Natural England Commissioned Report NECR151

Assessing and addressing the impacts of ash dieback on UK woodlands and trees of conservation importance (Phase 2)

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. This report has been jointly funded by Defra, Department of the Environment Northern Ireland, Forestry Commission, Scottish Natural Heritage and Natural Resources Wales.

Background

Ash dieback (or '*Chalara*'), is the fungal tree disease which is increasingly affecting ash (*Fraxinus excelsior*) trees in the UK. Ash trees are important for biodiversity and ash dieback could affect biodiversity with consequences for species conservation through to impacts on woodland ecosystem health. Deciding how to manage woodlands infected by ash dieback that also conserves biodiversity is an important issue.

The aim of this project is to assess the potential ecological impact of ash dieback on UK woodlands and species and to investigate possible woodland management options which might ameliorate the problems caused. In particular to:

- Identify the ecological function of ash (decomposition, litter quality, nutrient cycling).
- Identify the ecological function of 11 alternative species that might replace ash and compare their functioning to ash.
- Identify ash-associated species and their level of association with ash.
- Assess the suitability of alternative tree species.

The results have been and will continue to be used to help:

- Develop management options and to assess changes in woodland composition following infection of ash dieback in the 9 ash-relevant regions of the UK.
- Evaluate the short and long term impacts on ash related biodiversity of ash dieback.

Develop resources (tools and case studies) for woodland managers.

This report details the second phase of the work. The report relating to phase 1 can be found **here**.

This report should be cited as:

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Natural England Project Manager - Christine Reid, Peterborough - Suite D, Unex House, Bourges Boulevard, Peterborough, PE1 1NG **chris.reid@naturalengland.org.uk**

Contractor - The James Hutton Institute, Craigiebuckler, Aberdeen, AB14 8QH and Forest Research

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Further information
This report can be downloaded from the Natural England website: **www.naturalengland.org.uk**. For information on Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**.

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The James Hutton Institute led the project and was the main author of Chapters 1, 2, 3, 4, 6, and 8. Expertise on individual taxa was provided by: Royal Botanic Garden Edinburgh for lichens, Hodgetts - Independent Consultant for bryophytes, University of Aberdeen and the James Hutton Institute for fungi, RSPB for birds and the James Hutton Institute for invertebrates and mammals. Forest Research was the main author of Chapters 5 and 7 and of the case studies which are published separately from this report. The James Hutton Institute led the production of the AshEcol spreadsheets which are also published separately.

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Authors' Organisations are as follows:

Beaton, J.K., Brooker, R.W., Hester, A.J., Iason, G.R., Littlewood, N.A., Mitchell, R.J., Pakeman, R., Pozsgai, G., Ramsay, S., Riach, D., Stockan, J.A. and Taylor, A.F.S.
The James Hutton Institute, Craigiebuckler, Aberdeen, AB14 8QH.

Bellamy, P.E.
RSPB Centre for Conservation Science. The Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire, SG19 2DL

Broome, A.
Forest Research, Northern Research Station, Roslin, Midlothian, EH25 9SY.

Ellis, C.J.
Royal Botanic Garden Edinburgh, 20A Inverleith Row, Edinburgh, EH3 5LR.

Harmer, R.
Forest Research, Alice Holt Lodge, Farnham, Surrey, GU10 4LH.

Hodgetts, N.G.
Bryophyte Consultant, Cuillin Views, 15 Earlish, Portree, Isle of Skye, IV51 9XL.

Ray, D.
Forest Research, Head of Land Use and Ecosystem Services Programme Group
Centre for Ecology, Society and Biosecurity.

Woodward, S.
University of Aberdeen, Institute of Biological and Environmental Sciences, Department of Plant and Soil Sciences, Cruickshank Building, St. Machar Drive, Aberdeen, AB24 3UU.

Summary[1]

Introduction

1. *Hymenoscyphus pseudoalbidus* (anamorph *Chalara fraxinea*) is an invasive fungus from East Asia that is currently causing the death or dieback of *Fraxinus excelsior* trees throughout Europe. For simplicity the disease is called 'ash dieback' throughout this report although other diseases can also cause the dieback or death of *F. excelsior*. *F. excelsior* is called ash throughout.

2. Previous work (Mitchell et al 2014, referred to as 'Phase 1' throughout this report) has already identified some potential ecological impacts of ash dieback on UK woodlands and on ash-associated species; has assessed the suitability of 22 alternative tree species to support ash-associated species; and has looked at the impact of various management scenarios on ash-associated biodiversity. This report is an extension of that work.

3. The objectives of this project are to:
    a. examine the ecological function of 11 tree species considered most likely to replace ash across the UK,
    b. assess the use ash-associated species make of a further 28 alternative tree species,
    c. undertake a 'traits analysis' of these 28 tree species to see how similar they are to ash,
    d. develop further management scenarios and assess the implication of these scenarios on ash-associated species,
    e. develop 15 case studies showing how existing management plans may be adapted to conserve ash-associated biodiversity should significant ash dieback occur at these sites, and to
    f. develop an Excel database containing information on ash-associated species and which alternative trees and shrubs support them.

Methods to assess alternative trees to ash

4. One way of adapting to the potential loss of ash is to encourage the establishment of other tree species to replace ash. Such tree species are termed alternative trees throughout. From an nature conservation viewpoint the most suitable alternative trees are those that are as ecologically similar to ash as possible.

5. The ecological similarity of alternative trees to ash may be assessed by
    a. their ecological functioning,
    b. the number of ash-associated species they support, and
    c. their traits.

   Ideally any alternative tree should be similar to ash in all of these characteristics.

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[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 the strength of this data is provided eg proportion of records in the database.

Ecological functioning of alternative tree species

6. Phase 1 showed that ash lies at an extreme of the ecological range of native tree species in the UK. It produces nutrient-rich highly degradable litter that does not form a deep litter layer and which maintains a high soil pH. This report assesses the ecological functioning of 11 tree species (rowan, birch (silver or downy), field maple, sycamore, aspen, oak (pedunculate or sessile)[2], beech, lime, alder, walnut (black or common) and wild cherry) considered most likely to replace ash and identifies how similar these tree species are to ash in terms of ecological function.

7. There are three main groups of tree species in terms of leaf litter decomposition rates: high (alder, ash, lime, rowan), medium (sycamore, field maple, aspen), and low (oak, beech). (Large number of studies showing consistent pattern of results. *Confidence: high)*

8. The chemical and physical properties of leaf litter causes differences between tree species in the rate of nutrient and carbon cycling within ecosystems. In general nutrient and carbon cycling are enhanced by a higher nutrient content in the litter (termed high litter quality). The litter quality of the trees may be ranked from high to low as Walnut> Alder> Ash> Lime> Aspen=Field maple=Sycamore> Oak=Rowan=Birch> Beech> Wild cherry. (Large number of studies showing similar results. *Confidence: high*)

9. Litter inputs into the soil have an impact on nutrient cycling within soils, and hence soil fertility. The soil nutrient cycling of the trees was ranked from high to low as Alder=Ash> Lime> Field maple=Sycamore> Oak=Birch> Beech. (Large number of studies showing similar results. *Confidence: high*)

10. Of the 11 species studied beech, oak, field maple, sycamore, lime and wild cherry were most similar to ash with respect to their successional stage (all described as late successional species). (Large number of studies showing similar results. *Confidence: high*)

11. A change from ash to a tree species with very different ecosystem functioning (eg oak or beech) will result in changes in the characteristics of the woodland: slower nutrient cycling, increased carbon storage and changes in the ground flora species present. (*Confidence: high.*)

Use made of alternative trees by ash-associated species

12. The number of species that 'use' ash trees (termed ash-associated species) was updated from the 953 reported in Phase 1 to 955.

13. Information on whether the 955 ash-associated species used 28 alternative tree species was collated and combined with the 20 alternative tree species assessed in Phase 1 to show the use of 48 alternative tree species by ash-associated species (Table B).

14. Tree species native to the UK support more ash-associated species than non-native tree species (Table B). Non-native (although often described as naturalised) sycamore is the exception – it supports a similar number of ash-associated species to some native species. (Data is missing for some non-native tree species. *Confidence: Medium*)

[2] Wherever the generic term 'oak' is used without qualification it refers to *Quercus robur/petraea* (pedunculate/sessile oak), and the species name is always used for any other oaks.

15. 67% of ash-associated species (640 species) are also associated with native oak species. More than 400 ash-associated species are also associated with each of the following tree species: beech, elm, sycamore, hazel and birch (*Confidence: high*)

16. Four non-native ash species were included in the assessment: manna ash, American ash, green ash and Manchurian ash. There are few studies showing species use of non-native ash in the UK, but these tree species were assessed as 'likely'[3] to support over 200 of the ash-associated species. However some of these non-native ash tree species may also be susceptible to ash dieback. (Assessment based on expert knowledge, data missing for many species. *Confidence: low*)

17. Native oak species support the greatest number of ash-associated birds (100%), invertebrate (30%), lichen (85%) and mammal (61%) species, but hazel supports more bryophyte species (95%) and elm more fungi species (31%), with oak in second place for bryophytes (91%) and third for fungi (26%). Beech is second place for fungi species (28%). Percentages are the percentage of ash-associated species in each group supported. (Good data for native tree species. *Confidence: high*)

18. Elm supports the greatest number of the ash-associated species that are most vulnerable to ash-dieback (species with an obligate or high association with ash and/or a high conservation status). Hazel, oak, aspen and sycamore also support a high number of ash-associated species that are most vulnerable to ash-dieback. However elm remains susceptible to Dutch elm disease and is therefore not widely suitable as an alternative to ash. (Good data for native tree species. *Confidence: high*).

19. This report has identified those alternative tree species for which there is little information on the use made of them by ash-associated species (Table B). If these tree species are planted then we cannot say what the ecological impact on ash-associated species will be.

Traits of alternative tree species

20. The traits of trees such as tree height, bark pH and fruit type indicate, in part, the type of habitat created by a tree species and the resources available to species that use the tree. Ideally the traits of any alternative tree should be as similar as possible to ash. The Phase 1 project assessed the traits of 22 alternative trees. Here the traits of a further 28 tree species are collated and the results combined with those from Phase 1 to provide an assessment for 50 tree species.

21. The traits considered were: deciduous/evergreen, floral reward, fruit type, leaf shape, mycorrhizal association, pollen vector, tree height, leaf dry matter content, specific leaf area and length of flowering time.

22. Of the native tree species assessed elm had the most traits the same as ash followed by silver birch and rowan. Non-native trees with the greatest number of traits that were the same as ash were: American ash, common walnut, green ash, black walnut and Manchurian ash. (Data missing for some tree species. *Confidence: Low*)

23. The species most dissimilar to ash when assessed by their traits were small-leaved lime, wild cherry, blackthorn, field maple, privet, wild service, bird cherry, hawthorn, holly, large-leaved lime, Scots pine, whitebeam, Norway maple, Douglas fir, silver fir and

[3] Likely = there was no specific information on the use of the tree species by the ash-associated species but expert judgement, based on ecological knowledge of the species, suggested that the ash-associated species was likely to use that tree species.

European larch which all had five or more of the eleven traits classed as very dissimilar to ash (Data missing for some tree species. *Confidence: Low*)

Comparison of different methods to assess the similarity of alternative trees to ash

24. Perhaps surprisingly, this study found that the alternative tree species that support the greatest number of ash-associated species are very dissimilar to ash when assessed by traits and ecological function. Oak supports 640 of the 955 ash-associated species and beech supports 505 ash associated species. However, in terms of ecological function, oak and beech have much slower rates of leaf litter decomposition and nutrient cycling than ash and their canopies cast a much darker shade which will influence the ground flora species. Alder is similar to ash with respect to ecological function (leaf decomposition rates, litter quality and nutrient cycling) but supports fewer ash-associated species (389 out of 955) (*Confidence: High*)

25. The method that is most suitable to assess how similar the alternative tree species are to ash will depend on the objectives at the site eg maintaining ash associated species or maintaining the woodland character and ecological function.

Table A The suitability of 11 alternative tree species when ranked by number of ash-associated species they support, by their traits and by ecological functions. Those shaded green are classed as 'good' alternatives to ash, those shaded red as ecologically 'bad' alternatives to ash

No. of species[1]	Traits[2]	Decomposition[3]	Litter quality[3]	Nutrient cycling[3]
Oak	Alder	Alder	Walnut	Alder
Beech	Aspen	Lime	Alder	Lime
Sycamore	Sycamore	Rowan	Lime	Field maple
Birch	Beech	Sycamore	Aspen	Sycamore
Alder	Wild cherry	Field maple	Field maple	
Rowan		Aspen	Sycamore	
Aspen			Oak	
Field maple			Rowen	
Walnut	Oak		Birch	Oak
Wild cherry	Birch	Oak	Beech	Birch
Lime	Lime	Beech	Wild cherry	Beech

[1] Green = supports >450 ash-associated species, amber = supports 300-450 ash associated species, red = supports < 300 ash-associated species.
[2] Ranking of traits taken from Phase 1 report where a similarity index was calculated.
[3] Ranking taken from Chapter 2.

Management scenarios[4]

26. For six management scenarios that could be applied to woods once infected with ash-dieback, we considered the potential changes in woodland vegetation composition over two time periods (1-10 years and 50-100 years). The scenarios were:
    (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.
    (3) **Felling** – all ash trees and coppice removed in one operation with, if necessary, additional trees of other species cut to make the operation more viable.
    (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 more viable. Then active management to replant with alternative tree and shrub 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 more viable.
    (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 more viable. Then active management initially to achieve natural regeneration in the stand, with subsequent management to develop overstorey species.

27. Scenarios (1)-(4) were developed in Phase 1. Scenarios (5) and (6) are developed in Phase 2. Pen pictures' to describe changes in ash woodland vegetation composition that might occur under these scenarios were developed for 9 ash-relevant regions with in the UK over two time periods. (*Confidence: medium for years 1-10 years and low for years 50-100 taking into account uncertainties over interactions with climate change and other tree diseases)*

28. Previous 'pen pictures' (Phase 1 scenarios (1)-(4) and this report scenarios (5) and (6)) developed descriptions of woodland vegetation composition for the ash canopy cover (<20% or >20%) most likely to be found in each ash-relevant region. Here 'pen pictures' are developed for woodlands with more than 20% ash canopy for all management scenarios for two time periods for the 9 ash-relevant regions. (*Confidence: medium for years 1-10 years and low for years 50-100 taking into account uncertainties over interactions with climate change and other tree diseases)*

Impact of management scenarios (5) thinning and (6) felling with natural regeneration promoted on species obligate and highly associated with ash[5]

29. The assessment of the impact of the management scenarios on ash-associated species in this report is based on a worst case scenario of 95% or more of ash trees being lost due to ash-dieback. We don't have sufficient understanding to predict the actual future impact of ash-dieback on ash trees in the UK with any confidence.

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[4] The management scenarios presented are explorations of examples of what might be done to manage woods impacted by ash dieback and are not necessarily the management that should be carried out at all ash woodland sites. In any particular wood, a combination of these scenarios might be employed by the woodland manager.

[5] Obligate species are those that only use ash, highly associated species are species that are rarely found on tree species other than ash.

30. In the short term (1-10 years) more ash-associated species were supported under scenario (5) ‘thinning’ than scenario (6) ‘felling with natural regeneration promoted’ (Assessment based on level of association with ash. *Confidence: medium*).

31. In the long-term (50-100 years) there was little difference between scenarios (5) and (6) in their impact on obligate and highly associated ash species with of these species predicted to decline in abundance or be at risk of extinction. (Assessment based on level of association with ash. *Confidence: Low*).

Impact of management scenarios on partially[6] associated species

32. Species partially associated with ash are generally predicted to decline initially following the onset of ash dieback but after 50-100 years the majority of partially associated species are predicted to be unchanged in abundance compared to current population levels due to an increase in the abundance of other tree species which they utilise. (Assessment based on predicted changes in vegetation and on level of association with ash and alternative tree species. *Confidence: medium*)

33. There is a clear difference in the response of highly associated species, which are predicted to either decline or go extinct and the majority of partially associated species which are predicted to remain unchanged in abundance after 50-100 years. (Assessment based on level of association with ash and alternative tree species. *Confidence: medium*)

34. The results suggest that for the majority of partially associated ash species appropriate management can significantly mitigate the impacts of ash dieback. (Assessment based on level of association with ash and alternative tree species. *Confidence: medium*)

Tools and case studies to aid the management of ash-associated biodiversity

35. This report provides information for advisors and policy makers to aid woodland managers in conserving ash-associated biodiversity. This report does not provide a complete woodland planning tool - it is intended for use alongside other resources (eg ESC) to develop appropriate woodland management plans.

36. A five-step procedure to develop management recommendations for ash associated species is provided.

37. Information on ash-associated species and which alternative tree species they will use is provided in the Excel file AshEcol which is available at weblink.

38. This project has undertaken 15 cases studies, providing a range of examples of how current management plans may be adapted to manage for ash-associated biodiversity if ash dieback affects these sites, and examples of how to use the information provided in this and the Phase 1 report. These case studies are available at weblink.

39. When woodland managers are considering which alternative tree/shrub species to regenerate or plant in order to mitigate the impacts of ash-dieback on biodiversity, the number of ash-associated species supported is only one factor to consider. Woodland managers should also think about other information provided in this report such as the impact alternative trees might have on ecosystem function and factors which will influence the occurrence of ash-associated species in the woodland, such as: woodland structure, food availability, the size, shape and number of holes in trees for roosting bats

[6] Partially associated species are those that use ash more frequently than its availability in the environment but are less closely associated with ash than obligate or highly associated species.

and hole nesting birds, interactions between species, and changes in woodland ground flora composition.

40. Ash dieback is just one of several diseases and other potential drivers of change within woodlands within the UK. Other tree diseases and drivers such as grazing, pollution and climate change will also need to be taken into account. Management for biodiversity will usually be considered together with the other objectives of woodland management including timber production, amenity, flood prevention and carbon sequestration.

Table B Number of ash associated species supported by different alternative trees

Alternative tree species		Number of ash-associated species supported	% of species with evidence showing their use.
English name	Latin name		
	Native		
Field maple	*Acer campestre*	256	88
Alder	*Alnus glutinosa*	389	89
Birch spp.	*Betula pubescens/pendula*	423	90
Hornbeam	*Carpinus betulus*	169	88
Hazel	*Corylus avellana*	430	88
Hawthorn	*Crataegus monogyna*	302	88
Beech	*Fagus sylvatica*	505	92
Holly	*Ilex aquifolium*	251	77
Privet	*Ligustrum vulgare*	92	75
Crab apple	*Malus sylvestris*	272	83
Scots pine	*Pinus sylvestris*	216	81
Black poplar	*Populus nigra*	76	30
Aspen	*Populus tremula*	370	89
Wild cherry	*Prunus avium*	116	88
Bird cherry	*Prunus padus*	95	87
Blackthorn	*Prunus spinosa*	167	81
Oak spp.	*Quercus robur/petraea*	640	94
Goat willow	*Salix caprea*	105	32
Grey willow	*Salix cinerea*	91	31
Elder	*Sambucus nigra*	96	29
Whitebeam	*Sorbus aria*	100	82
Rowan	*Sorbus aucuparia*	387	84
Wild service tree	*Sorbus torminalis*	7	22
Yew	*Taxus baccata*	89	86
Small leaved lime	*Tilia cordata*	84	31
Large leaved lime	*Tilia platyphyllos*	242	81
Elm spp.	*Ulmus procera/glabra*	477	86
	Non-native		
Silver fir	*Abies alba*	74	30
Norway maple	*Acer platanoides*	60	31
Sycamore	*Acer pseudoplatanus*	473	88
Horse chestnut	*Aesculus hippocastanum*	208	81
Italian alder	*Alnus cordata*	6	23
Shagbark hickory	*Carya ovata*	1	19
Sweet chestnut	*Castanea sativa*	148	88
American ash	*Fraxinus americana*	12	29
Manchurian ash	*Fraxinus mandschurica*	6	29
Manna ash	*Fraxinus ornus*	29	30
Green ash	*Fraxinus pennsylvanica*	12	29
Black walnut	*Juglans nigra*	126	80
Common walnut	*Juglans regia*	149	81
European larch	*Larix decidua*	166	79
Hop-hornbeam	*Ostrya carpinifolia*	10	20
Plane	*Platanus x hybrid*	96	76
Douglas fir	*Pseudotsuga menziesii*	8	29
Caucasian wingnut	*Pterocarya fraxinifolia*	1	19
Turkey oak	*Quercus cerris*	70	32
Red oak	*Quercus rubra*	28	29
Western red cedar	*Thuja plicata*	17	22

[1]Number of ash associated species, out of 955, which are known to use the alternative tree species.
[2]Percentage of ash associated species with evidence showing whether they did or did not use the alternative tree species.

Contents

List of figures

List of tables

Preface

Policy Relevance

Chalara fraxinea or *Hymenoscyphus pseudoalbidus* is the fungus that causes the tree disease known as ash dieback. Chalara has already affected a high proportion of ash (*Fraxinus excelsior*) trees in Northern Europe and is now spreading in the UK. This report and related case studies aims to provide advisors and policy makers with advice on how to manage ash associated biodiversity in the light of the potentially damaging impacts of ash dieback on both ash trees and its' associated biodiversity.

Chalara was first recorded in Great Britain 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

The Chalara Management Plan[7] published by Defra in March 2013 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 noted 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 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[8].

The Chalara Management Plan noted the importance of ash, but did not 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[9], the EU Biodiversity Strategy[10] and individual country biodiversity strategies. 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 a report on the potential ecological impacts of ash dieback in the UK[11]. This report 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 current report represents a follow on study; further advice and management options for managing ash-associated biodiversity in the light of ash-dieback are explored.

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[7] https://www.gov.uk/government/publications/chalara-management-plan
[8] https://www.gov.uk/government/publications/chalara-in-ash-trees-a-framework-for-assessing-ecosystem-impacts-and-appraising-options
[9] http://www.cbd.int/
[10] http://ec.europa.eu/environment/nature/biodiversity/policy
[11] http://jncc.defra.gov.uk/page-6322

Scope of the research

The research done for this report focussed on options to manage ash-associated biodiversity in the light of the potential impacts of ash-dieback. Specifically, it assessed the suitability of trees that might be considered as an alternative to ash and developed further management scenarios that were not assessed in the previous report. The work also included the development of 15 case studies where the resources developed by this and the Phase 1 report were used to assess how 15 example ash woodlands might be managed to support ash-associated biodiversity if ash dieback should arrive at these sites. Excel spreadsheets documenting the species that are associated with ash, and also which alternative tree species ash-associated species will use, were developed as a resource for woodland managers, advisors and policy makers.

The management scenarios and case studies in this report are explorations of examples of what might be done to manage for ash dieback. 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 desirable traits, and can support some of the species that are dependent on, or associated with, ash. The most appropriate replacement tree species and management for each site will depend on the species present at the site, the aims of the woodland management, and the environmental conditions present at the site.

Woodlands are subject to many other pressures in addition to ash dieback, such as climate change, pollution or over-grazing. The interactions between ash dieback and the impacts of other drivers were beyond the remit of this project, but should be taken into account when implementing the results from this work.

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 were 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.

Uses and Users of this Report

This report is aimed at advisors and policy makers 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 as and when ash dieback takes effect.

This report follows on from Mitchell et al (2014) 'The potential ecological impact of ash dieback in the UK'. Where necessary, information from this previous report has been summarized first in order to set the results of the current study in context.

Related resources

The following resources may also be useful to woodland managers, advisors and policy makers:

- The potential ecological impact of ash dieback in the UK http://jncc.defra.gov.uk/page-6459.
- Excel spreadsheets containing data associated with Phase 1 of this project: http://jncc.defra.gov.uk/page-6459.
- Case studies developed as part of the current project see weblink.

- AshEcol: an Excel spreadsheet aimed at woodland managers, detailing ash associated species and the alternative trees see weblink.

1 Introduction

<u>Chapter summary</u>

1. *Ash dieback or Chalara is caused by an invasive fungus, the ascomycete* Hymenoscyphus pseudoalbidus *(anamorph* Chalara fraxinea*).*

2. *Previous work (Mitchell et al 2014, referred to as Phase 1 throughout) has already identified the potential ecological impact of ash dieback, assessed the suitability of 22 alternative tree species, and the impact of various management scenarios on ash-associated biodiversity. This report continued this work.*

3. *The objectives of this research are to:*
    - *Examine the ecological function of 11 tree species likely to replace ash*
    - *Assess whether ash-associated species use 28 alternative tree species*
    - *Undertake a 'traits analysis' of 28 alternative tree species*
    - *Develop additional management scenarios to those already considered in Phase 1*
    - *Assess the implication of the management scenarios on ash-associated species*
    - *Develop 15 case studies showing how existing management plans may be adapted if ash dieback arrives at these sites*
    - *Develop an Excel spreadsheet containing information on ash-associated species which may be used by woodland managers.*

1.1 Introduction to the research

Hymenoscyphus pseudoalbidus (anamorph *Chalara fraxinea*) is an invasive fungus from East Asia that is currently causing the death or dieback of *Fraxinus excelsior* trees throughout Europe. For simplicity the disease is called 'ash dieback' throughout this report although other diseases can also cause the dieback or death of *F. excelsior*. *F. excelsior* is called ash throughout. All trees are referred to by their English names with the Latin equivalent listed in Table 13.1 in Appendix 1.

Ash dieback first appeared in the UK in February 2012. Evidence from continental Europe suggests that there could be rapid spread of the disease and a high level of tree death in the UK (Kjaer et al 2012; Pautasso et al 2013). Widespread death of ash trees within the UK has the potential to impact on populations of species that in some way depend on ash to complete their life-cycle. Depending on the scale and extent of loss of ash trees, and the level of the dependence of the associated species, this may be in the form of extinction of the associated species, or declines in their abundance due to reduction in feeding/breeding or habitat (e.g. epiphytic lichens, bryophytes, specialist invertebrates) (Jonsson and Thor, 2012).

When assessing the potential ecological and conservation impacts of any tree disease there are four actions that must be taken:

1. The ecosystem functions associated with the tree species under threat must be identified and an assessment made of how these may change if the species is lost or replaced by other tree species.

2. Information about which species use the tree (and how) must be collated across ecological guilds.

3. The suitability of alternative tree species to replace the threatened tree species must be assessed.

4. Potential management options to mitigate or reduce the impact of the disease must be identified and the impact these options on ash-associated species assessed.

The first two actions assess the potential ecological impacts and the final two actions assess potential 'solutions' to the problem. Mitchell et al 2014 carried out the first two actions identified above, and made an initial start on steps 3 and 4 for a selection of alternative tree species and management options. This report continues this work by assessing the suitability of a further 28 tree species as alternatives to ash and developing further management scenarios. For simplicity the Mitchell et al (2014) report is referred to as Phase 1 throughout this report, with the current work being referred to as Phase 2. The Phase 1 report can be found at: http://jncc.defra.gov.uk/page-6322.

1.2 Objectives

This research aimed to:

1 Examine the ecological function of 11 tree species likely to replace ash, and assess how they might affect woodland ecosystems if they became more prevalent (compared with the current 'niche'/functions of ash) (Chapter 2).

2 Assess whether the ash-associated species identified in Phase 1 use 28 alternative tree species (Chapter 3)

3 Undertake a 'traits analysis' of 28 alternative tree species (Chapter 4).

4 Develop two additional management scenarios to cover 'thinning' and 'felling with natural regeneration' (Chapter 5).

5 Develop management scenarios to include ash woodlands with >20% ash in the canopy (Chapter 7).

6 Assess the implication of the management scenarios on ash-associated species (Chapters 6 & 8).

7 Develop 15 cases studies showing how existing management plans may be adapted if ash dieback arrives at these sites. The case studies provide worked examples of how the information provided in this and the Phase 1 project can be used to inform management choices at a site level (Chapter 9).

8 Develop a simple Excel database to enable woodland managers & decision-makers to access the information (Chapter 9).

In order to set these aims within the context of the Phase 1 report, the introduction section to each of the relevant chapters (listed in parenthesis) expands these aims.

2 Ecological Functioning of alternative tree species

Chapter summary

1. *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.*

2. *The tree species that may replace ash if ash dieback-related mortality is high may not preserve these ecosystem characteristics. This chapter assesses the ecological functioning of 11 tree species (rowan, birch (silver or downy), field maple, sycamore, aspen, oak (pedunculate or sessile), beech, lime, alder, walnut (black or common) and wild cherry) that may replace ash and identifies how similar (or not) these tree species are to ash with respect to the following ecological functions:*
   - *Volume of litter produced*
   - *Decomposition rates of litter*
   - *Chemical composition of litter (litter quality)*
   - *Impact of soil fertility*
   - *Succession, gaps and colonisation.*

3. *Changes between tree species will not alter volumes of litter produced.*

4. *There are three main groups of species in terms of mass loss and decomposition rates: high (alder, ash, lime, rowan), medium (sycamore, field maple, aspen), and low (oak[12], beech).*

5. *Some species (e.g. birch) have a fairly inconsistent ranking with respect to rate of decomposition – decomposition of their litters may be more strongly influenced by local environmental factors.*

6. *Ash is a species with high litter quality, high soil nutrient turnover and high soil pH. The nearest species to it in the rankings were alder and lime.*

7. *Many studies showed that beech, birch and oak are all species with lower litter quality, slower soil nutrient turnover and lower soil pH than ash.*

8. *High litter quality (chemical composition of the litter such as carbon to nitrogen ratio and lignin to nitrogen ratio) is associated with a faster turnover of material. The litter quality of the trees may be ranked from high to low as: Walnut> Alder> Ash> Lime> Aspen= Field maple= Sycamore> Oak= Rowan= Birch> Beech> Wild cherry.*

9. *Higher nutrient content within the soil indicates higher soil fertility which then impacts on community composition. The soil nutrient cycling of the trees was ranked from high to low as: Alder= Ash> Lime> Field maple= Sycamore> Oak= Birch> Beech.*

10. *Ash, beech, oak, field maple, sycamore, lime and wild cherry are described as late successional species but are also found as single trees or even single-species woodlands, thus can act as pioneer species as well. Late successional species generally have heavy seeds, are shade tolerant and relatively long lived but their*

[12] Wherever the generic term 'oak' is used without qualification it refers to *Quercus robur/ petraea* (pedunculate/sessile oak), and the species name is always used for any other oaks.

respective heights reflect their different roles as canopy dominants (e.g. beech, lime and oak) or sub-dominants (field maple). Rowan was variously described as early, mid or late successional. Aspen, although often described as early successional, is commonly found in established woodlands as well. Both species exhibit mostly intermediate traits. Birch is a classic early successional species with small seeds, high light requirements for germination, early and later growth, and relatively short lifespan. Alder commonly acts as a pioneer, as do aspen and rowan (but the latter two not exclusively).

11. *Confidence in conclusions for litter production is low due to low study number. Confidence in conclusions for mass loss, decomposition rates, litter quality and soil nutrient cycling is high due to the number of high quality studies with similar results showing consistent patterns. There was good data on successional processes for beech, oak, birch, lime, sycamore, field maple and rowan, somewhat less for alder and aspen; and very little relevant data for common and black walnut and wild cherry.*

2.1 Introduction

The Phase 1 report literature review showed that ash lies at the extreme of the range of UK tree species:

- 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 rapidly, little soil carbon is sequestered, and the rates of nutrient turnover around ash trees are high.
- The nutrient cycling characteristics of ash, and high light penetration through its leaves, contribute to the diversity of the associated ground flora.
- The species composition of the soil decomposer community, from bacteria through to soil macro-invertebrates, and of the associated arbuscular mycorrhizal fungi, is of considerable functional significance for ash, shaping its ecosystem functions and the biodiversity of associated assemblages.
- 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.

The tree species that may replace ash if ash dieback-related mortality is high may not preserve these ecosystem characteristics. This chapter assesses the ecological functioning of 11 tree species (Table 2.1) that may replace ash, and identifies how similar (or not) these tree species are to ash.

Table 2.1 Tree species assessed for their ecological functioning

Latin	English
Sorbus aucuparia	Rowan
Betula pubescens /pendula	Birch, downy or silver
Acer campestre	Field Maple
Acer pseudoplatanus	Sycamore
Populus tremula	Aspen
Quercus petraea/robur	Oak, sessile or pedunculate
Fagus sylvatica	Beech
Tilia cordata	Lime
Alnus glutinosa	Alder
Juglans nigra/regia	Walnut, black or common
Prunus avium	Wild cherry

2.2 Methods

A literature review to identify the ecological function of the 11 tree species was carried out using key-word driven searches undertaken during the 6-24 January 2014 in Web of Knowledge (http://wok.mimas.ac.uk/). Three searches were conducted for each tree species. Search terms included the Latin name of the tree species together with keywords categorised as group 1: carbon, nutrient or nitrogen and cycling; group 2: litter, decomposition; group 3: succession, gaps, colonization and light (Table 2.2).

