typical** species. Canopy closes. Shrub cover declines. Ground flora dominated by **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (drier sites).	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **oaks**, **holly** and **sycamore**. Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites).
	2	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy is composed of **typical** species. Canopy closes. Shrub cover declines. Regeneration difficult to achieve. Ground flora dominated by **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (drier sites).	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **oaks**, **holly** and **sycamore**. Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites). Regeneration difficult to achieve.
	3	**No ash trees (living or dead).** Existing canopy is composed of **typical** species. Some gaps in canopy. Shrub cover declines. Regeneration difficult to achieve. Ground flora dominated by **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (drier sites).	**No ash trees (living or dead).** Canopy composed of **alder**, **oaks**, **holly** and **sycamore**. Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites).
	4	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover declines. Regeneration difficult to achieve. Weeding will favour development of diverse, herb-rich ground flora containing **creeping buttercup**, **tufted hair-grass**, **creeping soft-grass**, **stinging nettle**, **soft rush** and some **yellow pimpernel**, **wood sorrel**, **pendulous sedge** (wetter sites) and **stinging nettle**, **creeping soft-grass**, and some **bluebell**, **wood anemone**, **dog violet**, **male** and **broad buckler fern** (drier sites). Trees planted in gaps: **pedunculate oak** (wetter sites) and **sycamore** or **Douglas fir** (drier sites).	**No ash trees (living or dead).** A full canopy composed of **alder**, **oaks**, **holly** and **sycamore**, with more **pedunculate oak** (wetter sites) and **sycamore** or **Douglas fir** (drier sites) – up to 20% of Douglas fir but perhaps more of oak and sycamore. Sparse vegetation cover but some **broad buckler fern**, **lady fern**, **creeping soft-grass**, **rough meadow-grass** and **wood sorrel** (wetter sites) and **bramble** and **honeysuckle** (drier sites).

Table 16.12. Management scenario for Lowland Wales (Region 6), where the main canopy has >20% ash.

Current ash dominance		**Woodlands where main canopy has >20% ash.**	
6. Lowland Wales		Typical canopy species: **beech**, **birch**, **goat willow**, **holly**, **oak**, **rowan**, **field maple**, **wild cherry**, **yew**, **poplars**, **crab apple** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **blackthorn**, **elder**, **guelder rose**, **privet** and **grey willow**. Typical ground flora species: W8, W9a.
Mmt. scenario		After 1–10 years	After 50–100 years
	1	**Significant decline in cover of ash – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) will start to become a dominant feature. **Typical** canopy species show canopy growth. Rapid growth of **typical** shrubs and small trees. Partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **creeping thistle**, **bramble** and **rough meadow-grass**) become abundant.	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Large gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **typical** species. Good shrub cover composed of **typical** species. Ground flora a mosaic of browse-resistant vernal species (e.g. **bluebell**, **wild garlic**, **wood anemone**) and partially shade-tolerant species (e.g. **bramble**, **tufted hair-grass** and **Yorkshire fog**).
	2	**Significant decline in cover of ash – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) will start to become a dominant feature. **Typical** canopy species show canopy growth and understorey trees grow up into the gaps. Expansion of the **typical** shrub species is kept in check and their cover is reduced. Ground flora dominated by **dog's mercury**, **wild garlic**, **bluebell**, **ivy** and **bramble**. Regeneration is sparse and only **sycamore** regeneration survives.	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Large gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **typical** species. Good shrub cover composed of **typical** species. Ground flora a mosaic of browse-resistant vernal species (e.g. **bluebell**, **wild garlic**) and partially shade-tolerant species (e.g. **bramble**, **tufted hair-grass** and **Yorkshire fog**). Regeneration is likely to be sparse.
	3	**No ash trees (living or dead).** **Typical** canopy species show canopy growth. Some understorey trees grow up to fill canopy gaps. Gaps in canopy. Rapid growth of **typical** shrubs and small trees Early successional species (e.g. **primrose** and **violets**) establish but are replaced by vigorous competitive species like **bramble**, **pendulous sedge** and grasses (e.g. **tufted hair-grass**, **false oat grass**, **Yorkshire fog**, **cocksfoot**). Regeneration of trees is sparse.	**No ash trees (living or dead).** Some gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **typical** species. Some shrub cover composed of **typical** species. Ground flora a mosaic of browse-resistant vernal species (e.g. **bluebell**, **wild garlic**) and partially shade-tolerant species (e.g. **bramble**, **tufted hair-grass** and **Yorkshire fog**). Regeneration of trees is sparse.
	4	**No ash trees (living or dead).** **Typical** canopy species show canopy growth and understorey trees grow up in to the gaps. Rapid growth of **typical** shrubs and small trees. Gaps in canopy. Early successional species (e.g. **primrose** and **violets**) establish, but ground disturbance leads to **stinging nettle**, **creeping thistle**, **rosebay willow herb** and **cocksfoot** establishing; **wood anemone**, **bluebell** and **broad buckler fern** may invade later. Gaps are planted with **pedunculate oak** or **alder** (wetter sites) and **sweet chestnut** or **Douglas fir** (drier sites).	**No ash trees (living or dead).** A full canopy composed of the **typical** species but with large amounts of **pedunculate oak** or **alder** (wet sites), **sweet chestnut** or **Douglas fir** (free draining sites). A diverse shrub layer composed of the **typical** species. Sparse vegetation cover but with some species (e.g. **bluebell**, **wild garlic**, **false brome** and **male fern**).

Table 16.13. Management scenario for Clay Southern England (Region 7), where the main canopy is >20% ash.

Current ash dominance		**Woodlands where main canopy is >20% ash.**	
7. Clay south England		Typical canopy species: **beech**, **crab apple**, **birch**, **oak**, **sweet chestnut**, **whitebeam**, **hornbeam**, **rowan**, **goat willow**, **holly**, **field maple**, **wild cherry**, **yew**, **poplar** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **grey willow**, **blackthorn**, **elder**, **guelder rose**, **dogwood**, **spindle** and **privet**. Typical ground flora species: W12a, W8.
Mmt. scenario		After 1–10 years	After 50–100 years
	1	**Significant decline in cover of ash – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) will start to become a dominant feature. **Typical** canopy species show canopy growth. Rapid growth of **typical** shrubs and small trees. Partially shade-tolerant species (e.g. **bramble**, **ivy** and **false brome**) become abundant.	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Large gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **typical** species. Good shrub cover composed of **typical** species. Gaps still present. Ground flora: a mosaic of browse-resistant vernal species (e.g. **bluebell**, **ivy**) and partially shade-tolerant species (e.g. **false oat-grass**, **tor-grass**, **false brome**).
	2	**Significant decline in cover of ash – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) will start to become a dominant feature. **Typical** canopy species show canopy growth and understorey trees grow up into the gaps. Expansion of the **typical** shrub species is kept in check and their cover is reduced. Ground flora dominated by **dog's mercury**, **bluebell**, **ivy**, **enchanter's nightshade** and **false brome**. Regeneration is sparse and only **sycamore** regeneration survives.	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Large gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **typical** species. Good shrub cover composed of **typical** species. Ground flora a mosaic of browse-resistant vernal species (e.g. **bluebell**, **ivy**) and partially shade-tolerant species (e.g. **false oat-grass**, **tor-grass**, **false brome**). Regeneration is likely to be sparse.
	3	**No ash trees (living or dead).** **Typical** canopy species show canopy growth. Understorey trees grow up to fill canopy gaps. Rapid growth of **typical** shrubs and small trees Large gaps in canopy. Early successional species (e.g. **primrose** and **violets**) establish but are replaced by vigorous competitive species like **bramble**, **stinging nettle**, **creeping thistle**, **rosebay willow herb** and **grasses** (e.g. **reed grass**, **tufted hair-grass**, **cocksfoot**). Regeneration of trees is sparse.	**No ash trees (living or dead).** Some gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **typical** species. Some shrub cover composed of **typical** species. Ground flora a mosaic of browse-resistant vernal species (e.g. **bluebell**, **ivy**) and partially shade-tolerant species (e.g. **false oat-grass**, **tor-grass**, **false brome**). Regeneration of trees is sparse.
	4	**No ash trees (living or dead).** **Typical** canopy species show canopy growth and understorey trees grow up in to the gaps. Rapid growth of **typical** shrubs and small trees. Large gaps in canopy. Early successional species (e.g. **primrose** and **violets**) establish, but ground disturbance leads to **stinging nettle**, **hogweed**, **false oat-grass** and **cocksfoot** establishing; **dog's mercury**, **false brome**, **enchanter's nightshade** and **bluebell** may invade later. Gaps planted with **pedunculate oak** (wet sites) and **hornbeam or Douglas fir** (free draining sites).	**No ash trees (living or dead).** A full canopy composed of the **typical** species but with more **pedunculate oak** (wet sites), **hornbeam** or **Douglas fir** (free draining sites) – exceeding 20% cover. A diverse shrub layer composed of **typical** species. Sparse ground flora a mosaic of browse-resistant vernal species (e.g. **bluebell**, **ivy** and **false brome**).

Table 16.14. Management scenario for Calcareous Southern England (Region 8), where the main canopy is >20% ash.

Current ash dominance		**Woodlands where main canopy is >20% ash.**	
8. Calcareous south England		Typical canopy species: **beech**, **crab apple**, **birch**, **oak**, **sweet chestnut**, **whitebeam**, **hornbeam**, **rowan**, **goat willow**, **holly**, **field maple**, **wild cherry**, **yew**, **poplar** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **grey willow**, **blackthorn**, **elder**, **guelder rose**, **dogwood**, **spindle** and **privet** Typical ground flora species: W8.
Mmt. scenario		After 1–10 years	After 50–100 years
	1	**Significant decline in cover of ash – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) will start to become a dominant feature. **Typical** canopy species show canopy growth. Rapid growth of **typical** shrubs and small trees. Partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **creeping thistle**, **bramble** and **rough meadow-grass**) become abundant.	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Large gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **typical** species. Good shrub cover composed of **typical** species. Gaps still present. Ground flora a mosaic of browse-resistant vernal species (e.g. **bluebell**, **wild garlic**, **wood anemone**) and partially shade-tolerant species (e.g. **bramble**, **false oat-grass** and **Yorkshire fog**).
	2	**Significant decline in cover of ash – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) will start to become a dominant feature. **Typical** canopy species show canopy growth and understorey trees grow up into the gaps. Expansion of the **typical** shrub species is kept in check and their cover is reduced. Ground flora dominated by **dog's mercury**, **wild garlic**, **bluebell**, **ivy** and **bramble**. Regeneration is sparse and only **sycamore** regeneration survives.	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Large gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **typical** species. Good shrub cover composed of **typical** species. Ground flora a mosaic of browse-resistant vernal species (e.g. **bluebell**, **wild garlic**, **wood anemone**) and partially shade-tolerant species (e.g. **bramble**, **false oat-grass** and **false brome**). Regeneration is likely to be sparse.
	3	**No ash trees (living or dead).** **Typical** canopy species show canopy growth. Understorey trees grow up to fill canopy gaps. Rapid growth of **typical** shrubs and small trees Large gaps in canopy. Early successional species (e.g. **primrose** and **violets**) establish but are replaced by vigorous competitive species like **bramble** and grasses (e.g. **tufted hair-grass**, **false oat-grass**, **Yorkshire fog**, **cocksfoot**). Regeneration of trees is sparse.	**No ash trees (living or dead).** Some gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **typical** species. Some shrub cover composed of **typical** species. Ground flora a mosaic of browse-resistant vernal species (e.g. **bluebell**, **wild garlic**) and partially shade-tolerant species (e.g. **bramble**, **false oat-grass** and **false brome**). Regeneration of trees is sparse.
	4	**No ash trees (living or dead).** **Typical** canopy species show canopy growth and understorey trees grow up in to the gaps. Rapid growth of **typical** shrubs and small trees. Large gaps in canopy. Early successional species (e.g. **primrose** and **violets**) establish, but ground disturbance leads to **stinging nettle**, **creeping thistle**, **rosebay willow herb** and **cocksfoot** establishing; **wood anemone**, **bluebell** and **broad buckler fern** may invade later. Gaps are planted with **small-leaved lime** or **Norway maple**.	**No ash trees (living or dead).** A full canopy composed of the **typical** species but with more **small-leaved lime** or **Norway maple** exceeding 20% cover. A diverse shrub layer composed of the **typical** species. Sparse vegetation cover but with some species (e.g. **bluebell**, **wild garlic**, **false brome**, **ivy**, **dog's mercury** and **male fern**).

Table 16.15. Management scenario for Northern Ireland (Region 9), where the main canopy is <20% ash.

Current ash dominance		**Woodlands where main canopy is <20% ash.**	
9. Northern Ireland		Typical canopy species: **alder**, **birch**, **oak**, **rowan**, **goat willow**, **holly** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **blackthorn**, **elder**, **guelder rose**, **bird cherry**, **spindle** and **grey willow**. Typical ground flora species: W7, W10.
Mmt. scenario		After 1–10 years	After 50–100 years
	1	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy composed of **typical** species. Canopy closes. Ground flora dominated by **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (drier sites).	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites).
	2	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (mainly ash) begins to increase in amount. Existing canopy composed of **typical** species. Canopy closes. Shrub cover will decline. Regeneration difficult to achieve. Ground flora dominated by **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (drier sites).	**No living ash trees.** Significant quantities of deadwood (mainly ash) – most on ground. Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** likely to remain. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites). Regeneration difficult to achieve.
	3	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover will decline. Ground flora dominated by: **meadowsweet**, **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (drier sites).	**No ash trees (living or dead).** Canopy composed of **alder**, **holly**, **oak** and **sycamore** (**birch**, **rowan** and **goat willow** lost). Shrub and small tree cover has declined with only **hazel** and **hawthorn** remaining. Ground flora sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites).
	4	**No ash trees (living or dead).** Existing canopy composed of **typical** species. Some gaps in canopy. Shrub cover will decline. Weeding will favour development of diverse, herb rich ground flora including **creeping buttercup**, **tufted hair-grass**, **creeping soft-grass**, **stinging nettle** and **soft rush** and some **yellow pimpernel**, **wood sorrel**, **pendulous sedge** (wetter sites) and **stinging nettle**, **creeping soft-grass**, and some **bluebell**, **wood anemone**, **dog violet**, **male** and **broad buckler fern** (drier sites). Trees planted in gaps: **pedunculate oak** (wetter sites); **sycamore** or **Douglas fir** (drier sites).	**No ash trees (living or dead).** A full canopy composed of **alder**, **holly**, **oak** and **sycamore**, with up to 20% more **pedunculate oak** (wet sites) and possibly more than 20% **sycamore** (drier sites). Sparse vegetation cover but some **broad buckler fern**, **lady fern**, **creeping soft-grass**, **rough meadow-grass** and **wood sorrel** (wetter sites) and **bramble** and **honeysuckle** (drier sites).

16.5 Limitations and suggested improvements

The four management scenarios selected are only a small subset of what woodland managers might choose to do, but they give a flavour of possible outcomes within the limited scope of this contract. At present, ash is only a small component of most of the woods in Britain, with ash being scattered throughout other woodland types and typically occurring in small clumps. Removal of diseased and dead trees from most of the woodlands will most likely match a thinning intervention (scenario (5) – we would recommend future testing of this scenario). We propose that scenario (6) (felling with natural regeneration promoted), would also be a useful additional one to consider in future, because in most ash woods removal of ash would only create small gaps, and management for regeneration would necessarily include enlarging gaps, leading to the more likely success of regeneration; and the removal of the overstorey all at once would more likely lead to regeneration occurring when ground vegetation is still somewhat suppressed.

Considering only one proportion of ash in the canopy class per region also limits the outcomes of this work – in most sub-regions there are some woodlands where ash is more or less dominant than the chosen scenario. We would recommend consideration of both conditions of <20% and >20% ash in the canopy for all sub-regions for future work on habitat responses to management.

The overall effect of climate warming and the projected regional differences in, for example rainfall patterns, are likely to exert an influence on woodlands over the long term. However, this added layer of complexity was felt to be beyond the scope of the project. Consequently the predicted habitat responses to the various management scenarios do not take climate change into account. This is with the exception of species suggested for planting which were selected on the basis of their suitability under future climates for the different sub-regions and site types.

Future work could develop these management scenarios further and include site studies that illustrate the type of change on the ground that are predicted in this chapter. This would provide a partial validation of these predictions.

17 Impacts of management scenarios

<u>Chapter Summary</u>

1. *For all species that were identified as obligate or highly associated with ash, the impact of a change from the current ash woodland habitat to that described by the management scenarios in Chapter 16 was assessed for each of the nine ash-relevant regions over two time-periods: after 1–10 years and after 50–100 years. The impact was assessed as a change in the species population from current levels within that region.*
2. *Ash-associated species were classified as: extinct, decline, no change, increase, colonise, unknown, not present or distribution unknown.*
3. *The assessment of the impact of the management scenarios was collated in a standard format across species groups and included in the Access database.*
4. *Overall, management scenarios (1) (non-intervention) and (2) (no felling with natural regeneration promoted) are predicted to be better for ash-associated biodiversity in the short term as they retain the ash and dead ash in the woodland for longer compared to management scenarios (3) (felling) and (4) (felling and replanting).*
5. *Species that utilise deadwood (fungi and some invertebrate species) may initially increase in population in the first 1–10 years under scenarios (1) and (2) due to an increase in the availability of deadwood. However, after 50–100 years their populations are predicted to decrease compared to current levels if all dead ash wood is lost.*
6. *After 50–100 years there is considered to be little difference between the four scenarios in terms of their impact on obligate and highly associated species, with most species declining or becoming extinct. This is due to the assumption that in scenarios (1) and (2) all ash will be lost by 50–100 years; this may not happen, and if some ash survives then obligate species may just decline rather than becoming extinct.*
7. *There is considered to be little regional variation in the predicted impact of the management scenarios for most species groups.*

17.1 Assessment of impact

The management of woodlands following ash dieback will result in changes in the vegetation (Chapter 16). This in turn will impact on the other species associated with the ash woodlands. For all species that were identified as obligate or highly associated with ash, the impact of a change from the current ash woodland habitat to that described in Tables 16.7–16.15 was assessed for each of the nine regions (Figure 2.5) over two time-periods: after 1–10 years and after 50–100 years. This resulted in 72 assessments being made for each species. The impact was assessed as a change in the species population from current levels within that region (Table 17.1).

Table 17.1. Criteria used to assess impact of management scenarios.

Value	Definition
Extinct	Scenario is likely to result in the species going regionally extinct in currently existing ash woodlands within that region.
Decline	Scenario will result in the species declining in currently existing ash woodlands.
No change	Scenario will result in no change in the species population in currently existing ash woodlands within the region.
Increase	Increase in population in currently existing ash woodlands within the region.
Colonise	Species not currently present in region but likely to colonise due to change in habitat.
Unknown	Species present within region but impact of management scenario on species is unknown due to lack of information on species habitat requirements.
Not present	Species is not present within region and unlikely to become so.
DD	Distribution unknown. No information on species distribution available – see below.

Information on a species presence/absence within each of the nine regions was taken from species atlases and the NBN Gateway. The lines demarking the regions were deliberately developed to be 'fuzzy' lines to avoid a suggestion of greater accuracy than was realistic (Chapter 2). If a species was shown to occur on the border between two regions and it was not possible to assess if it was present or absent within a region it was assumed to be present – thus taking the precautionary approach to assess any impact within the region.

In some cases there was no distribution data for a species such as an atlas but the general habitat (lowland or upland) or countries within Great Britain where the species occurs was known. In this case an assessment was made for the appropriate regions, and the data quality recorded appropriately (Table 17.2).

Table 17.2. Quality of distribution data.

Data quality	Definition
Data	Data taken from atlas, NBN, vice county lists, etc.
EJ	Expert judgement – based on general knowledge of species ecology and distribution between countries with UK.
None	No distribution data.

The assessment of the impact of the management scenarios was collated in a standard format across species groups and included in the Access database (Appendix 1).

For birds and mammals there were no obligate or highly associated species, so the impact of the management scenarios was not assessed for each species. This provided a consistent approach across all species groups for the development of maps of regional impacts (Section 17.8). The impact of the management scenarios on vascular plants was not assessed in the same way as for other species as the output from the management scenarios in Chapter 16 gives descriptions of the vascular plant communities resulting from the management.

The results of this assessment are held in the table 'Management scenarios' within the database. Summary results by species groups and then by regions are given below.

17.2 Lichens

17.2.1 Impact under different management scenarios

The mean number of species per region was *c*8.5 (i.e. when focussing on 16 taxonomically well-delimited lichens with an obligate or high association with ash). In addition to the 11 lichens of conservation concern (Section 7.2), this expanded list therefore included (Section 7.3): *Gyalecta derivata*, *Mycobilimbia epixanthoides*, *Pyrenula chlorospila*, and *Strigula taylorii*. It is interesting to note that of those species with obligate or high association with ash, the majority (75%) have been designated with an IUCN conservation criterion. A further obligate species, *Ochrolechia bahusiensis*, was not treated during the regional assessment because of taxonomic complexity. In delivering the regional assessment of management scenarios, the expected consequences for eight obligate and high association species occurring in Northern Ireland have been predicted and mapped spatially (Section 17.8). However it should be noted that while the lichen distribution in Northern Ireland (presence/absence) was assessed using data from Northern Ireland (the Northern Ireland Lichen Database, visualised on the NBN Gateway), the level of association between the lichens and tree species was quantified using data from England, Scotland and Wales, and then extrapolated to Northern Ireland. It is assumed that the level of association between the lichen species and the tree species in Northern Ireland will be the same as in the rest of the UK.

The region with the most species (*n* = 15) was Upland Scotland, while Lowland Northern England had the fewest of the obligate and high association lichens present (*n* = 5).

The impact of the designated management scenarios was treated systematically for lichens with an obligate and high association with ash.

- **Obligate Species**. Species obligately associated with ash were designated with the *extinct* status, under landscape scenarios in which no ash trees survived (e.g. *Lithothelium phaeosporum*, and *Thelenella modesta*). For scenarios which included ash tree dieback, as opposed to absolute loss, these same species where assigned a *decline* status. Both *Leptogium hildenbrandii* (considered extinct) and *Ochrolechia bahesensis* (taxonomically complicated recording data) are each obligate with one record from ash only, and for the sake of this exercise were designated as *extinct* under both scenarios (absolute loss and ash dieback).

- **High Association Species, Absolute Loss of Ash**. Species with a high association with ash, and with fewer than 10 records from alternative tree species, were given an *extinct* status under the scenario of absolute loss of ash (management scenarios (3) and (4)) (e.g. *Catapyrenium psoromoides*, and *Collema nigrescens*). However, for species with more than 10 records from alternative tree species, the scored impact depended on the expected structure of the canopy, and the pattern of lichen association with alternative trees. For lichens associated with other dominant trees (e.g. *Leptogium cochleatum* on hazel, *Leptogium saturnium* on aspen and sycamore, *Mycobilimbia epixanthoiodes* mainly on oak, *Pyrenula chlorospila* on sycamore, beech, hazel and oak, *Strigula taylorii* on oak and beech, and *Wadena dendrographa* on oak), the impact was scored as *decline*. This encompasses a loss of suitable habitat in the first 10 years, and with potentially stabilising though smaller populations in the longer term (50–100 years), when accounting for shifts in woodland structure and the availability of the lichen species' alternative host trees. If the lichen species didn't appear to occur on other dominant trees, but there were records of the species from a non-corticolous substratum (e.g. *Vezdaea stipitata*), the impact was scored *decline* to account for the loss of its corticolous habitat.

- **High Association Species, Live Wood Species**. Species scored a *decline* status where they had a high association with ash, and for management scenarios where ash trees were still present but had declined (scenarios (1) and (2)).

- **High Association, Deadwood Species**. Where a species is highly associated with ash trees and occurs on lignum, it was scored *no change* under scenarios (1) and (2). Where the management scenario does not involve dead ash trees, it was assumed the species would decline (e.g. *Caloplaca flavorubescens*).

Additionally, for species which are highly associated with ash, but which tend to be less closely associated with closed canopy woodlands, than open pasture woodlands, or parkland type settings (e.g. *Fuscopannaria ignobilis*, or *Gyalecta derivata*), the change in woodland composition was discounted, and these species were scored as *extinct* or *decline*, depending on ash availability. Species for which little is definitively known about their habitat requirements (e.g. *Bacidia auerswaldii*) were scored as *data deficient*.

17.2.2 Habitat management implications

The association of ash epiphytes with alternative trees, analysed for those lichens that have obligate, high and partial association with ash (Section 6.2), suggested that landscape management scenarios which include the provision of oak, hazel and sycamore, and possibly aspen, may provide an opportunity to offset the negative impacts of ash dieback. It has been clearly established that lichen epiphyte composition is related to the structure and chemistry of the tree bark substratum (Ellis 2012). On this basis, the transition of former ash woodland towards more acid-barked tree species (e.g. birch, or pine), could be detrimental, while an opportunistic shift to non-native planting would be devastating.

17.3 Bryophytes

17.3.1 Impact under different management scenarios

The bryophytes with a high preference for ash are not really woodland plants, so detailed effects of management scenarios on woodland ground flora and shrub layer are more-or-less irrelevant to these species. The main criterion for their survival is the continuing availability of suitable substrate trees, of which ash is an important example. They are relatively light-demanding species that grow on isolated trees, or trees in very open situations, so any scenario that might result in an increase in shade from the canopy or from an increased growth of under-shrubs is likely to be detrimental. All six of the bryophytes identified as having a 'high' preference for ash are rare, but their preference for ash may have been overstated. Nearly all of them are able to use alternative substrates, but they are more likely to remain rare in a landscape from which ash is absent than from one in which it is present and frequent. *Lejeunea mandonii* could be threatened by changes in vegetation structure at its recently discovered site in south Wales, but possible effects cannot be predicted in detail. If the canopy closes, or if there is an 'explosion' of woody shrubs it is likely that it could be negatively impacted.

Overall, the impact of ash dieback may be more serious for bryophytes that are currently common and widespread, especially in south-east England and the Midlands, where there are fewer natural rock exposures that can be used as alternative substrates. A combination of Dutch elm disease and atmospheric pollution hit many of these species hard, and some (notably species of *Orthotrichum*) virtually disappeared during the mid-20th century. Improvements in air quality resulted in widespread re-colonisation more recently, showing just how mobile and resilient many of these species are, given favourable conditions. Ash dieback could impede this recovery process.

Of the long-term management scenarios presented, the ones most likely to be most detrimental to bryophytes with a high affinity for ash are those in which light levels decrease and alternative tree species (notably willow) also decline. On the other hand, if sycamore and/or hazel increase, this might compensate.

Projected increases in deadwood in the long term would be beneficial to a suite of deadwood specialist bryophytes, but these are mostly a different group to those identified in Chapter 7 (with the exceptions of *Brachythecium salebrosum* and *Pylaisia polyantha*). However, this may more realistically be thought of as a medium-term phenomenon, as amounts of dead ash wood will decrease eventually.

17.3.2 Habitat management implications

It may be that more planting of alternative tree species becomes necessary eventually, but in general it is recommended that the situation is monitored closely in order to determine the response of key species to ash dieback, especially rare species in non-woodland habitats. Bryophytes are astonishingly resilient and able to grow on a range of host trees as long as other environmental conditions such as climate, pollution levels and bark pH are suitable. It is considered likely that most species will weather this particular storm, although there may well be changes in frequency and distribution patterns.

There is the possibility of resistance to ash dieback in some trees, and also the possibility that ash trees in the UK, on the oceanic fringe of Europe, may behave somewhat differently to those in more continental climates. Thus, while we must not under-estimate the potentially catastrophic effect of ash dieback on bryophytes in the UK, it is probably too soon to embark on a widespread programme of replanting.

The rarest of the species identified could be taken into *ex situ* conservation. A number of institutions Europe-wide, including Kew Gardens, are currently researching *ex situ* techniques for bryophytes (see, for example, http://www.ebesconet.org/EBESCONet.html). These include cryo-storage of gametophytic material and of spores, and relationships between bryophytes and endophytic fungi, as these increasingly seem to be important in the success of re-establishing populations in the wild. This may be particularly important for globally rare or threatened species such as *Lejeunea mandonii*.

17.4 Fungi

17.4.1 Impact under different management scenarios

The Fungal Records Database of Britain and Ireland (FRDBI) feeds into the National Biodiversity Network (NBN) (http://www.nbn.org.uk/) and the NBN was used during assessments of regional distribution and potential impacts of management scenarios.

Many of the fungal taxa within the high priority group are saprotrophic fungi, growing on dying or dead ash wood. Management scenarios which allow the accumulation of both standing and lying deadwood are therefore likely to lead to an increase in the abundance of these taxa in the short- to medium-term. Conversely, the removal of dying trees or dead-wood is likely to have an immediate detrimental impact on the populations of these taxa.

Large trees may take several seasons to completely die from infection by *H. pseudoalbidus*. The removal of infected trees, which may still support green shoots, leaves and seeds, in an attempt to halt or reduce the spread of the pathogen, will hasten the decline of the obligate species which rely on living tissue to colonise ash.

In the management scenarios which involve removal of ash from woodlands, the disturbance to the ground could be a significant factor influencing the litter saprotrophs growing on the ground in the vicinity of the ash.

17.4.2 Habitat management implications

It is difficult to suggest alternative management scenarios that would favour the fungi associated with ash. The greatest impact on fungal communities with the demise of ash will clearly be on the obligate taxa, in particular those species which require live ash material to infect. One possibility would be to have patches of other members of the Oleaceae, such as *Ligustrum*, as understorey plants, as at least some of the obligate species may be able to infect these plants. However, there is the risk that these could act as reservoirs of infection by *H. pseudoalbidus*, although it is currently unclear if *H. pseudoalbidus* can infect other woody Oleaceae shrubs.

17.5 Invertebrates

17.5.1 Impact under different management scenarios

General impact of loss of ash on invertebrates
Ash has fewer invertebrate species directly associated with it than do most other native broadleaf tree species in the UK (see comparisons of ash with other tree species: Kennedy and Southwood 1984; Southwood 1961). Hence any future management will have a lesser impact on species than would be the case if, for example, birch or oak suffered significant declines. Nonetheless for those species that are obligate on or highly associated with ash, loss of habitat will clearly impact on their populations and range. The impact of the management scenarios on invertebrates differs in ways that can be summarised broadly along the lines of different feeding strategies.

Phytophagous species
Phytophagous species that are dependent on or highly associated with ash will clearly decline or become extinct under any management scenario. It is possible that small pockets of some species may survive on non-native *Fraxinus* species if these prove to be resistant to ash dieback, but many such species may either not be able to sustain populations on other *Fraxinus* species or may be more vulnerable to stochastic events. There was little pattern in terms of alternative hosts for species highly or partly associated with ash.

Saproxylic and Xylophagous species
Saproxylic and Xylophagous species have the potential to increase in the short term with the increased availability of deadwood under management scenarios (1) and (2). A large number of species may use ash with, for example, Rotheray *et al* (2001) recording that ash has the second highest number of species recorded on it in their studies of saproxylic Diptera in Scotland. However, in most cases this reflects simply the availability of dead ash as a resource, and most species were specialised in terms of microhabitat or breeding site rather than tree species. Where strong association was noted on ash, this may be a result of localized deadwood availability rather than a true preference, but for species restricted to a small number of sites, there is nonetheless the potential for a change in tree species composition to impact on small populations.

Predatory species
Predatory species are most frequently not strongly associated with particular tree species. However, a minority of predators do have a close link with particular prey which does increase their level of association. For example, early records of the aphid-predator *Anthocoris amplicollis* (Hemiptera) have all been on ash, although it is not clear what the prey species is in the UK (Kirby 1992).

17.5.2 Habitat management implications

For species that do use alternative tree species, retention or expansion of the most frequent alternative species, listed in Section 9.4, may reduce the risk of population declines or range loss.

A diverse woodland structure will help to maintain more generalist species that make some use of ash. Where active removal of ash from woodlands is being carried out, efforts should be made to avoid removal of too much deadwood of other tree species that might provide alternative microhabitat niches. The majority of saproxylic insects that use ash are not dependent on the species but require structural diversity in woodland and, in particular, a range of deadwood habitat will maximise the availability of habitat niches.

Some localised management may help reduce the impact of ash dieback on especially vulnerable species. For example, retention or expansion of *Ligustrum vulgare* (wild privet) is important at sites that support populations of Barred Tooth-striped moth.

17.6 Mammals

17.6.1 Mammals other than bats

Insectivores
Under scenarios (1) and (2), there will be an expected increase in the abundance of invertebrates associated with greater quantities of deadwood on the ground which may benefit insectivorous mammals.

Lagomorphs
Unlikely to show any marked response to ash dieback or associated changes in woodland vegetation community under any of the scenarios described.

Rodents
Species that rely on a varied source of seed, nut, berry and mast producing species may show some population response to loss of ash keys and associated change in the structure and composition of small trees, shrubs and ground flora. Ash keys may provide an alternative source of food in, for example, poor mast years. The initial opening of the canopy associated with all scenarios and increase in oak, sycamore, bramble and possibly hazel may counteract any detriment due to loss of ash keys. Planting of fir and oak proposed under scenario (4) may benefit rodents. Many small rodents prefer dense ground vegetation for cover and changes in ground flora associated with initial opening of the canopy and then later closing of the canopy, shading and spare ground layer suggested under scenarios (1)–(3) may affect habitat suitability for small rodents. Where red squirrels occur in mixed woodlands an initial opening of the canopy under all scenarios is likely to have a negative effect as this species is largely arboreal and at greater risk of predation on the ground, whereas grey squirrels spend a significant amount of time foraging on the woodland floor (note the red squirrel is not present in most of the UK). Fungi can provide an important seasonal food source for rodents and increased deadwood and fungi may benefit some rodent species under scenarios (1) and (2).

Carnivores
Carnivores are unlikely to show any direct response to loss of ash or changes in woodland community associated with any of the proposed scenarios. Carnivores may be affected by changes in small mammal (insectivore and small rodent) populations; a decline in rodents and insectivores will likely have negative effect on carnivores that rely on small mammalian prey. In Scotland, an increase in standing deadwood, that will increase under scenarios (1) and (2), may provide more nesting holes for pine marten, but the use of ash for this purpose is unknown.

Ungulates
Impact on the smaller deer species; roe deer and muntjac that favour dense well-established understory is likely to depend on how the understory changes as ash declines. All scenarios suggest an initial increase in understory growth associated with opening up of the canopy which may initially favour roe and muntjac. However, later closing of the canopy and decline in the understory may not favour these species. Rich ground layer in the early stages of scenarios (3) and (4) may provide favourable grazing. Similarly increased patchiness and prevalence of woodland edge habitat likely to occur under all scenarios may provide more rough grazing and browsing opportunities, though overall loss of ground flora, particularly under scenarios (1)–(3), may have a negative effect. However, deer also make extensive use of neighbouring fields and arable land, and it is difficult to predict how changes in woodland browsing and grazing will affect these species. Impacts on the larger red and sika deer which can be locally numerous in deciduous, coniferous and open hill habitats is difficult to predict.

Ungulates themselves will influence the outcome of these management scenarios with grazing by ungulates driving changes in the structure and composition of the woodland.

17.6.2 Bats

The loss of ash trees from the potential pool of trees that may provide roosts used by bats in the UK would be expected to impact negatively overall on the populations of bats, particularly those that roost most often in trees (see Chapter 10). This would be the default outcome of all the management scenarios. However, management scenarios (1) and (2) are likely to have initially a progressively positive impact in as much as the death of ash trees will provide a larger number of roosting opportunities. Although this assumes that roost sites are limiting for many bats, this is not an unreasonable assumption since the decline in bat numbers has been associated with a general deforestation of the landscape in favour of open land-use types. Furthermore, the fact that bats evolved as forest-dwelling species and the different patterns of usage of roosts among different bat species, divided between trees and man-made structures, reflects different degrees of adaptation of those species to roosting in novel environments. Larger and older trees, with decaying and dead sections of wood, harbour larger holes that may be used by bats. The greater availability of roosting sites, with progression of the disease suggests an initially increasing availability of roosting sites. This will be expected to decline subsequently as larger trees rot and fall. The larger the tree, the longer this process will take. Smaller ash stems may succumb more rapidly and provide roosting opportunities for small numbers of bats beneath rotting bark, but these enhancements will be nullified more rapidly as the smaller trees fall.

The impact of the disease in combination with management scenarios (3) and (4) would be negative for bats, since it would remove fairly rapidly, the potentially positive impacts of formation of the additional roosting habitat by decaying trees. Under all four management scenarios it is likely that any lost ash trees would ultimately be replaced by alternative trees of a different species, either by natural processes or by assisting those processes with intervention (scenarios (2) and (4)). Where large/old ash trees are lost they might eventually be replaced by large old trees of other species; however for the next 50-100 years the net effect will be a shift downward in the age structure of the woods.

Where bats use wooded areas for foraging on insect populations associated with the trees, then the overall effect on bats is likely to be dependent upon the proportion of the local woodland formed by ash. A large proportion of ash in the woodland, means that the death of the trees would result in large gap formation and loss of foraging habitat. Where ash forms a smaller proportion of the total woodland then the death of some trees in the forest will result in the formation of smaller forest gaps, which will enhance the foraging habitat available for those bat species using gaps habitat edges for foraging.