Table 2.2 Search terms used for the example "Sorbus aucuparia"

Latin
"Sorbus aucuparia" AND (carbon OR "nutrient cycling" OR nitrogen)
"Sorbus aucuparia" AND (litter OR decomposition)
"Sorbus aucuparia" AND (succession OR gaps OR colonisation OR light)

For each search the abstracts of all the extracted articles were read, and if the abstract was relevant to the project (i.e. including references to more than one tree species and so enabling comparisons to be made) the full manuscript was obtained. This first sift of papers resulted in over 420 papers being obtained. The papers were then read and, if found to contain relevant information, were used to rank the species relative to each other with respect to the three functions studied. The detailed rankings are shown in Appendix 2 together with the references used.

2.3 Results

2.3.1 Litter production

Overall, studies of litter production and decomposition tend to focus on particular tree species, specifically ash, sycamore, oak and beech. The other species in our list are less well represented, and so assessment of their litter production and decomposition processes are more tentative, but the functions of these “other” species can be aligned relative to the position of these four frequently-studied species.

Volumes of litter produced by trees are obviously dependent on stand age, and so comparisons of litter production must account for stand age effects. We excluded any papers that confounded species and stand age comparisons, and overall found far fewer useful studies of the amount (volume or mass) of litterfall than we did of decomposition rates and mass loss.

Our data do not show clear patterns in litter production. The relative order of species can switch between studies. For example Carnol & Bazgir (2013) found that birch produces more litter than oak, whereas Varnagiryte *et al* (2005) found the opposite. But more commonly, and if stand age is accounted for, there are no differences in litter production between species. Hence the data suggest that replacing one species with another will not alter volumes of litter produced for trees of a given age. But it is worth stressing again that this conclusion is based on only a handful of studies.

It is also worth noting that we are not sure about the mechanistic link between the volume of litter produced and rate of decomposition and mass loss. In our data tables (Appendix 2, Table 14.2) we have tried to place “productive” species to the left of the tables: i.e. fast-growing species that produce highly decomposable (=high quality) litter. But we do not know whether production of large or small amounts of litter might be expected by these species, and so for litter production the ordering of species in the data table (from left to right) is tentative.

2.3.2 Mass loss and decomposition rates over time

A common approach to studying the decomposability of leaf litter is to look at its mass loss over time. Data on decomposition are then often expressed as percentage mass lost (or remaining) after a certain time period, or in some cases as a decomposition rate constant k calculated from regressions of mass loss against time. Although not the same (as litter quality can change through time, altering proportional mass loss depending on the length of a study) the results of our review indicate a close concordance between these two metrics, and so here they are dealt with together.

In general we find three rough groupings. Ash commonly has one of the most rapidly decomposing litters, oak and beech litters are generally the slowest to decompose, and sycamore litter tends to sit between these two extremes. Other species can be associated – in a crude way – with two of these three consistent points. Alder, lime and rowan decompose relatively quickly, like ash; field maple and aspen group in the middle along with sycamore (Table 2.3). The full data from all the studies used in this assessment can be found at Appendix 2, Table 14.3. More guidance on relative rankings can be gained from looking at the tissue properties, as effectively it is litter quality (e.g. lignin content, C:N ratios) that commonly has a strong impact on decomposition rates.

Table 2.3 Hierarchy of mass loss and decomposition rates

High	Low
Ash= Alder= Lime= Rowan> **Sycamore**= Field maple= Aspen> **Oak= Beech**	

Level of confidence is shown by the darkness of the writing. There is greatest confidence in the results for those species shown in bold.

Finally, some of the species have quite variable decomposition rates. Birch, for example, shifts from being amongst the slowest decomposers in some studies (e.g. Hobbie et al 2006) to being the fastest decomposer in others (e.g. Cotrufo et al 1998a, b). It may be that the “weedy” nature of birch means that its litter quality - and hence decomposability - is strongly influenced by changes in environmental conditions between sites.

Overall, these results appear to tie in well with those for tissue nutrient content and cycling, i.e. similar groupings appear (as detailed below, Section 2.3.3) and patterns in the rate of decomposition can be linked to patterns in leaf litter quality.

2.3.3 Litter quality

The chemical and physical properties of leaf litter cause marked interspecific differences in the rate of cycling of nutrients and carbon within ecosystems (Cornelissen & Thompson 1997). In general nutrient and carbon cycling are enhanced (positively correlated) by higher nutrient contents in litter; usually the focus is on litter nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Cycling is delayed by leaf investment in structural materials such as lignin, and so cycling is negatively correlated with measures such as carbon:nitrogen (C:N) or lignin:N ratios (Wardle et al 2002). As a shorthand, ‘litter quality’ is used to group these measures together, with a high litter quality implying faster turning-over material.

There was a high degree of consensus amongst the studies and the measured litter variables (Appendix 2, Table 14.4). However, a number of the species were represented in a relatively small number of studies so they are placed in the hierarchy with less confidence than others. There were a large number of studies that dealt with ash, lime, oak/birch and beech, but far fewer with alder, aspen, field maple, rowan, sycamore and wild cherry. No published studies directly measured the nutrient content of walnut litter, though the TRY database (Kattge et al 2011) has entries for leaf C:N which is generally correlated with litter C:N (Kurokawa et al 2010).

Of the species commonly measured in the course of these studies, ash was almost always the highest in the nutrients measured followed by lime, then oak, then birch, and beech always had the lowest (or equal lowest) nutrient content. This order was largely consistent with, for example, lime exceeding ash in litter quality measures for three variables, tying with ash for 6, and being exceed by ash for 16 in the studies where they we both measured. Birch was the most variable of these species in its place in the order, particularly with respect to oak and, as they were measured only a few times in the same study, it was difficult to separate them. This plastic behaviour of birch suggests that its litter quality is more context dependent than other species (see also section 2.3.2).

Of the species more rarely found in litter studies, then the data suggest alder has generally higher litter nutrient contents than ash; aspen, field maple and sycamore fall between lime and oak/birch; rowan has similar litter quality to oak and birch; and wild cherry has a lower litter quality than beech. Walnut had the lowest leaf C:N measured, suggesting it should have the highest litter turnover rate.

A final hierarchy of litter quality results is shown in Table 2.4 with the detailed results in Appendix 2, Table 14.4.

Table 2.4 Hierarchy of litter quality

High	Low
Walnut> Alder> **Ash**> **Lime**> Aspen= Field maple= Sycamore> **Oak**= Rowan= **Birch**> **Beech**> Wild cherry	

Level of confidence is shown by the darkness of the writing. There is greatest confidence in the results for those species in bold and least confidence in the ranking for those species in grey.

2.3.4 Soil quality

Litter inputs into the soil have an impact on nutrient cycling within soils, and hence soil fertility. Higher nutrient contents within soil indicate higher soil fertility which then impacts on community composition (Wardle et al 2002). As for litter, a high C:N ratio indicates a soil with slow nutrient turnover. In addition, in a number of studies soil pH was measured. This is somewhat independent of fertility, but acid soils tend to be nutrient poor, whilst neutral and basic soils show a greater range in fertility (Augusto et al 2002). However, the impact of tree species on soil fertility is context dependent and depends upon the interaction between the tree species and the bedrock in determining soil evolution (Augusto et al 2002).

There was a high degree of consensus amongst the studies and the soil variables measured (Appendix 2, Table 14.5). A good range of studies covered ash, birch, beech, lime and oak, but few other species were covered. Consequently, beyond the five listed it is difficult to be certain of their place in the ranking of nutrient cycling rates in the soil.

As for litter quality, ash tended to have the highest nutrient contents in the soil beneath it compared to the other species, though it often was at a very similar level to lime. Oak and birch tended to have lower soil nutrient contents and pHs and higher C:N ratios than soils under ash and lime. Beech usually had the lowest nutrient contents and pHs, whilst having the highest C:N ratios. Of the species less commonly found in the studies, alder had similar soil nutrient levels beneath as ash, and field maple and sycamore were intermediate between ash/lime and oak/birch.

A final hierarchy of soil nutrient cycling data is shown in Table 2.5 with the full data in (Appendix 2, Table 14.5). This ranking broadly agrees with a previous ranking on the effects of different tree species on soil acidifying ability by Augusto et al (2002) who ranked trees from low to high as Ash= Lime< Beech= Birch= Oak.

Table 2.5 Hierarchy of soil nutrient cycling

Fast	Slow
Alder= **Ash**> **Lime**> Field maple= Sycamore> **Oak= Birch> Beech**	

Level of confidence is shown by the darkness of the writing. There is greatest confidence in the results for those species in bold and least confidence in the ranking for those species in grey.

2.3.5 Succession, gaps, colonization and light

Tables 14.7-14.14 in Appendix 2 summarise data considered important in comparing and categorising species in terms of their role in colonisation and succession. As well as successional status, the table gives information on seed weights; formation of ‘seedling banks’, light requirements at germination, early growth and mature stages of tree growth; tree height and longevity. Unless otherwise specified (with references in brackets), the statements below relate to data and references given in Tables 14.7-14.14 which are designed to be cross-referenced whilst reading the text below.

<u>Late successional species</u>

Along with ash, beech, oak, field maple, sycamore, lime and wild cherry are described as late successional species. However these species are also found as single trees or even single-species woodlands, thus can act as pioneer species as well. All have relatively heavy seeds, with those seed reserves facilitating initial growth in shade. Beech was most consistently recorded as the most shade tolerant tree species at germination/young seedling stage, but oak, ash, sycamore and lime were recorded as similar or only slightly less shade tolerant. We found only one paper defining the shade tolerance of germinating wild cherry (medium-high shade tolerance) and one for field maple which referred to studies stating different germination shade-tolerance for this species.

There are generally strong positive linkages reported between seed size and species shade tolerance – shade tolerators tend to have larger initial size, as well as advance regeneration, absolute growth rate and survivorship in low light despite their generally lower relative growth rate, with a range of associated physiological attributes/responses (Welander & Otterson 1998; Hattenschwiler 2001; Pitchler et al 2001; Wittmann et al 2001; Kull & Tulva 2002; Schmid et al 2005; Niinemets 2006; Portsmuth & Niinemets 2006; Rammig et al 2006; Petritan et al 2010). Not all studies consistently found such differences. Ligot et al 2013, for example, found that beech had higher growth rates than oak at all light levels sampled across a Belgian mixed forest, but the optimal growth of beech was indeed at lower light levels (10%) than for oak (>20% - also found by von Lupke 1998; see also Jarcuska 2009). Petritan et al 2009 found optimal growth of beech to be at about 35% light, whereas ash and sycamore showed increasing growth with increasing light levels.

Persistent seedling/sapling banks are important for rapid gap colonisation in closed forest (Madsen & Hahn 2008; Diaci et al 2012). Species recorded as readily forming 'seedling banks' (advance regeneration) were beech, ash, sycamore, field maple and rowan. Gaps confer different characteristics (Latif & Blackburn 2010) which different tree species can respond to. It has been suggested that shade-tolerant species show lower plasticity than light-demanding species (e.g. Lawesson & Oksanen 2002), which may make them less responsive to rapidly changing conditions, such as gap creation, but this is not supported by all studies (e.g. Wyka et al 2007). Furthermore, within the shade-tolerators listed here, different levels of plasticity have been recorded – Einhorn et al (2004), for example, found greater phenotypic plasticity of ash seedlings as compared to beech in terms of their photosynthesis, which can give this species an advantage in terms of rapid gap colonisation from established seedling banks (Emborg 1998).

The degree of response to light has been shown to differ with age and stage for some species - Peltier et al (1997), for example, found strong shade tolerance at young seedling stage for both beech and ash, but better growth of older beech seedlings (> 3 years) under higher light levels (not specified) (see also Szwagrzyk et al 2001; Schnitzler & Closset 2003). Increases in light requirements with age (germination-seedling-sapling-tree) were also reported for oak species in particular, also sycamore, field maple and lime.

These late successional species are all relatively long-lived, but vary in their mean heights, reflecting in some cases different roles as canopy dominants (e.g. beech, lime and oak) or sub-dominants (field maple).

<u>Mid successional species</u>

Rowan was variously described as early, mid or late successional and the characteristics recorded in Tables 14.7-14.14 reflect this – intermediate seed weights, shade tolerance, lifespan and tree height; presence of advance regeneration. One of the main seed dispersal mechanisms is by birds and therefore the location of regeneration often reflects presence of perching places (trees, rocks etc) rather than presence of light or shade (Raspe et al 2000). As with the late successional species described above, rowan displays strong shade tolerance for germination/young seedling stage, but increasing light requirements with increasing age. Aspen, although often described as early successional, is commonly found in established woodlands as well. It exhibits mostly intermediate traits, but also has strong vegetative regeneration capacity which facilitates persistence of this species once established. The seeds are very small and seed germination requires light, but regeneration from seed is recorded as rare in UK and good seed years are also very infrequent (Vehmas et al 2009; Myking et al 2011).

Early successional species

The classic, well-studied early successional species on our list are birch species. These species display all the expected traits of small seeds, high light requirements for germination, early and later growth, and relatively short lifespan. Aspen and rowan commonly act as pioneers (but not exclusively, as above), as does alder. All three can also form monospecies stands. Alder has relatively small seeds but there is some indication that germination light requirements may not be as great for this species as for birch species (McVean 1953). All other growth stages for alder are recorded as requiring light. The trees are relatively short-lived and short to intermediate in height.

2.3.6 Confidence in results

Overall there is medium-high confidence in the results presented as most of the studies on which the review is based were undertaken in a systematic way with adequate replication, and appropriate experimental designs. For most of the functions reviewed there were many studies showing similar results.

There is low confidence for the assessment of volume of litter produced due to low replication. There are few studies from which to draw our conclusions and consequently, although individual studies are well designed, power for generalisation is limited.

We have better replication for studies of decomposition rates and mass loss. The more pertinent issue is how well the individual studies quantify the processes that are occurring in woodlands. For example, many of them use either microcosms (isolated chambers or pots in which the litter is decomposed) or litter bags (where set amounts of litter are enclosed within a mesh bag and then placed on or in soil for a fixed period). Such approaches have limitations, and the environmental conditions experienced by the litter may differ from those experienced by “natural” litter on the forest floor. For example, moisture content may differ between experimental and natural litters, and soil macrofauna (e.g. large earth worms) may be excluded from litter bags with fine mesh. However, when factors such as litter bag mesh size or study period have been explored explicitly, the relative rankings between species of decomposition rates remain constant despite variation in their absolute levels - see for example the study by Schadler & Brandl (2005). Overall, therefore, we feel that we can have relatively high confidence in the results for decomposition and mass loss because relative rankings are fairly consistent across multiple studies (despite their using a wide range of experimental approaches), and because the data for decomposition and mass loss match closely with expectations based on tissue quality.

The studies used to assess litter quality and nutrient cycling range widely in quality. Some of the litter quality data come from tables of initial litter compositions from decomposition experiments, and do not have any formal statistical testing. These were ranked low in quality. Also, a small number of studies were based on experiments with seedlings and saplings, and hence any impacts on the soil could not be judged in terms of their long-term consequences. However, there are sufficient high quality and well replicated studies to have a high degree in confidence with respect to ranking the species in terms of both their litter quality and the impact they have on the soil.

Most references used in to review ‘succession, gaps, light and colonisation’ have been classified as containing data of medium (=generally single forest/area studies but good sample design and replication) to high confidence (=numerous studies; good, well replicated experimental data). Some of the older references, especially several Biological Flora, included much information that seemed to be of anecdotal or observational origin, so these have been classed as medium-low or low quality information. For the 11 species listed (in addition to ash – see also Phase 1 report), we found the most data for beech, oak, birch, lime, sycamore, field maple and rowan, somewhat less for alder and aspen; and very little relevant data for common and black walnut and wild cherry. Much literature on these latter species refers to cultivating these trees for their fruit/nuts as opposed to recording natural successional processes.

3 Alternative tree species: use by ash-associated species

<u>Chapter summary</u>

1. *The number of ash-associated species that use the tree as opposed to just the ash woodland habitat was updated from the Phase 1 figure of 953 to the new total of 955. This increased the number of obligate species (species identified as only occurring on either living or dead ash trees) from 44 to 45: 4 lichen species, 11 fungi and 30 invertebrates; 62 highly associated species were identified: 19 fungi, 13 lichens, 6 bryophytes and 24 invertebrates.*

2. *Information on whether the 955 ash-associated species used 28 alternative tree species was collated and combined with the data for a different set of 20 alternative tree species assessed in Phase 1.*

3. *Most native trees have information on species use for 75% of ash-associated species. The exceptions to this were goat willow, small-leaved lime, grey willow, black poplar, elder and wild service tree which although native to the UK had information for less than 35% of ash-associated species.*

4. *Most non-native tree species only had information for less than 35% of ash-associated species. The exceptions to this were sycamore, sweet chestnut, horse chestnut, common walnut, black walnut, and European larch where information was available for over 75% of ash-associated species.*

5. *Of the tree species assessed those native to the UK support more ash-associated species than non-native tree species, although data was lacking for many non-native species. Non-native (although often described as naturalised) sycamore is the exception – it supports a similar number of ash-associated species to some native species (473 species ash-associated supported).*

6. *67% of ash-associated species (640 species) are also associated with native oak species (sessile and pedunculate). More than 400 ash-associated species are also associated with each of the following tree species: beech, elm, sycamore, hazel and birch.*

7. *Of the newly assessed tree species (ie not considered in Phase 1), elm spp. and rowan supported the greatest number of ash associated species (over 300).*

8. *Four non-native ash species were included in the assessment: manna ash, American ash, green ash, Manchurian ash. These species were assessed as 'likely' to support over 200 ash-associated species particularly ash-associated bird, fungi and invertebrate species. However some of these non-native ash species may also be susceptible to ash dieback.*

9. *Of the non-native alternative tree species considered, sycamore (473), horse chestnut (208), European larch (166), common walnut (149), sweet chestnut (148) and black walnut (126) support the greatest number of ash-associated species; the number of ash-associated species supported is given in parentheses. However, data is missing for many non-native tree species, making comparisons difficult.*

10. *Native oak species (sessile and pedunculate) support the greatest number of ash-associated birds (100%), invertebrate (30%), lichen (85%) and mammal (61%)*

species, but hazel supports more bryophyte species (95%) and elm spp. more fungi species (31%), with oak in second place for bryophytes (91%) and third for fungi (26%). Beech is second place for fungi species (28%). Percentages given in parentheses are the percentage of ash-associated species in each group supported.

11. *Elm spp. supports the greatest number of the ash-associated species that are most vulnerable to ash-dieback (species with an obligate or high association with ash and/or a high conservation status). Hazel, oak, aspen and sycamore also support a high number of ash-associated species that are most vulnerable to ash-dieback. However, elm spp. remains susceptible to Dutch elm disease and is therefore not considered to be widely suitable as an alternative to ash.*

3.1 Introduction

Species that use ash may be termed ash-associated species. Phase 1 identified 1,058 ash-associated species, 953 of which use ash trees, the rest being associated with the ash woodland habitat. In this report we confine our research to the species that use ash trees rather than the ash habitat.

Due to changes in taxonomy and additional information obtained during this project, the list of ash-associated species was updated to 955 ash-associated species (those associated with the tree, not just the habitat). The following changes were made:

- *Astiosoma rufifrons* (an invertebrate) was incorrectly identified as being obligate on ash in Phase 1 and was removed from the list.
- *Brachynotocoris puncticornis*, an obligate Heteropteran bug recently arrived in the UK, was added to the list.
- *Prays ruficeps*, an obligate moth recently split from *Prays fraxinella* on taxonomic grounds, was added to the list. *P. fraxinella* was included in the Phase 1 list.
- *Lonchaea patens*, a partially-associated fly, was added to the list on advice from Iain MacGowan who is the UK expert on this genus.

These changes increased the number of obligate species (species identified as only occurring on either living or dead ash trees) from 44 to 45: 4 lichen species, 11 fungi and 30 invertebrates. Sixty two species were found to be ‘highly associated’ with ash: 19 fungi, 13 lichens, 6 bryophytes and 24 invertebrates (Table 3.1). See Table 3.3 for definitions of level of association with ash.

Table 3.1 Number of ash-associated species and their level of association

Group	Obligate	High	Partial	Cosmopolitan	Uses	Total
Bird			7	5		12
Bryophyte		6	30	10	12	58
Fungi	11	19	38			68
Invertebrate	30	24	37	19	131	241
Lichen	4	13	231	294	6	548
Mammal			1	2	25	28
Total	45	62	344	330	174	955

3.2 Rationale for choosing alternative tree species

One 'solution' to the potential loss of ash is to encourage the establishment of alternative tree species that ash-associated species will use. Phase 1 assessed whether ash-associated species used 20 alternative trees species. This report assesses the use made of a further 28 alternative tree species and combines the results with Phase 1 to assess the relative potential of 48 tree species to support ash-associated biodiversity (Table 3.2). The tree species chosen include all native tree species likely to occur on ash sites, plus a range of non-native species which have been proposed as possible alternatives where commercial production of ash is the primary objective of woodland management. Given that woodland managers may wish to use these species for commercial reasons, the Steering Group felt it was important to understand the potential ecological implications of using these species.

The 48 species included three groups of two tree species which were combined into single assessments (silver and downy birch, sessile and pedunculate oak, English and wych elm). 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. Other tree species in addition to those assessed here may also support ash-associated species.

It should be noted that:

- throughout the report the alternative tree species are classified as native and non-native on a UK basis. At a regional or country level within the UK some of the native tree species are not native, eg beech in Scotland;

- in Scotland licences are required for the planting of certain non-native tree species under the WANE act see: http://www.forestry.gov.uk/forestry/INFD-8VPE56. A list of species approved for planting in Scotland may found at: http://www.forestry.gov.uk/pdf/FCSlistofapprovedspeciesforplantingunderWANE.pdf/$FILE/FCSlistofapprovedspeciesforplantingunderWANE.pdf

Table 3.2 Alternative tree species for which an assessment was made

Tree alternative	English name[3]	Phase[1]	Native[2]
Abies alba	Silver fir	2	No
Acer campestre	Field maple	1	Yes
Acer platanoides	Norway maple	1	No
Acer pseudoplatanus	Sycamore	1	No
Aesculus hippocastanum	Horse chestnut	2	No
Alnus cordata	Italian alder	2	No
Alnus glutinosa	Alder	1	Yes
Betula pubescens/pendula	Birch spp. (downy & silver)	1	Yes
Carpinus betulus	Hornbeam	1	Yes
Carya ovata	Shagbark hickory	2	No
Castanea sativa	Sweet chestnut	1	No
Corylus avellana	Hazel	1	Yes
Crataegus monogyna	Hawthorn	1	Yes
Fagus sylvatica	Beech	1	Yes
Fraxinus americana	American ash	2	No
Fraxinus mandschurica	Manchurian ash	2	No
Fraxinus ornus	Manna ash (or south European flowering ash)	2	No
Fraxinus pennsylvanica	Green ash (or red ash)	2	No
Ilex aquifolium	Holly	2	Yes
Juglans nigra	Black walnut	2	No
Juglans regia	Common walnut	2	No
Larix decidua	European larch	2	No
Ligustrum vulgare	Privet	2	Yes
Malus sylvestris	Crab apple	2	Yes
Ostrya carpinifolia	Hop-hornbeam	2	No
Pinus sylvestris	Scots pine	2	Yes
Platanus x hybrid	Plane	2	No
Populus nigra	Black poplar	2	Yes
Populus tremula	Aspen	1	Yes
Prunus avium	Wild cherry	1	Yes
Prunus padus	Bird cherry	1	Yes
Prunus spinosa	Blackthorn	2	Yes
Pseudotsuga menziesii	Douglas fir	1	No
Pterocarya fraxinifolia	Caucasian wingnut	2	No
Quercus cerris	Turkey oak	2	No
Quercus robur/petraea	Oak spp. (pedunculate & sessile)[4]	1	Yes
Quercus rubra	Red oak	2	No
Salix caprea	Goat willow	1	Yes
Salix cinerea	Grey willow	1	Yes
Sambucus nigra	Elder	2	Yes
Sorbus aria	Whitebeam	1	Yes
Sorbus aucuparia	Rowan	2	Yes
Sorbus torminalis	Wild service tree	2	Yes
Taxus baccata	Yew	1	Yes
Thuja plicata	Western red cedar	2	No
Tilia cordata	Small leaved lime	1	Yes
Tilia platyphyllos	Large leaved lime	2	Yes
Ulmus procera/glabra	Elm spp. (English Elm & Wych)	2	Yes

[1]Phase indicates the Phase of the project - 1 or 2 - during which an assessment was made.
[2]Different tree species are native or non-native in different parts of the UK. This indicates if the tree species is native at the UK scale.
[3] Where two species are combined into one assessment, or where there are several different English names, the species is referred to as the English name outside the parentheses in all graphs/tables that follow in this report.
[4]Wherever the generic term 'oak' is used without qualification it refers to Quercus robur/ petraea (pedunculate/sessile oak), and the species name is always used for any other oaks.

3.3 Assessment methods

The level of association between the ash-associated species and the alternative tree species was categorised into one of nine categories as defined in Table 3.3. To simplify the analysis these categories were reduced to ‘yes’ (the species uses this alternative tree), ‘no’ the species does not use this tree), ‘unknown’, ‘rare’, and ‘likely’ (Table 3.3).

Table 3.3 Definition of levels of association between ash-associated species and alternative tree species

Level of association[1]	Definition	Simplified terminology for level of association
Highly associated	In relation to the use of a tree species by a taxon: the taxon rarely uses other tree species	Yes
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	Yes
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	Yes
Uses	In relation to the use of a tree species by a taxon: the taxon uses the tree species but the importance of this tree species for this taxon is unknown	Yes
Rare	In relation to the use of a tree by a taxon: the taxon has been recorded on this tree species but only rarely.	Rare
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 when there was no specific information on the use of the tree species by the taxon but expert judgement suggested that the taxon was likely to use that tree species, for example when the taxon was known to use other tree species in the same genera or known to use a wide range of deciduous tree species.	Likely
No	In relation to the use of a tree by a taxon: the taxon does not use this tree species, or where information is lacking on the use of the tree species by the taxon it is thought unlikely that the taxon uses this tree species.	No
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.	Unknown
Unknown	In relation to the use of a tree species by a taxon: it is not known if the taxon uses this tree species.	Unknown

[1]Note an additional level of association ‘obligate’ was used when assessing the level of association with ash (the species was only found on ash). This level of association, by definition, was not appropriate in the assessment of alternative trees.

The level of association between the ash-associated species and the alternative tree species were first assessed in the same way as for Phase 1. Many of the tree species assessed in this second phase were non-native tree species, resulting in there being little or no information on the use made by the ash-associated species of these tree species in the databases/literature used in Phase 1. Therefore additional extensive literature searches/google searches were undertaken to try and provide levels of association. These extensive searches aimed to confirm as many of the 'unknowns' as possible so that the genuine evidence gaps are identified.

For each species group there were limitations on the data available to make these assessments. These limitations are detailed in Appendix 4, and the references used to make the assessments in addition to those used in Phase 1 are listed in Appendix 5.

3.4 Quality of data

Details on data quality for individual species groups are presented in Appendix 4. Here a summary of the data quality across all groups is presented.

The quality of the data used to assess the level of association between the ash-associated species and the alternative tree species was categorised into five classes (Table 3.4). Data was first classed as 'expert judgement', '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 because there is evidence that some species use different host species in the UK than in other countries.

Table 3.4 Criteria used to assess data quality

Data quality	Definition
Expert judgement	Decision on level of association is based on 'expert opinion' and ecological knowledge of the species habitat requirements rather than on literature stating that species has been found using a particular tree species. This category frequently used for the likely, no and unknown categories of association.
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.

In total 45840 assessments of the level of association between an ash-associated species and an alternative tree species were made. Levels of association classed as 'yes' generally have a high level of confidence associated with them: 91% of 'yes' records are based on peer reviewed data from the UK. Associations that were classified as 'likely' are largely based on expert judgement (74% of likely records). These records therefore have a lower confidence associated with them, and this should be taken into account when considering which tree species to plant to promote ash-associated biodiversity, with tree species classed as 'yes' being prioritised over those classed as 'likely'. Eighty-seven percent of associations classed as 'no' were based on peer-reviewed data from within the UK, with 10% based on expert judgement. Associations classed as 'unknown' were predominantly based on expert judgement, with 70% of unknown associations in this category. Therefore, if the aim is to conserve ash-associated biodiversity, planting of alternative tree species with a level of association 'unknown' is not recommended.

Table 3.5 Relationship between levels of association with alternative tree species and data quality. Number of records in each class are shown. See Table 3.3 for definitions of level of association, and Table 3.4 for definitions of data quality

	Level of association					
Data quality	Yes	Likely	Rare	No	Unknown	Total
Expert judgement	94	2056	61	1755	12602	16568
NR-NonUK	87	104	1	42	117	351
NR-UK	285	377	27	283	1454	2426
PR-NonUK	279	122	16	102	164	683
PR-UK	7402	111	103	14561	3635	25812
Total	8147	2770	208	16743	17972	45840

Generally there were more data on species associations with alternative tree species that are native to the UK than for those that are non-native (Figure 3.1). Most native trees had information on species use for 75% of ash-associated species. The exceptions to this were goat willow, small-leaved lime, grey willow, black poplar, elder and wild service tree which, although native to the UK, had information for less than 35% of ash-associated species. Most non-native tree species only had information for less than 35% of ash-associated species. The exceptions to this were sycamore, sweet chestnut, horse chestnut, common walnut, black walnut, and European larch, where information was available for over 75% of ash associated species. Thus generally, and due to a lack of data, there is lower confidence in the use made by ash-associated species of non-native tree species than native tree species.

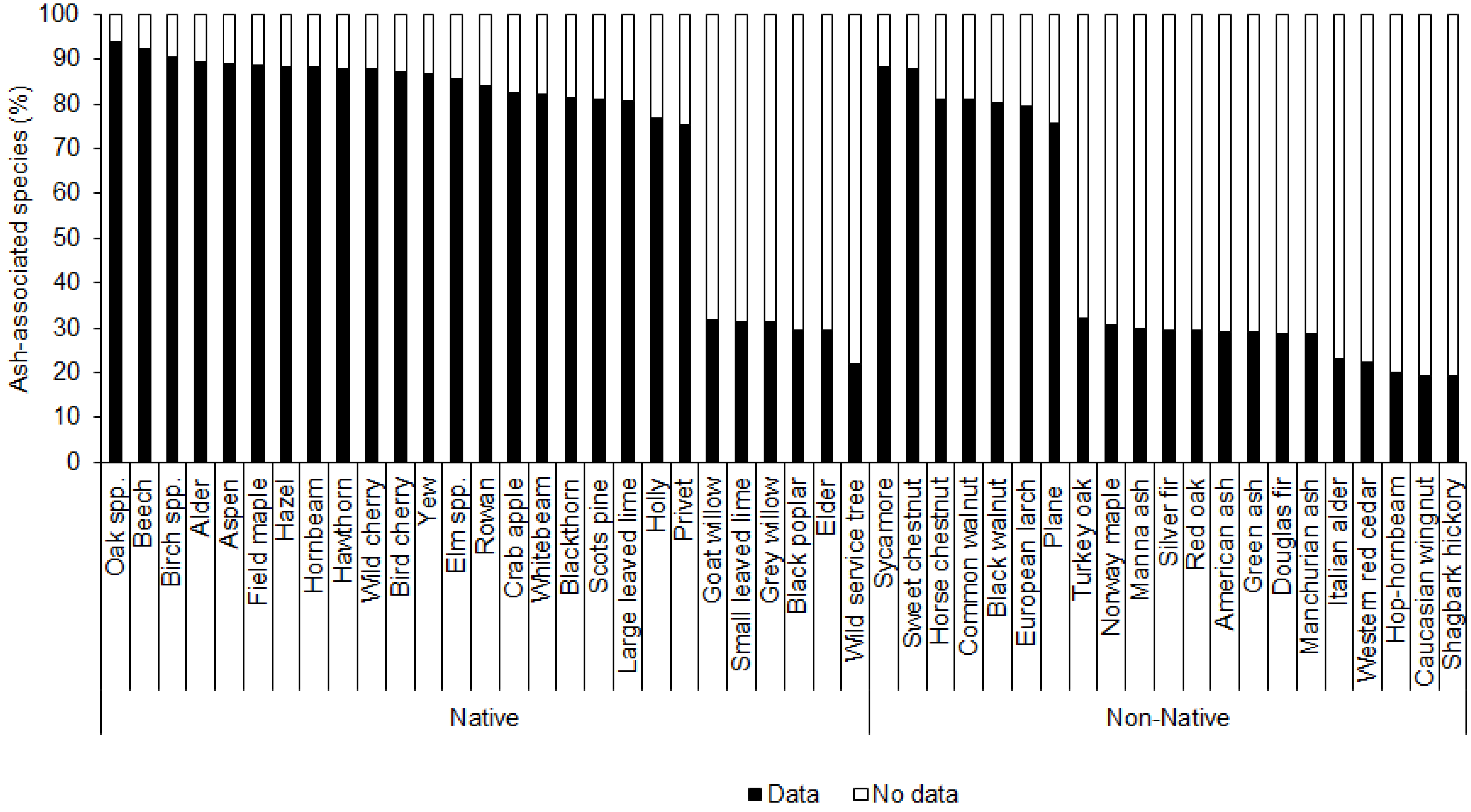

Figure 3.1 Percentage of ash-associated species for which there was data (categories 'Yes', 'No', 'Likely', 'Rare') and no data (unknown) on the use made of 48 alternative tree species. Alternative tree species are grouped according whether they are native to the UK, and then ranked by the percentage of species for which there was known data

3.5 Assessment of single tree species alternatives

Sessile and pedunculate oak (combined as one assessment) are known to support 67% of ash-associated species (640 of the 955 species), with oak spp. beech, elm spp., sycamore, hazel and birch spp. all known to support more than 400 ash-associated species (Figure 3.2).