A potentially negative result of the ash dieback for bats, is likely to be the initial loss of connectivity between bat roosts and their foraging habitat, and between foraging areas. This may occur where areas of woodland are lost, or where ash formed a component of another habitat, such as a hedgerow, or riparian vegetation. This fragmentation of habitats could potentially exacerbate the effects of an already fragmented environment for bats. Although we know that many bat species use linear landscape features for foraging and commuting, the impact of further environmental fragmentation would be hypothesised to act via increasing foraging costs and mortality via increased predation risk, and would be difficult to quantify. It is anticipated that the replacement of trees would ultimately make good any effects of habitat fragmentation, but there will be a hiatus in many localities, before this occurs with progressive regeneration or establishment of replacement trees.

It should be noted that all species of bat, except for the whiskered bat, Daubenton's bat, Natterer's bat, noctule, soprano pipistrelle, common pipistrelle, and brown long-eared, are distributed in only a restricted subset of the regions used in this analysis of the effects of ash dieback. The majority of the other species are restricted in their distributions to mainly the southern England, Welsh and northern England regions, and consequently if there were to be impacts upon them, then we would expect some regional specificity. However, most of the expected impacts would vary locally with the proximity of ash to bat roosts and foraging areas, with regional effects being of subsidiary importance.

17.7 Birds

17.7.1 Impact under different management scenarios

Management scenarios (1) and (2) are likely to have a positive impact on woodland structure for birds, and may benefit understorey nesting species (e.g. willow warbler *Phylloscopus trochilus*) and introduce deadwood, which is likely to have a short-term benefit for woodpecker species that feed on beetle larvae in deadwood. However, lesser spotted woodpecker prefers to feed on small diameter deadwood in crowns of living trees and this will decline in the long term, and oak is preferred over ash for nesting and foraging, so the temporary abundance of deadwood will not necessarily be used by this species (Charman *et al* 2012).

In ash-dominated woodland, all management scenarios will result in a large reduction of the mature trees and canopy cover. This is likely to be detrimental to marsh tits and other species of mature woodland, but the loss of trees in woods with low ash dominance is more likely to provide short-term gaps in canopy which may allow a boost to growth in the understorey, to the benefit of some species.

The opportunity to change the canopy composition through natural succession (scenario (2)) or planting (scenario (4)) has potential long-term benefits for several bird species. Hawfinch is currently highly restricted in distribution to the New Forest, South Cumbria, Dolgellau area of North Wales and the Wye Valley/Forest of Dean. Recent research suggests that they are persisting in these areas due to the availability of woodlands with large trees that have seeds palatable to hawfinches (e.g. hornbeam, yew, cherry (RSPB unpublished data)). Therefore, replacement of ash with species suitable for hawfinches may have long-term benefits. Similarly, several bird species prefer oak, including lesser spotted woodpecker. However, these birds are all species of mature forest and need large trees, so habitat is unlikely to become suitable for about 50–100 years.

One of the likely effects of management of ash dieback is the increase in low shrub cover (<2m height) in woodlands dominated by ash. This could be beneficial to a number of bird species (e.g. blackcap and dunnock). The density and structure of this low shrub cover affects the species that will benefit from this increase. Retaining some canopy as in scenarios (1) and (2) will benefit chiffchaff and blackcap that use the shrub layer in mature woodland. In scenario (2), control of deer will increase density of low cover. However, if management to encourage tree regeneration includes removal of competing scrub such as bramble this may be detrimental.

More importantly, scenarios (3) and (4) have the potential to create areas of early successional habitat in woodland, which has declined in the lowlands over the past 20 years due to a reduction of new plantings and a move away from clear felling as a harvesting system. This type of habitat has the potential to benefit some declining bird species (e.g. willow warbler, willow tit *Poecile montanus*, and grasshopper warbler *Locustella naevia*) (Bellamy *et al* 2009; Gilbert 2012; Lewis *et al* 2009). Again, the details of how low scrub is managed in these habitats will be important for determining habitat suitability, if competitive scrub is regularly removed from areas planted up, this may reduce its value for birds.

17.7.2 Habitat management implications

The management scenarios considered compare the effects of woodland management on woodland birds. Within farmland, mature ash is an important structural element in the landscape. A number of bird species associated with farmland nest in large tree holes and farm buildings (e.g. kestrel *Falco tinnunculus*, stock dove *Columba oenas*, barn owl *Tyto alba*, and tawny owl *Strix aluco*). In south and east England, holes in mature farmland trees are frequently used as nest sites; where this coincides with ash being the dominant farmland tree, any large-scale felling of mature ash is likely to reduce abundance for some of these bird species.

17.8 Regional differences

For each species group/region combination, the percentage of obligate or highly associated ash species that are predicted to increase, decrease, decline or go extinct, was calculated as a percentage of the total number of species in that region for which there was data and it was possible to make a prediction (species scored as ‘increase’, ‘colonise’, ‘decrease’, ‘extinct’, ‘no change’). Species that were scored as ‘data deficient’, ‘unknown’, or ‘not present’ (Table 17.1) were excluded. These results are shown in Figures 17.1–17.10. It should be noted that the number of species represented by each pie-chart is different across regions within each species group due to differences in species distributions. The total number of species represented by each pie-chart is shown in Table 17.3, and for some groups in some regions is very low.

When interpreting the predicted impact of the management scenarios it should be noted that within the timescale available to do this work the predictions were necessarily simplistic, confined to the categorical results of ‘increase’, ‘colonise’, ‘decrease’, ‘extinct’ and ‘no change’ with no attempt made to define levels of change within these variables e.g. a big or small decrease in population. In management scenarios (1) and (2) it is assumed that all the ash trees will have died after 50-100 years; this may not happen, in which case the rate of decline of ash-associated species may be slower than predicted. In management scenarios (3) and (4) it is assumed that all dead wood will be removed, in reality some small bits of dead wood will be left which may slow the rate of loss of species associated with dead ash wood under these scenarios. Therefore, there is some uncertainty over the timescale of these predicted changes and whether species predicted to go extinct will actually just decline in abundance. The predictions below and Figures 17.1-17.10 should therefore be interpreted in light of these limitations. Nonetheless, the scenarios highlight important differences between management scenarios which remove ash (3) and (4) and those that don't (1) and (2) and identify the number of obligate and highly associated species in each ash-relevant region that might be affected by these scenarios.

When assessed across all species groups, more than 75% of obligate and highly associated species are predicted to first decline (1–10 years, Figure 17.1) and then go extinct (50–100 years, Figure 17.2). More species will go extinct quicker in years 1–10 if management scenarios (3) or (4) are carried out than if management scenarios (1) or (2) are carried out. However, in the long term (50–100 years), the results are similar for all management scenarios, with over 50% of the species predicted to go extinct. However, it should be noted that in scenarios (1) and (2) it is assumed that all ash will be lost by 50–100 years; this may not happen and if some ash survives then obligate species may just decline rather than go extinct. In the first 10 years some species may increase in abundance if management scenarios (1) or (2) are carried out, but no species will increase if management scenarios (3) or (4) are carried out. This is due to species that utilise deadwood increasing under management scenarios (1) and (2), but as scenarios (3) and (4) will remove all the deadwood this increase does not occur.

The six highly associated bryophyte species are predicted to show different, species-specific responses. The few (one or two) species present in lowland Scotland and upland Wales are predicted to be unchanged by any of the management scenarios. In region 7 (southern England, clay) where all six highly associated bryophyte species occur, half of the species are predicted to decline in the first ten years under management scenarios (1) and (2) and then become extinct after 50-100 years if all ash is lost; under management scenarios (3) and (4) the extinction is predicted to occur within the first ten years if all ash is lost (Figures 17.3 & 17.4). However the other three highly associated species in this region are predicted to be unchanged by any of the management scenarios. The other regions show a mixed response with species predicted to decline/go extinct or showing no change depending on the species occurring. None of the obligate or highly associated bryophyte species are known to occur in Northern Ireland.

Obligate and highly associated lichen species are generally predicted to decline under all management scenarios in the first 10 years (Figure 17.5), but with more extinctions under management scenarios (3) and (4). After 50–100 years, all obligate and highly associated lichen species will have either declined or gone extinct under management scenarios (3) and (4), with the majority of species declining or going extinct under management scenarios (1) and (2) (Figure 17.6). There was little regional variation in how the lichens responded to the management scenarios.

Under management scenarios (1) and (2), obligate and highly associated fungi species will either decline in the first 10 years if they require live ash trees or increase if they use deadwood (Figure 17.7). Under scenarios (3) and (4), which involve the removal of deadwood, nearly all fungi in all regions will decline in the first 10 years. After 50–100 years most obligate and highly associated fungi are predicted to have either declined or gone extinct (Figure 17.8).

In the first 10 years, obligate and highly associated invertebrate species are predicted to decline under management scenarios (1) and (2), and go extinct in scenarios (3) and (4), with the exception of a few ash-associated species that utilise dead ash wood which are predicted to increase under scenarios (1) and (2) (Figure 17.9). After 50–100 years obligate or highly associated invertebrates are predicted to have either declined or gone extinct (Figure 17.10). There is very little variation between regions in how the invertebrates are predicted to respond.

Overall, management scenarios (1) and (2) are considered better for ash-associated biodiversity, as they retain the ash and dead ash in the woodland for longer. They therefore slow the loss of species. However, after 50–100 years there is generally little difference between the four scenarios in terms of their predicted impact on obligate and highly associated species. The figures 17.1–17.10 generally showed little regional variation in how the species might respond. The biggest differences in predicted responses were between management scenarios rather than regions.

Table 17.3. Number of species i.e. obligate and highly associated ash species (pie total) represented in each pie-chart for each species group/region combination.

Species group	Region	Pie Total
Bryophyte	1	2
Bryophyte	2	4
Bryophyte	3	2
Bryophyte	4	2
Bryophyte	5	1
Bryophyte	6	3
Bryophyte	7	6
Bryophyte	8	4
Bryophyte	9	0
Fungi	1	13
Fungi	2	16
Fungi	3	13
Fungi	4	24
Fungi	5	16
Fungi	6	14
Fungi	7	24
Fungi	8	25
Fungi	9	13
Invert	1	23
Invert	2	21
Invert	3	23
Invert	4	35
Invert	5	29
Invert	6	25
Invert	7	44
Invert	8	35
Invert	9	14
Lichen	1	11
Lichen	2	14
Lichen	3	6
Lichen	4	5
Lichen	5	7
Lichen	6	9
Lichen	7	9
Lichen	8	8
Lichen	9	8

(1 = Lowland Scotland; 2 = Upland Scotland; 3 = Upland Northern England; 4 =Lowland Northern England; 5 = Upland Wales; 6 = Lowland Wales; 7 = Clay Southern England; 8 = Calcareous Southern England; 9 = Northern Ireland.)

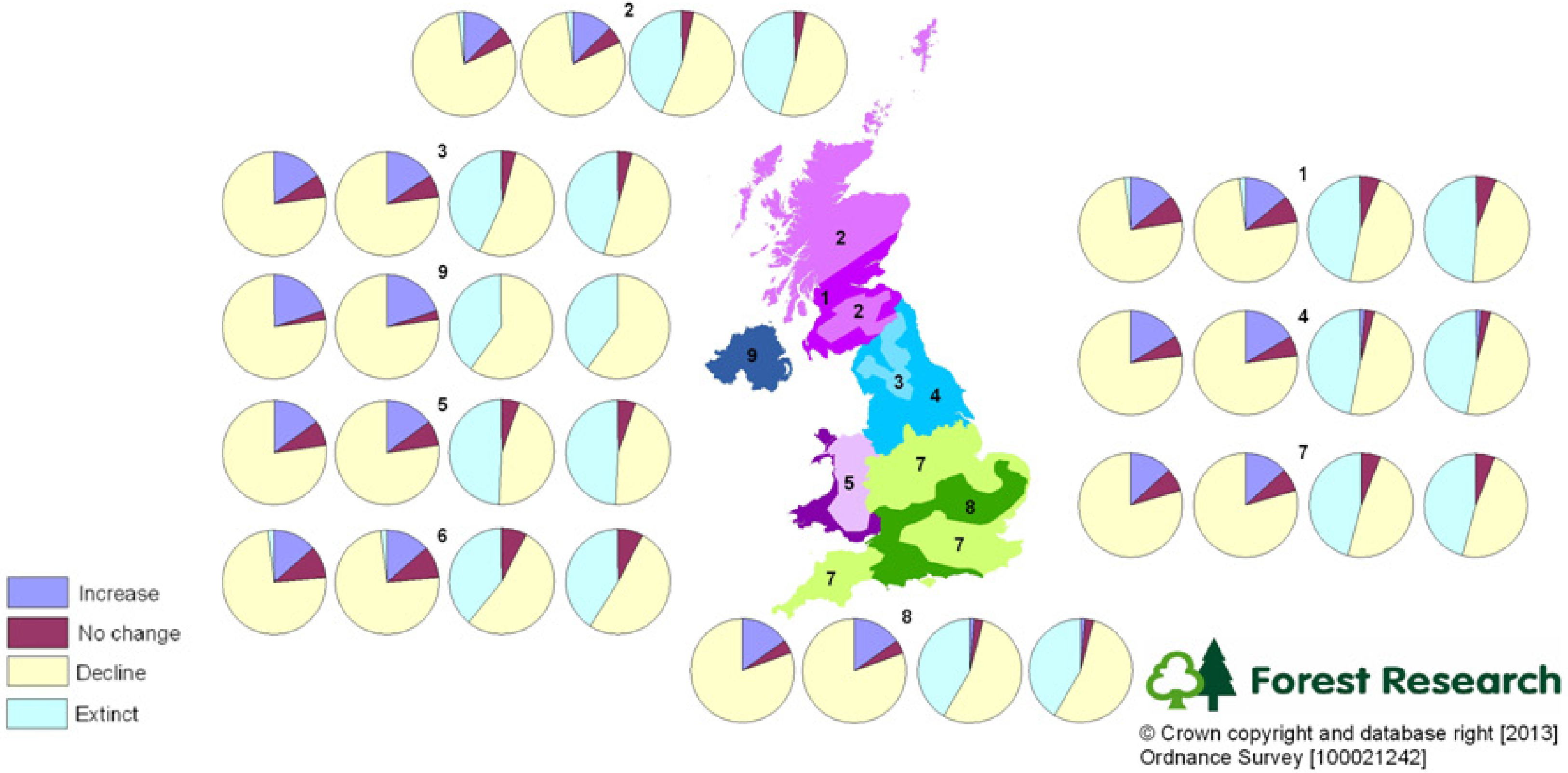

Figure 17.1. Projected response of ash obligate and highly associated species (overall for bryophyte, lichen, fungi and invertebrates), 1 to 10 years following the loss of ash in the nine sub-regions, with the effect of woodland management scenarios (1)–(4), left to right.
(1) – Non-intervention; (2) – No felling with natural regeneration promoted; (3) – Felling and no active management; (4) – Felling and replanting shown in pie-charts from left to right, respectively.

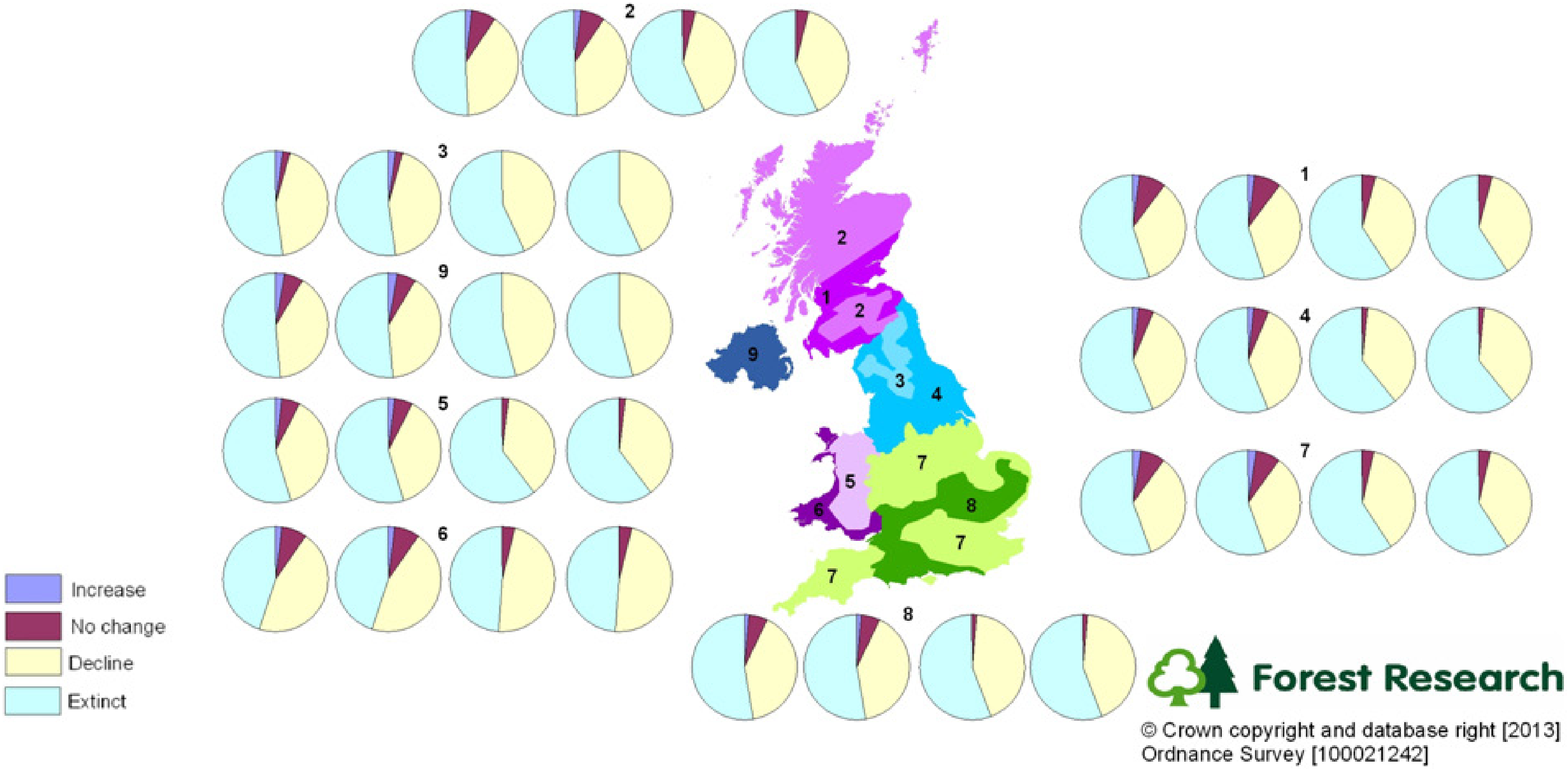

Figure 17.2. Projected response of ash obligate and highly associated species, 50 to 100 years following the loss of ash in the nine sub-regions, with the effect of woodland management scenarios (1)–(4).
(1) – Non-intervention; (2) – No felling with natural regeneration promoted; (3) – Felling and no active management; (4) – Felling and replanting shown in pie-charts from left to right, respectively.