Of those tree species not previously considered in Phase 1, elm spp. and rowan were known to support the greatest number of ash-associated species (over 300). Elm spp. is no longer a common mature tree species within the UK due to Dutch elm disease and young elm rarely grows to maturity. Elm spp. is therefore unlikely to be a suitable alternative to ash. Crab apple, holly, large-leaved lime, Scots pine, blackthorn, European larch, common walnut and black walnut are all known to support over 100 (out of 955) ash-associated species. Wild service tree, Italian alder, Manchurian ash, shagbark hickory and Caucasian wingnut are all known to support less than ten ash-associated species from available data, but data quality is low for these species with data on association unknown for most species.

Four other ash species (other than *F. excelsior*) were included in the assessment: manna ash, American ash, green ash, Manchurian ash; these trees are respectively known to support 29, 12, 12 and 6 ash-associated species. However, it is thought 'likely' that they will support a further 202, 211, 211 and 212 ash-associated species, respectively. These non-native ash species may therefore be viable alternatives to common ash for some ash-associated species. However the level of susceptibility to ash dieback varies between different species of ash. Experimental work has shown that Manchurian ash is also susceptible to ash dieback, but results so far indicate that manna ash, American ash and green ash may be more resistant or tolerant to ash dieback (Lösing 2013).

Of the tree species assessed, native tree species are generally known to support more ash-associated species than non-native tree species, but part of this difference is likely to reflect the poorer data availability for many non-native species. Oak spp. beech, elm spp., hazel, birch spp., rowan and aspen are all known to support more than 300 ash-associated species; the only non-native tree species known to support more than 300 ash-associated species was sycamore.

Of the non-native tree species considered, sycamore, horse chestnut, European larch, common walnut, sweet chestnut and black walnut were known to support the greatest number of ash-associated species (over 125 ash-associated species). However data are missing for many non-native tree species making comparisons difficult. It should be noted that non-native tree species as alternatives to ash might also bring with them other ecological risks, not just partial benefits in terms of potential habitat for some ash-associated organisms. Such ecological risks include the invasion and modification of sensitive ecosystems, changes in habitat provision for native taxa, altered risk of pest and pathogen outbreaks, and hybridization with native con-generics (Felton et al. 2013).

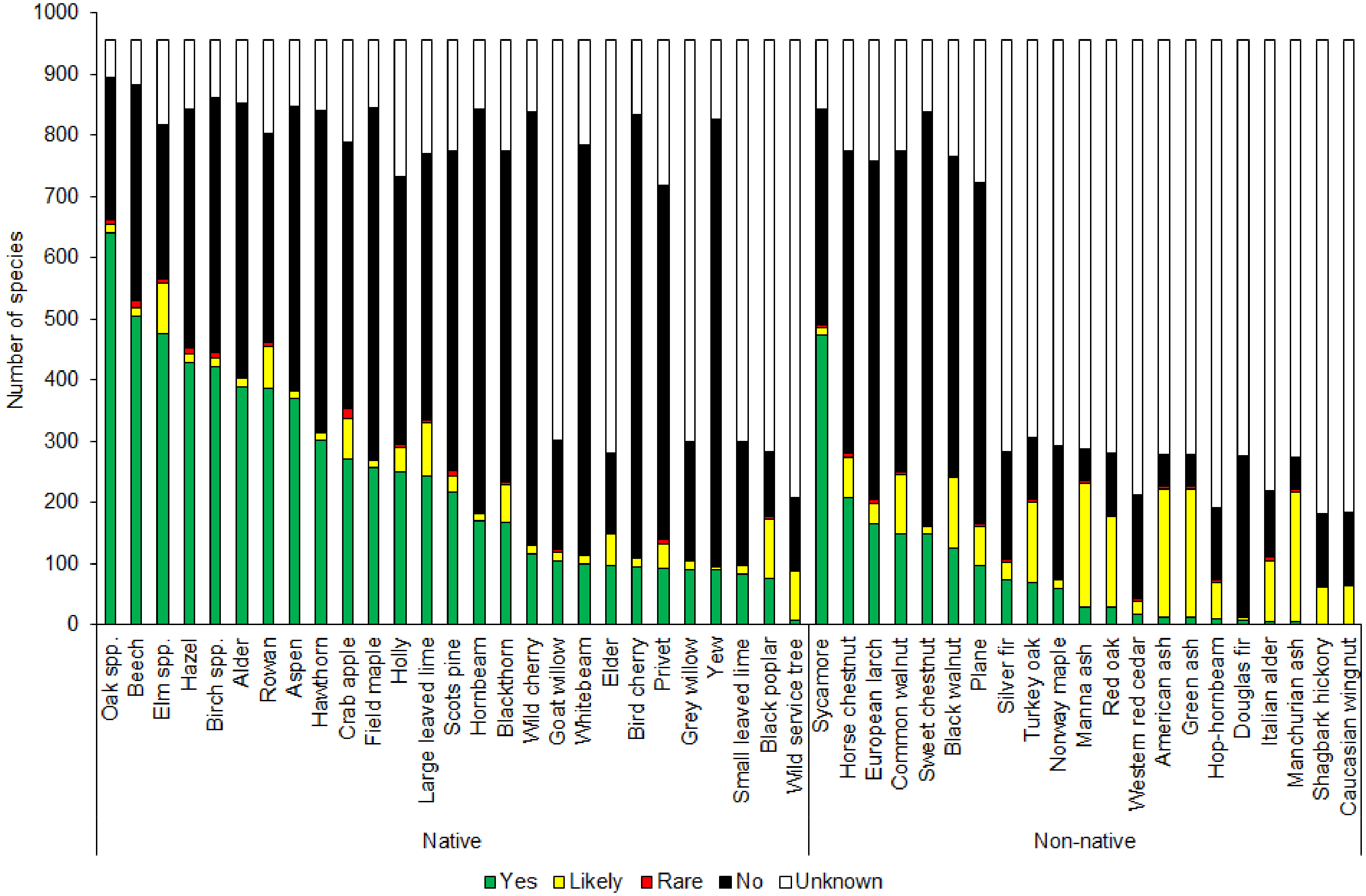

Figure 3.2 Number of ash-associated species and their level of association with each of 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of ash-associated species they support ('Yes' association)

3.5.1 Assessment within species groups

When assessed by the number of ash-associated species known to be supported ('yes' category) the most suitable alternative tree species from those assessed differ between the different species groups (Figures 3.3-3.8, Table 3.6). Oak spp. are known to support the greatest number of ash-associated birds, invertebrates, lichens and mammals, hazel is known to support the greatest number of ash-associated bryophytes (55 of the 58 ash-associated bryophytes), and elm spp. is known to support the greatest number of ash-associated fungi, with oak in second place for bryophytes and third for fungi. Beech is known to support the second greatest number of ash-associated fungi.

If the 'likely' category is taken into account in addition to the 'yes' category, then the greater potential for other tree species to support ash-associated species is demonstrated, particularly the potential for non-native ash species to support ash-associated birds, fungi and invertebrate species, for rowan to act as a good alternative tree for ash-associated mammals, and for Turkey oak and red oak to be good alternative trees for ash-associated invertebrates.

Of those species not considered in Phase 1, rowan is known to be good for ash-associated birds, elm spp. is known to support a good number of ash-associated fungi and invertebrates, and horse chestnut and Scots pine are known to support good numbers of ash-associated mammals.

Within species groups a similar pattern to that for all ash-associated species was found with native tree species known to support more ash-associated species than non-native tree species. Oak spp., birch spp., rowan, beech, aspen, elder, alder, hornbeam, Scots pine, small-leaved lime and elm spp. all support more than 50% of ash-associated birds ('yes' category) (Figure 3.3). None of the non-native trees are known ('yes' category) to support 50% of ash-associated birds.

Hazel, oak, goat willow, grey willow, aspen, field maple, alder, beech, hornbeam, hawthorn, small-leaved lime, elm, elder, crab apple all support more than 50% of ash-associated bryophytes. Of the non-native tree species considered, only sycamore and Norway maple support more than 50% of the ash-associated bryophytes (Figure 3.4).

None of the trees assessed are known ('yes' category) to support 50% of the ash-associated fungi (Figure 3.5). Elm, beech and oak are known to support over 25% of ash-associated fungi, while none of the non-natives are known to support 25% of ash-associated fungi. Sycamore was the non-native tree species that was known to support the greatest number of ash-associated fungi, but it only supported 20%.

None of the native or non-native trees are known ('yes' category) to support 50% of the ash-associated invertebrates (Figure 3.6). Oak and beech are known to support over 20% of ash-associated invertebrates. None of the non-native tree species are known to support 20% of ash-associated invertebrates; manna ash and horse chestnut are known to support 11% and 10% respectively.

Oak spp., elm spp., beech, hazel, birch spp., rowan, alder and aspen are all known to support more than 50% of ash-associated lichens (Figure 3.7). Sycamore was the only non-native tree species known to support more than 50% of the ash-associated lichens.

Oak spp. was the only native tree species to known to support 50% of ash-associated mammals, none of the non-native tree species supported 50% of ash-associated mammals, with horse chestnut and sycamore supporting the most species, 32% and 21% respectively.

Table 3.6 The 5 alternative tree species for each species group that support the greatest number of ash-associated species as assessed using the 'yes' category and the 'yes' + 'likely' categories. Percentages are calculated within each species group

Species group	Yes		Yes + Likely	
	Tree species	%	Tree species	%
Bird	Oak spp.	100	Oak spp.	100
	Birch spp.	83	Manchurian ash	92
	Rowan	67	American ash	92
	Beech	58	Green ash	92
	Aspen	58	Birch spp.	83
Bryophyte	Hazel	95	Hazel	95
	Oak spp.	91	Oak spp.	91
	Goat willow	91	Goat willow	91
	Grey willow	91	Grey willow	91
	Aspen	88	Aspen	88
Fungi	Elm spp.	31	American ash	96
	Beech	28	Manchurian ash	96
	Oak spp.	26	Manna ash	96
	Birch spp.	22	Green ash	96
	Sycamore	21	Black poplar	62
Invertebrates	Oak spp.	30	Manna ash	41
	Beech	25	American ash	38
	Birch spp.	19	Green ash	38
	Elm spp.	16	Turkey oak	37
	Goat willow	14	Red oak	37
Lichen	Oak spp.	85	Oak spp.	85
	Sycamore	70	Sycamore	70
	Elm spp.	67	Elm spp.	67
	Beech	66	Beech	66
	Hazel	61	Hazel	61
Mammal	Oak spp.	61	Rowan	71
	Beech	36	Horse chestnut	68
	Horse chestnut	32	Scots pine	68
	Hazel	32	Turkey oak	68
	Scots pine	32	Red oak	68

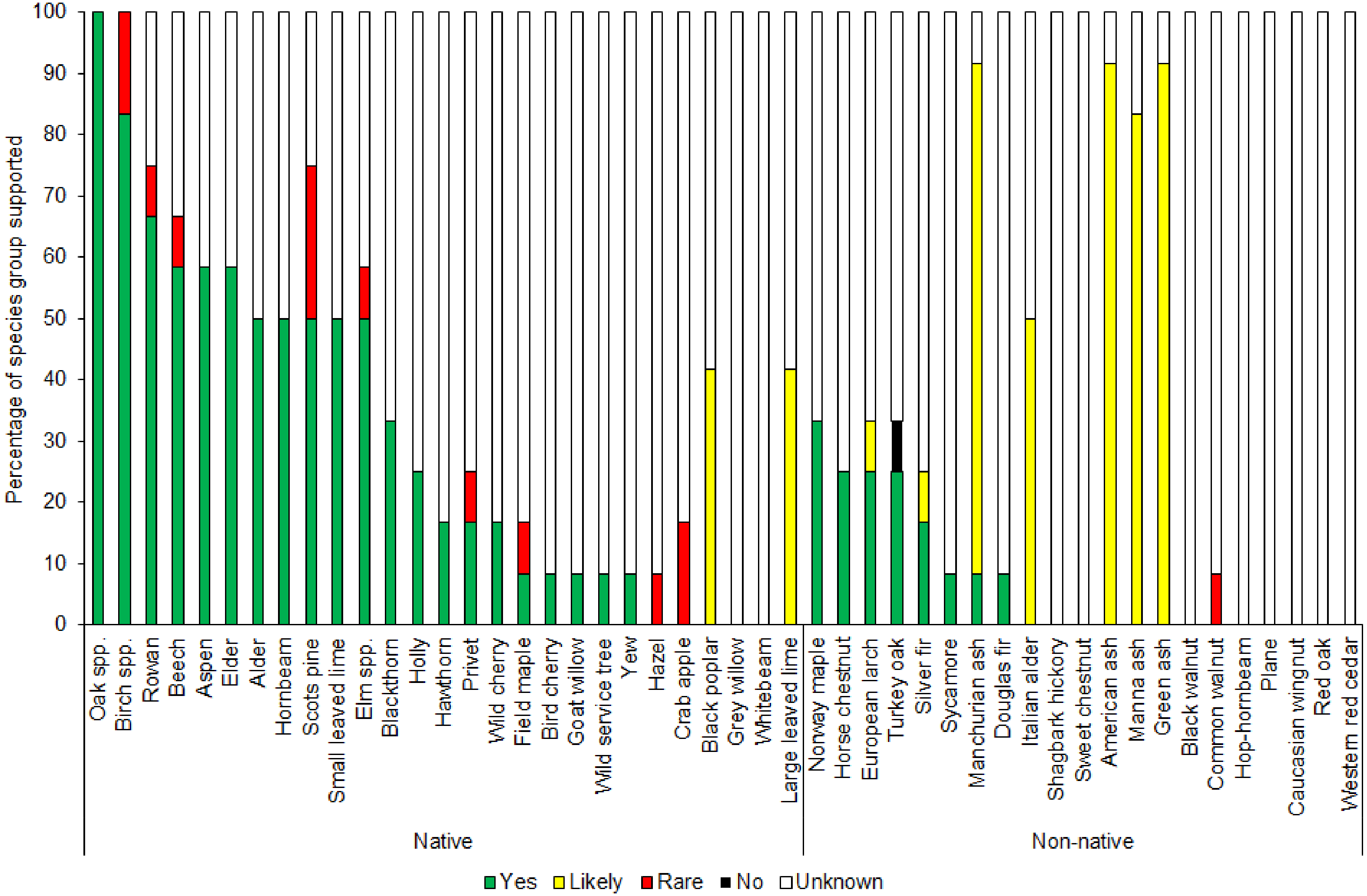

Figure 3.3 The use by ash-associated birds of 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of ash-associated species they support ('Yes' association). Percentages are from a total of 12 birds

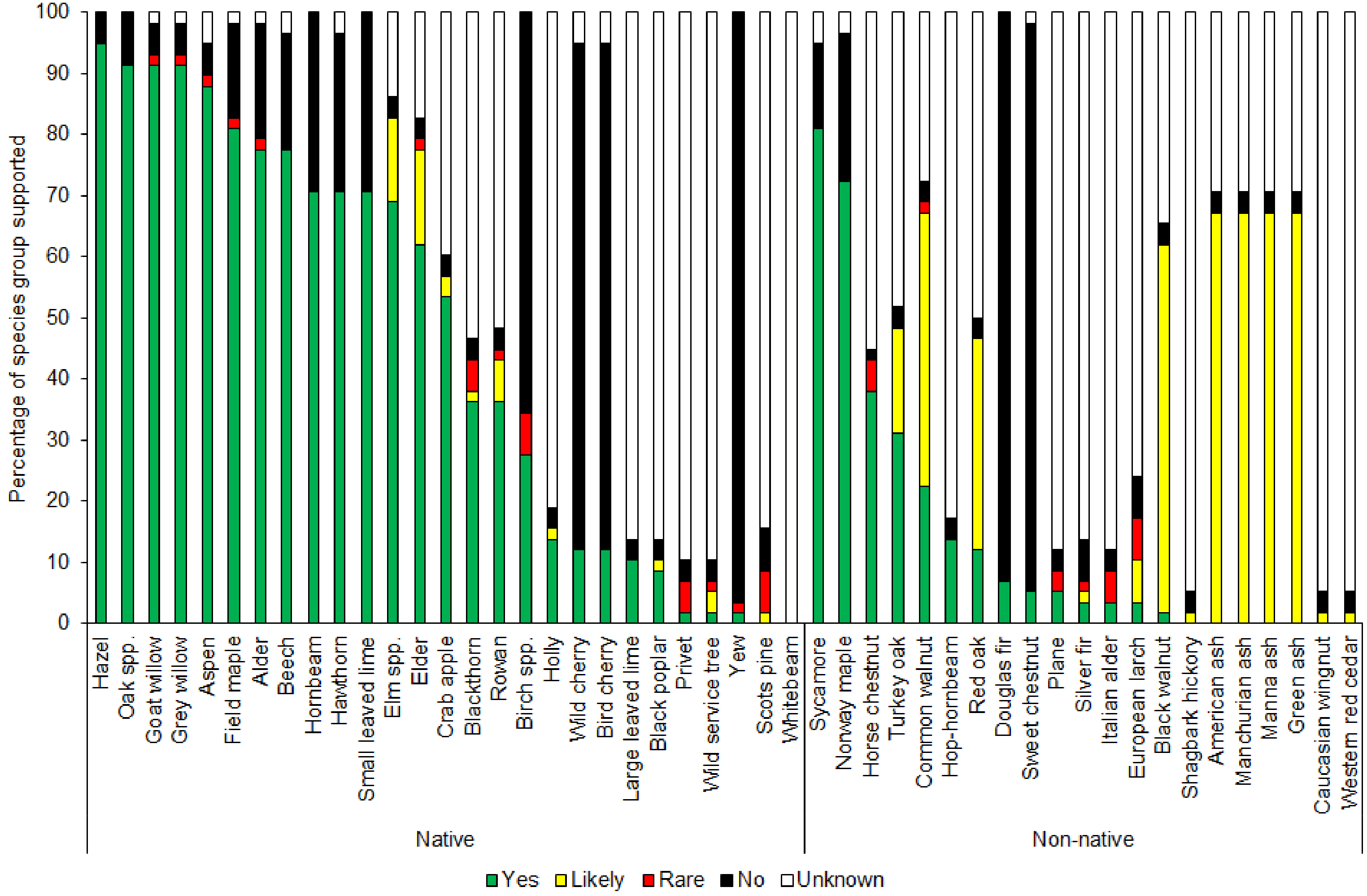

Figure 3.4 The use by ash-associated bryophytes of 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of ash-associated species they support ('Yes' association). Percentages are from a total of 58 bryophytes

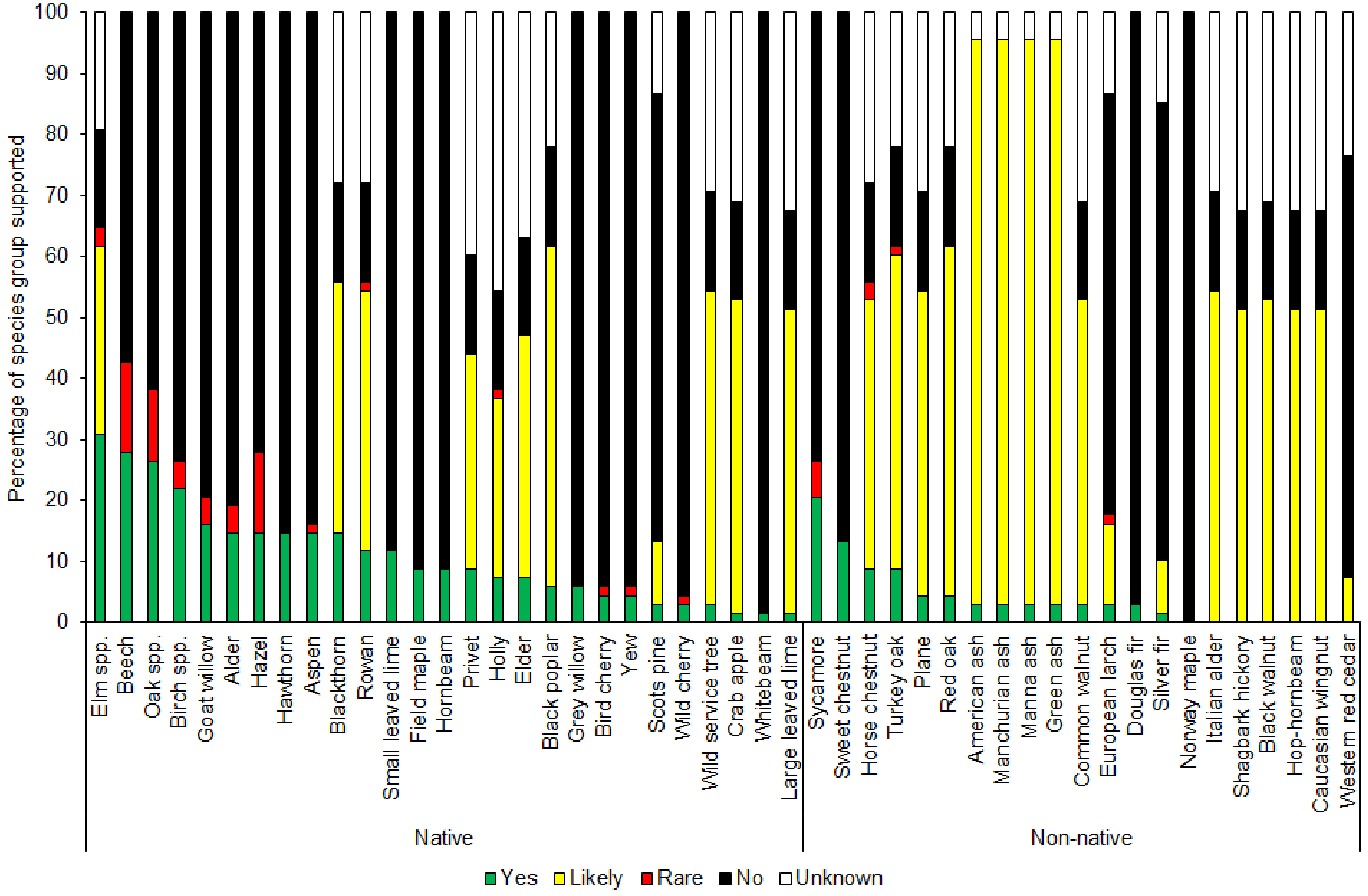

Figure 3.5 The use by ash-associated fungi of 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of ash-associated species they support ('Yes' association). Percentages are from a total of 68 fungi

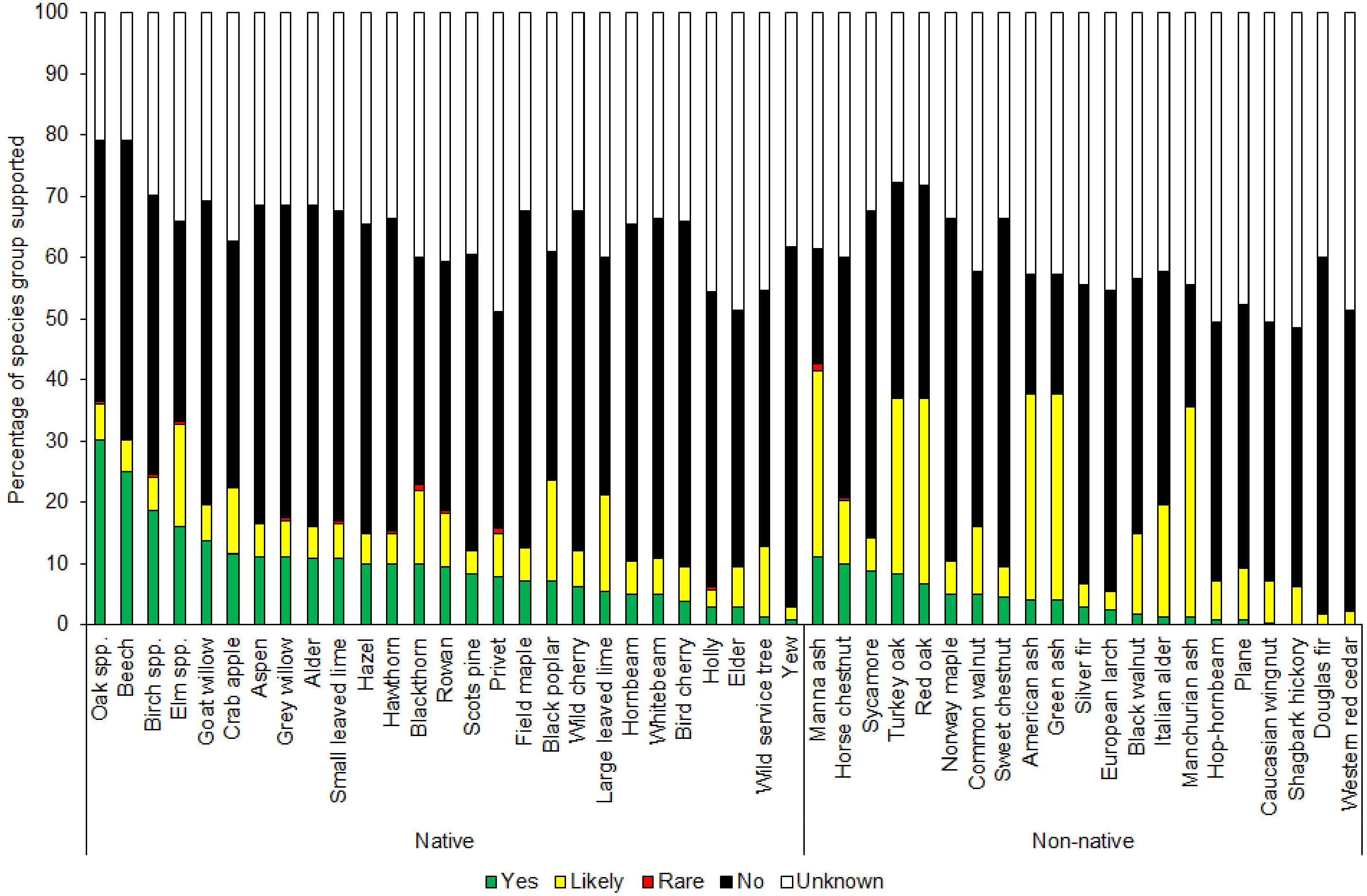

Figure 3.6 The use by ash-associated invertebrates of 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of ash-associated species they support ('Yes' association). Percentages are from a total of 241 invertebrates

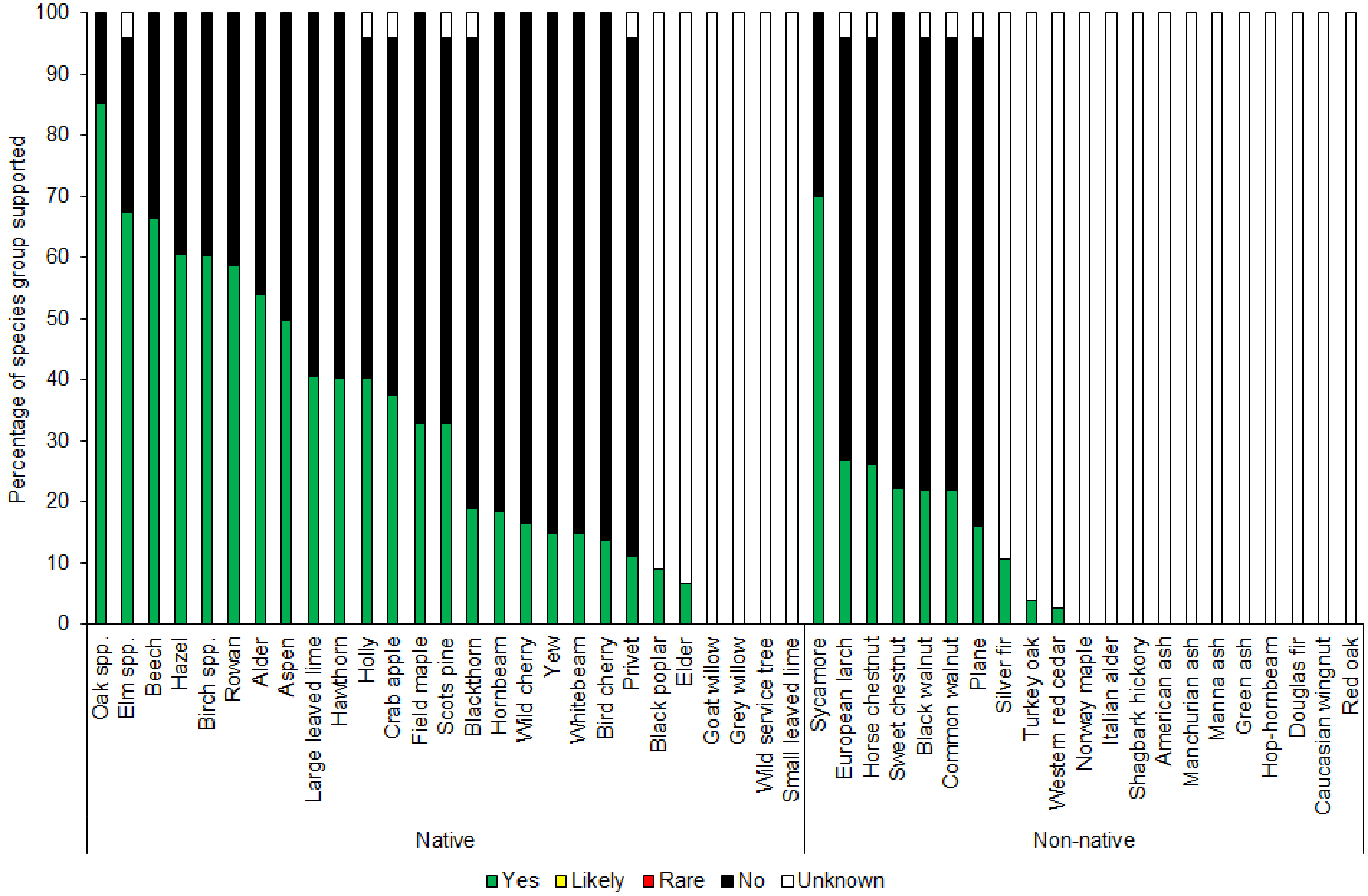

Figure 3.7 The use by ash-associated lichens of 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of ash-associated species they support ('Yes' association). Percentages are from a total of 546 lichens

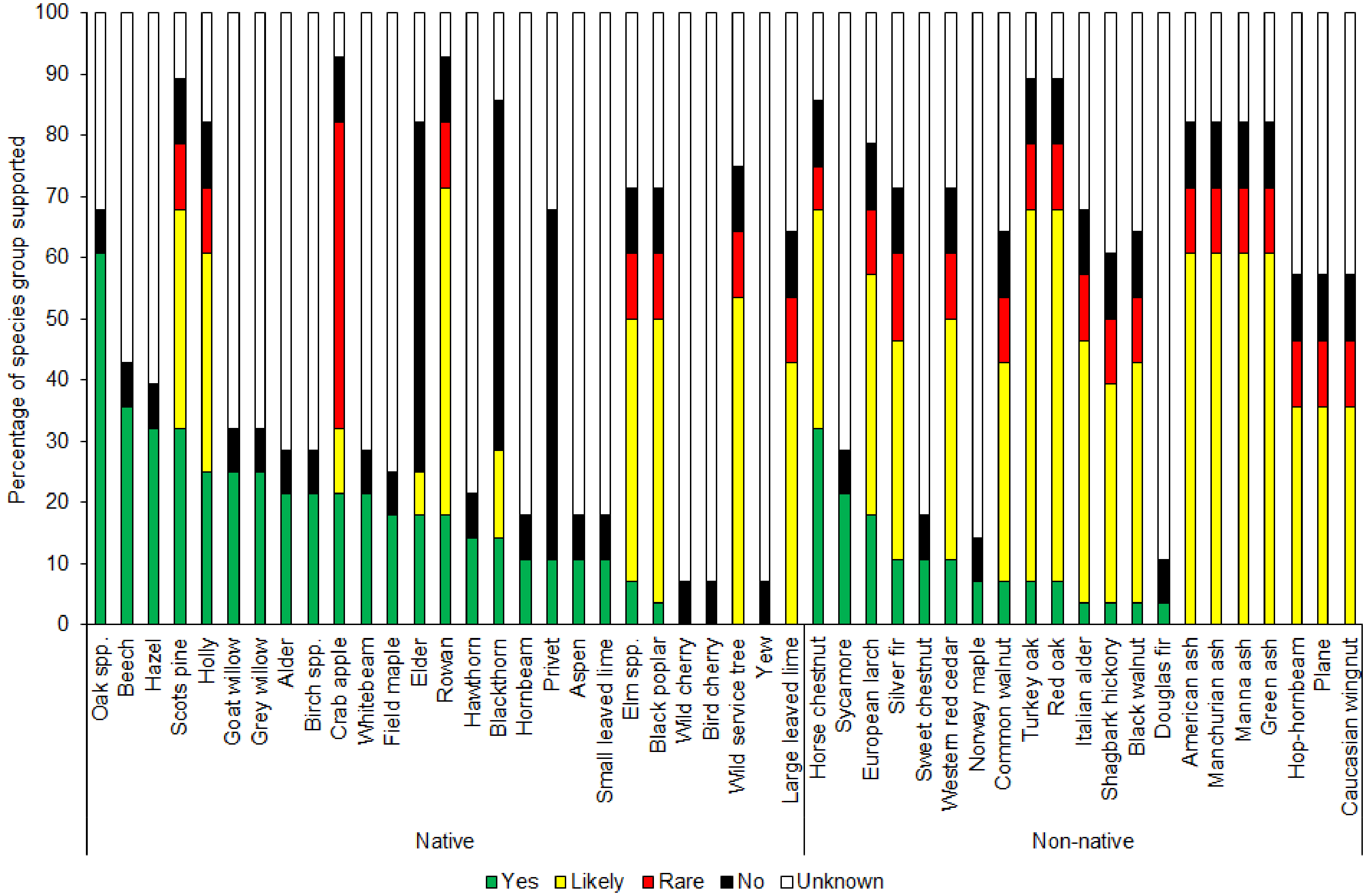

Figure 3.8 The use by ash-associated mammals of 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of ash-associated species they support ('Yes' association). Percentages are from a total of 28 mammals

3.6 Which trees support those species most at risk from ash-dieback?

The previous sections identified the most suitable alternative tree species as assessed by how many ash-associated species they are known to support. However, it could be argued that it is more important to support those species that are at greatest risk from ash-dieback rather than those that are cosmopolitan in their use of ash. In addition, those species that are already of conservation concern may be considered to be at greater risk from ash dieback than those that are not. The Phase 1 report classified how at risk species were from ash dieback using a combination of their level of association with ash and their level of conservation concern (see Table 3.7 for the approach adopted for classifying species relative to level of conservation concern).