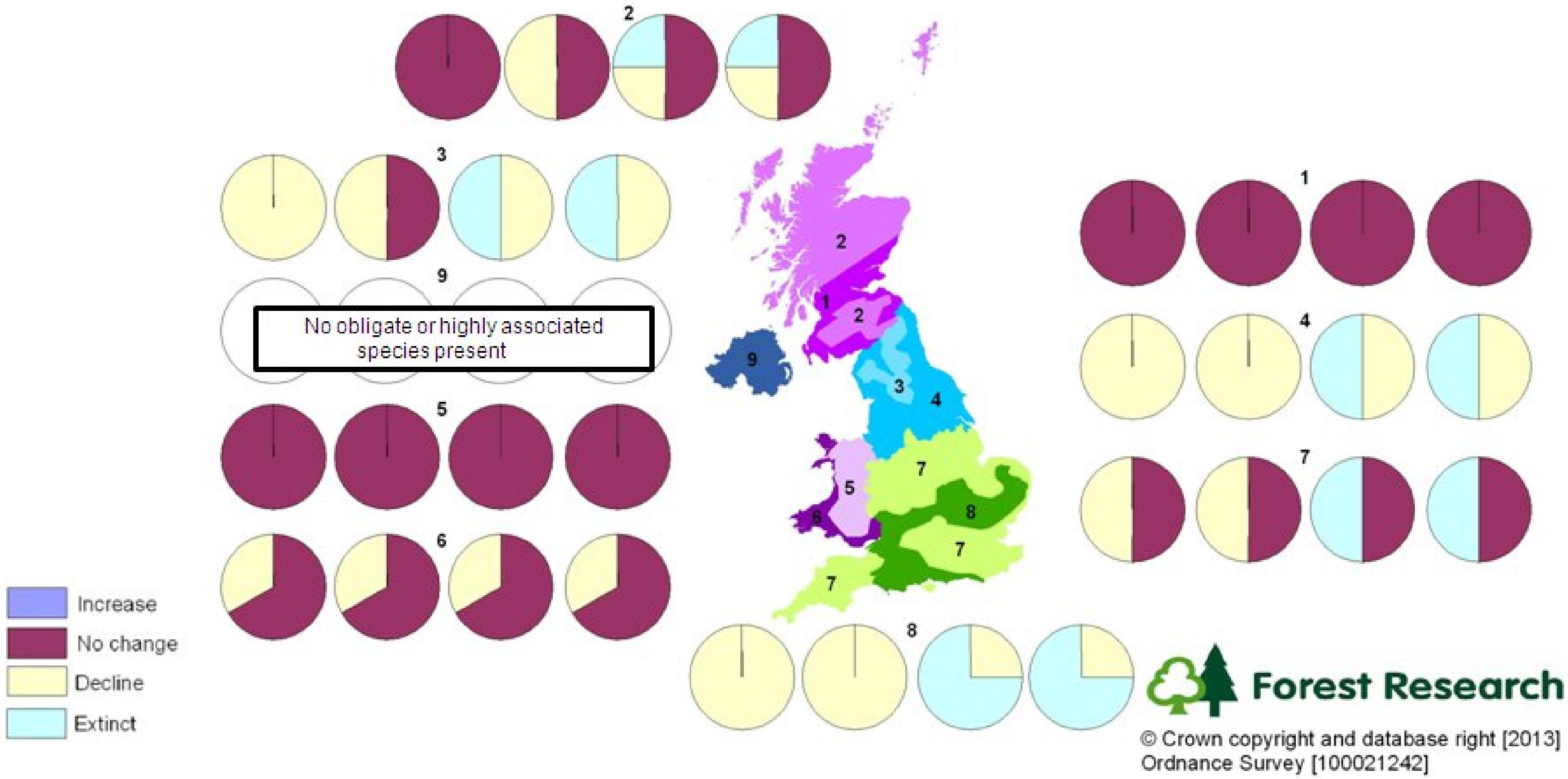

Figure 17.3. Projected response of ash obligate and highly associated bryophyte species, 1 to 10 years following the loss of ash in the nine sub-regions, with the effect of woodland management scenarios (1)–(4).
(1) – Non-intervention; (2) – No felling with natural regeneration promoted; (3) – Felling and no active management; (4) – Felling and replanting shown in pie-charts from left to right, respectively.

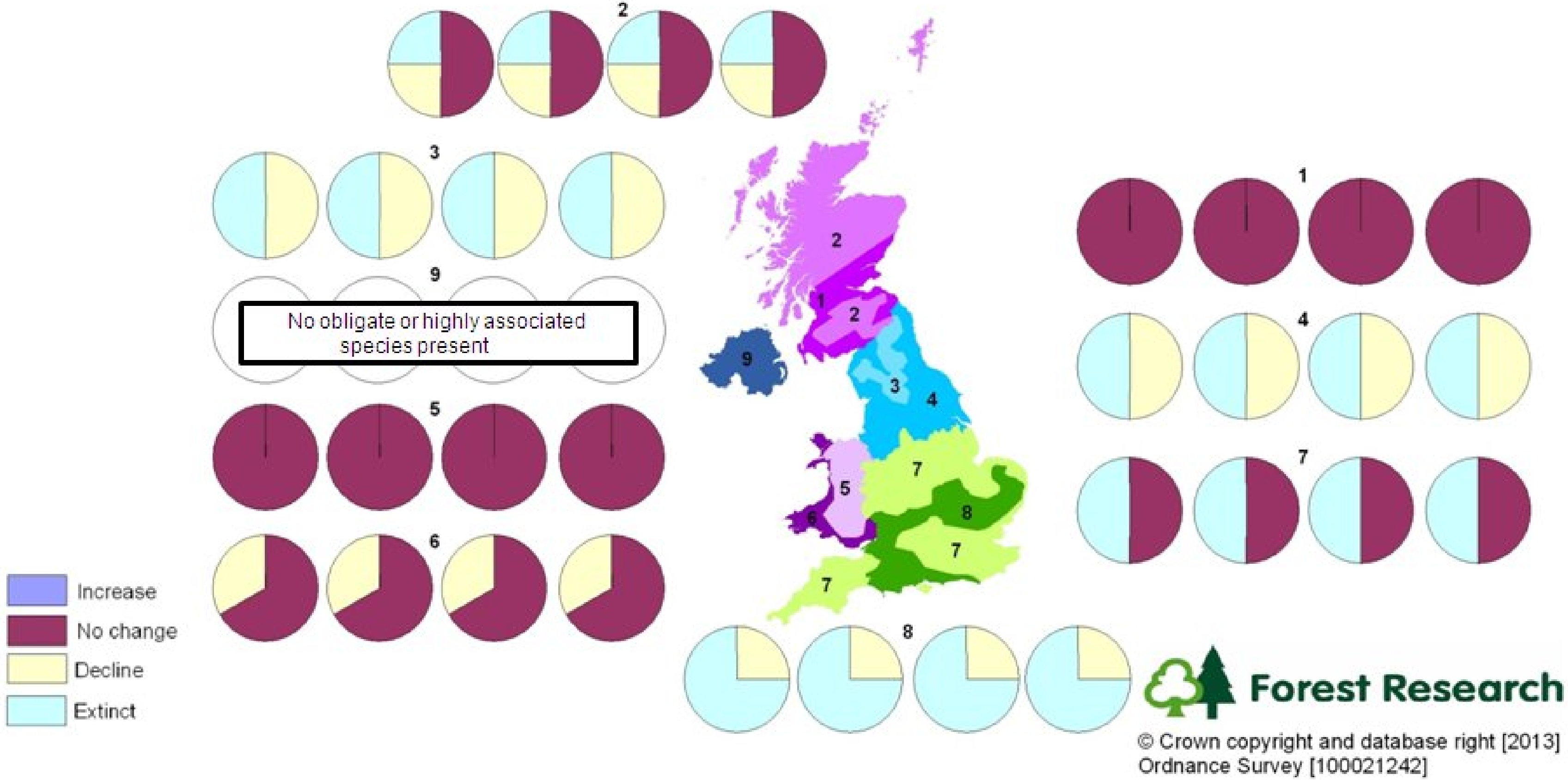

Figure 17.4. Projected response of ash obligate and highly associated bryophyte species, 50 to 100 years following the loss of ash in the nine sub-regions, with the effect of woodland management scenarios (1)–(4).
(1) – Non-intervention; (2) – No felling with natural regeneration promoted; (3) – Felling and no active management; (4) – Felling and replanting shown in pie-charts from left to right, respectively.

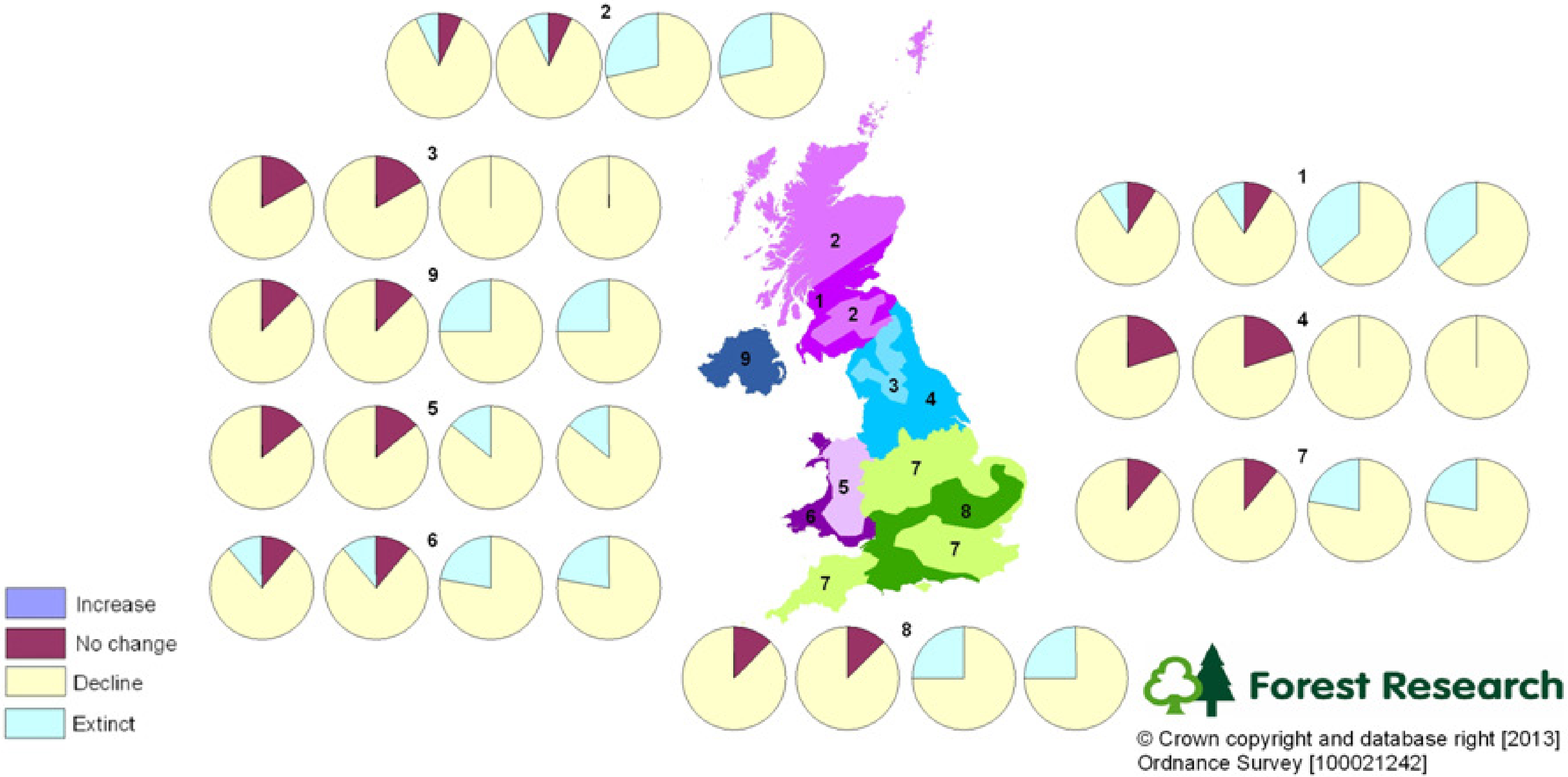

Figure 17.5. Projected response of ash obligate and highly associated lichen species, 1 to 10 years following the loss of ash in the nine sub-regions, with the effect of woodland management scenarios (1)–(4).
(1) – Non-intervention; (2) – No felling with natural regeneration promoted; (3) – Felling and no active management; (4) – Felling and replanting shown in pie-charts from left to right, respectively.

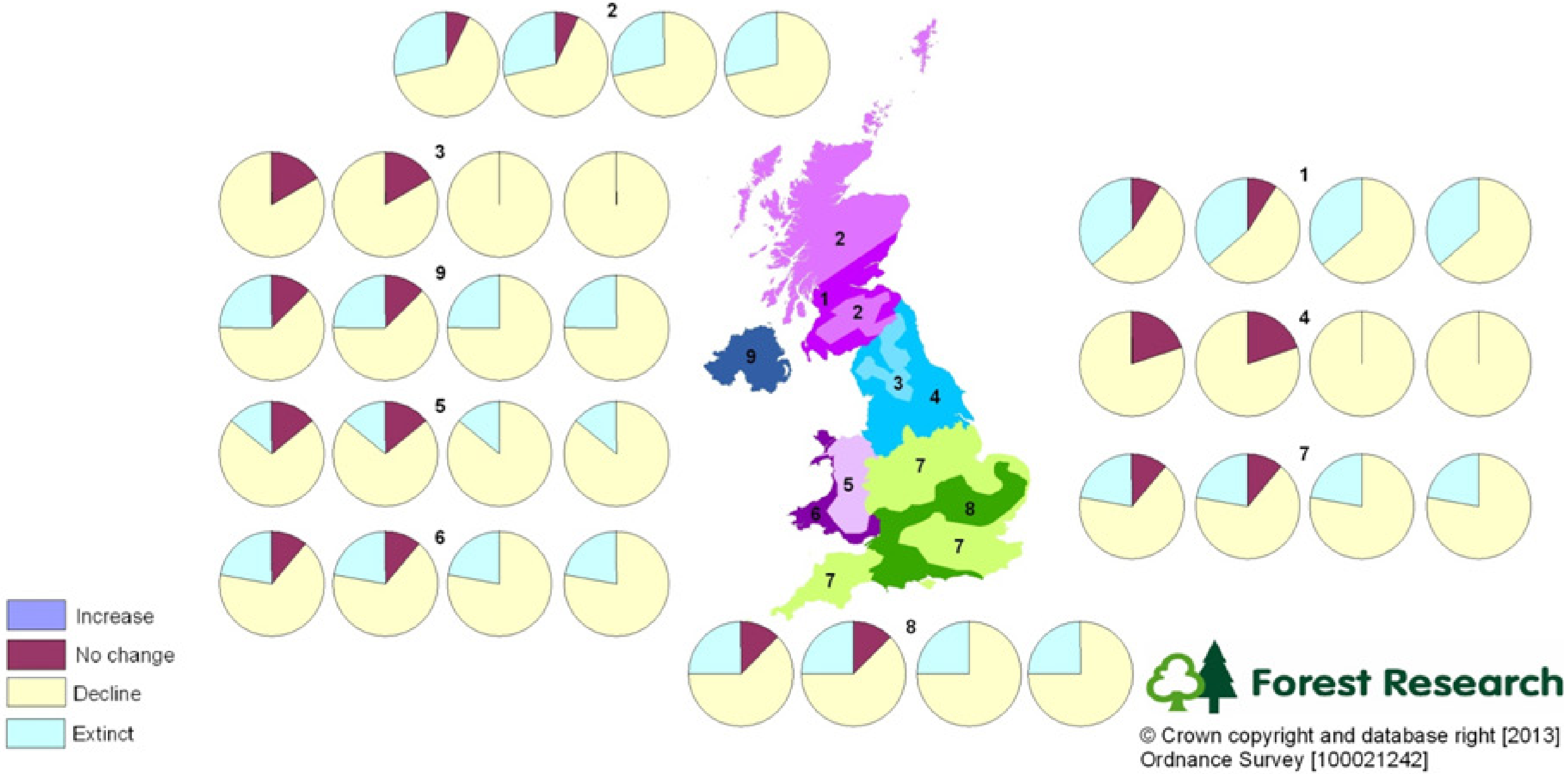

Figure 17.6. Projected response of ash obligate and highly associated lichen species, 50 to 100 years following the loss of ash in the nine sub-regions, with the effect of woodland management scenarios (1)–(4).
(1) – Non-intervention; (2) – No felling with natural regeneration promoted; (3) – Felling and no active management; (4) – Felling and replanting shown in pie-charts from left to right, respectively.