Associated species were given a RED code if they were either: a) obligate on ash; or: b) highly associated with ash trees and had a conservation status of either “yes” or “unknown” (this takes the precautionary approach, as it is currently unknown whether or not these species are of conservation concern) (Table 3.8). This identified 69 species as RED (‘high risk’) in relation to ash dieback (Table 3.9), and these species are considered to be in danger of either going extinct or their populations severely declining if ash dieback causes a major decline in the population and abundance of ash. Species were given an AMBER code if they were defined as highly associated with ash trees but were currently of no conservation concern, or only partially associated with ash but already of conservation concern (Table 3.8). 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 concern or of unknown conservation concern (this again takes a precautionary approach). This gave a total of 169 species as AMBER-coded (‘medium risk’) in relation to ash dieback (Table 3.9). Species coded YELLOW were defined as those of no current conservation concern and whose level of associated with ash was either ‘partial’ or ‘uses’; these species may also decline but are considered unlikely to be greatly impacted by the loss of ash (Table 3.8). This process produced 383 YELLOW-coded (‘low risk’) species (Table 3.9). Species coded GREEN were 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 (Table 3.8). There were 330 GREEN-coded (‘no risk’) species (Table 3.9).

Thus the ‘yes’ category of Figures 3.2-3.8 may be sub-divided to show the number of RED and AMBER -coded species known to be supported (Figures 3.9-3.15).

Table 3.7 Conservation designation used to class the species as being of conservation concern

Species group	Conservation designation	Reference
Mammal	UK BAP species	http://jncc.defra.gov.uk/page-5717
Birds	classified as red or amber in the birds of conservation concern	Eaton et al 2009
Fungi	Red data book	Evans et al 2006
Invertebrate	Red data book or BAP species	Kirby 1992; Conrad et al 2006; Davis,2012
Vascular plants	Red data book	Cheffings and Farrel 2006
Lichens	Classified as Critically Endangered, Endangered, Near Threatened or Vulnerable using IUCN criteria	Woods and Coppins 2012
Bryophytes	Classified as Critically Endangered, Endangered, Near Threatened or Vulnerable using IUCN criteria	Hodgetts 2011

Table 3.8 Classification of ash-associated species into red, amber, yellow and green as affected by ash dieback[1]

		Conservation status		
		No	Unknown	Yes
Birds	Obligate			
	High			
	Partial	4		3
	Uses			
	Cosmopolitan	2		3
Bryophytes	Obligate			
	High			6
	Partial	27		3
	Uses	12		
	Cosmopolitan	10		
Fungi	Obligate	11		
	High	17		2
	Partial	37		1
	Uses			
	Cosmopolitan			
Invertebrates	Obligate	23	3	4
	High	16	6	2
	Partial	27	1	9
	Uses	68	13	50
	Cosmopolitan	14	4	1
Lichens[2]	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	17		8
	Cosmopolitan	1		1

[1]Numbers of species updated from Phase 1 to include the additional species identified in Phase 2.
[2]546 lichens not 548 lichens shown as two of the lichen species are species which have only recently been taxonomically separated from other lichen species. Thus, although known to occur on ash their level of association and conservation status is unknown, see Phase 1.

Table 3.9 Summary of classification of ash-associated species in to red, amber, yellow and green as affected by ash dieback[1]

	Red	Amber	Yellow	Green	Total
Birds	0	3	4	5	12
Bryophytes	6	3	39	10	58
Fungi	13	18	37	0	68
Invertebrates	38	89	95	19	241
Lichens	13	49	190	294	546
Mammals	0	8	18	2	28
Total	70	170	383	330	953

[1]Numbers of species updated from Phase 1 to include the additional species identified in Phase 2.

[2]546 lichens not 548 lichens shown as two of the lichen species are species which have only recently been taxonomically separated from other lichen species. Thus, although known to occur on ash their level of association and conservation status is unknown, see Phase 1.

When assessed across all species groups, elm spp. is known to support the greatest number of RED-coded ash-associated species (12) followed by oak, hazel and aspen which are known to support 11, 10 and 9 RED-coded species respectively (Figure 3.9). Oak is known to support more AMBER-coded species than elm spp. (85 versus 55).

The alternative tree species that are known to support the greatest number of RED and AMBER-coded species varies between species groups. There are no RED-coded birds but oak is known to support three AMBER-coded birds (Figure 3.10).

Horse chestnut and field maple are known to support five RED-coded bryophytes with, sycamore, alder, aspen, oak spp., goat willow, grey willow, Norway maple, hornbeam, hazel, hawthorn, beech, small-leaved lime and elm spp. all known to support four RED-coded bryophytes (Figure 3.10).

Elm spp., oak spp., beech, Turkey oak, black poplar and red oak are all known to support one RED-coded fungus, with elm spp., oak spp., beech, aspen, sycamore, birch spp., alder and sweet chestnut all known to support four AMBER-coded fungi (Figure 3.11). Manna ash is known to support seven RED-coded invertebrates, with green and American ash known to support three and two RED-coded species respectively (Figure 3.12). Beech, oak spp. and birch spp. are known to support 34, 31 and 17 AMBER-coded invertebrate species respectively (Figure 3.13).

Oak spp. and elm spp. are known to support six RED-coded lichen species, with hazel and sycamore known to support five and four RED-coded species (Figure 3.14). Oak is also known to support 37 AMBER-coded species, and elm 31.

There are no RED-coded mammal species, but oak spp. are known to support five AMBER-coded mammals (Figure 3.15).

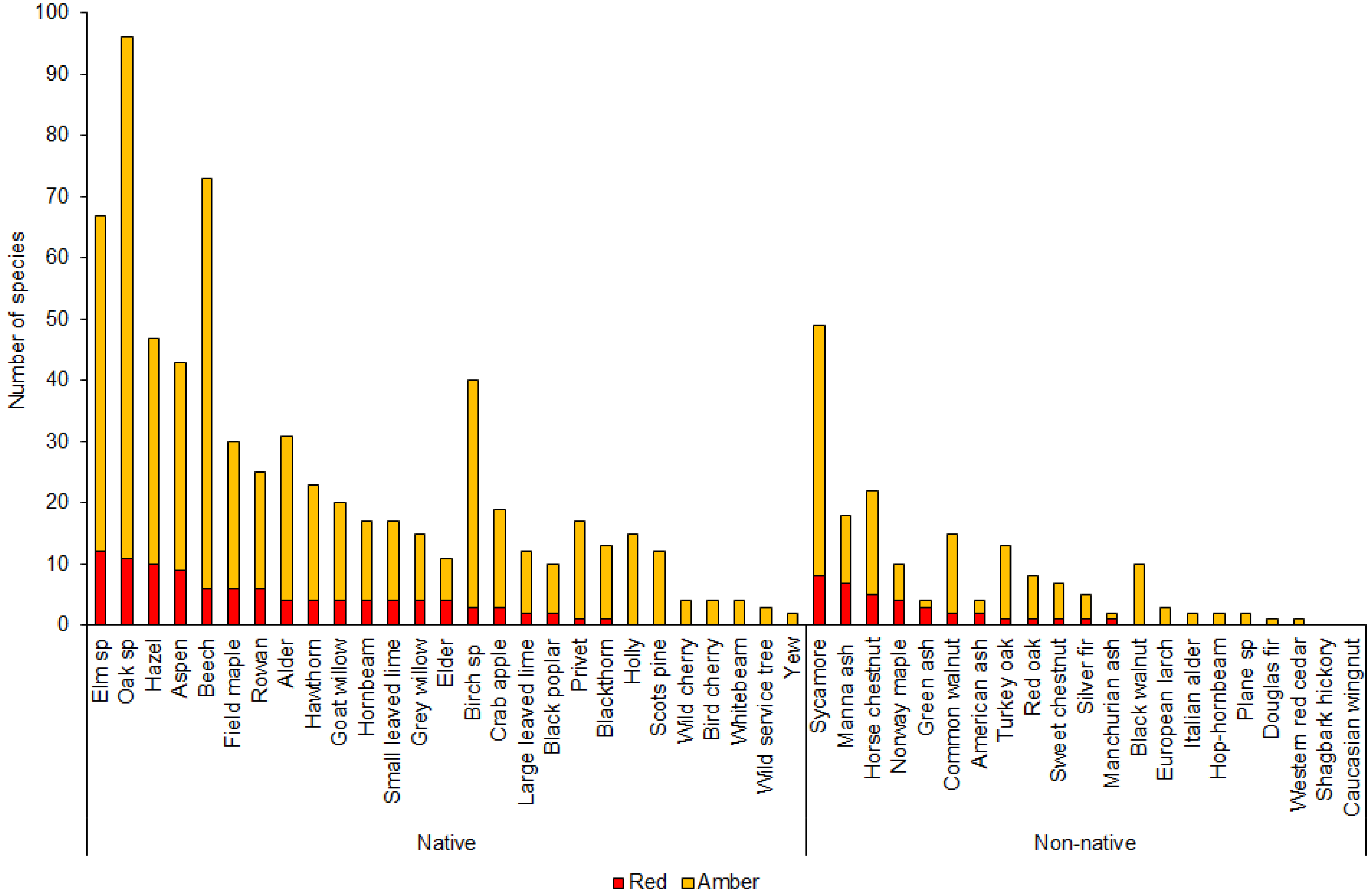

Figure 3.9 Number of RED and AMBER-coded species supported by 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of RED-coded species supported

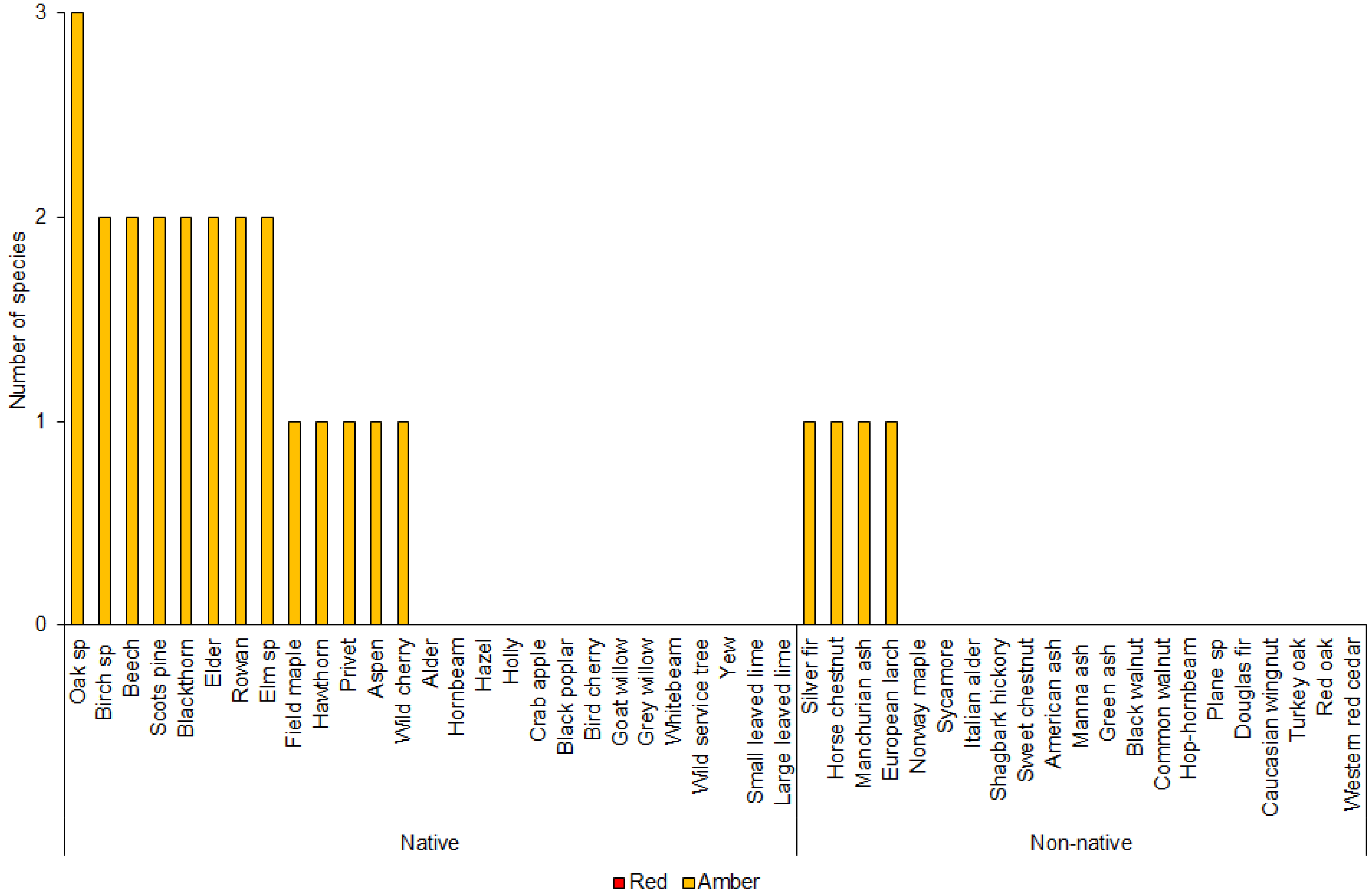

Figure 3.10 Number of RED and AMBER-coded bird species supported by 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of RED-coded species supported

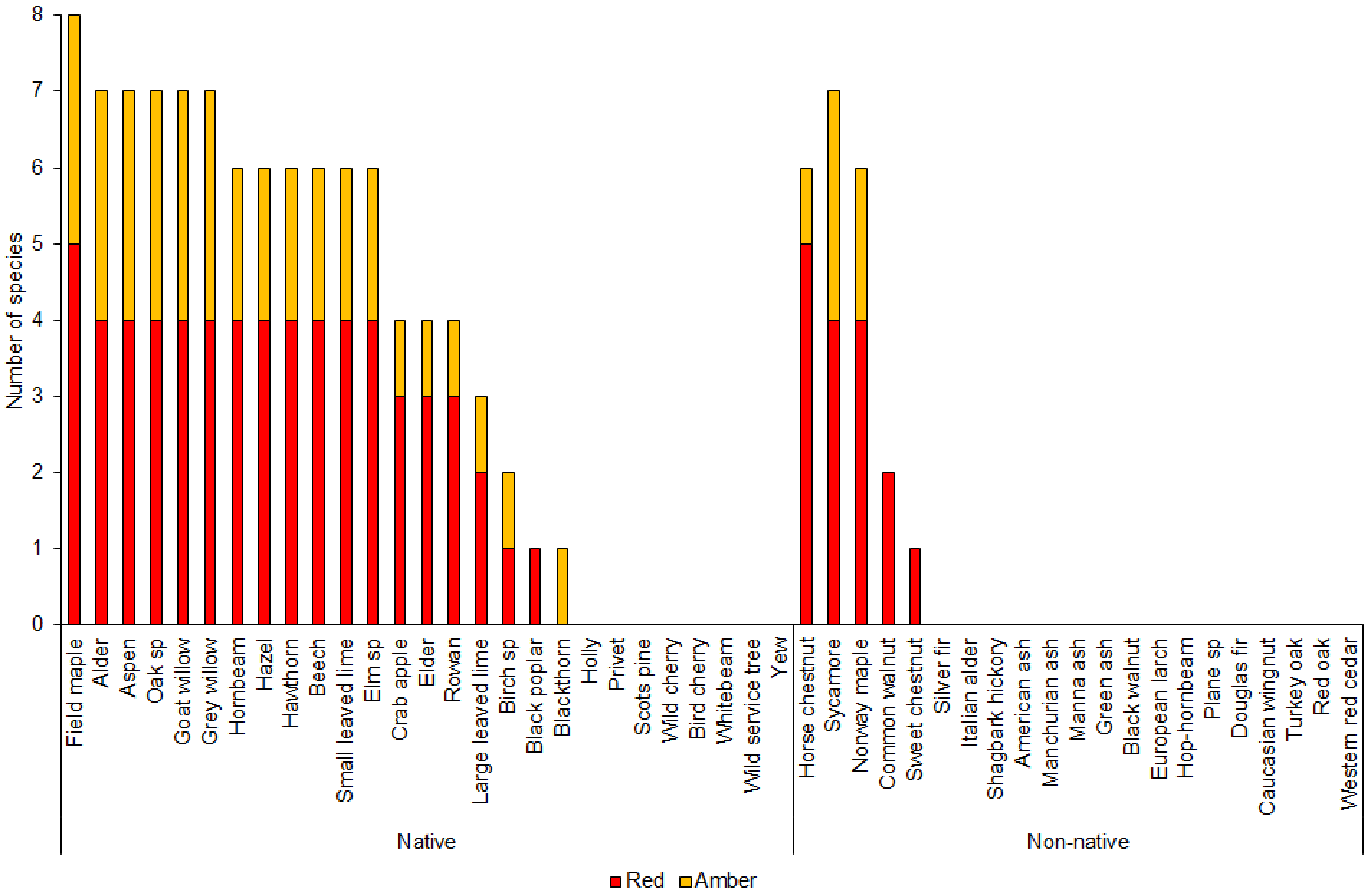

Figure 3.11 Number of RED and AMBER-coded bryophyte species supported by 48 alternative tree species. Tree species are ranked by the number of RED-coded species supported

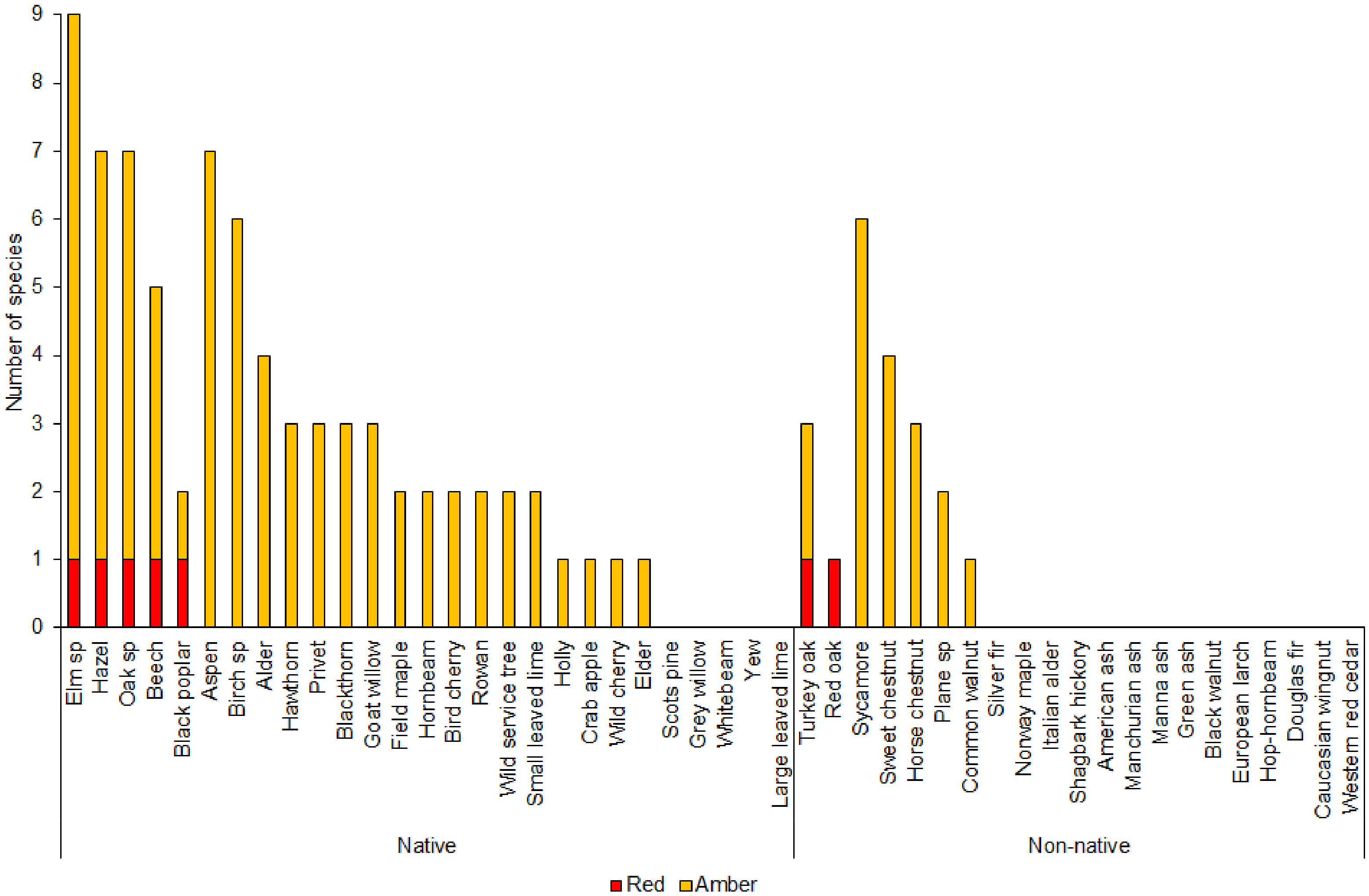

Figure 3.12 Number of RED and AMBER-coded fungi species supported by 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of RED-coded species supported

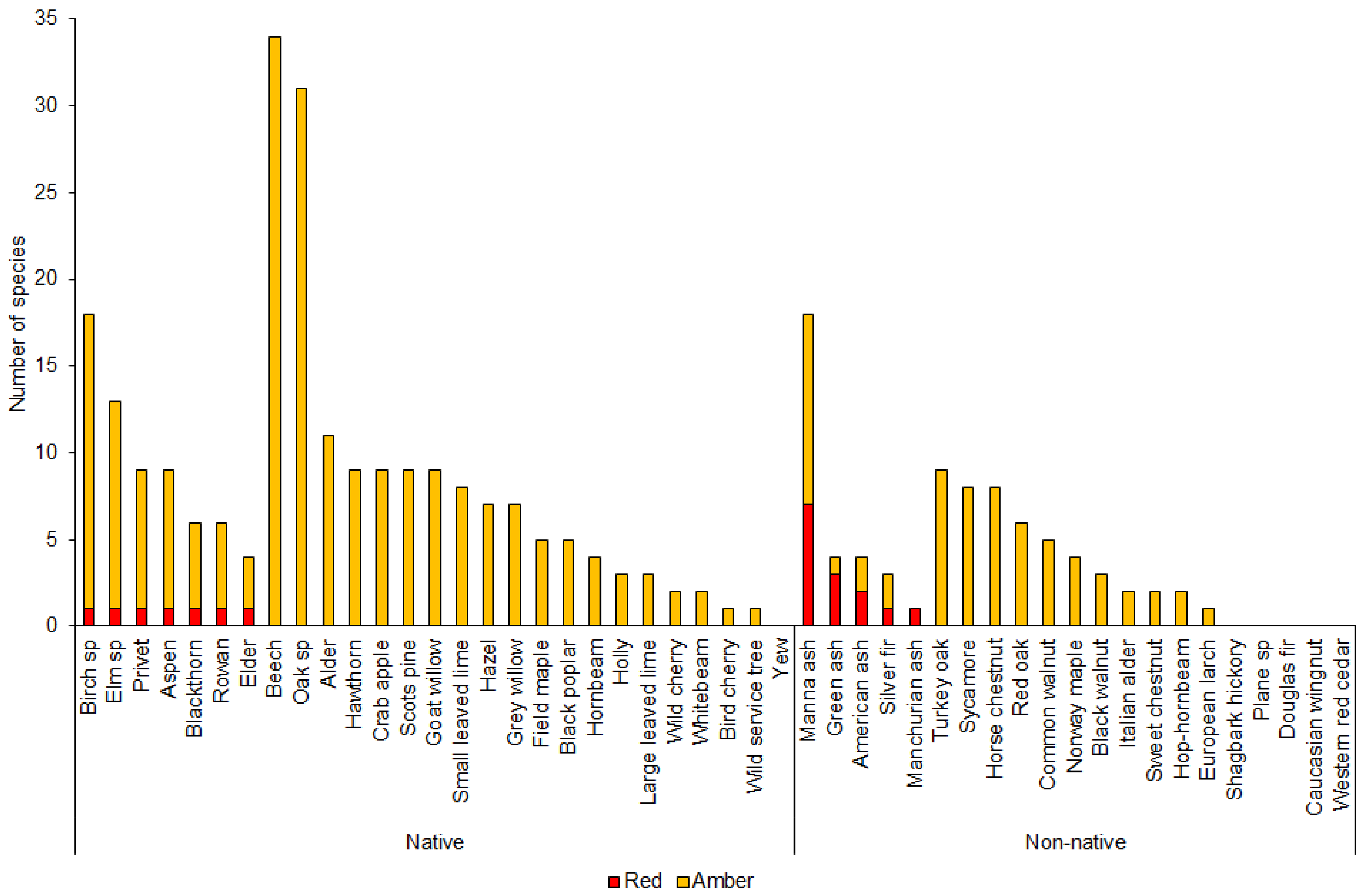

Figure 3.13 Number of RED and AMBER-coded invertebrate species supported by 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of RED-coded species supported

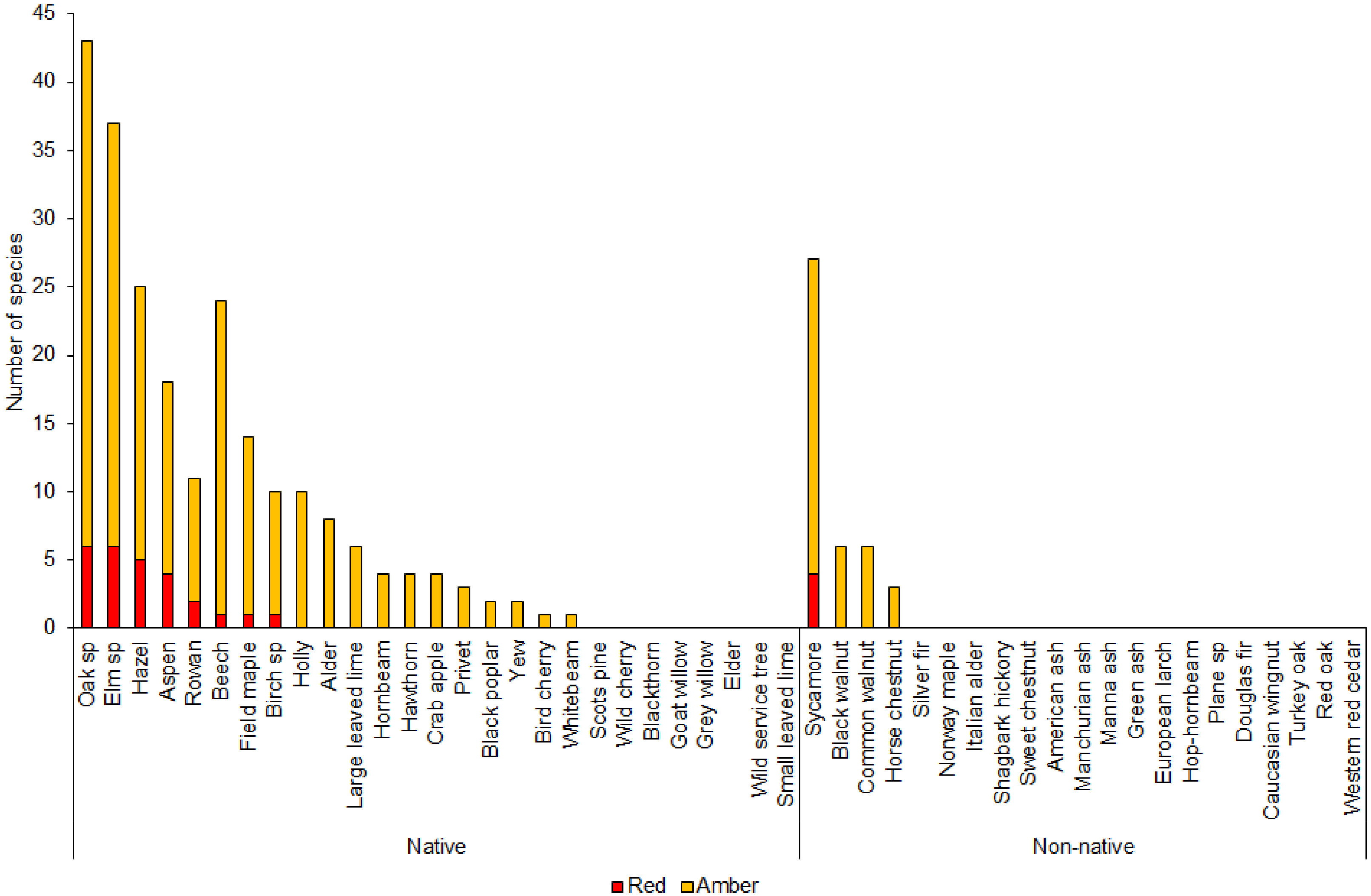

Figure 3.14 Number of RED and AMBER-coded lichen species supported by 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of RED-coded species supported

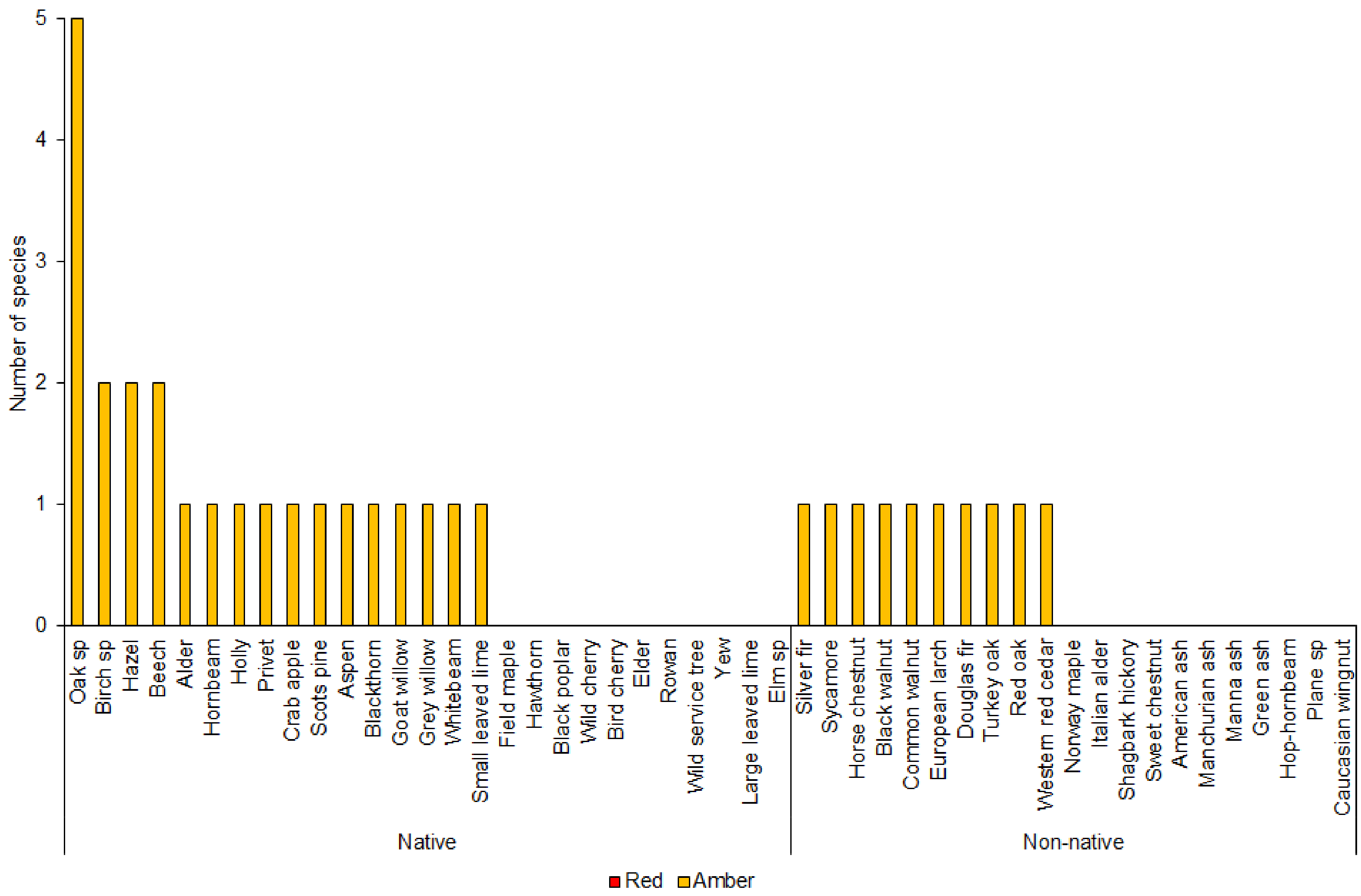

Figure 3.15 Number of RED and AMBER-coded mammal species supported by 48 alternative tree species. Tree species are first ranked according to whether they are native to the UK, and then by the number of RED-coded species supported

3.7 Assessment of mixtures of alternative tree species

In order to assess which mixtures of alternative tree species support the greatest number of ash associated species, the use of the alternative tree by the ash-associated species was simplified into 'uses' (which combined the categories of 'yes' and 'likely'); 'does not use' (which combined the categories of 'no', 'unknown' and 'rarely'), this takes a precautionary approach, as we consider that planting trees that ash-associated species rarely or 'never' use will do little to aid the survival of these species. Including the 'likely' category within the 'uses' class means that these results are based to some extent on expert opinion not data and as such have a lower level of confidence. This should be taken into account when interpreting the results, particularly when non-native species of ash are included within the mixtures as most of the information on the use made of these tree species by ash-associated species is based on expert opinion (the 'likely' category). The full results from these analyses are shown in Appendix 3.

The analysis simply calculates the mixture of tree species that supports the greatest number of ash-associated species, but takes no account of the site conditions nor which mixtures of tree species will grow together. In addition the analysis assumes all ash-associated species are present. Ideally, separate analyses should be done for each ash-relevant region, using only those alternative tree species which are suitable for the climate/soils in that region and including only those ash-associated species known to occur in that region.

3.7.1 All ash-associated species

Oak spp. and elm spp. together support 79% of ash-associated species. A mixture of oak spp., elm spp. and manna ash would support 84% of ash-associated species, with the addition of hazel bringing the total to 86%. The addition of either beech or Scots pine to the mixture supports a further 13 ash-associated species, bringing the total to 87% of ash-associated species supported. Mixtures of 13 alternative tree species support 91% of the ash-associated species: oak, elm, manna ash, hazel, Scots pine, beech, privet, blackthorn, aspen, red oak, holly, and then either black poplar and horse chestnut, or large-leaved lime and black poplar, or horse chestnut and large-leaved lime.

3.7.2 Birds

All ash-associated birds will use sessile/pedunculate oak so encouraging mixtures of alternative tree species will not increase the number of ash-associated birds supported.

3.7.3 Bryophytes

Hazel supports 55 of the 58 ash-associated bryophytes; this could be increased to 57 species if field maple is also present. Fifty-seven is the maximum number of bryophytes that can be supported by the tree species considered, so a mixture of tree species with a greater variety of trees was not considered.

3.7.4 Fungi

American ash, manna ash and green ash are all thought likely to support 65 of the 68 ash-associated fungi. The addition of red oak or beech increases the number of species supported to 67; addition of red oak and beech to the species mix would support all ash-associated fungi.

3.7.5 Invertebrates

Manna ash is thought likely to support 100 of the 241 ash-associated invertebrates. With the addition of oak, the mixture would support 132 ash-associated invertebrates. Manna ash, oak spp., and elm spp. would support 146 ash-associated invertebrates. Ten species (black poplar, red oak, Scots pine, blackthorn, hazel, elm, oak (sessile or pedunculate), manna ash, privet and beech) support a total of 184 ash-associated invertebrate species.

3.7.6 Lichens

A mixture of oak (sessile and pedunculate) and elm spp. would support 500 of the 548 ash-associated lichens. The addition of holly, hazel and aspen would support 525 of the ash-associated lichens.

3.7.7 Mammals

A mixture of rowan and horse chestnut would support 21 of the ash-associated mammals. These tree species, with the addition of any of 15 other tree species that support grey squirrel, would increase the number of ash-associated mammals supported to 22 which is the maximum number of mammals supported by the tree species considered.

4 Alternative tree species: traits

<u>Chapter summary</u>

1. *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.*

2. *Phase 1 assessed the traits of 22 alternative trees. This chapter assesses the traits of a further 28 tree species and presents the combined results.*

3. *Trait data was unavailable for some tree species preventing one similarity index being calculated across all traits.*

4. *Trait data was collected for deciduous/evergreen, floral reward, fruit type, leaf shape, mycorrhizal association, pollen vector, tree height, leaf dry matter content, specific leaf area and length of flowering time*

5. *Of the native tree species assessed, elm had the most traits which were the same as ash (8 out of 11), followed by silver birch and rowan with 7 and 6 traits the same as ash, respectively.*

6. *Many of the non-native trees assessed were as similar to ash as the native tree species when assessed by these traits. American ash, common walnut, green ash, black walnut and Manchurian ash had between eight and six traits the same as ash.*

7. *The species most dissimilar to ash when assessed by their traits were small-leaved lime, wild cherry, blackthorn, field maple, privet, wild service, bird cherry, hawthorn, holly, large-leaved lime, Scots pine, whitebeam, Norway maple, Douglas fir, silver fir and European larch which all had five or more of the eleven traits classed as very dissimilar to ash*

8. *There was no relationship between the number of traits of the alternative tree species that were the same as ash and the number of ash-associated species supported.*

9. *Ellenberg values describe the environmental conditions in which a tree grows. None of the alternative tree species matched ash for all four Ellenberg values considered. Field maple matched ash for three of the four Ellenberg values (light, acidity and nitrogen).*

4.1 Introduction to 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 the traits of ash and alternative tree species is one way to assess how similar a tree species is to ash. If ash is lost, in order to minimise subsequent impacts the tree species that replace it should have as many as possible of the same characteristics as ash.

Phase 1 assessed the traits of 22 alternative trees; here we assess the traits of a further 28 tree species (Table 3.2).

A summary of how different tree traits may influence the species that use the tree and ecosystem functioning is shown in Table 4.1. There are many different traits which could be included, but we focussed on those for which data are readily available for the majority of the alternative trees.

Table 4.1 Tree traits and how they influence ecosystem function

Trait	Ecosystem function
Bark pH	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. Different tree species can generally be classified as having sub-neutral, intermediate or acidic bark.
Deciduous	If a tree is deciduous or evergreen this will influence 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).
Floral reward	Flowers attract insects by offering floral rewards of either nectar or pollen, which can be important food sources for insects
Fruit type	Describes the type of fruit produced by the tree. Fruits can be important food sources for some species.
Height	Tree height will influence the light reaching the ground flora and the level of competition between species. In addition it will also have wider visual impacts at the landscape scale.
Leaf dry matter content (LDMC)	LDMC is a measure of tissue density which plays a central role in the nutrient dynamics of a species by determining the rate of biomass turnover. Low LDMC is associated with high growth rate, rapid nutrient cycling and decomposition.
Leaf shape	The shape of the leaf (e.g. needle, pinnate, full, lobate etc) will influence the shade cast by the tree.
Leaf size	The size of the leaf will influence the shade cast
Length of flowering time	The length of time that flowers are available will influence how long nectar and pollen 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.
Mycorrhizal association	A mycorrhiza is a symbiotic association between a fungus and the roots of a vascular plant. There are two types of association: arbuscular mycorrhizal fungi and ectomycorrhizal fungi. The type of mycorrhiza association will influence nutrient cycling and carbon storage.
Pollen vector	Trees may be either wind pollinated, pollinated by insects, or self-pollinated
Seed mass	The weight of the seed, related to seed size. Seeds can be an important food source for many species.
Specific leaf area (SLA)	The 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 a relatively high investment in leaf 'defences' (particularly structural ones). Leaf defences (structural and chemical) tend to cause the leaves to decompose more slowly.

4.2 Habitat preferences

Different tree species grow in different environmental conditions. One way to assess the similarity of trees to ash is to assess the similarity of their habitat preferences. Ellenberg (1988) described the realised ecological niche in which many European plant species are 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 four variables (light, moisture, reaction and nitrogen) there is an ordinal scale (usually 1-9) describing the conditions in which the plant is most commonly found. Ellenberg based these values on data from continental Europe; Hill *et al* (1999) modified these values for Britain to take into account the British growing conditions. Where possible the 'British' Ellenberg values (from Hill *et al* 1999) have been used in this report. However, for some species 'British' Ellenberg values were not available, and the 'continental' values from Ellenberg (1988) were used instead. For some of the alternative tree species no Ellenberg value was available.

Table 4.2 Habitat preferences as defined by Ellenberg scores

Ellenberg	Score	Description
Light (L)	1 to 9	1 = deep shade, 9 = full light
Moisture (F)	1 to 12	1 = extreme dryness, 12 = submerged plant
Reaction (R)	1 to 9	Reaction = soil pH. 1 = extreme acidity, 9 = basic
Nitrogen (N)	1 to 9	1 = extreme infertile site, 9 = extremely rich situations

4.3 Data sources and data quality

The primary sources of data used for the tree traits in this study were:

- BioFlor: 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. 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*. A link to the publication can be found here: http://nora.nerc.ac.uk/9535/

- TRY: The Try data based, a global archive of plant traits published by Kattge et al 2011 (http://www.trydb.org)

- Ellenberg 1988 provided Ellenberg values for some tree species for which British Ellenberg values (Hill et al 2004) were not available.

- BARKMAN (1958) provided the bark pH of some of the tree species.

However, not all traits for all tree species were covered by the above sources. Gaps in the data were filled on a case-by-case basis where possible, and using a range of literature. In some cases data from conspecifics was used. The data source for each tree by trait combination, and each tree by Ellenberg combination, is listed in the AshEcol spreadsheet available at weblink.

4.3.1 Data limitations

Trait data for many tree species were missing. Data were sought for all 50 alternative tree species. This is the same group of 48 alternative tree species as used in Chapter 3 but separate trait data were sought for the two birch (silver and downy) and the two oak species (sessile and pedunculate). The two elm species (English and Wych) were lumped, resulting in 50 assessments in total). Of these 50 tree species there was only data for all 12 traits for 25 species, and these species were predominantly those already studied in Phase 1. Despite searching international trait databases traits, data were unavailable for many of the non-native tree species. The proportion of traits with data for each tree species may be used as a measure of confidence in the data (Appendix 6). Data for all tree species were only available for the following traits: deciduous, fruit type, height, leaf shape, mycorrhizal association and pollen vector (Appendix 6)

Ellenberg values for all four Ellenberg scores considered were available for 38 species, and were completely missing for 10 species, with two species having data available for only some of the Ellenberg values (Appendix 6).

4.4 Methods to compare traits between alternative trees

Many of the alternative tree species match ash when assessed by single individual traits, but ideally any alternative tree species should match ash in a high proportion of traits. Analysis across multiple traits could be carried out using a similarity index; however the calculation of similarity indices is not possible with missing data.

For categorical traits (deciduous, floral reward, fruit type, leaf shape, mycorrhizal association and pollen vector) the alternative trees can be classed according to whether they do (green) or don't (red) occur in the same category as ash.

For traits with continuous variables the data were standardized.

Standardized data = $((Fex-Alt)/Fex)^2$

Where Fex = value for ash and Alt = value for alternative tree.

The standardization allowed comparisons across traits measured in different units and assigned a value of zero for ash, with higher values indicating a greater difference between the alternative tree and ash. For simplicity the species were then grouped as either having a value of 0-0.01 (identical, or nearly, to ash) and coded green; having a value of >0.01-0.49 and being coded amber (classed as intermediate); or having a value of greater than 0.50 and being coded red (very dissimilar to ash). The standardized data is in Appendix 6. The cut-off between the different colour coded groups is essentially arbitrary but does allow species very different from ash to be identified.

Species with the same Ellenberg value as ash are coded green, species that differ in their Ellenberg value by 1 unit were coded amber and species that differ from ash in their Ellenberg values by more than 1 unit were coded red (and considered very dissimilar to ash).

4.5 Comparison of traits between alternative tree species

The trait values collected are available as part of the AshEcol spreadsheets available at weblink. Here, a summary of the data is presented in Table 4.3. Comparison of data on leaf size is not presented, as for pinnate leaves the leaf area was measured for each leaflet but for entire leaves the whole leaf area is reported, and thus the data are not comparable.

Table 4.3 ranks the alternative trees by the number of green-coded traits. Of the eleven traits assessed, elm is the most similar native tree to ash with eight of the traits being the same. Silver birch and rowan are also very similar to ash with seven and six of the traits the same. Many of the non-native trees were also very similar to ash. American ash was very similar to ash with eight traits the same. Common walnut and green ash had seven traits the same as ash and black walnut and Manchurian ash had six traits the same.

For the continuous variables of height, LDMC, SLA and length of flowering time the data shows that there are a large number of tree species that are intermediate in their similarity to ash. At present it is not known at what point along these continuous variables a significant change occurs in ecosystem functioning or the number of ash-associated species supported.

Of the native tree assessed, small-leaved lime, wild cherry, blackthorn, field maple, privet, wild service, bird cherry, hawthorn, holly, large-leaved lime, Scots pine and whitebeam were very dissimilar to ash with five of these eleven traits classed as red. Of the non-native trees assessed, Norway maple had five of these traits classed as red, Douglas fir and silver fir had six and European larch had seven. These tree species may be classed as very dissimilar when assessed by these traits.

4.5.1 Limitations of approach

As missing data prohibit a more comprehensive comparison of the similarity of the alternative trees to ash, the above method provides a simplistic assessment. However the following points should be noted:

- All traits are given equal weight. Some traits maybe more important than others in maintaining ash-associated species or ecosystem functioning similar to ash.
- Some traits are correlated, e.g. there is some correlation between leaf dry matter content and leaf specific area.
- Some traits are known to be influenced by environmental conditions, e.g. specific leaf area. Therefore, the similarity of species to ash when assessed by this trait to ash may vary depending on the environmental conditions.
- The conversion of continuous variables into red, amber and green coding was based on a subjective cut off between continuous values.
- Comparisons and rankings of tree species take no account of the number of missing traits for any tree species.

4.5.2 Using mixtures of trees?

While none of the alternative tree species are known to have identical traits to ash, for all the traits assessed there are tree species with many of the same traits. Using a mixture of tree species it would be possible to establish woodlands containing all the traits of ash. However, it is currently unclear how the traits from different tree species would interact and hence the resulting impact on ecosystem functions. Would the effects be additive or is there an interaction? Further work is required to assess this.

Table 4.3 Similarity of alternative trees to ash for 11 traits. Those in green have the same trait as ash. No = no of ash-associated species supported

	Tree alternative	Bark pH	Deciduous	Floral reward	Fruit type	Leaf shape	Mycorrhizal association	Pollinator	Height	LDMC	flowering time	SLA	No.
Native	Wych & English Elm												477
	Silver birch												423
	Rowan												387
	Alder												389
	Aspen												370
	Downy birch												423
	Elder												96
	Goat willow												105
	Hornbeam												169
	Sessile oak												640
	Small leaved lime												84
	Wild cherry												116
	Beech												505
	Black poplar												76
	Blackthorn												167
	Field maple												256
	Grey willow												91
	Hazel												430
	Pedunculate oak												640
	Privet												92
	Wild service tree												7
	Yew												89
	Bird cherry												95
	Crab apple												272
	Hawthorn												302
	Holly												251
	Large leaved lime												242
	Scots pine												216
	Whitebeam												100
Non-native	American ash												12
	Common walnut												149
	Green ash												12
	Black walnut												126
	Manchurian ash												6
	Caucasian wingnut												1
	Horse chestnut												208
	Manna ash												29
	Plane sp												96
	Sycamore												473
	Italian alder												6
	Norway maple												60
	Red oak												28
	Sweet chestnut												148
	Douglas fir												8
	European larch												166
	Hop-hornbeam												10
	Shagbark hickory												1
	Turkey oak												70
	Western red cedar												17
	Silver fir												74

4.5.3 Using tree traits to predict species use?

Autecological knowledge of species shows that the characteristics of a tree (the traits) will influence which trees that species uses. In theory it should therefore be possible to use the traits of the tree species to predict if an ash-associated species will use any given alternative tree species. Ideally one would wish to find a correlation between the traits of the tree and the number of ash-associated species supported. This might allow the prediction of which non-native alternative trees would support the greatest number of ash-associated species, especially as for many non-native tree species information on which ash-associated species use them is lacking. However, Table 4.3 and Figure 4.1 show no clear relationship between the number of species supported and the number of traits that are the same as ash. Although Figure 4.1 may be influenced by missing data for some non-native tree species, a study of native tree species for which there is good data also shows no clear pattern. For example, oak supports the greatest number of ash-associated species (640) but only has four or five (pedunculate and sessile respectively) of the eleven traits the same as ash. Elm supports 477 ash-associated species and has eight of the eleven traits the same as ash yet beech supports 505 ash-associated species but only has four traits the same as ash. Thus while traits of trees may still be useful for assessing the use by individual ash-associated species (e.g. the relationship between bryophytes and lichens with that of bark pH), at the moment it is not possible to make broad generalizations about traits of trees and the number of ash-associated species supported. This may be due to lack of data on traits for some tree species and/or traits other than those assessed being important in influencing which ash-species use the alternative trees. In addition it may be the presence or absence of a few traits that determine the number of ash-associated species supported, rather than the overall number of traits that are the same.

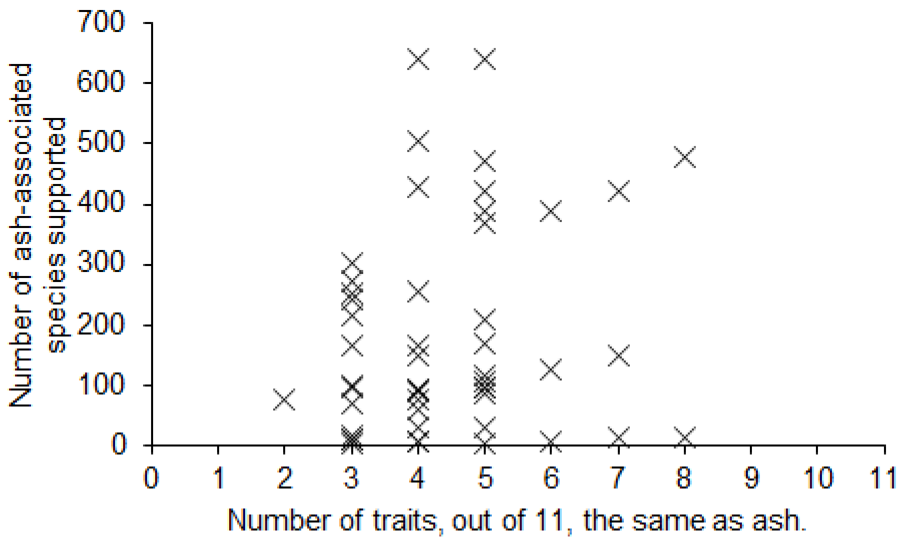

Figure 4.1 No clear relationship between the number of traits of the alternative trees that are the same as ash and the number of ash-associated species supported by the alternative trees

4.5.4 Using traits to predict differences changes in ecosystem function?

A summary of how the traits studied relate to species use and ecosystem function is provided in Table 4.1 with further details already given in Phase 1. Here the main changes that would occur if a change from ash to one of the alternative tree species are highlighted for those traits where there is a clear link to ecosystem function.

Most of the alternative trees assessed are deciduous and will therefore continue to produce a similar seasonal pattern of shading and litter fall to ash, if they replace ash. The exceptions to this are yew, holly, Scots pine, Douglas fir and silver fir; if these tree species replace ash then there will be a change to a continuous canopy cover with heavy shade all year and a switch to a more continuous litter fall. These changes will influence nutrient cycling and ground flora composition, likely to be a more species-poor ground flora than a typical ash woodland ground flora due to lack of light (Phase 1).

The structure of the wood in terms of tree height will change little if silver birch, small-leaved lime, wild cherry, American ash, common walnut or green ash replace ash as these tree species are generally (subject to local growing conditions) similar in height to ash. Blackthorn, hazel, privet, plane, Douglas fir, European larch and Silver fir are all very different from ash in terms of height and will therefore result in a very different woodland structure if they replace ash.

Leaf dry matter content (LDMC) was shown to be similar to ash for a wide range of species including oak. This is surprising as LDMC is known to be related to decomposition rates and the detailed literature review in Chapter 2 showed that the rate of decomposition of oak litter, for example, is much slower than for ash. Thus using LDMC as a simple measure of change in decomposition rates should be treated with caution. It may be that a far smaller cut off than 0.01 standardized units is required to classify this trait as green (similar to ash). Scots pine, American ash and European larch all have much higher LDMC values than ash, suggesting that the rate of decomposition of their litter may be much slower than ash (but see above).

Most temperate European woodland trees form ectomycorrhizal associations (ECM) with a wide range of soil fungi, whereas ash forms only arbuscular mycorrhizal (AM) associations with a more restricted group of fungi. Thirty of the alternative tree species assessed also form AM associations, but 20 of them form ECM. More soil carbon is stored in systems dominated by ecotomycorrhizal associations than in ecosystems dominated by AM-associated plants (Averill et al 2014). Therefore if there was a major change to a system dominated by trees with ECM associations this would increase the amount of carbon stored in the system.

4.6 Comparison of Ellenberg values between alternative tree species

Ellenberg values are not traits of trees but rather describe the ecological niche in which a tree species grows. None of the alternative tree species matched ash for all the Ellenberg values (Table 4.4). Field maple matched ash for three of the Ellenberg values (light, acidity and nitrogen). Horse chestnut, alder, hawthorn, bird cherry, blackthorn, large leaved lime and elm matched ash for two Ellenberg values with the other two Ellenberg values differing by a score of one from ash.

Table 4.4 Similarity of alternative trees to ash for Ellenberg moisture (F), light (L), acidity (R), nitrogen (N) scores. Green = same value as ash, amber = differs from ash by one unit, red = differs from ash by more than one unit. Trees ranked by whether they are native to the UK and then by the number of green cells

	Tree Alternative	F	L	R	N
Native	Field maple	Amber	Green	Green	Green
	Alder	Red	Green	Amber	Green
	Hawthorn	Amber	Amber	Green	Green
	Bird cherry	Green	Green	Amber	Amber
	Blackthorn	Amber	Amber	Green	Green
	Large leaved lime	Amber	Amber	Green	Green
	Wych & English Elm	Amber	Amber	Green	Green
	Hornbeam	Amber	Amber	Red	Green
	Hazel	Amber	Amber	Amber	Green
	Holly	Amber	Green	Red	Amber
	Privet	Amber	Amber	Green	Amber
	Crab apple	Amber	Red	Amber	Green
	Scots pine	Green	Red	Red	Red
	Black poplar	Red	Amber	Green	Amber
	Aspen	Amber	Amber	Red	Green
	Wild cherry	Amber	Amber	Amber	Green
	Sessile oak	Green	Amber	Red	Red
	Goat willow	Amber	Red	Green	Amber
	Elder	Amber	Amber	Green	Amber
	Whitebeam	Red	Amber	Green	Red
	Rowan	Green	Amber	Red	Red
	Yew	Red	Amber	Green	Amber
	Small leaved lime	Amber	Green	Amber	Amber
	Wild service tree	Amber	Amber	Amber	Amber
	Beech	Amber	Red	Red	Amber
	Grey willow	Red	Red	Amber	Amber
	Silver birch	Amber	Red	Red	Red
	Downy birch	Amber	Red	Red	Red
	Pedunculate oak	Amber	Red	Red	Red
Non-native	Horse chestnut	Amber	Green	Green	Amber
	Norway maple	Amber	Amber	Green	Amber
	Sycamore	Amber	Amber	Amber	Green
	Sweet chestnut	Amber	Green	Red	Amber
	Douglas fir	Green	Amber	Red	Red
	Turkey oak	Red	Amber	Amber	Green
	Common walnut	Red	Amber	Amber	Amber
	European larch	Red	Red	Amber	Red
	Hop-hornbeam	Red	Amber		Amber
	Western red cedar	Amber	Amber	Red	Red
	Silver fir		Red		
	Italian alder				
	Shagbark hickory				
	American ash				
	Manchurian ash				
	Manna ash				
	Green ash or red ash				
	Black walnut				
	Plane spp.				
	Caucasian wingnut				
	Red oak				

5 Management scenarios (5) & (6): thinning and felling with natural regeneration promoted

<u>Chapter summary</u>

1. *This chapter develops 'pen pictures' to describe changes in ash woodland vegetation composition that might occur under scenarios of thinning or felling with natural regeneration.*

2. *The scenarios are developed for 9 ash-relevant regions with in the UK over two time periods (1-10 years and 50-100 years).*

3. *The management scenarios presented here are explorations of examples of what might be done to manage for ash dieback and are not necessarily the management that should be carried out.*

5.1 Introduction

Phase 1 identified the six management scenarios considered most likely to occur following ash dieback. The management scenarios may be summarized as:

(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 more viable. 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 more viable. 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 more viable.
(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 more viable. Then active management initially to achieve natural regeneration in the stand (e.g. fencing and vegetation management), with subsequent management to develop overstorey species.

Phase 1 provided a detailed assessment of the changes in woodland composition and structure following management scenarios (1)-(4) in 9 regions within the UK. This chapter develops management scenarios (5) and (6). Details of how the management scenarios were developed are provided in Phase 1, with a summary below in section 5.2. Figure 5.1 shows the 9 ash-relevant regions for which an assessment was made (see Phase 1 report for details of how these regions were developed). Chapter 6 provides an assessment of the impact of these scenarios on obligate and highly associated species.

5.2 Method used for developing ‘pen pictures’

5.2.1 Ash proportions in canopy-method

The likely minimum proportion of ash expected in the canopy for woodlands dominated by ash is indicated at the beginning of the set of habitat pen pictures for each sub-region. The proportions are based on an analysis of the frequency of ash within the woodland NVC sub community occurring in each sub-region. These results were verified against the NFI data to check that broadleaved woodlands with the indicated proportion of ash were actually recorded in each sub-region.

5.2.2 Approach used in writing pen-pictures

For describing habitat response (see pen-pictures) to the 6 management scenarios:

<u>In the first 1-10 years</u>

- The trees and shrub species are those most likely to be present in the NVC community occurring in the particular sub-region (described as ‘Typical’ trees or shrubs in the pen pictures).
- Their occupancy of the canopy or understorey is based on the trees’ and shrubs’ light requirements.
- The ground vegetation reflects the components of the NVC community present in the sub-region and the likely influence on this by changes in the canopy and ground disturbance related to the management applied.
- Species reported as regenerating reflect the influences of potential seed sources, the site type as indicated by the NVC community and sub-region, and the changes in light and ground disturbance related to the management applied.
- The amount of ash (living, dying or dead) is influenced by the management applied.

<u>After 50-100 years</u>

- The stand structure (and any remaining ash deadwood) reflects the influence of management history (as applied under each scenario).
- The composition of trees and shrub species in each scenario was developed by considering the likely succession of species described as present in the first time period. Factors considered included: growth and persistence in the canopy of components of understorey species, longevity of different component tree and shrub species, competition between different species and potential of regeneration.
- The ground vegetation reflects the components of the NVC community present in the sub-region and the likely influence on this by changes in the canopy.
- Species reported as regenerating reflect the influences of potential seed sources, the site type as indicated by the NVC community, and the availability of light.

5.2.3 Limitations of the management scenarios

The management scenarios selected are only a subset of what woodland managers might choose to do. They are explorations of examples of what might be done to manage for ash dieback; but they give a flavour of possible outcomes within the limited scope of this contract. The exact management suitable for any given site will depend on the management objectives at that site and the species present.

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. Removal of diseased and dead trees from most of the woodlands will most likely match a thinning intervention (scenario (5)). We propose that scenario (6) (felling with natural regeneration promoted), is also likely to occur widely 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.

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 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.

5.2.4 Use of the pen pictures

The pen pictures were developed as one step in the procedure of assessing the impact of the management scenarios on ash-associated species (Chapter 6). Changes in the abundance of ash are shown in red text, potential alternative host species are shown in bold text.

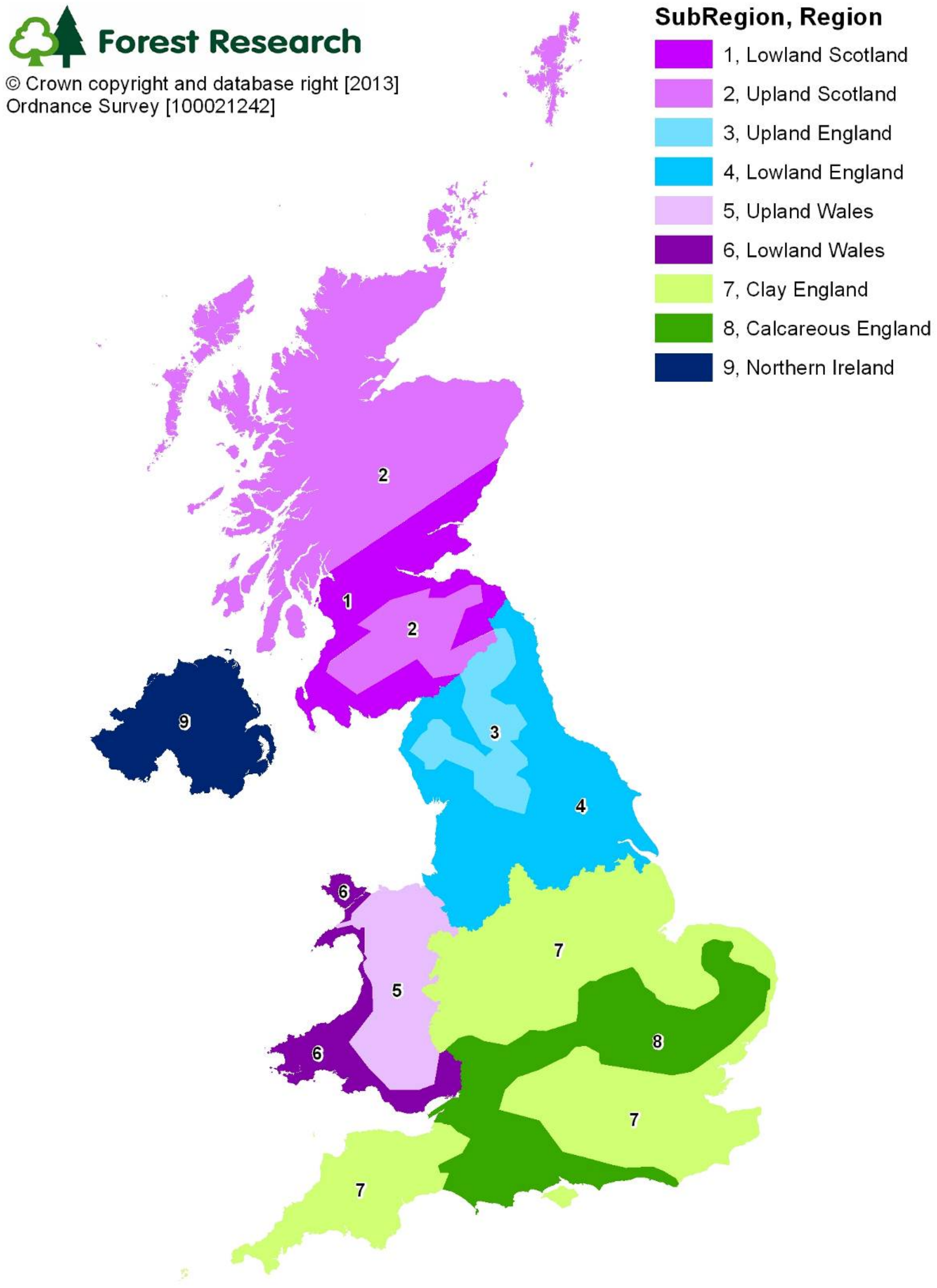

Figure 5.1 Ash-relevant regions and sub-regions used in this Report. Scotland, Wales and Northern England are divided into Upland and Lowland sub-regions (sub regions 1-6); Southern England is divided into Clay South England (7) and Calcareous South England (8). NB sub-regions are defined by general 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

5.3 Descriptions of ash-woodland vegetation under management scenarios (5) & (6)

Table 5.1 Lowland Scotland (sub-region 1), where the main canopy is not dominated by ash (ash <20%)

Current ash dominance	Woodlands where main canopy is not dominated by ash (ash <20%).		
Typical species	Typical canopy tree species: **alder**, **downy** and **silver birch**, **goat willow**, **holly**, **sessile oak**, **bird cherry** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **grey willow**, and **blackthorn.**	Field layer of composed of species typical of NVC community: **W7, W10**
Management Scenario	After 1–10 years	After 50–100 years	
5	Canopy composed of **birch, sycamore,** (**alder** on the wetter sites) and **sessile oak,** mixed with a few other **typical** canopy species. **Some dead but no living ash trees remain.** Some gaps in canopy. Positive growth of understorey of young **sycamore**, **sessile oak, alder,** and **holly** and **bird cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs e.g. **hazel** present but **ash coppice** is cut. Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, alder** thrive and grow. Field layer dominated by: **Lady fern, creeping soft-grass**, **yellow pimpernel** (wetter sites), **bramble**, **bluebell** and **honeysuckle** (free draining sites).	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: - a full canopy composed of **sycamore,** (**alder** on the wetter sites) and **sessile oak,** mixed with a few other **typical** canopy species. - an understorey of a mixture of typical canopy species e.g. **sycamore**, **alder** - a mixture of the **typical** shrubs e.g. **hawthorn, hazel** show positive growth. Seedlings of all the **typical** canopy tree species present in gaps. Field layer dominated by: **Lady fern, creeping soft-grass**, **yellow pimpernel** (wetter sites), **bluebell** and **honeysuckle** (free draining sites).	
6	Canopy composed of **birch, sycamore,** (**alder** on the wetter sites) and **sessile oak,** mixed with a few other **typical** species. **No ash trees (living or dead).** Some large gaps in canopy. Understorey of young **sycamore**, **sessile oak, alder,** and **holly** and **bird cherry** show positive growth in gaps but **ash** absent. **Typical** shrubs (and **ash**) are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow.	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: -a full canopy composed of **sycamore,** (**alder** on the wetter sites) and **sessile oak,** mixed with a few other **typical** species. -an understorey of a mixture of young, **sycamore**, **sessile oak, alder,** and **holly** -a range of **typical** shrubs e.g. **hawthorn, hazel** are well developed. Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore** establish. Field layer sparse with some **broad buckler fern**, **lady fern**, **creeping**	

	Weeding will favour development of diverse, herb-rich field layer 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** (drier sites).	**soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites).