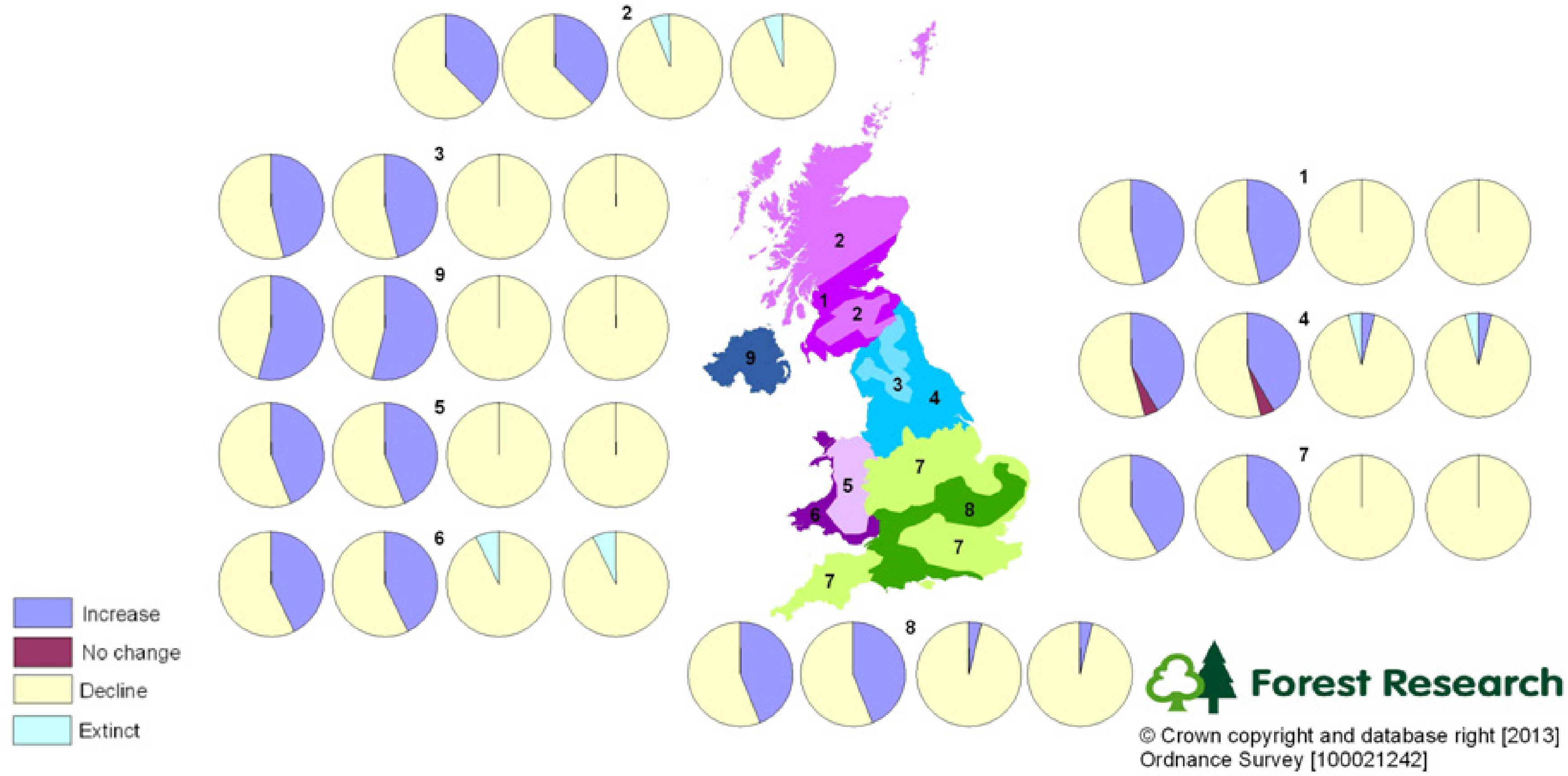

Figure 17.7. Projected response of ash obligate and highly associated fungi species, 1 to 10 years following the loss of ash in the nine sub-regions, with the effect of woodland management scenarios (1)–(4).
(1) – Non-intervention; (2) – No felling with natural regeneration promoted; (3) – Felling and no active management; (4) – Felling and replanting shown in pie-charts from left to right, respectively.

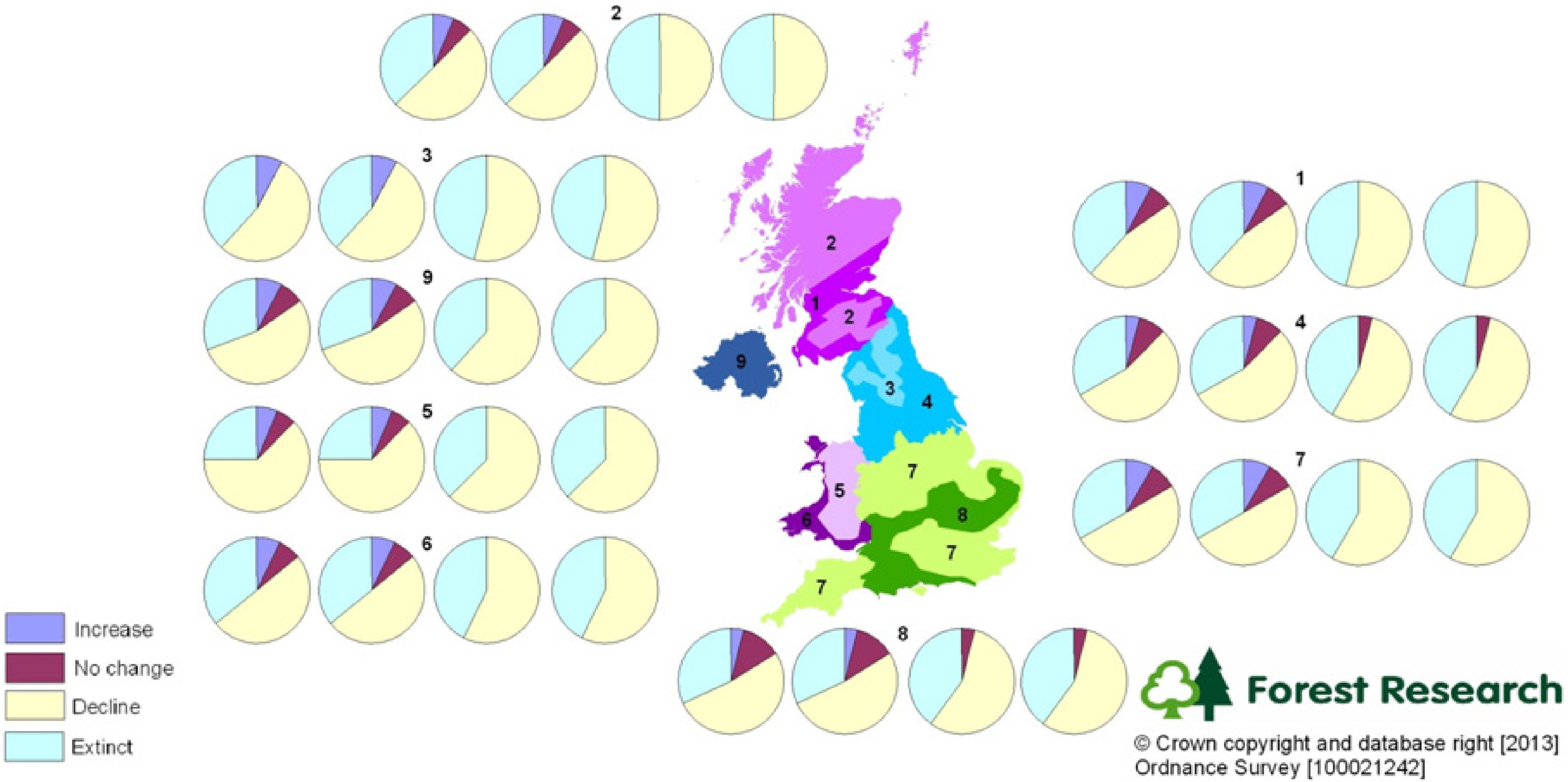

Figure 17.8. Projected response of ash obligate and highly associated fungi species, 50 to 100 years following the loss of ash in the nine sub-regions, with the effect of woodland management scenarios (1)–(4).
(1) – Non-intervention; (2) – No felling with natural regeneration promoted; (3) – Felling and no active management; (4) – Felling and replanting shown in pie-charts from left to right, respectively.

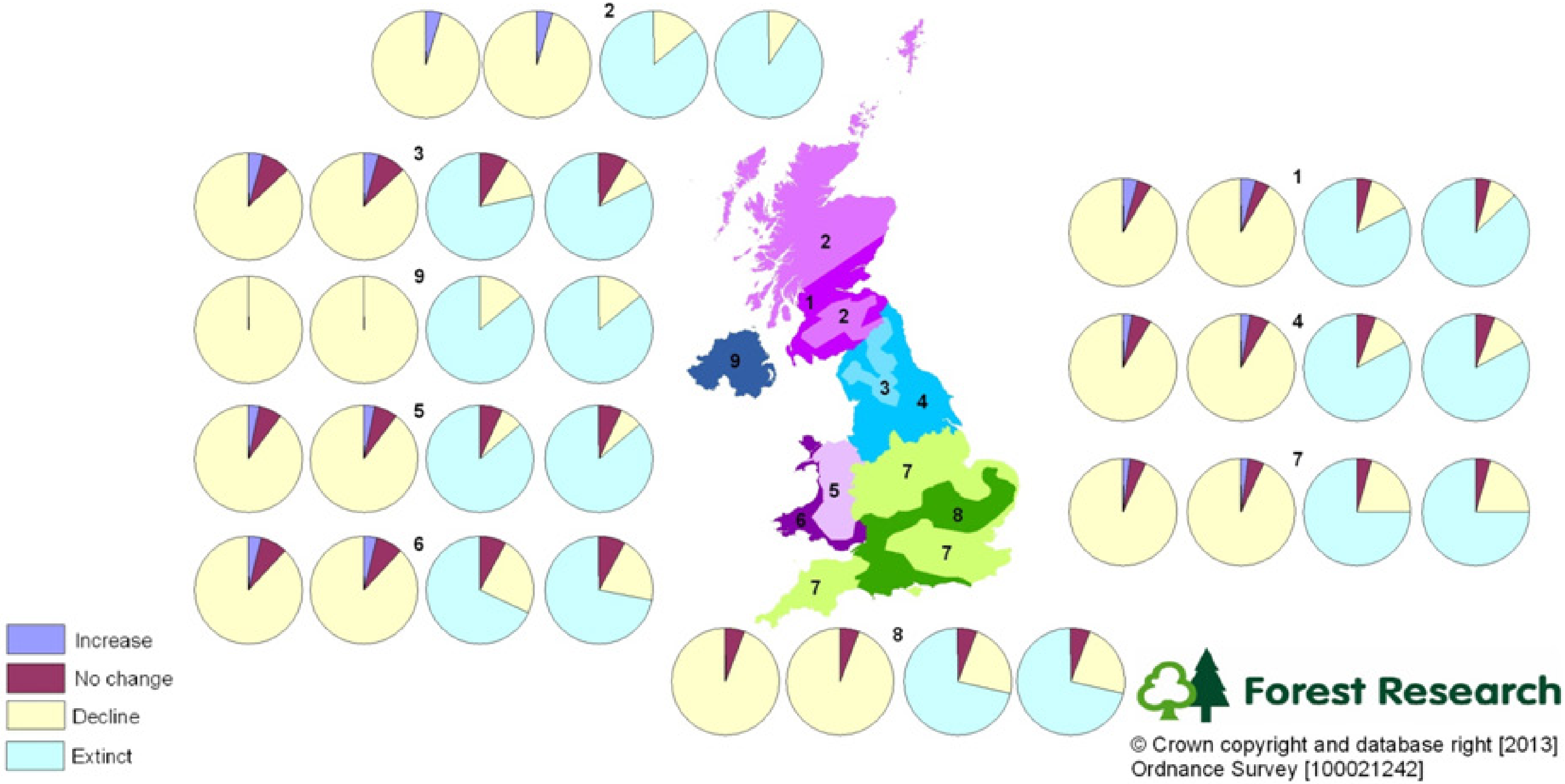

Figure 17.9. Projected response of ash obligate and highly associated invertebrate species, 1 to 10 years following the loss of ash in the nine sub-regions, with the effect of woodland management scenarios (1)–(4).
(1) – Non-intervention; (2) – No felling with natural regeneration promoted; (3) – Felling and no active management; (4) – Felling and replanting shown in pie-charts from left to right, respectively.

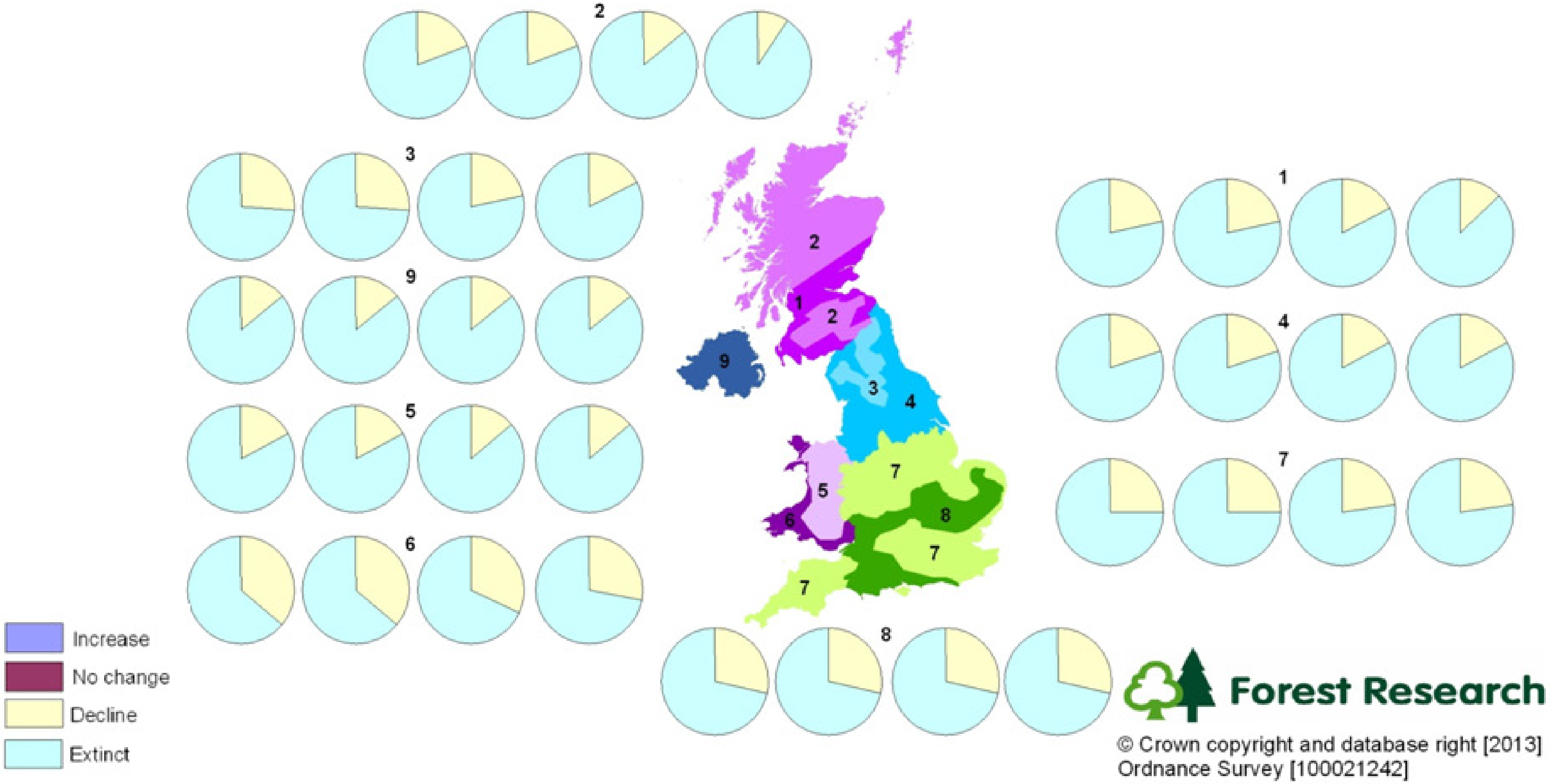

Figure 17.10. Projected response of ash obligate and highly associated invertebrate species, 50 to 100 years following the loss of ash in the nine sub-regions, with the effect of woodland management scenarios (1)–(4).
(1) – Non-intervention; (2) – No felling with natural regeneration promoted; (3) – Felling and no active management; (4) – Felling and replanting shown in pie-charts from left to right, respectively.

18 Discussion and Conclusions

Chapter summary

1. *This project has made a first attempt at prioritising which species are most at risk from ash dieback. This list could be used by conservation agencies to assess whether management might be altered to aid the survival of any Red- or Amber-coded species, and appropriate monitoring schemes can be put in place to assess the impact of ash dieback.*
2. *Leaving ash (living and dead) within ash woodlands rather than removing it is better for ash-associated biodiversity and will allow a longer time period for ash-associated biodiversity to colonize alternative hosts.*
3. *No single tree species will provide a suitable alternative for all ash-associated species but oak will support 69% of the ash-associated species identified.*
4. *Mixtures rather than a single species of tree replacing ash would support a much greater number and variety of ash-associated species than any single alternative tree species.*
5. *A mixture of oak and beech could support 74% of ash-associated species*
6. *A mixture of field maple, sycamore, birch, hazel, hawthorn, beech, poplar, bird cherry, oak, goat willow and small-leaved lime could support 84% of the ash-associated species.*
7. *The exact mixture of tree species considered best at any particular site to replace ash will depend on which ash-associated species are present on the site and the site suitability for the tree species concerned.*
8. *Tree species that create similar environmental conditions to ash (light levels of shade, high soil pH and rapid decomposition of leaf litter) are more likely to maintain species typical of ash woodlands (species associated with the woodland habitat but not necessarily the tree). Therefore if the objective is to manage the woodland for biodiversity, site managers should avoid replacing ash with species such as conifers which create very different environmental conditions.*

18.1 The importance of ash

Ash is a widespread tree within the UK occurring within woodlands, parks and gardens. Ash is more common, as assessed by a number of measures (area, percentage of woodland total, standing volume and number of trees) in Wales and the more southerly areas of England, than in Scotland, Northern England and Northern Ireland. The UK may be divided into nine 'ash relevant' regions, based on the amount of ash present, soils, climate and political boundaries.

Ash has a special place in the ecosystem function of woodlands, as it lies at the extreme end of the spectrum of UK tree species, with regards to the degradability of its litter. Ash withdraws relatively few nutrients from its leaves prior to abscission, and because both its leaves and roots are readily degradable, it accumulates relatively little litter and maintains a high nutrient turnover. It also results in a higher soil pH than other tree species. These characteristics strongly influence its ecology and drive its inter-relationships with other components of biodiversity, including the associated above- and below-ground species assemblages. The high carbon-cycling and soil respiration rates that are characteristic of ash systems are not conducive to accumulation of soil organic matter which can help to reduce atmospheric carbon dioxide. Ash often grows in association with other tree species, and any death of ash under these circumstances is likely to create fine-scale gaps within woodland, and replacement ultimately by another tree species is likely. The spatial distribution of dying and decaying ash will clearly impact on a wide range of above- and below-ground processes. A loss of ash and replacement with an alternative tree species is likely to lead to local soil acidification, although this may not represent an environmental issue, since ash often establishes on base-rich and fairly dry soils.

This work has identified 1,058 species associated with ash; this is composed of 12 birds, 55 mammals, 78 vascular plants, 58 bryophytes, 68 fungi, 239 invertebrates, and 548 lichens. Of the 55 mammals, 28 use the ash trees and the remainder use the ash woodland habitat. Vascular plants only use the ash woodland habitat, not the trees themselves. Forty-four species have been identified as obligate on ash: 11 fungi, 29 invertebrates and four lichens; and 62 species were classed as highly associated. While ash does not support the large numbers of some species groups (like invertebrates) compared with other tree species such as oak, its loss from the UK will impact on many species. Species of invertebrates, lichens and bryophytes are at most risk from ash dieback when assessed by the number of species affected. Using a combination of the conservation importance of the species and their level of association with ash, the species that use ash were classified as Red, Amber, Yellow and Green with respect to the likely impact of ash dieback (red meaning the species is likely to severely decline in population or become extinct, amber and yellow some impact and decline in population, to green, where ash dieback will have little impact). This gave 69 Red-coded species, 169 Amber-coded species, 383 Yellow-coded species and 330 Green-coded species.

Eight NVC sub-communities that are dominated by ash have been identified: W8d, W8e, W8g, W8a, W8b, W8c, W9a and W12a. Changes in light and soil moisture following the loss of ash from woodlands will be the primary drivers of change in the ground flora community. If the replacement tree species cast a heavier shade than ash (e.g. sycamore, yew, Douglas fir) light-loving species within the ground flora community will decline. If large gaps in the canopy open up as a result of the loss of ash, there is likely to be an initial increase in the diversity of shrubs and ground flora, until the canopy closes.

18.2 Alternative tree species

Twenty-two tree species were assessed as potential alternatives or replacements for ash: field maple, Norway maple, sycamore, alder, silver birch, downy birch, hornbeam, sweet chestnut, hazel, hawthorn, beech, aspen, wild cherry, bird cherry, Douglas fir, sessile oak, pedunculate oak, goat willow, grey willow, whitebeam, yew and small-leaved lime. These species may regenerate naturally or are suitable for planting on sites where ash currently grows. Douglas fir and sweet chestnut were included on the list for climate proofing (coping with possible climate climate), as they have been suggested as possible commercial alternatives to ash for timber.

Five different methods were used to assess similarities between these possible alternative trees and ash. Chapter 12 assessed the similarity based on 'species use': the level of use made by ash-associated species of these alternative tree species; and Chapter 15 assessed similarity based on 'traits': the similarity of the traits of the alternative tree species to those of ash. The results showing which alternative tree is most similar to ash depended on the method used to assess similarity (Table 18.1).

In terms of the number of ash-associated species supported, the top five most suitable alternative trees of those assessed (first column of Table 18.1) are oak, beech, sycamore, hazel and birch (in descending order of similarity). Using methods that evaluated similarity in terms of 'species use', sweet chestnut, Douglas fir and yew were identified as amongst the 'worst' alternatives to ash,' (first three columns of Table 18.1). Mixtures of tree species rather than a single species of tree were shown to support a greater number of ash-associated species. The exact mixture of tree species considered best at any specific site to replace ash will depend on which ash-associated species are present on the site and the site suitability for the tree species concerned.

When the measure of similarity is based on plant traits, multi-variate analysis of all traits showed that none of the 22 tree species were very similar to ash, although single traits of some of the alternative tree species matched ash. Alder and aspen were identified as the trees most similar to ash, while sweet chestnut and Douglas fir were the most dissimilar to ash. The meaningfulness of the trait-based similarity indices depends on whether the associated species is most reliant on the specific traits of the tree species (bark pH, fruit type etc.), in which case the similarity indices, or data on individual traits will help reflect this. Conversely, the trait-based similarity indices are likely to be less meaningful the species relies more on the habitat conditions created by the tree (shade, shelter, soil chemical properties), as they do not capture all these variables.

The most appropriate method (species use or traits) for identifying alternative trees to ash depends on the aims of the assessment. If the aim is identify alternative host trees for ash-associated species, for which information on their use of alternative trees is already available, then it is clearly better to use this information. When there is no information on the use of alternative tree species by ash-associated species, matching the traits of the alternative tree with ash may be the best solution available. In particular, when non-native trees which are not currently grown in the UK are considered as alternative trees, information on their use by ash-associated species in the UK is likely to be sparse or lacking. It is important to note that the traits used in these analyses largely describe the tree and its characteristics and the environmental conditions required by the tree (Ellenberg values), as opposed to the type of woodland that these tree species will produce. This is clearly seen with the example of yew which is assessed as having a similarity index of 0.747 yet will produce a very different woodland habitat from ash in terms of: angiosperm / gymnosperm; shade level and seasonality of shading; leaf litter; decomposition and associated ground flora, and has a very different complement of associated species.

Future work should distinguish between traits that relate to the species use of the tree (e.g. bark acidity), traits that that relate to the ecological functioning of the tree (e.g. leaf dry matter content) and traits that relate to habitat requirements of the tree (Ellenberg values). This should enable a better ‘matching’ of alternative trees by their traits.

Table 18.1. Comparison of different methods to assess the similarity of alternative tree species to ash.

Rank of similarity	Number of ash-associated species known to use the alternative tree species[1]	Number of ash-associated species that are known not to use the alternative tree species[1]	Similarity index based on the level of association with the alternative tree[2]	Traits: Analysis 1[3]	Traits: Analysis 2[4]
Most similar to ash	Oak	Goat willow	Oak	Alder	Alder
	Beech	Grey willow	Alder	Aspen	Aspen
	Sycamore	Small-leaved lime	Beech	Hazel	Yew
	Hazel	Norway maple	Aspen	Yew	Hazel
	Birch	Oak	Sycamore	Hornbeam	Beech
	Alder	Douglas fir	Hornbeam	Sycamore	Sycamore
	Aspen	Sycamore	Birch	Beech	Hornbeam
	Hawthorn	Beech	Hazel	Field maple	Silver birch
	Field maple	Hazel	Hawthorn	Wild cherry	Downy birch
	Hornbeam	Birch	Small-leaved lime	Bird cherry	Wild cherry
	Sweet chestnut	Alder	Field maple	Norway maple	Norway maple
	Wild cherry	Aspen	Norway maple	Pedunculate oak	Field maple
	Goat willow	Hawthorn	Grey willow	Silver birch	Bird cherry
	Whitebeam	Field maple	Wild cherry	Downy birch	Goat willow
	Bird cherry	Hornbeam	Sweet chestnut	Goat willow	Sessile oak
	Grey willow	Whitebeam	Goat willow	Sessile oak	Whitebeam
	Small-leaved lime	Sweet chestnut	Whitebeam	Grey willow	Small-leaved lime
	Yew	Wild cherry	Yew	Whitebeam	Pedunculate oak
	Norway maple	Bird cherry	Bird cherry	Hawthorn	Hawthorn
Least similar to ash	Douglas fir	Yew	Douglas fir	Small-leaved lime	Grey willow
				Douglas fir	Sweet chestnut
				Sweet chestnut	

[1]See Figure 12.4 for further details; [2]see Table 12.6 for further details; [3]see Table 15.3 for further details; [4]see Table 15.4 for further details

18.3 Dynamics of ash woodland vascular plant communities

Ash is dominant in eight NVC communities: W8a, W8b, W8c, W8d, W8e, W8g, W9a and W12a. The impact of the loss of ash on the vascular plant species within these communities will depend on changes in light levels, moisture and nutrient cycling and which tree species replace ash. In addition other factors such as site management and herbivory levels will also influence changes. For each community, predictions based on expert opinion and ecological information were made about the changes in vegetation following the loss of ash.

Regional differences in the response of tree and ground flora of woodland communities following the loss of ash were assessed. These predictions assumed natural regeneration was unhindered and sites were not modified beyond that caused by the dying of ash trees. For woodlands where ash currently occupies less than 10% of the canopy, the other tree species currently forming the main canopy cover are expected to grow and fill the spaces left by any dead ash, resulting in little new recruitment of trees or expansion of the shrub layer. Shade-tolerant shrubs already present in the understorey may grow to fill gaps in woodlands containing 10 to 20% ash in the canopy. This response is anticipated in three quarters or more of the current ash-containing woods in Scotland, Northern England and Northern Ireland.

For woodlands where there is a greater component (>20%) of ash in the canopy, canopy gaps are anticipated to be larger and/or more frequent. Under these conditions, existing shrubs and particularly saplings are expected to fill the spaces in the canopy in addition to some expansion by other existing canopy tree species. Over a longer time-period, established saplings will replace shrubs and fill the canopy gaps. Sycamore is predicted to become particularly dominant in many of the sub-regions in this regard. Beech and small-leaved lime may form larger components in ‘former’ ash woodlands in southern England.

18.4 Management scenarios and their impacts

This project identified six management scenarios that are likely to occur following ash dieback: (1) – non-intervention; (2) – no felling with natural regeneration promoted; (3) – felling; (4) – felling and replanting; (5) – thinning; (6) – felling with natural regeneration promoted. The work identified the vegetation that is likely to result from each of these management scenarios in two time frames (1-10 years and 50-100 years). The impact of a predicted change from the current ash woodland habitat as a result of the management scenarios is assessed for all species that were identified as obligate or highly associated with ash.

Overall, management scenarios (1) (non-intervention), and (2) (no felling with natural regeneration promoted), are predicted to be better for ash-associated biodiversity in the short term, as they retain the ash and dead ash in the woodland for longer compared to management scenarios (3) (felling) and (4) (felling and replanting). Species that utilise deadwood (fungi and some invertebrate species) may initially increase in population in the first 1–10 years under scenarios (1) and (2), due to an increase in the availability of deadwood. However, after 50–100 years they are predicted to have decreased in population compared to current levels. After 50–100 years there is generally little difference between the four management scenarios in terms of their impact on obligate and highly associated species, with most species declining or becoming extinct. Greater differences between the management scenarios may be seen if future work also assesses the impact of these scenarios on partially associated species. There was little regional variation in the predicted impact of the management scenarios for most species groups.

18.5 Future work on species associated with ash

This project was conducted within a limited time-period: 5 weeks. As such there were limitations as to what could be achieved. Future work to extend this project further includes:

- The list of Red-, Amber-, Yellow-, and Green-coded species with respect to ash dieback provided in Chapter 12 and Appendix 2 is provisional, and should be reviewed and updated by species experts.
- The large data gathered in the database of species that use ash, could be further interrogated.
- Access to the NFI sample square data for all tree species and ground flora species would allow a far more accurate analysis of response and succession to be modelled for responder trees and shrubs in Chapter 14. This would also allow fairly reliable estimates of canopy composition and the calculation of Ellenberg number for light under canopy (Hill *et al* 1999). This would improve on the broad, shade-changing rules used in this analysis. Further, the availability of the NFI sample square ground flora data would facilitate the analysis of spatial congruence between existing canopy species, likely responder plants and species of ground flora tree species, across a large sample of woodlands in Britain.
- Deciding on whether ground flora species would be lost due to a change in light levels, or indeed if they had the potential to re-colonise had they been lost, was not considered within Chapter 14. A review of empirical evidence would be needed on plant responses to changes in shading over long time-periods before meaningful estimations of change could be made.
- Deciding on whether ground flora species would be lost due to competition between species could be a useful additional analysis in Chapter 14. This might be achieved through an analysis of C-S-R classes from Grime *et al* 2007.
- With the exception of ground flora species and a few mammals, the potential impacts of ash dieback on species found in ash woodlands but not directly associated with ash trees was not assessed. These species may be impacted by changes in light levels, litter quality, humidity or changes in the ground flora composition following an opening up of the canopy if ash is lost. Further work could try to assess these impacts, although likely complex, multiple interactions may make predicting outcomes difficult and data for many faunal groups is likely to be sparse.
- Analysis of the management scenarios (5) (thinning), and (6) (felling with natural regeneration promoted) would be useful. From this project we have learnt that, at present, ash occurs mostly as a small and scattered component of other woodland types in the UK. The application of management scenario (5) would create conditions most like those which would be created by removal of diseased and dead trees from most of its UK range. Scenario (6) considers the impacts of the intervention that are most likely to create successful regeneration. In most ash woods, removal of ash would only create small gaps, and 'management for' regeneration under this scenario would necessarily include enlarging gaps. Further, the removal of the overstorey all at once would allow regeneration to establish and grow when the ground vegetation is still somewhat suppressed. These conditions are more likely to favour regeneration than those created by scenario (2), (no felling with natural regeneration promoted) where management for regeneration is promoted through, for example, weed control and grazing/ deer browsing management.
- Further work on assessing the impacts of management scenarios should include both conditions of <20% and >20% ash in canopy on habitat response. Considering only one proportion of ash in the canopy class per region, as currently done in Chapter 16, may not accurately reflect conditions within each of the sub-regions because there are some woodlands where ash is more dominant or where it occurs at a lower cover.

- The impact of the management scenarios should be assessed for those species highly (Chapter 17) and partially associated with ash, with obligate species excluded from the analysis. Understandably, obligate species fare better under the management scenarios which retain the ash for longer but their inclusion in the analysis perhaps masks the value of the other management scenarios to the highly/partially associated species. It would be valuable to know which management scenario would be of most benefit to highly/partially associated species, assuming that ash and its obligate species will eventually be lost from the UK.
- The predictions of species responses to ash dieback, and to the various management scenarios, took no account of climate change, except that tree species suggested for planting were selected on the basis of their suitability under future climates for the different sub-regions and site types. Future work could incorporate the impacts of climate change into the predictions.
- Changes in the abundance of ash may mean that its importance is under- or over-emphasised when seen in a longer-term perspective. Future work could assess likelihoods of longer-term changes in ash populations to take this into account.
- This report did not cover the impacts of ash dieback on ash trees themselves (e.g. the extent of dieback within a tree, the proportion of affected trees, etc). Other projects are currently assessing this. This information could be combined with the information in this report to provide more detailed predictions of the likely impacts of ash dieback on ash-associated species if a proportion of ash trees survive ash dieback. More detailed information on the likely proportion of surviving ash trees could be used to assess which associated species might be more or less severely affected than the general assessments made here.

18.6 Future work on ash woodland habitats

Monitoring the impact of the loss of ash on changes in woodland composition and structure as well as on selected species will enable better predictions to be made about the impact of ash dieback. It will also enable explanations for recorded changes in species composition/abundance/distribution and will enhance our knowledge of woodland ecology. Other studies are currently identifying suitable monitoring programmes to assess the impact of ash dieback on woodlands/hedgerows and ash-associated biodiversity.

18.7 Ash resistance and other ash diseases

The medium and long-term impacts of ash dieback in the UK are unknown. Throughout this report we have assumed a worst case scenario, based on experiences in parts of continental Europe where this disease has already spread widely infecting a high proportion of ash. However, it is important to be aware that the UK may not follow a similar pathway, for example if some ash are resistant to the disease and survive (there is currently extensive research to identify ash-resistant varieties).

The actual extent and severity of ash dieback will clearly alter the impacts of ash dieback on ash-associated biodiversity as predicted in this report. Any ash trees that are resistant to ash-dieback may still be susceptible to other diseases. It is therefore essential to examine broad-based resistance to a range of pests and pathogens in order to successfully manage and minimise future losses.

The emerald ash borer, *Agrilus glabripennis*, a bark borer of Asian origin, has already invaded North America where up to 100 million ash trees have been killed. Ash species planted in central and southern America are severely damaged by ash yellows, a phytoplasma disease. Attempts to select genotypes of European ash showing resistance (or tolerance) to ash dieback may prove fruitless if other diseases also hit this species; it is therefore essential to examine broad-based resistance to a range of pests and pathogens in order to successfully manage and minimise future losses.

18.8 Future work on other tree species

The problem of ash dieback has raised awareness of alien invasive pests and pathogens that are threatening the integrity of forest ecosystems in the UK. The fungus responsible for causing ash dieback, Chalara (*Hymenoscyphus pseudoalbidus and Chalara fraxinea)* is not the only pathogen that is present in the UK that is having a major impact on our trees. Further alien invasive threats currently present in the UK include several species of *Phytophthora*, particularly *P. quercina* causing chlorosis and dieback of oaks (Cooke *et al* . 2005); *P. cambivora* attacking several tree species, but notable in affecting beech; *P. alni*, causing severe dieback of riparian *Alnus glutinosa*; and *P. austrocedrae*, which is threatening the survival of our rare juniper heaths in northern Britain (Green *et al* 2012). *P. ramorum* and *P. kernoviae* are well-known pathogens, and, apart from affecting larch and many ornamental plants, may also infect and kill native species, such as oak, beech and species of *Vaccinium*. Other species of *Phytophthora* are also present in the UK and causing damage, although some appear to be affecting only introduced woody plants (Brasier 2008).

In addition to the Oomycota, a number of true fungi have become established in the UK and are causing dieback problems on native woody plants. The most obvious amongst these species are the long-known *Ophiostoma novo-ulmi*, which is still active in the small populations of elm extant in northern Britain (Brasier 1996), and *Dothistroma septosporum*, which is proving highly aggressive on some planted species of pine (*Pinus contorta*, *P. nigra* var. *maritima*), and is now widespread in the native Scots pine in parts of Scotland, presumably where *Dothistroma* spore loads have reached threshold densities at which infection of this iconic tree occurs (Brown *et al* 2003). Both oak species native in the UK face a range of problems in addition to the threats from *Phytophthora* species. Acute oak decline, a syndrome of unknown cause, is increasing (Denman *et al* 2010). The oak processionary moth, *Thaumetopoea processionea*, is present in the south-east of England, and the range is expanding northwards and westwards.

Box, a native woody plant in the south of Britain, is severely defoliated and sometimes killed by box blight, caused by *Cylindrocladium buxicola* (Brasier 2008).

Although the UK is already facing up to 10–11 epidemics from alien invasive pests and pathogens, further potentially damaging invasive species are present elsewhere in Europe that almost certainly will enter Britain in the near future. Several examples have the ability to cause immense damage to Scots pine. *Fusarium circinatum* (teleomorph = *Gibberella circinata*), cause of pine pitch canker, is thought to be native to Mexico (Wingfield *et al* 2008), but over the last 50 years it has spread widely in many pine-growing areas of the world, including North and South America, Japan, the Republic of Korea, and South Africa (Wingfield *et al* 2008). Recently, a dieback of *Pinus radiata* in plantations in northern Spain was confirmed as *F. circinatum* infection (EPPO 2005; Landeras *et al* 2005), and the disease has also affected native *P. pinea* in that region, and subsequently in Portugal (Bragança *et al* 2009; EPPO 2009a,b). The discovery of this same disease in France in 2005 (EPPO 2005), and in Italy in 2007 (Carlucci *et al* 2007) lead to rapid eradication programmes which, to date, appear to have been successful (EPPO 2009a,b). A major factor in the spread of this pathogen, however, is that it can colonise seed of pine and Douglas fir (also a susceptible host; Viljoen *et al* 1994): this is the most likely pathway via which this highly damaging pathogen will enter the UK. Scots pine is highly susceptible to infection by *F. circinatum* (Perez-Sierra *et al* 2007).

Scots pine also faces the threat of pine processionary moth (*Thaumetopoea pityocampa*), a Mediterranean species, the range of which has been expanding rapidly over the last 25 years (Battisti *et al* 2005). Furthermore, pine wood nematode, *Bursaphelenchus xylophilus*, is present in Portugal and Spain, and may spread within Europe, in the absence of very strict quarantine actions. Although *B. xylophilus* is unlikely to kill pines in the UK, due to the temperature requirement for mortality to affected trees, if it were to infect UK pines, the transport and export of pine timber would be banned, resulting in great economic losses to the forest industry.

Many further species of *Phytophthora* with the capacity to cause severe damage in forest ecosystems are also present elsewhere in Europe and, without sufficient care in the distribution of live plant material, will enter the UK.

This brief summary of the actual and potential problems caused by alien invasive pests and pathogens to trees illustrates the need to expand the review of all organisms associated with *Fraxinus* to other tree species native to Britain. If the ecological function of these tree species and the species that are highly dependent on them are identified prior to the arrival of diseases, it may be possible to identify management strategies to aid the conservation of the most threatened species in the unfortunate event that these tree diseases do establish in the UK.