Table 5.2 Upland Scotland (sub-region 2), where the main canopy is not dominated by ash (ash<20%)

<table>
<tr><td>Current ash dominance</td><td colspan="4">Woodlands where main canopy is not dominated by ash (ash<20%).</td></tr>
<tr><td>Typical species</td><td>Typical canopy tree species: **alder**, **downy** and **silver birch**, **goat willow**, **holly**, **sessile oak**, **bird cherry** and **sycamore**.</td><td colspan="2">Typical shrub species: **hawthorn**, **hazel**, **grey willow**, and **blackthorn**.</td><td>Field layer of composed of species typical of NVC community: **W9b, W7.**</td></tr>
<tr><td>Management Scenario</td><td colspan="2">After 1–10 years</td><td colspan="2">After 50–100 years</td></tr>
<tr><td>5</td><td colspan="2">Canopy composed of **birch, sycamore, alder** and **sessile oak,** mixed with a few other **typical** species. **Some dead but no living ash trees remain.**
Some gaps in canopy.
Positive growth of understorey of young **sycamore**, **sessile oak, alder,** and **holly** and **bird cherry** but **ash saplings dying back.**
A mixture of the **typical** shrubs e.g. **hazel, grey willow** are present but **ash** coppice is cut.
Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, alder** (**birch** in gaps) thrive and grow.
Field layer dominated by:
wood sorrel, dog violet and **pignut** (free draining sites); **tufted hair-grass**, **creeping soft-grass**, **yellow pimpernel** (wetter sites).</td><td colspan="2">**No ash trees, saplings or coppice (living or dead).**
Multi-strata woodland with:
- a full canopy composed of **sycamore, alder** and **sessile oak,** mixed with a few other **typical** canopy species. -an understorey of a mixture of typical canopy species e.g. **sycamore**, **alder**
- a mixture of the **typical** shrubs e.g. **hazel** show positive growth.
Seedlings of all the **typical** canopy tree species present in gaps.
Field layer dominated by:
wood sorrel, dog violet and **pignut** (free draining sites); **tufted hair-grass**, **creeping soft-grass**, **yellow pimpernel** (wetter sites).</td></tr>
<tr><td>6</td><td colspan="2">Canopy composed of **birch, sycamore, alder** and **sessile oak,** mixed with a few other **typical** species. **No ash trees (living or dead).**
Some large gaps in canopy.
Understorey of young **sycamore**, **sessile oak, alder,** and **holly** and **bird cherry** show positive growth in gaps but **ash** absent.
Typical shrubs (and **ash**) are infrequent as removed by management.
Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow.
Weeding will favour development of diverse, herb rich field layer including **wood sorrel** and **dog violet** and **creeping buttercup**.</td><td colspan="2">**No ash trees, saplings or coppice (living or dead).**
Multi-strata woodland with:
- a full canopy composed of **sycamore, alder** and **sessile oak,** mixed with a few other **typical** species.
- an understorey of a mixture of young, **sycamore**, **sessile oak, alder,** and **holly**.
- a range of **typical** shrubs e.g. **hazel** are well developed.
Seedlings of the canopy tree species occur occasionally but few e.g. **alder** establish.
Sparse field layer with some **creeping soft-grass**, **wood sorrel**, **tufted hair-grass** and **dog violet**.</td></tr>
</table>

Table 5.3 Upland Northern England (sub-region 3), where the main canopy is not dominated by ash (ash <20%)

Current ash dominance	Woodlands where main canopy is not dominated by ash (ash <20%).		
Typical species	Typical canopy tree species: **alder**, **downy** and **silver birch**, **goat willow**, **holly**, **sessile oak**, **bird cherry** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **grey willow** and **blackthorn**.	Field layer of composed of species typical of NVC community: **W7,W9b.**
Management Scenario	After 1–10 years		After 50–100 years
5	Canopy composed of **birch, sycamore, alder** and **sessile oak,** mixed with a few other **typical** species. **Some dead but no living ash trees remain.** Some gaps in canopy. Positive growth of understorey of young **sycamore**, **sessile oak, alder,** and **holly** and **bird cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs e.g. **hazel, grey willow** are present but **ash** coppice is cut. Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, alder** (**birch** in gaps) thrive and grow. Field layer dominated by **yellow pimpernel**, **broad buckler fern**, **lady fern**, **tufted hair-grass** and **soft rush**.		**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: -a full canopy composed of **sycamore, alder** and **sessile oak,** mixed with a few other **typical** canopy species. -an understorey of a mixture of typical canopy species e.g. **sycamore**, **alder** - a mixture of the **typical** shrubs e.g. **hazel** show positive growth. Seedlings of all the **typical** canopy tree species present in gaps. Field layer dominated by **yellow pimpernel**, **broad buckler fern**, **lady fern**, **tufted hair-grass** and **soft rush**.
6	Canopy composed of **birch, sycamore, alder** and **sessile oak,** mixed with a few other **typical** species. **No ash trees (living or dead).** Some large gaps in canopy. Understorey of young **sycamore**, **sessile oak, alder,** and **holly** and **bird cherry** show positive growth in gaps but **ash** absent. **Typical** shrubs (and **ash**) are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow. 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**.		**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: - a full canopy composed of **sycamore, alder** and **sessile oak,** mixed with a few other **typical** species. -an understorey of a mixture of young, **sycamore**, **sessile oak, alder,** and **holly**. - a range of **typical** shrubs are well developed. Seedlings of the canopy tree species occur occasionally but few e.g. **alder** establish. Sparse vegetation cover but some **broad buckler fern**, **lady fern**, **creeping soft-grass**, **rough meadow-grass** and **wood sorrel**.

Table 5.4 Lowland Northern England (sub-region 4), where the main canopy is not dominated by ash (ash <20%)

<table>
<tr><td>Current ash dominance</td><td colspan="3">Woodlands where main canopy is not dominated by ash (ash <20%).</td></tr>
<tr><td>Typical species</td><td>Typical canopy tree species: alder, beech, oak, downy and silver birch, field maple, goat willow, holly, yew, crab apple, bird cherry and sycamore.</td><td>Typical shrub species: hawthorn, hazel, blackthorn, elder and grey willow.</td><td>Field layer of composed of species typical of NVC community: W10,W7.</td></tr>
<tr><td>Management Scenario</td><td>After 1–10 years</td><td colspan="2">After 50–100 years</td></tr>
<tr><td>5</td><td>Canopy composed of sycamore, birch, beech, oak, holly, mixed with a few other typical species.
Some dead but no living ash trees remain.
Some gaps in canopy.
Positive growth of understorey of young sycamore, beech, sessile oak, alder, and holly and bird cherry but ash saplings dying back.
A mixture of the typical shrubs e.g. hazel, hawthorn are present but ash coppice is cut.
Seedlings of a mixture of the typical canopy tree species frequent; some seedlings e.g. sycamore (birch in gaps), thrive and grow.
Field layer dominated by yellow pimpernel (wetter sites), bramble, bracken, bluebell and honeysuckle (drier sites).</td><td colspan="2">No ash trees, saplings or coppice (living or dead).
Multi-strata woodland with:
- a full canopy composed sycamore, beech, oak, holly, mixed with a few other typical species.
- an understorey of a mixture of young, sycamore, beech, sessile oak, alder, and holly.
- a range of typical shrubs abundant and well developed.
Seedlings of the canopy tree species occur occasionally but few e.g. beech establish.
Field layer dominated by yellow pimpernel (wetter sites) bracken, bluebell and honeysuckle (drier sites).</td></tr>
<tr><td>6</td><td>Canopy composed of sycamore, birch, beech, oak, holly, mixed with a few other typical species.
No ash trees (living or dead).
Some large gaps in canopy.
Positive growth of understorey of young sycamore, beech, sessile oak, alder, and holly and bird cherry, but no ash.
Typical shrubs (and ash) are infrequent as removed by management.
Seedlings of the typical canopy tree species frequent; some e.g. birch and sycamore thrive and grow.
Weeding will favour development of diverse, herb rich ground flora containing creeping buttercup,</td><td colspan="2">No ash trees, saplings or coppice (living or dead).
Multi-strata woodland with:
- a full canopy composed of sycamore, beech, oak, holly, mixed with a few other typical species.
- an understorey of a mixture of young, sycamore, beech, sessile oak, alder, and holly.
- a range of typical shrubs are well developed.
Seedlings of the typical canopy tree species e.g. beech and sycamore occur occasionally.
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</td></tr>
</table>

	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).	sites).

Table 5.5 Upland Wales (sub-region 5), where the main canopy is not dominated by ash (<20%)

<table>
<tr><td>Current ash dominance</td><td colspan="3">Woodlands where main canopy is not dominated by ash (<20%).</td></tr>
<tr><td>Typical species</td><td>Typical canopy tree species: **alder**, **birch**, **goat willow**, **holly**, **oak**, **rowan**, **bird cherry** and **sycamore**.</td><td>Typical shrub species: **hawthorn**, **hazel**, **blackthorn**, **elder** and **grey willow**.</td><td>Field layer of composed of species typical of NVC community: **W10, W7.**</td></tr>
<tr><td>Management Scenario</td><td>After 1–10 years</td><td colspan="2">After 50–100 years</td></tr>
<tr><td>5</td><td>Canopy composed of **sycamore, birch, oak, holly,** mixed with a few other **typical** species. **Some dead but no living ash trees remain.**
Some gaps in canopy.
Ash saplings dying back.
Positive growth of understorey of young **sycamore, alder, oak, holly,** and **bird cherry** but **ash saplings dying back.**
A mixture of the **typical** shrubs e.g. **hazel** are present but **ash** coppice is cut.
Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, (birch** in gaps)**,** thrive and grow.
Field layer dominated by **yellow pimpernel** (wetter sites), **bramble**, **bracken**, **bluebell** and **honeysuckle** (drier sites).</td><td colspan="2">**No ash trees, saplings or coppice (living or dead).**
Multi-strata woodland with:
- a canopy composed of **sycamore, alder, oak, holly, bird cherry,** mixed with a few other **typical** species. Canopy is closed with no gaps.
- an understorey of a mixture of young **sycamore, alder, oak, holly.**
- a range of **typical** shrubs abundant and well developed.
Seedlings of the **typical** canopy tree species occur occasionally in gaps.
Field layer dominated by **yellow pimpernel** (wetter sites) **bracken**, **bluebell** and **honeysuckle** (drier sites).</td></tr>
<tr><td>6</td><td>Canopy composed of **sycamore, birch, oak, holly,** mixed with a few other **typical** species. **No ash trees (living or dead).**
Some large gaps in canopy.
Positive growth of understorey of young **sycamore**, **alder, oak, holly,** and **bird cherry,** but no **ash.**
Typical shrubs (and **ash**) are infrequent as removed by management.
Seedlings of the **typical** canopy tree species frequent; some e.g. **birch** and **sycamore** thrive and grow.
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**,</td><td colspan="2">**No ash trees, saplings or coppice (living or dead).**
Multi-strata woodland with:
- a full canopy composed of **sycamore, oak, holly,** mixed with a few other **typical** species. an understorey of a mixture of young **sycamore**, **alder, oak,** and **holly**.
- a range of **typical** shrubs are well developed.
Seedlings of the **typical** canopy tree species occur occasionally but only a few e.g. **sycamore** are likely to establish.
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).</td></tr>
</table>

	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).	

Table 5.6 Lowland Wales (sub-region 6), where the main canopy has >60% ash

Current ash dominance	Woodlands where main canopy has >60% ash.		
Typical species	Typical canopy tree 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**.	Field layer of composed of species typical of NVC community: **W8, W9a.**
Management Scenario	After 1–10 years	After 50–100 years	
5	Canopy composed of many **dying/dead but no living ash trees,** and **beech, birch, oak, yew** and **poplar,** mixed with a few other **typical** species. Some gaps in canopy. Positive growth of understorey of young **sycamore**, **beech**, **oak** and **wild cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs eg **hazel** present but **ash** coppice is cut. Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, beech** thrive and grow. Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **creeping thistle**, **bramble** and **rough meadow-grass**) become abundant.	**No ash trees, saplings or coppice (living or dead).** Canopy composed of **sycamore** and **beech** with a few other **typical** species e.g. **wild cherry** present. Some large gaps in the canopy. Understorey depleted and composed of **yew**, **sycamore**, **beech** and **wild cherry** A mixture of the **typical** shrubs present. Seedlings of all the **typical** canopy tree species present in gaps. Field layer is 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**).	
6	Canopy composed of **beech, birch, oak** and **poplar,** mixed with a few other **typical** species. **No ash trees (living or dead).** Large gaps in canopy. Understorey of young **sycamore**, **beech**, **oak** and **wild cherry** show positive growth in gaps but **ash** absent. **Typical** shrubs (and **ash**) are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow. Field layer has early successional species (e.g. **primrose** and **violets**) establish, but ground disturbance leads to **stinging**	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: - a full canopy composed of the **typical** species but with large amounts **sycamore, beech, oak** and **birch.** - an understorey of a mixture of young, **sycamore**, **beech**, **oak, field maple, wild cherry** and **holly.** - a range of **typical** shrubs are well developed. Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore** and **beech** establish. Field layer has sparse vegetation cover but with some species (e.g. **bluebell**, **wild garlic**, **false brome** and **male fern**).	

	nettle, **creeping thistle**, **rosebay willow herb** and **cocksfoot** establishing; **wood anemone**, **bluebell** and **broad buckler fern** may invade later.	

Table 5.7 Southern England Clay (sub-region 7), where the main canopy has >40% ash

<table>
<tr><td>Current ash dominance</td><td colspan="3">Woodlands where main canopy has >40% ash</td></tr>
<tr><td>Typical species</td><td>Typical canopy tree species: **beech**, **crab apple**, **birch**, **oak**, **sweet chestnut**, **whitebeam**, **hornbeam**, **rowan**, **goat willow**, **holly**, **field maple**, **wild cherry**, **yew**, **poplar** and **sycamore**.</td><td>Typical shrub species: **hawthorn**, **hazel**, **grey willow**, **blackthorn**, **elder**, **guelder rose**, **dogwood**, **spindle** and **privet**.</td><td>Field layer of composed of species typical of NVC community: **W12a, W8.**</td></tr>
<tr><td>Management Scenario</td><td>After 1–10 years</td><td colspan="2">After 50–100 years</td></tr>
<tr><td>5</td><td>Canopy composed of many **dying/dead but no living ash trees,** and **beech, sycamore, birch, oak** and **holly,** mixed with a few other **typical** species.
Some gaps in canopy.
Positive growth of understorey of young **sycamore**, **beech**, **sweet chestnut, field maple** and **wild cherry** but **ash saplings dying back.**
A mixture of the **typical** shrubs eg **hazel** present but **ash** coppice is cut.
Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, beech** thrive and grow.
Field layer of partially shade-tolerant species (e.g. **bramble**, **ivy** and **false brome**) become abundant.</td><td colspan="2">**No ash trees, saplings or coppice (living or dead).**
Canopy composed of **sycamore** and **beech** with a few other **typical** species e.g. **wild cherry** present.
Some large gaps in the canopy.
Understorey depleted and composed of **hornbeam**, **yew**, **sycamore**, **beech** and **wild cherry.**
A mixture of the **typical** shrubs present.
Seedlings of all the **typical** canopy tree species present in gaps.
Field layer 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**).</td></tr>
<tr><td>6</td><td>Canopy composed of **beech, sycamore, birch, oak** and **holly,** mixed with a few other **typical** species. **No ash trees (living or dead).**
Some gaps in canopy.
Positive growth of understorey of young **sycamore**, **beech**, **sweet chestnut, field maple** and **wild cherry** but **ash** absent.
Typical shrubs (and **ash**) are infrequent as removed by management.
Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow.
Field layer of early successional species (e.g. **primrose** and **violets**) establish, but ground</td><td colspan="2">**No ash trees, saplings or coppice (living or dead).**
Multi-strata woodland with:
- a full canopy composed of **sycamore, oak, beech** and **sweet chestnut** with a few other **typical** species e.g. **wild cherry** present.
Some large gaps in the canopy.
- an understorey well developed and a mixture of young, **sycamore**, **beech**, **field maple, wild cherry, sweet chestnut** and **holly.**
- a mixture of the **typical** shrubs present.
Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore** and **beech** establish.
Field layer has sparse cover of browse-resistant vernal species (e.g. **bluebell**, **ivy** and **false brome**).</td></tr>
</table>

	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.	

Table 5.8 Southern England Calcareous (sub-region 8), where the main canopy has >60% ash

Current ash dominance	Woodlands where main canopy has >60% ash.		
Typical species	Typical canopy tree species: **beech**, **crab apple**, **birch**, **oak**, **sweet chestnut**, **whitebeam**, **hornbeam**, **rowan**, **goat willow**, **holly**, **field maple**, **wild cherry**, **yew**, **small leaved lime** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **grey willow**, **blackthorn**, **elder**, **guelder rose**, **dogwood**, **spindle** and **privet**	Field layer of composed of species typical of NVC community: **W8**
Management Scenario	After 1–10 years	After 50–100 years	
5	Canopy composed of many **dying/dead but no living ash trees,** and **beech, oak,** and **sycamore** mixed with a few other **typical** species. Some gaps in canopy. Positive growth of understorey of young **sycamore**, **beech**, **hornbeam, field maple** and **small leaved lime** but **ash saplings dying back.** A mixture of the **typical** shrubs eg **hazel** present but **ash** coppice is cut. Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, beech** and **hornbeam** thrive and grow. Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **creeping thistle**, **bramble** and **rough meadow-grass**) become abundant.	**No ash trees, saplings or coppice (living or dead).** A canopy of **beech, oak, sycamore, field maple, hornbeam** and **small leaved lime,** mixed with a few other **typical** species. Some large gaps in the canopy. Understorey depleted and composed of **hornbeam**, **yew**, **sycamore**, and **beech.** A mixture of the **typical** shrubs present. Seedlings of all the **typical** canopy tree species present in gaps. Field layer 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**).	
6	Canopy composed of **beech, oak** and **sycamore,** mixed with a few other **typical** species. **No ash trees (living or dead).** Some gaps in canopy. Positive growth of understorey of young **sycamore**, **beech**, **hornbeam**, **field maple** and **small leaved lime** but **ash** absent. **Typical** shrubs (and **ash**) are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow.	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: -a full canopy composed of **sycamore, oak, beech** and **small leaved lime** with a few other **typical** species e.g. **field maple** present. Some large gaps in the canopy. -an understorey well developed and a mixture of young, **sycamore**, **beech**, **field maple, hornbeam, wild cherry, yew, sweet chestnut,** and **holly.** -a mixture of the **typical** shrubs present. Seedlings of the canopy tree species occur occasionally but few e.g.	

	Field layer of 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.	**sycamore, beech** and **hornbeam** establish. Field layer has sparse cover but with some species (e.g. **bluebell**, **wild garlic**, **false brome**, **ivy**, **dog's mercury** and **male fern**).

Table 5.9 Northern Ireland (sub-region 9), where the main canopy is not dominated by ash (ash <20%)

Current ash dominance	Woodlands where main canopy is not dominated by ash (ash <20%).		
Typical species	Typical canopy tree species: **alder**, **birch**, **oak**, **rowan**, **goat willow**, **holly**, **bird cherry** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **blackthorn**, **elder**, **guelder rose**, **spindle** and **grey willow**.	Field layer of composed of species typical of NVC community: **W7, W10.**
Management Scenario	After 1–10 years	After 50–100 years	
5	Canopy composed of **birch, sycamore,** (**alder** on the wetter sites) and **oak,** mixed with a few other **typical** species. **Some dead but no living ash trees remain.** Some gaps in canopy. Positive growth of understorey of young **sycamore**, **oak, alder, holly** and **bird cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs e.g. **hazel** present but **ash** coppice is cut. Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, alder** thrive and grow. Field layer dominated by: **Lady fern, creeping soft-grass**, **yellow pimpernel** (wetter sites), **bramble**, **bluebell** and **honeysuckle** (free draining sites).	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: - a full canopy composed of **sycamore,** (**alder** on the wetter sites) and **oak,** mixed with a few other **typical** canopy species. - an understorey of a mixture of typical canopy species e.g. **sycamore**, **alder.** - a mixture of the **typical** shrubs show positive growth but ash coppice is absent. Seedlings of all the **typical** canopy tree species present in gaps. Field layer dominated by: **Lady fern, creeping soft-grass**, **yellow pimpernel** (wetter sites), **bluebell** and **honeysuckle** (free draining sites).	
6	Canopy composed of **birch, sycamore,** (**alder** on the wetter sites) and **oak,** mixed with a few other **typical** species. **No ash trees (living or dead).** Some large gaps in canopy. Understorey of young **sycamore**, **sessile oak, alder, holly** and **bird cherry** show positive growth in gaps but **ash** absent. **Typical** shrubs (and **ash**) are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow. Weeding will favour development of diverse, herb-rich field layer including **creeping buttercup**, **tufted hair-grass**, **creeping soft-**	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: - a full canopy composed of **sycamore,** (**alder** on the wetter sites) and **oak,** mixed with a few other **typical** species. - an understorey of a mixture of young, **sycamore**, **sessile oak, alder,** and **holly.** - a range of **typical** shrubs are well developed. Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore** establish. Field layer sparse with some **broad buckler fern**, **lady fern**, **creeping soft-grass** and **soft rush** (wetter sites) and **bramble**, **bluebell** and **ivy** (drier sites).	

	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** (drier sites) .	

6 Impact of management scenarios (5) & (6) on obligate and highly associated species

Chapter summary

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 'pen pictures' in Chapter 5 (management scenarios (5) thinning and (6) felling with natural regeneration promoted) was assessed by species experts in terms of predicted change in the species population from current levels within each region. This information was compared with the information on management scenarios (1)-(4) from the phase 1 report. The scenarios assume that the majority of ash trees will be lost due to ash dieback; if this does not happen then fewer ash-associated species may decline/go extinct.*

2. *In years 1-10 under scenarios (5) and (6) 22-61 obligate and highly associated ash species may decline in abundance and 1-22 species may go extinct if ash dieback kills the majority of ash trees.*

3. *In the short term (1-10 years) scenario (5) is better for ash-associated biodiversity than scenario (6) but after 50-100 years similar numbers of obligate and highly associated ash-associated species are at risk of declining in abundance or going extinct under both scenarios if ash dieback causes the loss of the majority of ash trees.*

4. *Some species are predicted to increase in abundance in the short-term (1-10 years) due to an increase in dead wood.*

5. *While the impact of the scenarios varies between species groups and individual species, generally scenarios (1) non-intervention and (2) no felling with natural regeneration promoted are predicted to have less of an impact on ash-associated species in the short-term (1-10 years) than scenarios (3) felling and (4) felling and replanting with scenarios (5) thinning and (6) felling with natural regeneration promoted in between these two extremes with respect to their impact on ash-associated species.*

6. *Regions 7 and 8 (Southern England – clay and Southern England – calcareous) are predicted to have more obligate and highly associated ash species declining and going extinct than other regions. This is due to more ash-associated species being present in these regions rather than a greater impact of scenarios (5) and (6) in these regions.*

6.1 Introduction

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 'pen pictures' in Chapter 5 was assessed by species experts in terms of predicted change in the species population from current levels within each region (Table 6.1). Information on species presence/absence within a region was taken from the UK National Biodiversity Network (NBN) (http://www.nbn.org.uk/) and from relevant species atlases and literature. The predicted impact was based expert knowledge of the habitat requirements of the ash-associated species and an assessment was made separately for each species for each management scenario in each region in each time period. The factors considered by the species experts may be summarized as:

- Complete loss of live ash trees: ash-obligate species may go extinct, highly associated species may decline, except in the short-term for species associated with dead wood which increase.
- Reduction in numbers of live ash trees: obligate and highly associated species decline.
- Increase in dead wood: increase in species associated with dead wood.
- 'Alternative tree species': species may not decline or go extinct if the replacement tree species (either through planting or natural regeneration) is one they will use or if the ground flora and shrub cover that develops following the loss of ash provides suitable alternative habitat for the ash-associated species.

This assessment was therefore carried out in the same way as in Chapter 17 of the Phase 1 report.

Table 6.1 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 is likely to result in the species declining in currently existing ash woodlands
No change	Scenario is predicted to result in no change in the species population in currently existing ash woodlands within the region
Increase	Scenario is likely to result in an 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
Data deficient	Distribution unknown. No information on species distribution available

6.2 Results

In order to aid comparisons between the management scenarios, data from all six management scenarios are shown, thus including data from the Phase 1 report on management scenarios (1)-(4). In total an assessment was made for 107 species (obligate and highly associated species). Species classed as data deficient, unknown or not present within a region are not shown in the figures for clarity.

The results from scenarios(1), (2) and (5) are based on the assumption that ash dieback causes large-scale loss of ash (95% or more). In scenarios (3), (4) and (6) all ash is felled so the scale of ash dieback is irrelevant. The predicted impact is based on simple assessments of decline, extinction, no change and increase. These are broad generalizations with no attempt to define different levels of decline (large or small). Depending on the impact of ash dieback on ash trees in the UK, some ash-associated species may just decline rather than go extinct. In addition the timescale over which ash dieback might kill ash trees in the UK is unknown and hence there is some uncertainly over the timescale of the impacts predicted below. The results aim to show the potential impact of ash dieback and the number of species that might be impacted; they do not provide definitive judgements on the exact number of species that will go extinct or decline.

Different numbers of obligate and highly associated species are present in different regions and the different management scenarios result in different numbers of species increasing/decreasing, therefore the number of species reported is often shown as a range.

6.2.1 All species

In years 1-10 under scenarios (5) and (6) 21-61 obligate and highly associated ash species may decline in abundance and 1-21 species may go extinct (ranges in numbers reflecting differences between regions in the number of ash-associated species present, Figure 6.1). More species are at risk of going extinct under scenario (6) than under scenario (5). A few species are predicted to increase in abundance due to an increase in dead wood. The impact varies between species groups and individual species; however, generally, scenarios (1) and (2) are predicted to have less of an impact on ash-associated species in the short-term (1-10 years) than scenarios (3) and (4) with scenarios (5) and (6) in between these two extremes with respect to their impact on ash-associated species.

Regions 7 and 8 show more species declining and going extinct than other regions. This is due to more ash-associated species being present in these regions rather than a greater impact of the scenarios in these regions.

Under scenarios (5) and (6) after 50-100 years 13-20 obligate and highly associated ash species may decline in abundance and 17-47 species may go extinct (Figure 6.2). If ash dieback causes the loss of most ash trees then only 1-3 highly associated species are predicted to remain unaffected under management scenarios (5) and (6) after 50-100 years.

6.2.2 Bryophytes

In total there are six highly associated bryophytes for which an assessment was made but not all species occurred in all regions. In the first ten years scenarios (5) and (6) are either predicted to have no impact on highly associated ash bryophytes or cause them to decline. The impact is very species specific with differences between regions reflecting the different species that occur in these regions (Figure 6.3). There are no obligate or highly associated bryophytes in Region 9 (Northern Ireland).

After 50-100 years under scenarios (5) and (6) 1-3 highly associated bryophyte species are predicted to go extinct and one species to decline with 1-2 species being unchanged in abundance, if ash dieback causes the loss of most ash trees (Figure 6.4).

6.2.3 Fungi

An assessment was made for 30 obligate or highly associated fungi. Regions 7 and 8 have the greatest number of ash-associated obligate or highly associated species and hence the greatest number of species at risk of declining in abundance. In the first 10 years species that used dead wood are predicted to increase in abundance under scenarios (5) and (6). More species are predicted to increase in abundance (four to eight) under scenario (5) than under scenario (6) (two to five) and more species are predicted to decrease in abundance under scenario (6) (9-20) than under scenario (5) (6-15) (Figure 6.5).

If ash dieback causes the death of the majority of ash trees then after 50-100 years there is no difference between scenarios (5) and (6) in the predicted impact on obligate and highly associated fungi with three to nine species predicted to go extinct depending on region and one to four species declining in abundance (Figure 6.6).

6.2.4 Invertebrates

An assessment was made for 54 obligate and highly associated invertebrate species. Fewer obligate and highly associated invertebrate species are predicted to go extinct under scenario (5) (1-4 species) than scenario (6) (12-19 species) in the first 10 years, due to the complete removal of ash in scenario (6). No obligate or highly associated invertebrate species are predicted to increase under scenario (6) but under scenario (5) one highly associated species is predicted to increase (Figure 6.7) due to the increase in dead wood.

After 50-100 years there is no difference between scenarios (5) and (6) in the predicted impact on obligate and highly associated ash invertebrate species with 12-33 species predicted to go extinct and 4-10 species declining in abundance if the majority of ash trees are lost due to ash dieback (Figure 6.8).

6.2.5 Lichens

In total the impact of scenarios (5) and (6) was assessed on 17 obligate and highly associated lichen species (Figures 6.9 and 6.10). In the first ten years four to nine obligate and highly associated lichen species may decline in abundance and one to four species are at risk of extinction under scenario (5) if ash dieback causes a substantial (>95%) loss of ash. A similar number of species are predicted to decline or go extinct under scenario (6). Compared to the other management scenarios the impacts on obligate and highly associated lichen species is predicted to be similar in the first ten years to that under scenarios (4) and (5).

After 50-100 years the predicted impacts on obligate and highly associated lichens are very similar between scenarios (5) and (6) with up to six species at risk of extinction and up to nine species declining in abundance.

6.2.6 Site versus landscape scale effects

This analysis has assessed the impact of the management scenarios at a region scale; no account was taken of how abundant the ash-associated species were. 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.

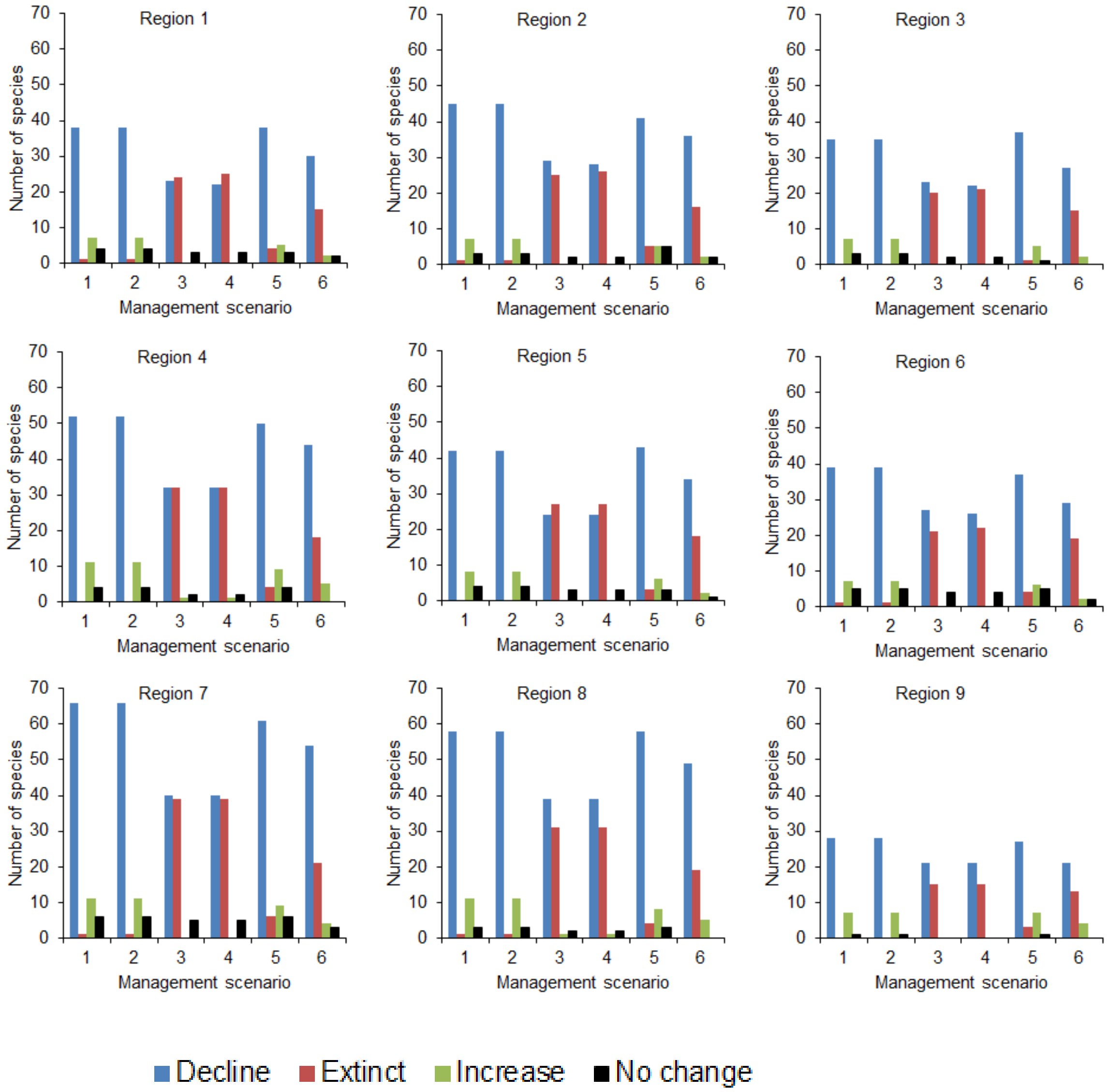

Figure 6.1 The predicted impact of different management scenarios on obligate and highly associated ash species after 1-10 years in 9 regions in the UK. See Chapter 5 for regions and management scenarios

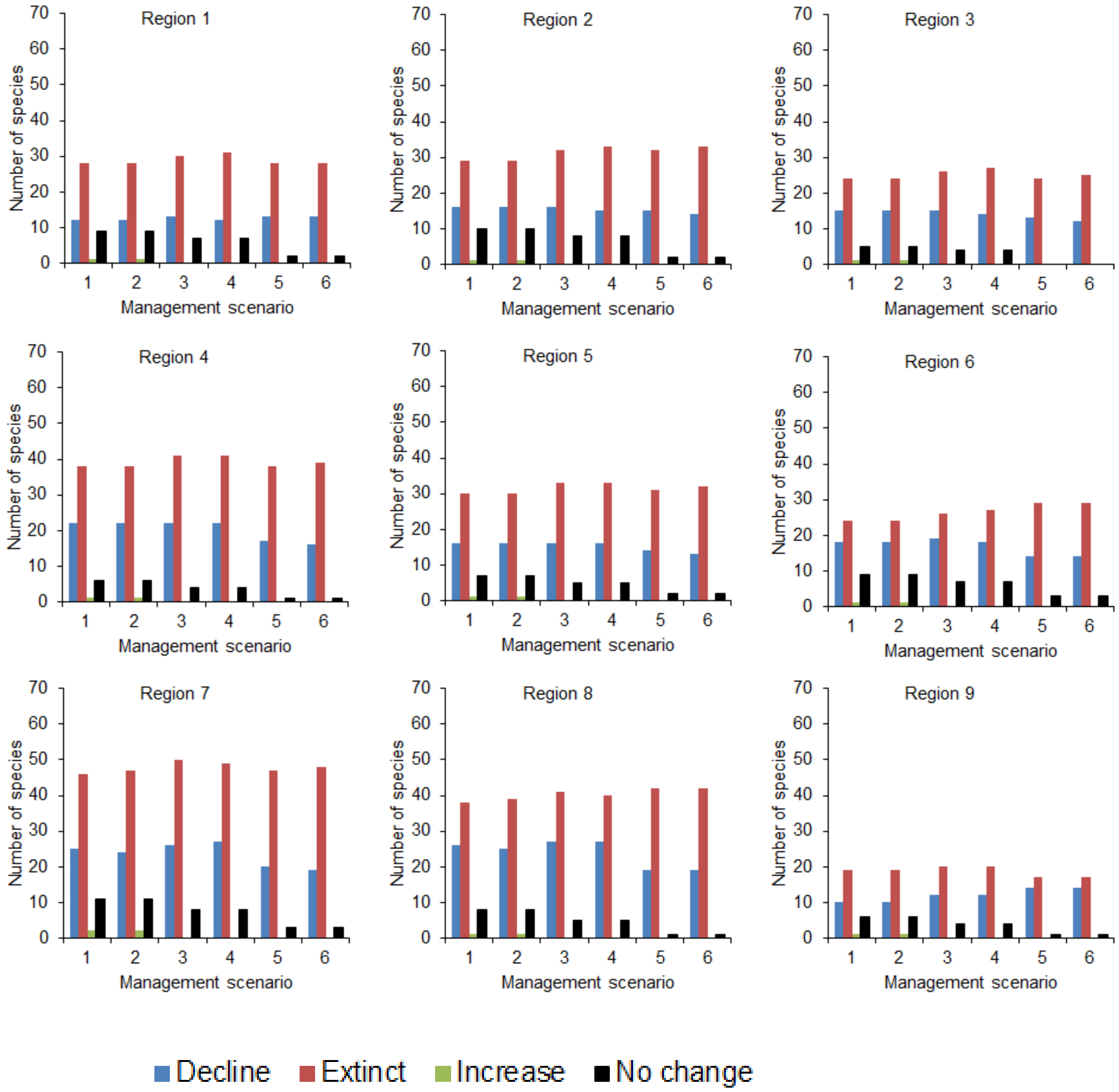

Figure 6.2 The predicted impact of different management scenarios on obligate and highly associated ash species after 50-100 years in 9 regions in the UK. See Chapter 5 for regions and management scenarios

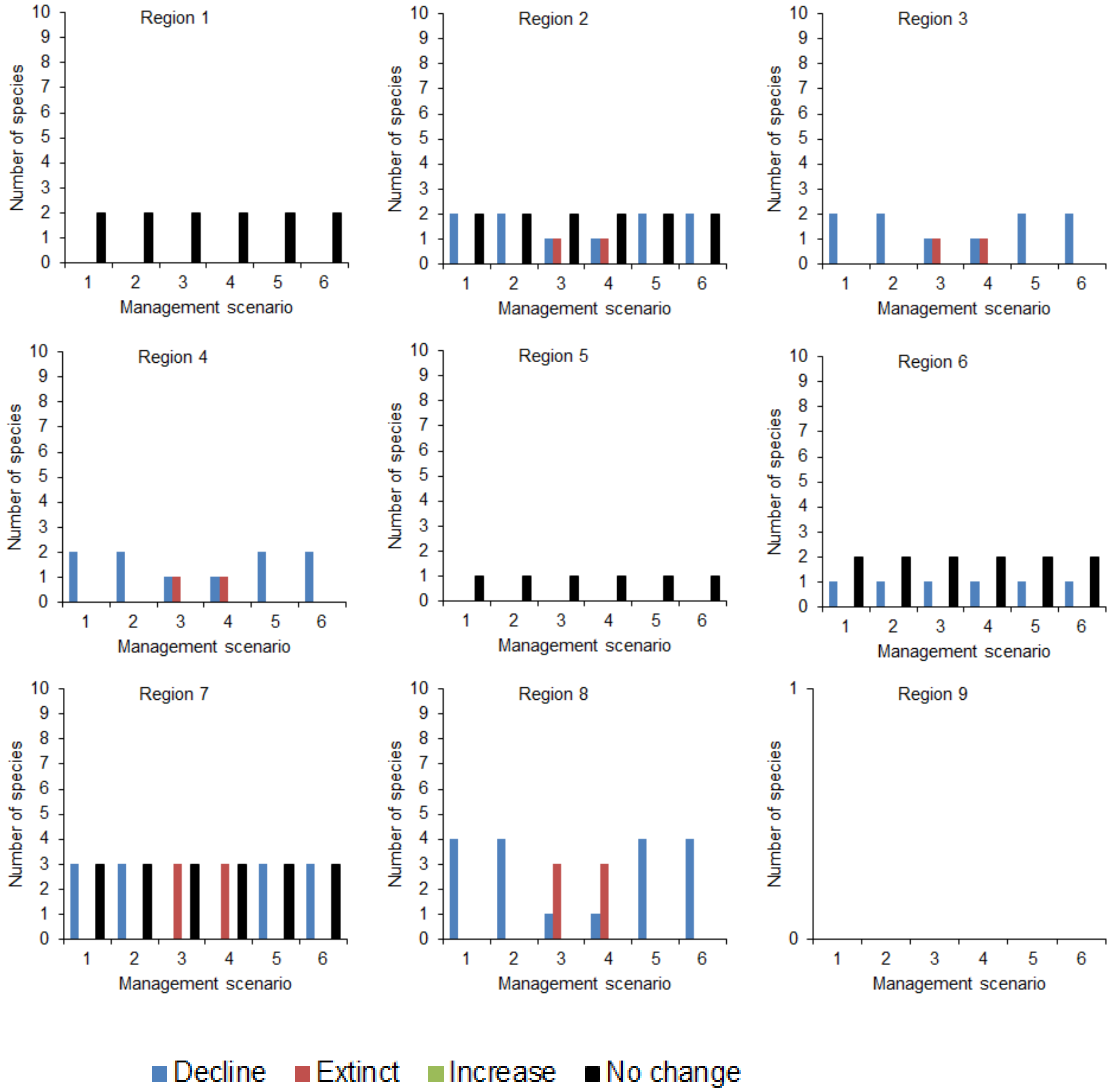

Figure 6.3 Bryophytes: the predicted impact of different management scenarios on obligate and highly associated ash species after 1-10 years in 9 regions in the UK. See Chapter 5 for regions and management scenarios

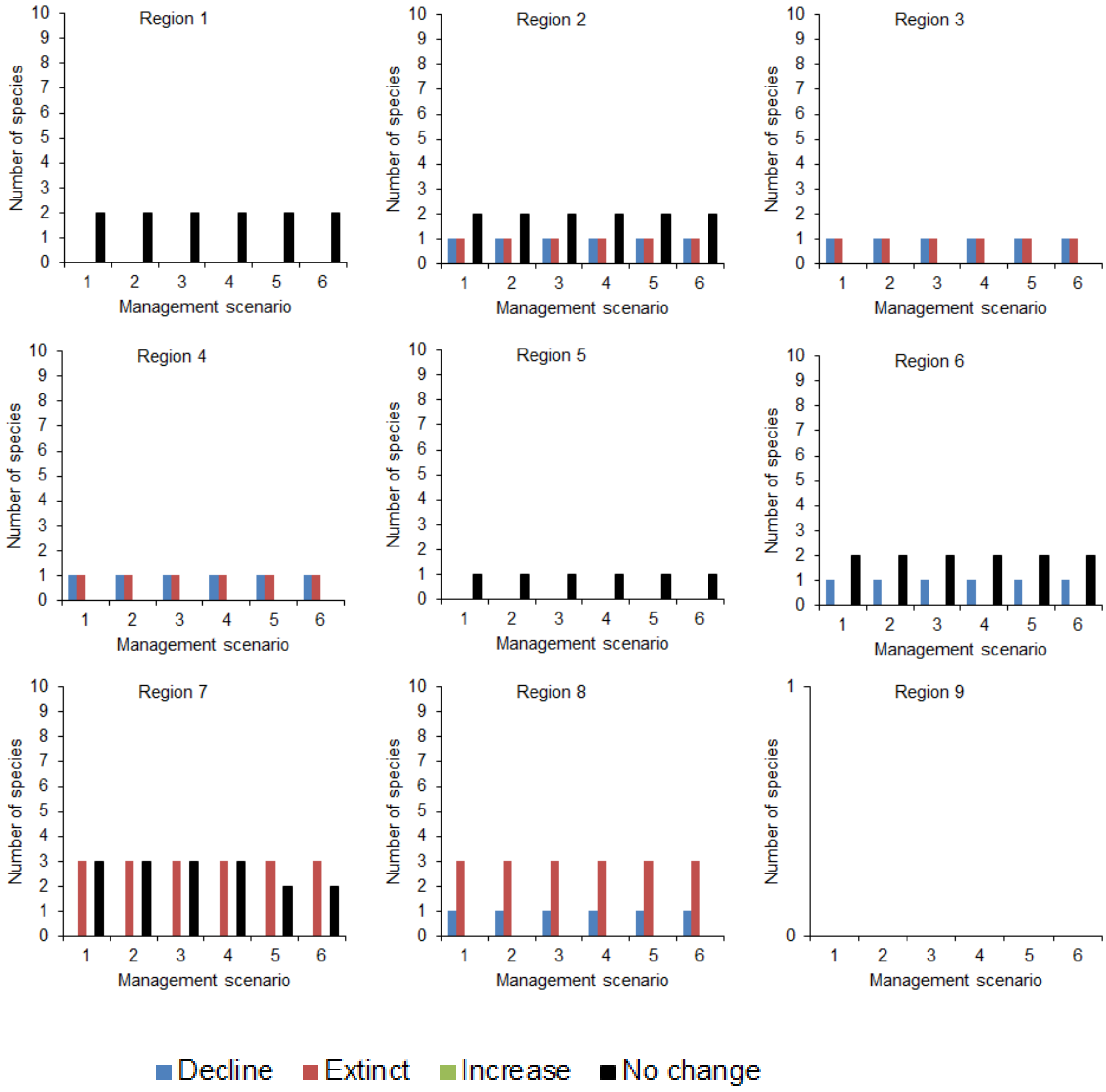

Figure 6.4 Bryophytes: the predicted impact of different management scenarios on obligate and highly associated ash species after 50-100 years in 9 regions in the UK. See Chapter 5 for regions and management scenarios

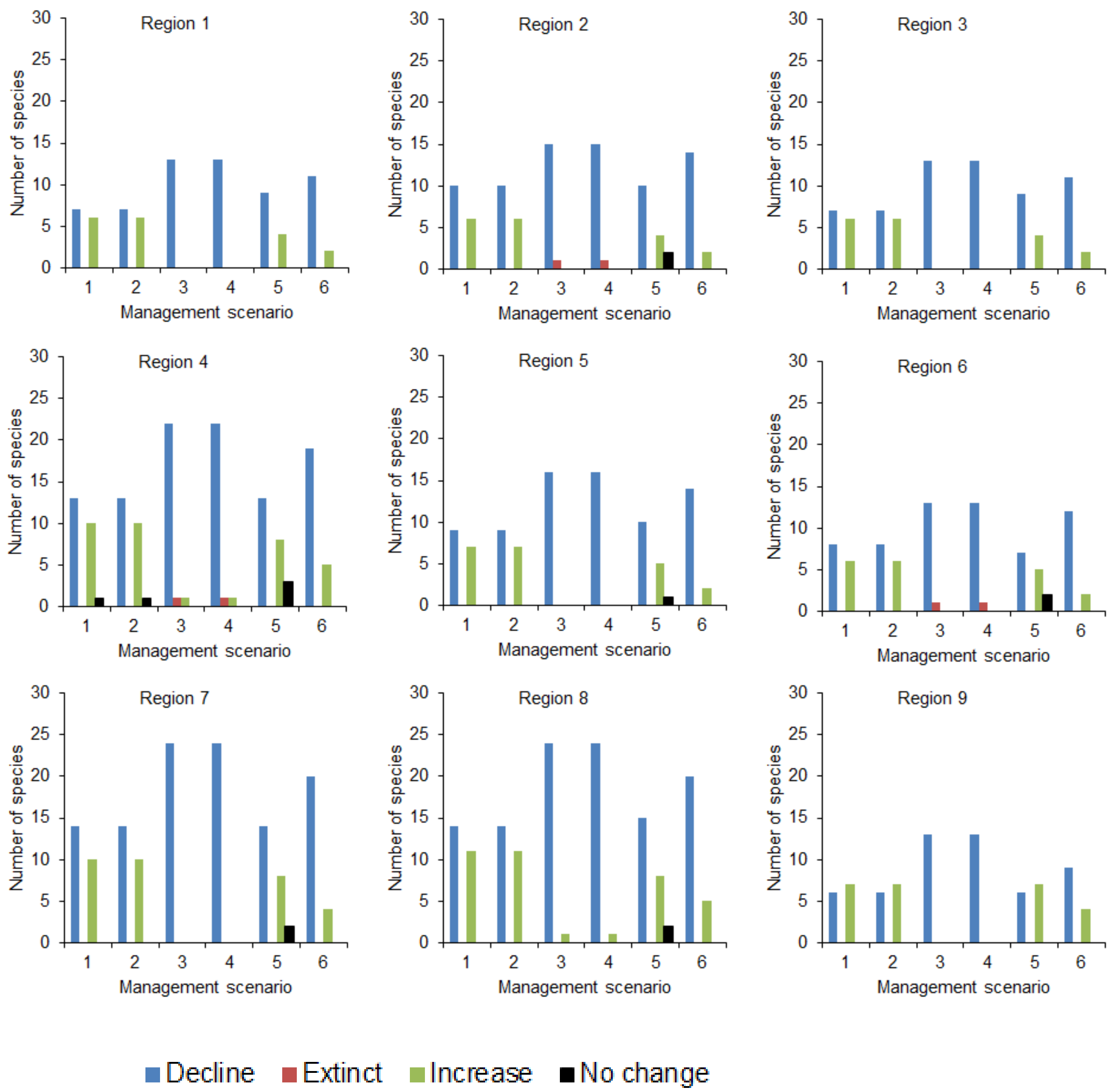

Figure 6.5 Fungi: the predicted impact of different management scenarios on obligate and highly associated ash species after 1-10 years in 9 regions in the UK. See Chapter 5 for regions and management scenarios

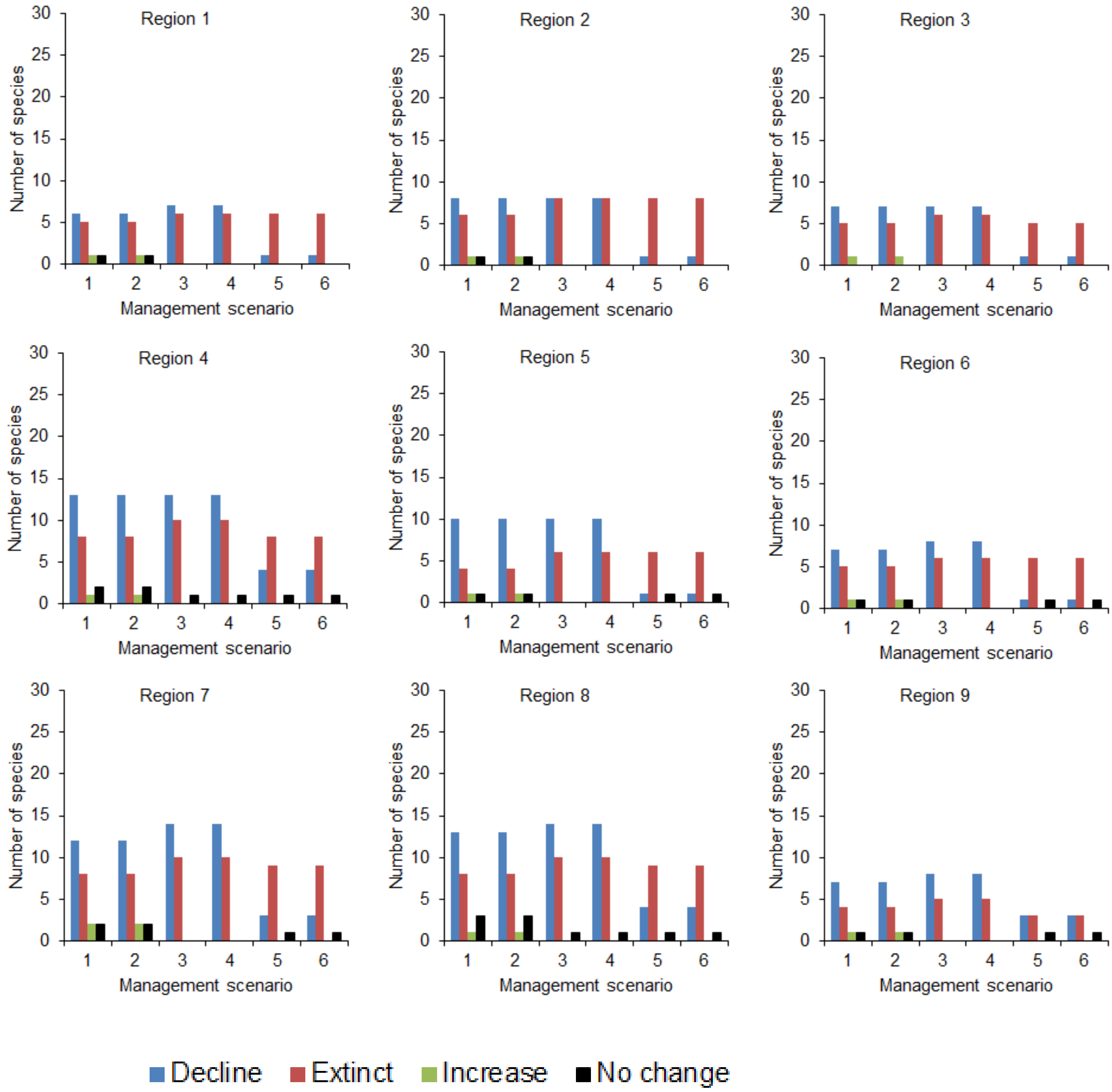

Figure 6.6 Fungi: the predicted impact of different management scenarios on obligate and highly associated ash species after 50-100 years in 9 regions in the UK. See Chapter 5 for regions and management scenarios

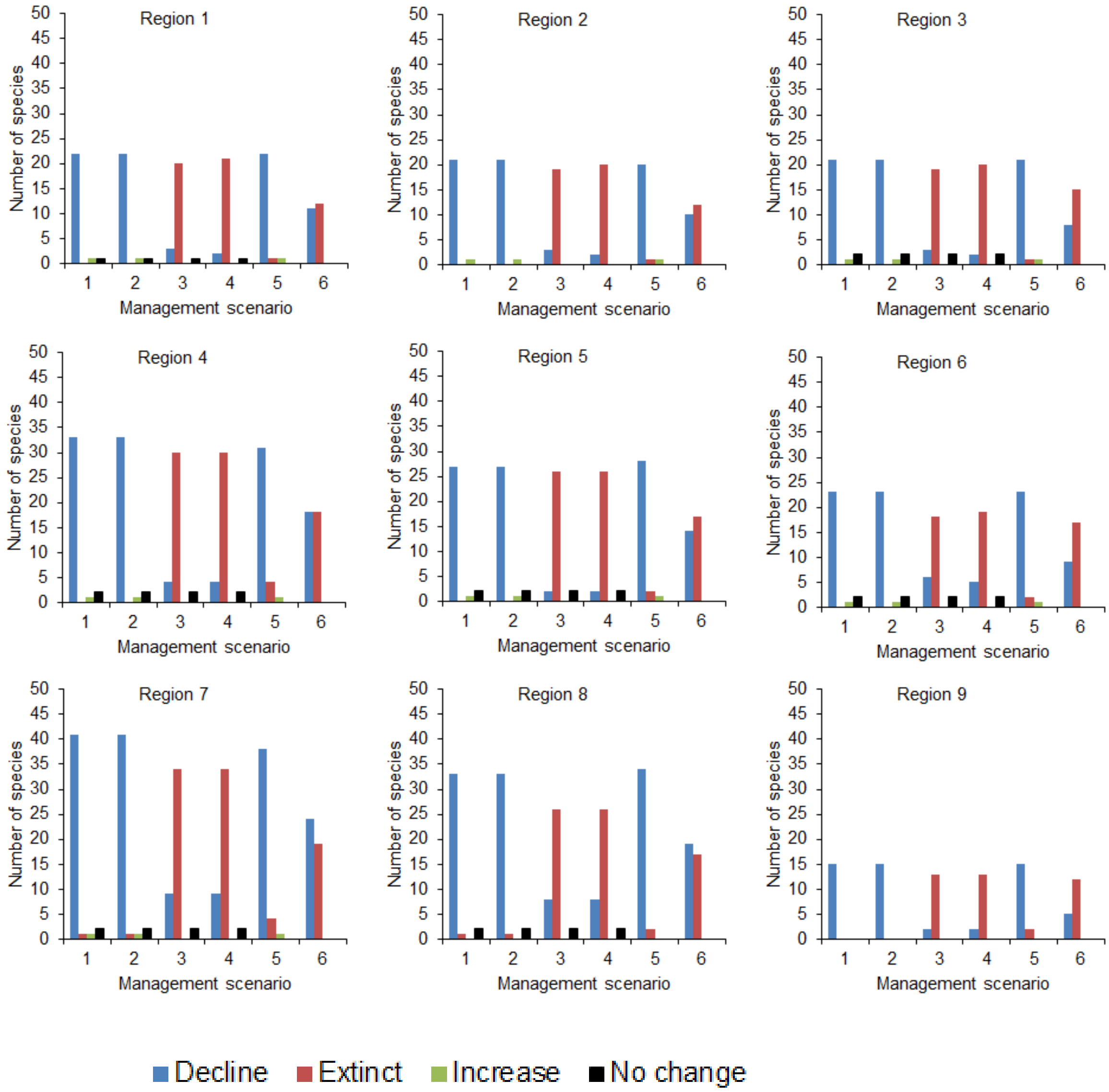

Figure 6.7 Invertebrates: the predicted impact of different management scenarios on obligate and highly associated ash species after 1-10 years in 9 regions in the UK. See Chapter 5 for regions and management scenarios

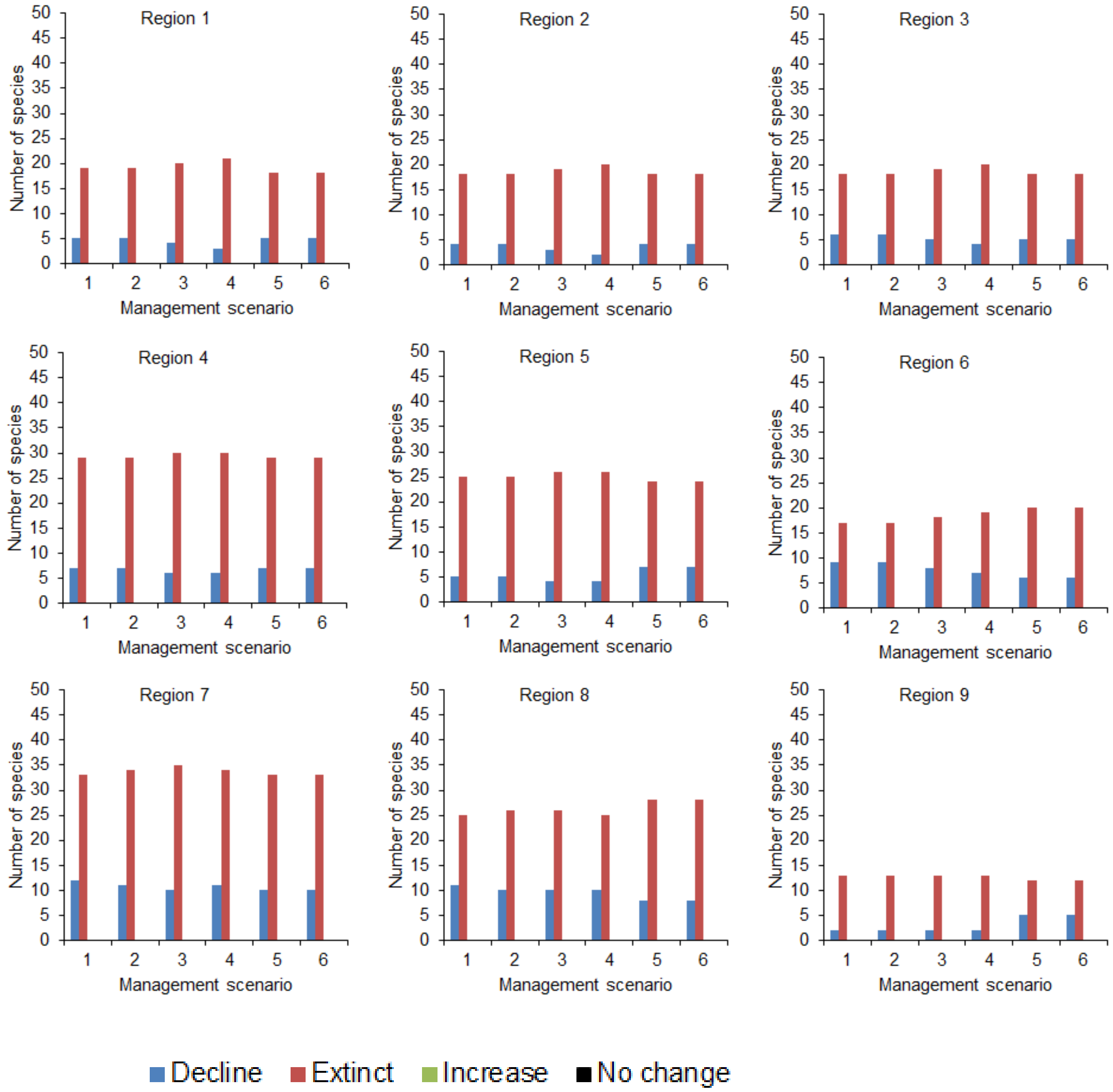

Figure 6.8 Invertebrates: the predicted impact of different management scenarios on obligate and highly associated ash species after 50-100 years in 9 regions in the UK. See Chapter 5 for regions and management scenarios

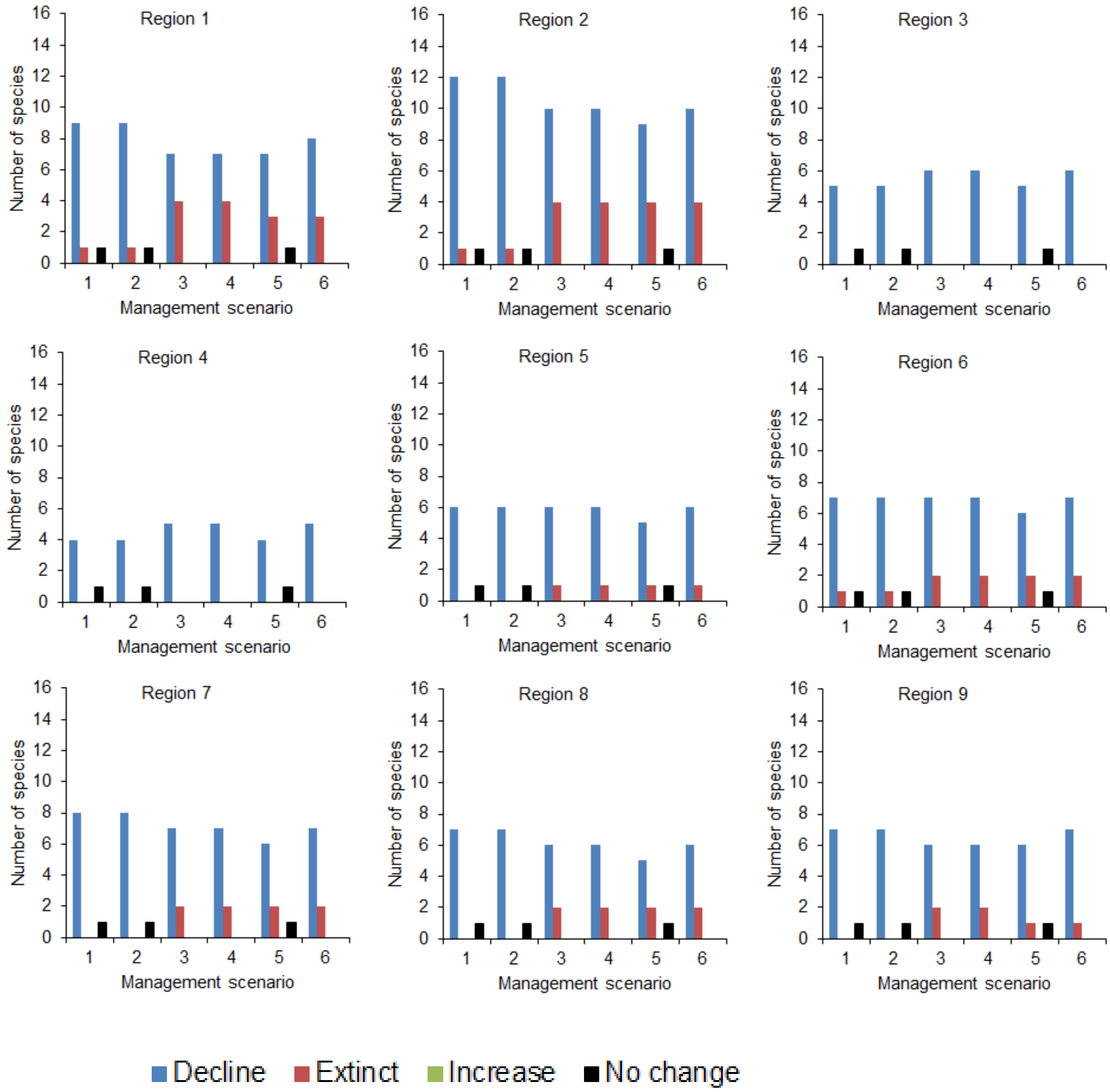

Figure 6.9 Lichens: the predicted impact of different management scenarios on obligate and highly associated ash species after 1-10 years in 9 regions in the UK. See Chapter 5 for regions and management scenarios