18.9 Conclusions: Ash dieback - conservation and management implications

- This report was produced in a limited time period (6 weeks) and represents the best evidence available at this time of the potential impacts of ash dieback on ash-associated biodiversity. It assumes that the impact of ash dieback in the UK will be similar to that in the rest of Europe with a high (>95%) loss of ash. This may not happen and the actually impact will depend on the extent and severity of ash dieback.

- This project represents a first attempt at prioritising, which species are most at risk from ash dieback in the UK. This list (Appendix 2) can be used by conservation agencies to assess whether management options to aid the survival of any Red- or Amber-coded species, and appropriate monitoring schemes can be put in place now to assess the impact of ash dieback as it spreads.

- Leaving ash (living and dead) within ash woodlands, rather than removing it, is considered to be better for ash associated biodiversity and will allow a longer time period for ash-associated biodiversity to colonize alternative hosts in the vicinity.

- Of 22 tree species assessed, no single tree species is considered able to provide a suitable alternative for all ash-associated species as well as ‘matching’ ash in terms of ecological function and plant traits.

- Oak will support 69% of the ash-associated species identified. In terms of the number of ash-associated species supported, the top five alternative tree species from those studied were: oak, beech, sycamore, hazel, and birch. However, this ranking takes no account of the ecological functions or traits of the trees, which could impact ground flora and other woodland characteristics.

- Establishing mixtures of tree species rather than a single species of tree in place of ash would support a much greater number and variety of ash-associated species than any single alternative tree species. For example, a mixture of oak and beech could support 74% of ash-associated species identified, and a mixture of field maple, sycamore, birch, hazel, hawthorn, beech, poplar, bird cherry, oak, goat willow and small-leaved lime could support 84% of the ash-associated species identified.

- If the aim is to conserve ash-associated biodiversity, the species or mixture of tree species considered most suitable to replace ash will vary between sites depending on which ash-associated species are present on the site and the site suitability for different tree species.

- Tree species that create similar environmental conditions to ash (light shade, high soil pH and rapid decomposition of leaf litter) are more likely to maintain species typical of ash woodlands (species associated with the woodland habitat but not necessarily the tree). Therefore, if the objective is to manage the woodland for ash-associated biodiversity, we recommend that site managers should avoid replacing ash with species such as conifers which create very different environmental conditions.

- A second phase of this project is currently underway (due to complete in spring 2014). One of its’ important outputs will be a series of case studies applying the knowledge gained of ash alternatives to management solutions in real woodlands. This will help woodland managers to make considered decisions and take action to mitigate the impacts of ash dieback on woodland ecology and biodiversity.

19 References

Note: References used to assess the association of species with ash and to complete the tables within the database are cited within the database, and are only listed below if they are also cited within the written report.

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20 Appendix 1 Database structure

20.1 Main tables

The tables within the database that contain the information gathered as part of Chapters 4–11 are shown in Table 20.1. All other tables/queries should not be altered, as they are working tables to create the final database. This was necessary in order to collate multiple excel spreadsheets from multiple uses, and to split various worksheets into different database tables. The tables/queries listed in Table 20.1 are also available as separate Excel worksheets. All the key information from these tables can be seen as one large table combined within the Access database by using the query All_sp. However, when using the database and developing additional queries it is recommended to use the separate tables listed in Table 20.1 joined by their relationships within the database.

Table 20.1. Tables and queries within the database.

Table/query title	Description of contents
Age	Age of tree used
Age list	Definitions of categories used in age table
Alternative	Plant species also used by species that use ash
ES_list	Definitions of ecosystem services
ES	Ecosystem services provided by species that use ash
Management_scenarios	The impact of the management scenarios on all obligate and highly associated species
Part_list	Definitions of the categories used in the Part table
References	References used during construction of the database
Ref_conn	Lists all species in database with a reference i.d. which links to the references table
Species	Species that use ash, their association with ash and conservation status
Species_all	Unique species code which links to the species table and references
Time	Time of year ash used
Time_list	Definitions of categories used in Time table
Treeform	Form of tree used such as pollard, coppice or natural
Treeform_list	Definitions of categories used in Treeform table
Use	Use made of ash tree
Use_list	Definitions of categories used in Use table
Woodland	The type of woodland or non-woodland that the species uses
Woodland_list	Definitions of categories used in Woodland table

20.2 The database structure

All records are linked to the Species table by the Latin species name. The relationship between the different tables is shown in Figure 20.1

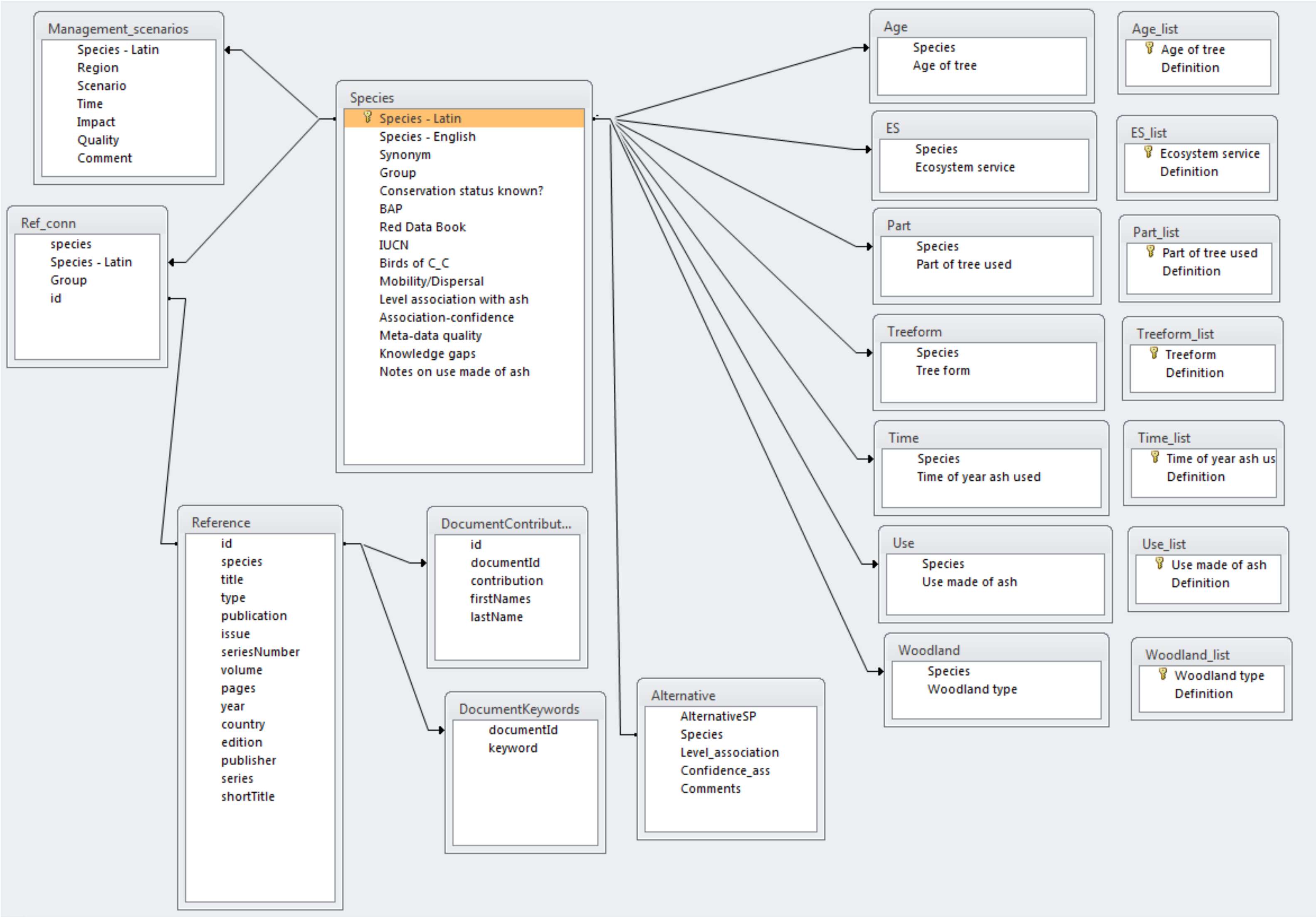

Figure 20.1. Relationships between the tables in the database.

20.3 Definitions of all values in database

Table 20.2. Definitions of values used in Age table.

Value	Definition
All trees	All live trees of any age excluding seeds and dead trees.
Ancient	Large girth (over 3m or a DBH of 100cm for Fraxinus excelsior, taking into consideration environmental conditions), past biological maturity and in the final, often longest, stage of life. Usually have a retrenching crown as a key feature and numerous 'Veteran' features.
Dead	Whole tree dead.
Mature	More than 2m in height and under 3m in girth (a DBH of 100cm).
Notable	Large girth (over 3m or a DBH of 100cm for *Fraxinus excelsior*, taking into consideration environmental conditions) but with no visible veteran features (see 'Veteran' definition for list of these). If information is only available that species occurs on trees >3m girth, record as 'Ancient', if you are able to be more specific about the use of 'Veteran' and 'Ancient' trees listed below, then include these ages as well.
Pole	>2m height, younger than 50 years.
Sapling	Under 2m in height.
Seed	Seed.
Seedling	1 year old or less.
Unknown	No specific information available on the age of tree used.
Veteran	Large girth (over 3m girth or a DBH of 100cm for *Fraxinus excelsior*, taking into consideration environmental conditions) with at least three 'Veteran' attributes (e.g. important habitats visible such as deadwood in the trunk, contain standing deadwood, have fallen wood around base, rot holes, water pockets, seepage lines, hollows in trunk or major limbs, etc.).
Woodland	Uses the woodland habitat not specific trees.

Table 20.3. Definitions used in Alternatives table.

Value	Definition
Obligate	Only uses this plant species*
High	Rarely uses plant species other than this tree species
Partial	Uses the alternative more frequently than its availability
Cosmopolitan	Uses the alternative as frequently or lower than availability
Rare	Has been recorded on the alternative but only rarely
Uses	Uses the alternative but its importance is unknown
Likely	Used for cosmopolitan invertebrates where the literature states that the species uses a wide range of food sources but no information is available on whether it actually uses this particular tree species. It is thought likely that is uses the species
Parasitoid	The species is parasitic on a species that uses ash, but is also parasitic on a range of other species. It was beyond the scope of this project to assess all the other food plants used by all the other hosts the parasite uses
Unknown	Not known if the species uses this alternative
No	The species does not use this alternative species

*Generally not applicable for assessment of use made of alternative plant species but was used occasionally for lichens – see Chapter 6 for explanation.

Table 20.4. Definitions of values used in ES (Ecosystem Services) table.

Value	Definition
Decomposition	The species is involved in decomposition
Dispersal-seeds	The species disperses seeds
Nutrient cycling	The species is involved in nutrient cycling
Pollination	The species is involved in pollination
Provisioning	The species provides humans with food (berries/fungi/meat)

Table 20.5. Definitions of values used in Part table.

Part of tree used	Definition
Bark	Species uses the bark of the tree
Canopy	Species uses the canopy of the tree
Dead wood	Species uses deadwood within the tree which may be alive or dead (see age of tree)
Flowers	Species uses the ash flowers
Leaves	Species uses the ash leaves
Limbs/branches/twigs	Species uses the limbs, branches and twigs of the ash trees
Litter	Species uses the litter (dead leaves on woodland floor)
Roots	Species uses the ash roots
Seeds	Species uses the ash seeds
Shoots	Species uses the ash shoots
Trunk	Species the trunk of ash trees
Woodland	Species uses the ash woodland habitat but not specifically the tree

Table 20.6. Definitions of values used in Time table.

Value	Definition
All year	All year
Autumn	September, October, November
Spring	March, April, May
Summer	June, July, August
Winter	December, January, February

Table 20.7. Definitions of values used in Treeform table.

Value	Definition
All	All growth forms
Coppice	Coppiced trees
Natural	Not managed by copping or pollarding
Pollard	Pollarded trees

Table 20.8. Definitions of values used in the Use table.

Use made of ash	Definition
Feeding - direct	Eats part of the ash
Feeding - indirect	Eats another organism found on the ash
Habitat - living space	Uses the ash as a habitat in which to live (e.g. epiphytes, bird nest holes, etc.)

Table 20.9. Definitions used in the Woodlands table.

Woodland type	Definition
Ancient woodland	An ancient system of land-use in which domestic animals were grazed within woodland or under widely scattered trees. The trees were often pollarded.
Non-woodland	Single trees, hedges.
Not restricted	All types of woods and single trees.
Recent woodland	Includes woodland established since AD1600 that have regenerated and planted native woodland.
Unknown	No information available on if the species uses a specific woodland type or single trees.
Wood pasture	An ancient system of land-use in which domestic animals were grazed within woodland or under widely scattered trees. The trees were often pollarded.
Woodland	All types of woodland but not single trees.

Table 20.10. Definitions of columns and cell values in the Species table.

Column name	Possible values	Definitions
Species - Latin	Scientific name	
Species - English	English name	English name if there is one
Synonym		Any commonly used synonym
Group	Bird	
	Mammal	
	Fungi	
	Vascular plant	
	Bryophyte	
	Lichen	
	Invert-Acari	Invertebrates - Acari - mites
	Invert-Coleoptera	Invertebrate - Coleoptera - beetles
	Invert-Diptera	Invertebrate - Dipetera - flies
	Invert-Hemiptera	Invertebrate - Hemiptera - bugs
	Invert-Hymenoptera	Invertebrate - Hymenoptera - ant, bees, wasps
	Invert-Lepidoptera	Invertebrate - Lepidoptera - butterflies and moths
	Invert-Thysanoptera	Invertebrate - Thysanoptera - thrips
	Invert-Insect	Invertebrate that is an insect not in one of the above lists
	Invert-Other	Invertebrate not in any of the above lists
Conservation status known	Yes	Species is listed as being of some conservation concern in one of UK BAP, Red Data Book, IUCN
	No	Species is known to be of no conservation concern
	Unknown	The distribution/population of the species is unknown and it is not known whether this species should be of conservation concern
BAP	YES	Species is on the UK BAP list : http://jncc.defra.gov.uk/page-5717
	No	Species is not on the UK BAP list
Red data book	Endangered	See the appropriate red data book (vascular plants - Cheffings & Farrell 2006; lichens - Church *et al* . 1997; fungi - Evans *et al* . 2006; moths - Conrad *et al* . 2006 and Davis 2012).

Column name	Possible values	Definitions
	Vulnerable	See the appropriate red data book (vascular plants - Cheffings & Farrell 2006; lichens - Church *et al* . 1997; fungi - Evans *et al* . 2006; moths - Conrad *et al* . 2006 and Davis 2012)
	Rare	See the appropriate red data book (vascular plants - Cheffings & Farrell 2006; lichens - Church *et al* . 1997; fungi - Evans *et al* . 2006; moths - Conrad *et al* . 2006 and Davis 2012)
	Out of danger	See the appropriate red data book (vascular plants - Cheffings & Farrell 2006; lichens - Church *et al* . 1997; fungi - Evans *et al* . 2006; moths - Conrad *et al* . 2006 and Davis 2012)
	Endemic	See the appropriate red data book (vascular plants - Cheffings & Farrell 2006; lichens - Church *et al* . 1997; fungi - Evans *et al* . 2006; moths - Conrad *et al* . 2006 and Davis 2012)
	Insufficiently Known	See the appropriate red data book (vascular plants - Cheffings & Farrell 2006; lichens - Church *et al* . 1997; fungi - Evans *et al* . 2006; moths - Conrad *et al* . 2006 and Davis 2012)
	Nationally Notable	See the appropriate red data book (vascular plants - Cheffings & Farrell 2006; lichens - Church *et al* . 1997; fungi - Evans *et al* . 2006; moths - Conrad *et al* . 2006 and Davis 2012)
IUCN	Critically Endangered	A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see Section V), and it is therefore considered to be facing an extremely high risk of extinction in the wild.
	Endangered	A taxon is ‘Endangered’ when the best available evidence indicates that it meets any of the criteria A to E for ‘Endangered’ (see Section V), and it is therefore considered to be facing a very high risk of extinction in the wild.
	Vulnerable	A taxon is ‘Vulnerable’ when the best available evidence indicates that it meets any of the criteria A to E for ‘Vulnerable’ (see Section V), and it is therefore considered to be facing a high risk of extinction in the wild.
	Near Threatened	A taxon is ‘Near Threatened’ when it has been evaluated against the criteria but does not qualify for ‘Critically Endangered’, ‘Endangered’ or ‘Vulnerable’ now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
	Least Concern	A taxon is ‘Least Concern’ when it has been evaluated against the criteria and does not qualify for ‘Critically Endangered’, ‘Endangered’, ‘Vulnerable’ or ‘Near Threatened’. Widespread and abundant taxa are included in this category.
	Data Deficient	A taxon is ‘Data Deficient’ when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.
Birds of C_C	Red	See www.rspb.org.uk/wildlife/birdguide/status_explained.aspx
	Amber	See www.rspb.org.uk/wildlife/birdguide/status_explained.aspx
	Green	See www.rspb.org.uk/wildlife/birdguide/status_explained.aspx
Mobility/Dispersal	within wood	Within stand (i.e. within a continuous bit of woodland, not able to cross over other habitats)

Column name	Possible values	Definitions
	<2km	Able to cross non woodland habitat, but less than 2km between woods
	>2km	Able to cross non woodland habitat, with more than 2km between woods
	Unknown	Mobility/dispersal unknown
Level association with ash	Obligate	Unknown from other tree species
	High	Rarely uses other tree species
	Partial	Uses ash more frequently than its availability
	Cosmopolitan	Uses ash as frequently or lower than availability
	Uses	Uses ash but the importance of ash for this species is unknown
Association-confidence	Anecdotal	Information on the use the species makes of ash is predominantly based on anecdotal evidence
	NR-NonUK	Information on the use the species makes of ash is predominantly based on literature that has a unknown review process and uses data from outside the UK
	NR-UK	Information on the use the species makes of ash is predominantly based on literature that has a unknown review process but is based on UK data
	PR-NonUK	Information on the use the species makes of ash is predominantly based on peer-reviewed literature but uses data from outside the UK
	PR-UK	Information on the use the species makes of ash is predominantly based on peer-reviewed literature using data from the UK
Meta-data quality	Free text	General comments on the quality of the data used
Knowledge gaps	Free text	Free text for notes on key knowledge gaps identified
Notes on use made of ash	Free text	Free text

20.4 How to look up references within the database

All references used in the construction of the database are held within the table References. Each reference has a unique i.d. As some references refer to all species within one species group and others to particular species, the column called "Species" in the reference table shows a mixture of species groups and species names. In order to search for all references for a particular species associated with ash, first of all look up that species in the 'Species - Latin' column in the Ref_conn table. This will give all the reference i.d. numbers associated with that species. Then look up those i.d. numbers in that reference table.

Also within the reference table are all references that were found during the literature search carried out for Chapter 3. These are grouped under the 'species' name B1 in the reference table. The references within this chapter are also shown grouped in categories of species richness/biodiversity, carbon/nitrogen/nutrient, litter/decay/decomposition, and succession/gaps/colonisation corresponding to the different sections within Chapter 3. These categories are listed as 'species' in the 'species' column in the reference table.

21 Appendix 2 Species classified as Red or Amber with respect to ash dieback.

Table 21.1. Species classified as Red-coded with respect to ash dieback.

Species Group	Species - Latin	Species - English
Bryophyte	*Habrodon perpusillus*	Lesser squirrel-tail moss
Bryophyte	*Lejeunea mandonii*	Atlantic pouncewort
Bryophyte	*Orthotrichum obtusifolium*	Blunt-leaved bristle-moss
Bryophyte	*Orthotrichum pallens*	Pale bristle-moss
Bryophyte	*Orthotrichum pumilum*	Dwarf bristle-moss
Bryophyte	*Rhynchostegium rotundifolium*	Round-leaved feather-moss
Fungi	*Botryodiplodia fraxini*	
Fungi	*Cryptosphaeria eunomia*	
Fungi	*Diaporthe samaricola*	
Fungi	*Gloeosporidiella turgida*	
Fungi	*Hypoxylon cercidicola*	
Fungi	*Macrophoma fraxini*	
Fungi	*Mycosphaerella fraxini*	
Fungi	*Phoma samararum*	
Fungi	*Phyllactinia fraxini*	
Fungi	*Phyllosticta fraxinicola*	
Fungi	*Venturia fraxini*	
Fungi	*Chlorencoelia versiformis*	
Fungi	*Geastrum berkeleyi*	Berkeley's Earthstar
Invertebrate	*Aceria fraxini*	
Invertebrate	*Aceria fraxinivora*	Ash flower gall mite
Invertebrate	*Aculus fraxini*	
Invertebrate	*Aeolothrips melaleucus*	
Invertebrate	*Anthocoris amplicollis*	
Invertebrate	*Arthrocnodax fraxinella*	
Invertebrate	*Astiosoma rufifrons*	
Invertebrate	*Atethmia centrago*	Centre-barred sallow
Invertebrate	*Aulagromyza heringii*	
Invertebrate	*Clinodiplosis botularia*	
Invertebrate	*Dasineura acrophila*	
Invertebrate	*Dasineura fraxinea*	
Invertebrate	*Dasineura fraxini*	
Invertebrate	*Lipsothrix nigristigma*	Scarce yellow splinter
Invertebrate	*Lithophane semibrunnea*	Tawny Pinion
Invertebrate	*Lonchaea fraxina*	
Invertebrate	*Lonchaea mallochi*	
Invertebrate	*Lonchaea nitens*	
Invertebrate	*Macrolabis pavida*	
Invertebrate	*Oxythrips halidayi*	
Invertebrate	*Pammene suspectana*	
Invertebrate	*Prays fraxinella*	
Invertebrate	*Psallus flavellus*	

Species Group	Species - Latin	Species - English
Invertebrate	*Psallus lepidus*	
Invertebrate	*Pseudoloxops coccineus*	
Invertebrate	*Psyllopsis fraxini*	
Invertebrate	*Psyllopsis fraxinicola*	
Invertebrate	*Taeniothrips inconsequens*	
Invertebrate	*Tomostethus nigritus*	Ash sawfly
Invertebrate	*Cercobelus jugaeus*	
Invertebrate	*Cryptophagus ruficornis*	
Invertebrate	*Hylesinus orni*	
Invertebrate	*Prociphilus bumeliae*	
Invertebrate	*Prociphilus fraxini*	
Invertebrate	*Pseudochermes fraxini*	
Invertebrate	*Psyllopsis discrepans*	
Invertebrate	*Psyllopsis distinguenda*	
Lichen	*Leptogium hildenbrandii*	
Lichen	*Lithothelium phaeosporum*	
Lichen	*Ochrolechia bahusiensis*	
Lichen	*Thelenella modesta*	
Lichen	*Bacidia auerswaldii*	
Lichen	*Caloplaca flavorubescens*	
Lichen	*Catapyrenium psoromoides*	
Lichen	*Collema nigrescens*	
Lichen	*Fuscopannaria ignobilis*	
Lichen	*Leptogium cochleatum*	
Lichen	*Leptogium saturninum*	
Lichen	*Vezdaea stipitata*	
Lichen	*Wadeana dendrographa*	

Table 21.2. Species classified as Amber-coded with respect to ash dieback.

Species group	Species - Latin	Species - English
Bird	*Muscicapa striata*	Spotted flycatcher
Bird	*Poecile Palustris*	Marsh tit
Bird	*Pyrrhula pyrrhula*	Bullfinch
Bryophyte	*Dendrocryphaea lamyana*	Multi-fruited cryphaea
Bryophyte	*Myrinia pulvinata*	Flood-moss
Bryophyte	*Orthotrichum speciosum*	Showy bristle-moss
Fungi	*Botryosphaeria stevensii*	none
Fungi	*Crepidotus calolepis*	none
Fungi	*Crocicreas dolosellum*	none
Fungi	*Cucurbitaria obducens*	none
Fungi	*Daldinia concentrica*	King Alfred's Cakes / Cramp Balls
Fungi	*Diaporthe scobina*	None
Fungi	*Episphaeria fraxinicola*	None
Fungi	*Hymenoscyphus albidus*	None
Fungi	*Hypoxylon intermedium*	None
Fungi	*Hypoxylon petriniae*	None
Fungi	*Hypoxylon rubiginosum*	Rusty Woodwart
Fungi	*Hysterographium fraxini*	None
Fungi	*Inonotus hispidus*	Shaggy Bracket
Fungi	*Kavinia alboviridis*	None
Fungi	*Nitschkia confertula*	None
Fungi	*Peniophora limitata*	None
Fungi	*Valsa cypri*	None
Fungi	*Ramariopsis pulchella*	Lilac Coral
Invertebrate	*Abdera biflexuosa*	
Invertebrate	*Acrocormus semifasciatus*	
Invertebrate	*Aculus epiphyllus*	
Invertebrate	*Aderus populneus*	
Invertebrate	*Aeolothrips gloriosus*	
Invertebrate	*Amiota alboguttata*	
Invertebrate	*Ampedus cardinalis*	
Invertebrate	*Ampedus rufipennis*	
Invertebrate	*Anisoxya fuscula*	
Invertebrate	*Anthocoris simulans*	
Invertebrate	*Aprostocetus balasi*	
Invertebrate	*Asterodiaspis minus*	
Invertebrate	*Brachyopa insensilis*	
Invertebrate	*Brachypalpus laphriformis*	
Invertebrate	*Bracon caudatus*	
Invertebrate	*Bracon ratzeburgi*	
Invertebrate	*Caloptilia cuculipenella*	
Invertebrate	*Cepphis advenaria*	Little Thorn
Invertebrate	*Cerocephala cornigera*	
Invertebrate	*Cerylon fagi*	
Invertebrate	*Contarinia marchal*	
Invertebrate	*Cossus cossus*	Goat Moth

Species group	Species - Latin	Species - English
Invertebrate	*Craniophora ligustri*	The Coronet
Invertebrate	*Cryptarcha strigata*	
Invertebrate	*Dendrothrips degeeri*	
Invertebrate	*Dorcatoma substriata*	
Invertebrate	*Dryocoetinus alni*	a bark or ambrosia beetle
Invertebrate	*Eledona agricola*	
Invertebrate	*Enicmus brevicornis*	
Invertebrate	*Enicmus rugosus*	
Invertebrate	*Ennomos fuscantaria*	Dusky Thorn
Invertebrate	*Eudonia delunella*	
Invertebrate	*Eulophus larvarum*	
Invertebrate	*Eupachygaster tarsalis*	Scarce black
Invertebrate	*Eupithecia innotata*	Angle-barred Pug
Invertebrate	*Euthyneura halidayi*	
Invertebrate	*Euzophera pinguis*	
Invertebrate	*Gyrophaena lucidula*	
Invertebrate	*Gyrophaena manca*	
Invertebrate	*Hallomenus binotatus*	
Invertebrate	*Helina vicina*	
Invertebrate	*Hylesinus crenatus*	Large Ash Bark Beetle
Invertebrate	*Hylesinus fraxini*	
Invertebrate	*Ischnodes sanguinicollis*	
Invertebrate	*Lathridius consimilis*	
Invertebrate	*Lepidosaphes conchyformis*	
Invertebrate	*Limoniscus violaceus*	Violet click beetle
Invertebrate	*Lissodema cursor*	
Invertebrate	*Lissodema denticolle*	
Invertebrate	*Lonchaea peregrina*	
Invertebrate	*Lucanus cervus*	Stag beetle
Invertebrate	*Lyctus linearis*	
Invertebrate	*Lytta vesicatoria*	Spanish fly
Invertebrate	*Medetera melancholica*	
Invertebrate	*Melandrya caraboides*	
Invertebrate	*Mycetobia pallipes*	
Invertebrate	*Nossidium pilosellum*	
Invertebrate	*Oecophora bractella*	
Invertebrate	*Orchesia micans*	
Invertebrate	*Orthotylus tenellus*	
Invertebrate	*Pammene ignorata*	
Invertebrate	*Pandivirilia melaleuca*	
Invertebrate	*Periscelis annulata*	
Invertebrate	*Phaonia exoleta*	
Invertebrate	*Phenacoccus aceris*	
Invertebrate	*Phloiotrya vaudoueri*	a false darkling beetle
Invertebrate	*Platycis minutus*	
Invertebrate	*Platyrhinus resinosus*	
Invertebrate	*Platystomos albinus*	
Invertebrate	*Pocota personata*	

Species group	Species - Latin	Species - English
Invertebrate	*Prionychus ater*	a darkling beetle
Invertebrate	*Pseudargyrotoza conwagana*	
Invertebrate	*Quadraspidiotus zonatus*	
Invertebrate	*Rhopalomesites tardyi*	
Invertebrate	*Scaphidema metallicum*	
Invertebrate	*Siphoninus phillyreae*	
Invertebrate	*Strigocis bicornis*	
Invertebrate	*Symbiotes latus*	
Invertebrate	*Tachypeza fuscipennis*	
Invertebrate	*Tanyptera nigricornis*	
Invertebrate	*Thecla betulae*	Brown Hairstreak
Invertebrate	*Theocolax formiciformis*	
Invertebrate	*Tipula selene*	
Invertebrate	*Trichopteryx polycommata*	Barred Tooth-striped
Invertebrate	*Trigonophora flammea*	Flame Brocade
Invertebrate	*Tropidosteptes pacificus*	
Invertebrate	*Xyleborus dispar*	
Invertebrate	*Xyloterus domesticum*	
Invertebrate	*Zelleria hepariella*	
Lichen	*Gyalecta derivata*	
Lichen	*Mycobilimbia epixanthoides*	
Lichen	*Pyrenula chlorospila*	
Lichen	*Strigula taylorii*	
Lichen	*Acrocordia cavata*	
Lichen	*Agonimia opuntiella*	
Lichen	*Anaptychia ciliaris subsp. ciliaris*	
Lichen	*Arthonia anglica*	
Lichen	*Arthonia zwackhii*	
Lichen	*Bacidia subincompta*	
Lichen	*Biatoridium delitescens*	
Lichen	*Biatoridium monasteriense*	
Lichen	*Calicium abietinum*	
Lichen	*Caloplaca herbidella*	
Lichen	*Caloplaca virescens*	
Lichen	*Chaenotheca chlorella*	
Lichen	*Chaenotheca laevigata*	
Lichen	*Collema fasciculare*	
Lichen	*Collema fragrans*	
Lichen	*Collema occultatum*	
Lichen	*Collema subnigrescens*	
Lichen	*Cryptolechia carneolutea*	
Lichen	*Eopyrenula leucoplaca*	
Lichen	*Fuscopannaria sampaiana*	
Lichen	*Gomphillus calycioides*	
Lichen	*Gyalecta flotowii*	
Lichen	*Lecania chlorotiza*	
Lichen	*Lecanora cinereofusca*	
Lichen	*Lecanora horiza*	

Species group	Species - Latin	Species - English
Lichen	*Lecanora sublivescens*	
Lichen	*Lecidea erythrophaea*	
Lichen	*Leptogium hibernicum*	
Lichen	*Megalospora tuberculosa*	
Lichen	*Menegazzia subsimilis*	
Lichen	*Opegrapha viridis*	
Lichen	*Pachyphiale fagicola*	
Lichen	*Parmeliella testacea*	
Lichen	*Parmelina carporrhizans*	
Lichen	*Phlyctis agelaea*	
Lichen	*Physcia clementei*	
Lichen	*Physcia tribacioides*	
Lichen	*Polychidium dendriscum*	
Lichen	*Pseudocyphellaria intricata*	
Lichen	*Pyrenula acutispora*	
Lichen	*Ramonia dictyospora*	
Lichen	*Rinodina biloculata*	
Lichen	*Schismatomma graphidioides*	
Lichen	*Teloschistes flavicans*	
Lichen	*Wadeana minuta*	
Mammal	*Barbastella barbastellus*	Barbastelle
Mammal	*Myotis bechsteinii*	Bechstein's Bat
Mammal	*Nyctalus noctula*	Common Noctule
Mammal	*Pipistrellus pygmaeus*	Soprano Pipistrelle
Mammal	*Plecotus auritus*	Brown Long-eared Bat
Mammal	*Rhinolophus hipposideros*	Lesser Horseshoe Bat
Mammal	*Sciurus vulgaris*	Red squirrel

22 Appendix 3 Glossary

Word	Definition as used in this report
Acer campestre	field maple
Acer platanoides	Norway maple
Acer pseudoplatanus	sycamore
Alnus glutinosa	alder
Ancient	In relation to ash trees: large girth (over 3m in girth or 100cm DBH for ash, taking into consideration environmental conditions), past biological maturity and in the final, often longest, stage of life. Usually have a retrenching crown as a key feature and numerous 'Veteran' features.
Ancient woodland	Any site that has always been wooded since at least 1600AD (in England and Wales), 1750 in Scotland, or 1830 in Northern Ireland, when the first maps appeared.
Ash-associated species	A species identified in this report as using ash to some degree. The level of association was split into: obligate, high, partial, uses and cosmopolitan. See glossary for further details of these definitions.
Betula pendula	silver birch
Betula pubescens	downy birch
Carpinus betulus	hornbeam
Castanea sativa	sweet chestnut
Chalara fraxinea	The asexual (anamorphic) stage of the fungus that causes ash dieback. It was subsequently named *Hymenoscyphus pseudoalbidus* when the sexual stage of the fungus was discovered.
Conservation concern	A species that has one of the following levels of conservation protection within the UK: red data book, Biodiversity Action Plan (BAP) species, International Union for Conservation of Nature (IUCN) threat category, Birds of Conservation Concern.
Corylus avellana	hazel
Cosmopolitan	In relation to the use of a tree species by a taxon: the taxon uses the tree species as frequently as, or less than, its availability in the environment
Crataegus monogyna	hawthorn
Ecosystem services	The outputs of ecosystems from which people derive benefits.
Ellenberg values	Indicator values describing the realised ecological niche of a plant, that is the environmental conditions (soil pH, moisture, light, nutrient levels) in which a plant occurs.
Fagus sylvatica	beech
Fraxinus excelsior	ash
Highly associated	In relation to the use of a tree species by a taxon: the taxon rarely uses other tree species
Hymenoscyphus pseudoalbidus	The scientific (Latin) name of the fungus that causes ash dieback. The fungus was first scientifically described in 2006 under the name *Chalara fraxinea*. Four years later it was discovered that *Chalara fraxinea* was only the asexual (anamorphic) stage of a fungus that was subsequently named *Hymenoscyphus pseudoalbidus*.
Likely	In relation to the use of a tree species by a taxon: it is likely that the taxon uses this tree species. This definition was used for cosmopolitan invertebrates where the literature stated that the taxon uses a wide range of food sources but no information is available on whether it actually uses this particular tree species.
Mature	In relation to ash trees: more than 2m in height and under 3m in girth (less than 100cm DBH).

Word	Definition as used in this report
NFI	National Forest Inventory
No	In relation to the use of a tree by a taxon: the taxon does not use this tree species.
Notable	Large girth (over 3m in girth or 100cm DBH for ash, taking into consideration environmental conditions) but with no visible 'Veteran' features (see 'Veteran' definition for list). If information is only available that the species occurs on trees >3m girth, record as 'Ancient', if you are able to be more specific about the use of 'Veteran' and 'Ancient' trees listed below, then include these ages as well.
NVC	National Vegetation Classification
Obligate	In relation to the use of a tree by a taxon: the taxon is unknown from other tree species
Parasitoid	In relation to the use of a tree by a taxon: the taxon is parasitic on another taxon that uses ash, but is also parasitic on a range of other taxa. It was beyond the scope of this project to assess all the other food plants used by all the other hosts the parasite uses.
Partially associated	In relation to the use of a tree by a taxon: the taxon uses the tree species more frequently than its availability in the environment
Pole	In relation to ash trees: under 2m in height, younger than 50 years.
Populus tremula	aspen
Prunus avium	wild cherry
Prunus padus	bird cherry
Pseudotsuga menziesii	Douglas fir
Quercus petraea	sessile oak
Quercus robur	pedunculate oak
Rare	In relation to the use of a tree by a taxon: the taxon has been recorded on this tree species but only rarely.
Recent woodland	Includes woodland established since AD1600 that have regenerated and planted native woodland.
Salix caprea	goat willow
Salix cinerea	grey willow
Sapling	In relation to ash trees: a tree under 2m in height.
Seed	Seed.
Seedling	In relation to ash trees: a tree 1 year old or less.
Similarity index	A statistical method to compare how similar two things are using more than one measure
Sorbus aria	whitebeam
Taxus baccata	yew
Tilia cordata	small-leaved lime
Trait	A characteristic of an organism
Unknown	In relation to the use of a tree species by a taxon: it is not known if the taxon uses this tree species.
Uses	In relation to the use of a tree species by a taxon: the taxon uses the tree species but the important of this tree species for this taxon is unknown
Veteran	In relation to ash trees a tree with a large girth (over 3m in girth or 100cm DBH for ash, taking into consideration environmental conditions) with at least three 'Veteran' attributes (e.g. important habitats visible such as deadwood in the trunk; contain standing deadwood; have fallen wood around base; rot holes; water pockets; seepage lines; hollows in trunk or major limbs, etc.).

Word	Definition as used in this report
Wood pasture	An ancient system of land-use in which domestic animals were grazed within woodland or under widely scattered trees. The trees were often pollarded. These habitats occur throughout the UK, though more extensively in some areas than others