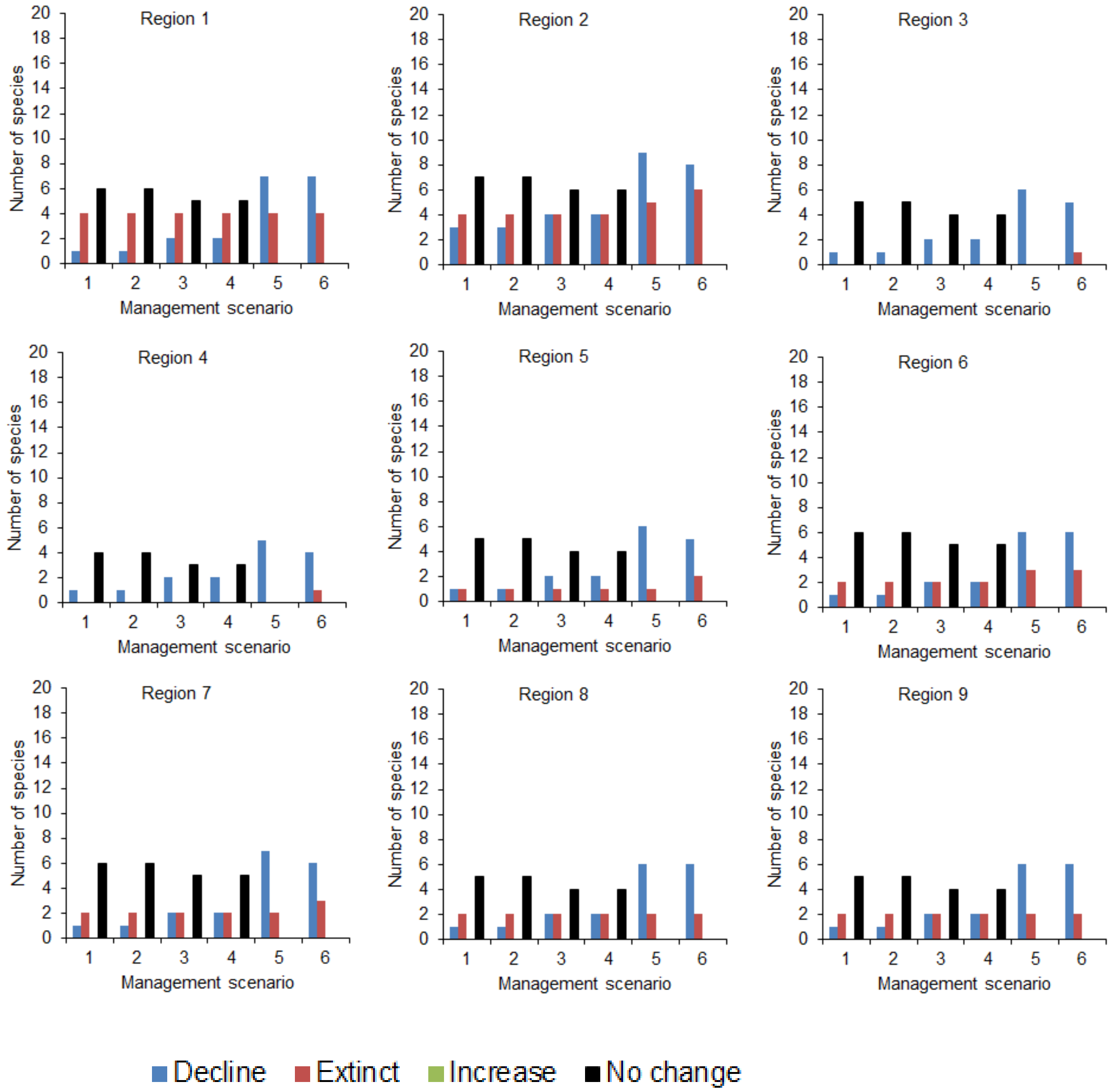

Figure 6.10 Lichens: the predicted impact of different management scenarios on obligate and highly associated ash species after 50-100 years in 9 regions in the UK. See Chapter 5 for regions and management scenarios

7 Management scenarios for woodlands with greater than 20% ash canopy

Chapter summary

1. *Previous 'pen pictures' developed descriptions of woodland vegetation composition for the ash canopy cover (<20% or >20%) most likely to be found in each region. Here (pen pictures) for all management scenarios for woodlands with more than 20% ash canopy, for two time periods for 9 ash-relevant regions are developed.*
2. *For management scenario (4) (felling and replanting) site type (climate, soil type, NVC), susceptibility to other tree diseases and risk of creating grey squirrel pest problems (large seeded trees) were used to first filter which non-native tree species might be suitable to plant in each region. Secondly the number of ash-associated species supported was used to refine the list further.*
3. *The management scenarios presented here are explorations of examples of what might be done to manage for ash dieback and are not necessary the management that should be carried out.*

7.1 Introduction

In the Phase 1 report the National Forestry Inventory was used to assess the ash resource within woods. This clearly showed that ash woodlands maybe split into two groups, those with less than 20% ash in their canopy and those with more than 20% ash in their canopy. In the Phase 1 report the 'pen pictures' (descriptions of the vegetation resulting from the management scenarios) for each region (Figure 5.1) were developed for the canopy class most often found in that region. Thus regions 6, 7, and 8 (lowland Wales, clay Southern England and calcareous southern England) had management scenarios developed for a canopy cover of ash of greater than 20% and the other regions for a canopy cover of ash of less than 20%.

In this Chapter management scenarios for woods with greater than 20% canopy cover were developed for all regions.

The management scenarios may be summarized as:

(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 more viable. 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 more viable. 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 more viable. Then active management initially to achieve natural regeneration in the stand (e.g. fencing and vegetation management), with subsequent management to develop overstorey species.

7.2 Methodology for developing 'pen pictures'

The methodology used was the same as that detailed in Section 5.2 but with an additional step for Scenario (4): felling and replanting. For Management scenario (4)**,** the potential of each of the 48 alternative tree species was considered as recommended planting choices within each sub-region. This required a consideration of:

- The site type as indicated by the climate, soil type and NVC communities identified for each sub-region.
- Choices of species suitable for planting on freely draining soil types and wet soil types where this variation was judged to occur within the sub-region.

-and particularly for the non-native alternative tree species a consideration of:

- The adequacy of knowledge on the site requirements for the different species on which to base planting recommendations e.g. Caucasian wingnut has very little information.
- Other factors that might make recommending the tree species for planting difficult, e.g. a disease risk with European larch, horse chestnut and Plane x hybrid; large seeds and potential grey squirrel pest problem with green ash, and robustness and reliability to varying site conditions of black walnut compared to common walnut.

The non-native tree species shortlisted for planting in each sub-region were then reviewed in terms of their value in supporting ash-associated species. Table 7.1 lists the non-native tree species which are known to be used by ash-associated species (the 'yes' category from Chapter 3). For tree species not recommended for planting (based on the assessment above), names have been greyed-out. The number of ash-associated species by level of association (particularly the classes 'high' and 'partial') has been used to assess the tree's value as an alternative to ash. For the purposes of completing the habitat pen-pictures, threshold values of ash-associated species have been set to determine the value of alternative species for planting. Tree species where cells are shaded green have been judged to have high value, yellow - marginal value and unshaded - little value, to ash-associated species.

Only three non-native alternative species (sycamore, sweet chestnut and black walnut) have therefore been considered as recommendations for planting from this analysis.

Table 7.1 The number of ash-associated species that are known to use the alternative trees

Alternative tree species[1]	Level of association with ash[2] Obligate	High	Partial	Cosmopolitan	Uses
Silver fir		1	26	38	9
Norway maple		4	26	15	15
Sycamore		17	228	202	26
Horse chestnut		9	116	60	23
Italian alder				2	4
Shagbark hickory					1
Sweet chestnut		5	61	72	10
American ash	2	1	5	2	2
Manchurian ash		1	3		2
Manna ash	5	6	5	3	10
Green ash	2	2	5	1	2
Black walnut		3	78	43	2
Common walnut		7	85	50	7
European larch			50	106	10
Hop-hornbeam			5	3	2
Plane hybrid		2	60	34	
Douglas fir			3	4	1
Caucasian wingnut				1	
Turkey oak		3	29	21	17
Red oak		1	13	4	10
Western red cedar			13	1	3

[1]Tree species not recommended for planting based on site requirements and disease risk are in grey.
[2]Cells are shaded green have been judged to have high value, yellow - marginal value and unshaded - little value, to ash-associated species.

7.3 Descriptions of ash-woodland vegetation in woodlands with greater than 20% ash canopy under all management scenarios

Table 7.2 Lowland Scotland (sub-region 1)

<table>
<tr><td>Current ash dominance</td><td colspan="3">Woodlands where main canopy has >40% ash.</td></tr>
<tr><td>Typical species</td><td>Typical canopy tree species:
sycamore, wych elm, goat willow, bird cherry, downy birch, alder, sessile oak</td><td>Typical shrub species:
hazel, grey willow, hawthorn blackthorn</td><td>Field layer of composed of species typical of NVC community:
W8</td></tr>
<tr><td>Management Scenario</td><td>After 1–10 years</td><td colspan="2">After 50–100 years</td></tr>
<tr><td>1</td><td>Ash trees die back – some live mature and veteran ash trees remain.
Standing deadwood (mainly ash) will start to become a dominant feature.
In the canopy, sycamore and other typical canopy species show canopy growth.
Understorey sycamore, alder, wych elm and bird cherry show rapid growth but ash saplings dying back.
Rapid growth of hazel and grey willow and other typical shrubs.
Seedlings of all typical species present but only alder and sycamore establish.
Field layer of partially shade-tolerant species (e.g. tufted hair-grass, stinging nettle, false brome and red campion) become abundant.</td><td colspan="2">No ash trees, saplings or coppice (living or dead).
No living ash trees.
Significant quantities of deadwood (mainly ash) – most on ground.
Large gaps in canopy.
Canopy composed mainly of sycamore, alder, oak with a few other typical species.
Canopy of simple structure with no understorey.
Good shrub cover composed of typical species e.g. hazel and grey willow.
Seedlings of all typical species present but only alder and sycamore establish.
Field layer a mosaic of sparse vegetation under canopy e.g. dog's mercury and wild garlic and denser cover of tufted hair-grass, stinging nettle and red campion in gaps.</td></tr>
<tr><td>2</td><td>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.
In the canopy, sycamore and other typical canopy species show canopy growth.
Understorey sycamore, alder, wych elm and bird cherry show rapid growth but ash saplings dying back.
Growth of hazel and grey willow and other typical shrubs is kept</td><td colspan="2">No ash trees, saplings or coppice (living or dead).
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 sycamore, birch, alder, oak and a few other typical species.
Good shrub cover composed of typical species e.g. hazel and grey willow.
Seedlings of all typical species</td></tr>
</table>

	in check and their cover is reduced. Seedlings of all typical species present but only **alder** and **sycamore** (and **birch** in gaps) establish. Field layer well developed and of typical species e.g. **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle .**	present but only **alder** and **sycamore** establish. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.
3	**No ash trees (living or dead).** In the canopy, **sycamore, birch, rowan** and other **typical** canopy species show growth. Some understorey trees e.g. **sycamore, wych elm, alder, bird cherry** and **oak** grow up to fill canopy gaps. Gaps in canopy. Rapid growth of **hazel, grey willow** and other **typical** shrubs. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **alder** may survive. Field layer contains **dog's mercury** and **wild garlic** below canopy but in gaps 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**).	**No ash trees (living or dead).** Few gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **sycamore, alder, oak** and a few other **typical** species. Limited shrub cover e.g. **hazel, grey willow** in gaps. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **alder** may survive. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.
4	**No ash trees (living or dead).** In the canopy, **sycamore, birch, bird cherry** and other **typical** canopy species show growth. Some understorey trees e.g. **sycamore, wych elm, alder, bird cherry** and **oak** grow up to fill canopy gaps. Gaps are planted with **pedunculate oak**, **common alder** or **black poplar** (wetter sites) and **bird cherry, wych elm** or **sycamore** (drier sites). Rapid growth of **hazel, grey willow** and other **typical** shrubs. Seedlings of potentially all	**No ash trees, saplings or coppice (living or dead).** A full canopy composed of the **sycamore** and **birch** but with large amounts of **pedunculate oak**, **common alder**, **black poplar** or (wet sites), and **bird cherry, wych elm,** or **sycamore** (free draining sites). Undersorey well developed and composed of a range of **typical** species. A diverse shrub layer composed of the **typical** species. Seedlings of potentially all **typical** species occur but very few establish.

	typical species occur and establishment is of species favoured by management e.g. **alder, oak, birch** is promoted. Early successional species (e.g. **primrose** and **violets**) establish, but ground disturbance leads to **stinging nettle**, **creeping thistle**, **rosebay willow herb** and **cocksfoot** establishing. These are controlled to favour a field layer of **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle.**	Sparse vegetation cover but with some species (e.g. **dog's mercury**, **wild garlic** and **wood avens.**).
5	Canopy composed of many **dying/dead but no living ash trees,** and **sycamore, birch,** and **oak,** mixed with a few other **typical** species. Some gaps in canopy. Positive growth of understorey of young **sycamore**, **wych elm**, **alder**, **oak** and **bird cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs e.g. **hazel** and **grey willow** present but **ash coppice is cut.** Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, oak,** (**birch** in gaps) thrive and grow. Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **false brome,** and **red campion)** become abundant.	Canopy composed of **sycamore** and **oak** with a few other **typical** species present. **No ash trees (living or dead).** Some large gaps in the canopy. Understorey depleted and composed of **sycamore** and **wych elm.** A mixture of the **typical** shrubs e.g. **hazel, grey willow** present. Seedlings of all the **typical** canopy tree species present in gaps. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.
6	Canopy composed **sycamore, birch, rowan** and **oak,** mixed with a few other **typical** species. **No ash trees (living or dead).** Large gaps in canopy. Understorey of young **sycamore**, **wych elm**, **alder**, **oak** and **bird cherry** show positive growth in gaps but **ash** absent. **Typical** shrubs (and **ash**) are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow.	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: - a full canopy composed of the **typical** species but with large amounts **sycamore, birch, oak** and **alder. No ash trees (living or dead).** -an understorey of a mixture of young, **sycamore**, **oak, alder** and **bird cherry** but **ash** absent**.** -a range of **typical** shrubs e.g. **hazel, grey willow** are well developed. Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore** establish.

	Early successional species (e.g. **primrose** and **violets**) establish, but ground disturbance leads to **stinging nettle**, **creeping thistle**, **rosebay willow herb** and **cocksfoot** establishing. These are controlled to favour a field layer of **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle.**	Field layer has sparse vegetation cover but with some species (e.g. **dog's mercury**, **wild garlic** and **wood avens.**).

Table 7.3 Upland Scotland (sub-region 2)

<table>
<tr><td>Current ash dominance</td><td colspan="3">Woodlands where main canopy has >40 % ash</td></tr>
<tr><td>Typical species</td><td>Typical canopy tree species:
wych elm, sycamore, downy birch, sessile oak, rowan, goat willow, bird cherry and alder.</td><td>Typical shrub species:
hazel, grey willow, eared willow.</td><td>Field layer of composed of species typical of NVC community:
W9</td></tr>
<tr><td>Management Scenario</td><td>After 1–10 years</td><td colspan="2">After 50–100 years</td></tr>
<tr><td>1</td><td>**Ash trees die back – some live mature and veteran ash trees remain.**
Standing deadwood (mainly **ash**) will start to become a dominant feature.
In the canopy, **birch** and other **typical** canopy species show canopy growth.
Understorey **oak**, **sycamore, alder, wych elm** and **bird cherry** show rapid growth but **ash saplings dying back.**
Rapid growth of **hazel** and **grey willow** and other **typical** shrubs.
Seedlings of all typical species present but only **alder** and **sycamore** establish.
Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **false brome, red campion, yellow pimpernel** and **male fern)** become abundant.</td><td colspan="2">**No ash trees, saplings or coppice (living or dead).**
Significant quantities of deadwood (**mainly ash**) – most on ground.
Large gaps in canopy.
Canopy composed mainly of **sycamore**, **alder**, **oak** and **bird cherry** with a few other **typical** species.
Canopy of simple structure with no understorey.
Good shrub cover composed of **typical** species e.g. **hazel** and **grey willow**.
Seedlings of all **typical** species present but only **alder** and **sycamore** establish.
Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **tufted hair-grass**, **stinging nettle**, **male fern** and **meadowsweet** in gaps.</td></tr>
<tr><td>2</td><td>**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.
In the canopy, **birch** and other **typical** canopy species show canopy growth.
Understorey **oak**, **sycamore, alder, wych elm** and **bird cherry** show rapid growth but **ash saplings dying back.**
Growth of **hazel** and **grey willow** and other **typical** shrubs is kept in check and their cover is reduced.
Seedlings of all typical species present but only **alder** and</td><td colspan="2">**No ash trees, saplings or coppice (living or dead).**
Significant quantities of deadwood (mainly **ash**) – most on ground.
Large gaps in canopy.
Canopy composed mainly of **alder, sycamore**, **oak** and **bird cherry** with a few other **typical** species.
Canopy of simple structure with no understorey.
Good shrub cover composed of **typical** species e.g. **hazel.**
Seedlings of all **typical** species present but only **alder** and **sycamore** establish.
Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **tufted hair-grass**, **stinging**</td></tr>
</table>

	sycamore (and **birch** in gaps) establish. Field layer well developed and of typical species e.g. **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle, yellow pimpernel.**	**nettle**, **male fern** and **meadowsweet** in gaps.
3	**No ash trees (living or dead).** In the canopy, **sycamore, birch, oak** and other **typical** canopy species show growth. Some understorey trees e.g. **sycamore, wych elm, alder, bird cherry** and **oak** grow up to fill canopy gaps. Gaps in canopy. Rapid growth of **hazel, grey willow** and other **typical** shrubs. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **alder** may survive. Field layer contains **dog's mercury, bluebell** and **wood sorrel** below canopy but in gaps early successional species (e.g. **primrose** and **violets**) establish but are replaced by vigorous competitive species **tufted hair-grass**, **false oat grass**, **Yorkshire fog** and **cocksfoot**.	**No ash trees, saplings or coppice (living or dead).** Few gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **sycamore, alder, oak, wych elm** and a few other **typical** species. Limited shrub cover e.g. **hazel,** in gaps. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **alder** may survive. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **tufted hair-grass**, **stinging nettle**, **male fern** and **meadowsweet** in gaps.
4	**No ash trees (living or dead).** In the canopy, **sycamore, birch, oak** and other **typical** canopy species show growth. Some understorey trees e.g. **sycamore, wych elm, alder, bird cherry** and **oak** grow up to fill canopy gaps. Gaps in canopy. Rapid growth of **hazel, grey willow** and other **typical** shrubs. Gaps are planted with **common alder** or **downy birch** (wetter sites) and **aspen**, **wych elm** or **sycamore** (drier sites). Seedlings of potentially all **typical** species occur and establishment is of species favoured by management e.g. **alder, oak, birch**. Early successional species (e.g. **primrose** and **violets**) establish,	**No ash trees, saplings or coppice (living or dead).** A full canopy composed of the **sycamore, alder,** and **oak** but with large amounts of **common alder** or **downy birch** (wet sites), **aspen, wych elm** or **sycamore** (free draining sites). Understorey well developed and composed of a range of **typical** species. A diverse shrub layer composed of the **typical** species. Seedlings of potentially all **typical** species occur but very few establish. Sparse vegetation cover but with some species (e.g. **dog's mercury**, **wood sorrel, bluebell, wood avens, false brome** and **stinging nettle**).

	but ground disturbance leads to **tufted hair-grass**, **false oat-grass, creeping soft-grass, common bent, cocksfoot** and **bramble** establishing. These are controlled to favour a field layer of **dog's mercury**, **bluebell**, **wood avens, herb robert** and **sanicle.**	
5	Canopy composed of some **dying/dead but no living ash trees,** and **sycamore, birch,** and **oak,** mixed with a few other **typical** species. Some gaps in canopy. Positive growth of understorey of young **sycamore**, **wych elm**, **alder**, **oak** and **bird cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs e.g. **hazel** and **grey willow** present but **ash coppice is cut.** Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, oak** (**birch** in gaps) thrive and grow. Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **false brome, red campion, yellow pimpernel** and **male fern)** become abundant.	Canopy composed of **sycamore** with a few other **typical** species present. **No ash trees, saplings or coppice (living or dead).** Some large gaps in the canopy. Understorey depleted and composed of **sycamore, wild cherry** and **wych elm.** A mixture of the **typical** shrubs e.g. **hazel** and **grey willow** present. Seedlings of all the **typical** canopy tree species present in gaps. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **tufted hair-grass**, **stinging nettle**, **male fern** and **meadowsweet** in gaps.
6	Canopy composed of **sycamore, birch,** and **oak,** mixed with a few other **typical** species. **No ash trees (living or dead).** Large gaps in canopy. Positive growth of understorey of young **sycamore**, **wych elm**, **alder**, **oak** and **bird cherry** in gaps. **Typical** shrubs are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow. Early successional species (e.g. **primrose** and **violets**) establish, but ground disturbance leads to **tufted hair-grass**, **false oat-grass, creeping soft-grass, common bent, cocksfoot** and	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: -a full canopy composed of **sycamore, alder** and **sessile oak,** mixed with a few other **typical** species. -an understorey of a mixture of young, **sycamore**, **sessile oak, alder** and **bird cherry**. A mixture of the **typical** shrubs e.g. **hazel** and **grey willow** present. Seedlings of the canopy tree species occur occasionally but few e.g. **alder** establish. Sparse vegetation cover but with some species (e.g. **dog's mercury**, **wood sorrel, bluebell, wood avens, false brome** and **stinging nettle**).

	bramble establishing. These are controlled to favour a field layer of **dog's mercury**, **bluebell**, **wood avens, herb robert, sanicle.**	

Table 7.4 Upland North England (sub-region 3)

Current ash dominance	Woodlands where main canopy has >40% ash.		
Typical species	Typical canopy tree species: **sycamore, downy birch, silver birch, sessile oak, pedunculate oak, holly, rowan, goat willow, bird cherry and alder.**	Typical shrub species: **blackthorn, elder, grey willow, hawthorn , hazel.**	Field layer of composed of species typical of NVC community: **W9, W8**
Management 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**) will start to become a dominant feature. In the canopy, **birch**, **sycamore** and **oak** other **typical** canopy species show canopy growth. Understorey **sycamore, sessile oak** and **alder,** and show rapid growth but **ash saplings dying back.** Rapid growth of **hazel** and **grey willow** and other **typical** shrubs. Seedlings of all typical species present but only **alder** and **sycamore** establish. Field layer of partially shade-tolerant species (e.g. **bluebell, lady fern, wood avens, yellow pimpernel** and **wood sorrel)** become abundant.	**No ash trees, saplings or coppice (living or dead).** Significant quantities of deadwood (**mainly ash**) – most on ground. Large gaps in canopy. Canopy composed mainly of **alder**, **sycamore, oak, holly** and **bird cherry** with a few other **typical** species. Canopy of simple structure with no understorey. Good shrub cover composed of **typical** species e.g. **hazel** and **grey willow**. Seedlings of all **typical** species present but only **sycamore** and **alder** establish. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **cock's- foot**, **tufted hair-grass**, **male fern** and **meadowsweet** in gaps.	
2	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (**mainly ash**) will start to become a dominant feature. In the canopy, **birch**, **sycamore** and **oak** other **typical** canopy species show canopy growth. Understorey **sycamore, sessile oak** and **alder,** and show rapid growth but **ash saplings dying back.** Rapid growth of **hazel** and **grey willow** and other **typical** shrubs is kept in check and their cover is reduced. Seedlings of all typical species	**No ash trees, saplings or coppice (living or dead).** Significant quantities of deadwood (**mainly ash**) – most on ground. Large gaps in canopy. Canopy composed mainly of **alder, birch, sycamore**, **oak, holly** and **bird cherry** with a few other **typical** species. Canopy of simple structure with no understorey. Good shrub cover composed of **typical** species e.g. **hazel** and **grey willow**. Seedlings of all **typical** species present but only **sycamore** and **alder** establish. Field layer a mosaic of sparse	

	present but only **alder** and **sycamore** establish but **oak, birch**, **holly** may establish in gaps. Field layer shows an increase in **dog's mercury, bluebell, wood sorrel** and **lady fern.**	vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **cock's- foot**, **tufted hair-grass**, **male fern** and **meadowsweet** in gaps.
3	**No ash trees (living or dead).** In the canopy, **sycamore, birch, oak** and other **typical** canopy species show growth. Some understorey trees e.g. **sycamore, oak, alder** and **holly** grow up to fill canopy gaps. Rapid growth of **hazel** and **grey willow** and other **typical** shrubs. Seedlings of all typical species present but only **alder** and **sycamore** establish. Field layer contains **dog's mercury, bluebell** and **wood sorrel** below canopy but in gaps early successional species (e.g. **primrose** and **violets**) establish but are replaced by vigorous competitive species **tufted hair-grass**, **false oat grass**, **Yorkshire fog**, and **cocksfoot**).	**No ash trees, saplings or coppice (living or dead).** Few gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **sycamore, alder, oak, holly** and a few other **typical** species. Limited shrub cover e.g. **grey willow,** in gaps. Seedlings of all **typical** species present but only **alder** and **sycamore** establish. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **cock's- foot**, **tufted hair-grass**, **male fern** and **meadowsweet** in gaps.
4	**No ash trees (living or dead).** In the canopy, **sycamore, birch, oak** and other **typical** canopy species show growth. Some understorey trees e.g. **sycamore, oak, alder** and **holly** grow up to fill canopy gaps. Rapid growth of **hazel** and **grey willow** and other **typical** shrubs. Gaps are planted with **common alder** or **downy birch** (wetter sites) and **aspen** or **sycamore** (drier sites). Seedlings of all typical species present but only **oak, birch** and **sycamore** establish. Field layer contains **dog's mercury, bluebell** and **wood sorrel** and **lady fern,** and some early successional species (e.g. **primrose** and **violets**).	**No ash trees, saplings or coppice (living or dead).** A full canopy composed of the **sycamore, alder,** and **oak** but with large amounts of **common alder** or **downy birch** (wet sites), **aspen** or **sycamore** (free draining sites). Understorey well developed and composed of a range of **typical** species. A diverse shrub layer composed of the **typical** species. Seedlings of potentially all **typical** species occur but very few establish. Sparse vegetation cover but with some species (e.g. **dog's mercury**, **wood sorrel, bluebell, wood avens** and **lady fern**).
5	Canopy composed of many **dying/dead but no living ash trees,** and **sycamore, birch,** and **oak,** mixed with a few other **typical** species.	Canopy composed of **sycamore** with a few other **typical** species e.g. **alder** present. **No ash trees, saplings or coppice (living or dead).**

	Some gaps in canopy. Positive growth of understorey of young **sycamore**, **alder** and **bird cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs e.g. **hazel** and **grey willow** present but **ash coppice is cut.** Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore** (**birch** in gaps) thrive and grow. Field layer shows an increase in **dog's mercury, bluebell, wood sorrel** and **lady fern.**	Some large gaps in the canopy. Understorey depleted and composed mainly of **sycamore.** A mixture of the **typical** shrubs e.g. **hazel** and **grey willow** present. Seedlings of all the **typical** canopy tree species present in gaps. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **cock's- foot**, **tufted hair-grass**, **male fern** and **meadowsweet** in gaps.
6	Canopy composed of **sycamore, birch,** and **oak,** mixed with a few other **typical** species. **No ash trees (living or dead).** Some large gaps in canopy. Positive growth of understorey of young **sycamore**, **alder** and **bird cherry** **Typical** shrubs (and **ash**) are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow. Field layer contains **dog's mercury, bluebell** and **wood sorrel** and **lady fern,** and some early successional species (e.g. **primrose** and **violets**).	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: -a full canopy composed of **sycamore, alder, birch** and **oak,** mixed with a few other **typical** species. -an understorey of a mixture of young, **sycamore**, **oak, alder, bird cherry** and **holly**. A mixture of the **typical** shrubs e.g. **hazel** and **grey willow** present. Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore** establish. Sparse vegetation cover but with some species (e.g. **dog's mercury**, **wood sorrel, bluebell, wood avens** and **lady fern**).

Table 7.5 Lowland North England (sub-region 4)

Current ash dominance	Woodlands where main canopy has >60% ash		
Typical species	Typical canopy tree species: **sycamore, yew, beech, sessile oak, pedunculate oak, holly, crab apple, field maple, downy birch, silver birch, rowan, goat willow, bird cherry and alder.**	Typical shrub species: **blackthorn, dogwood, elder, grey willow, guelder rose, hawthorn, hazel**.	Field layer of composed of species typical of NVC community: **W8**
Management 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**) will start to become a dominant feature. In the canopy, **beech, birch**, **sycamore** and **oak** and other **typical** canopy species show canopy growth. Understorey **sycamore, beech, alder, field maple** and **oak**, show rapid growth but **ash saplings dying back.** Rapid growth of **hazel** and other **typical** shrubs. Seedlings of all typical species present but only **beech, yew** and **sycamore** establish. Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **false brome** and **red campion)** become abundant.	**No ash trees, saplings or coppice (living or dead).** Significant quantities of deadwood (**mainly ash**) – most on ground. Large gaps in canopy. Canopy composed mainly of **sycamore, beech, sessile oak, alder, yew** and **field maple** with a few other **typical** species. Canopy of simple structure with no understorey. Good shrub cover composed of **typical** species e.g. **hazel**. Seedlings of all **typical** species present but only **sycamore** and **beech** establish. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.	
2	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (**mainly ash**) will start to become a dominant feature. In the canopy, **beech, birch**, **sycamore** and **oak** other **typical** canopy species show canopy growth. Understorey **sycamore, beech, alder, field maple** and **oak** show rapid growth but **ash saplings dying back.** Rapid growth of **hazel** and other **typical** shrubs is kept in check	**No ash trees, saplings or coppice (living or dead).** Significant quantities of deadwood (**mainly ash**) – most on ground. Large gaps in canopy. Canopy composed mainly of **sycamore, beech, sessile oak, alder, yew** and **field maple** with a few other **typical** species. Canopy of simple structure with no understorey. Good shrub cover composed of **typical** species e.g. **hazel**. Seedlings of all **typical** species present but only **sycamore** and **beech** establish.	

	and their cover is reduced. Seedlings of all typical species present but only **beech, yew** and **sycamore** establish (**birch** and **oak** may establish in gaps). Field layer well developed and of typical species e.g. **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle.**	Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.
3	**No ash trees (living or dead).** In the canopy, **sycamore, birch, beech, oak, alder, field maple** and other **typical** canopy species show growth. Some understorey trees e.g. **beech, sycamore, alder, field maple** and **oak** grow-up to fill canopy gaps. Rapid growth of **hazel** and other **typical** shrubs. Seedlings of all typical species present but only **beech, birch, alder** and **sycamore** establish. Field layer contains **dog's mercury** and **wild garlic** below canopy but in gaps, 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**).	**No ash trees, saplings or coppice (living or dead).** Few gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **sycamore, beech, alder, oak, field maple** and a few other **typical** species. Limited shrub cover e.g. **hazel,** in gaps. Seedlings of all **typical** species present but only **beech, birch, alder** and **sycamore** establish. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.
4	**No ash trees (living or dead).** In the canopy, **sycamore, birch, beech oak, alder, field maple** and other **typical** canopy species show growth. Some understorey trees e.g. **beech, sycamore, alder, field maple** and **oak** grow-up to fill canopy gaps. Rapid growth of **hazel** and other **typical** shrubs. Gaps are planted with **bird cherry** or **downy birch** (wetter sites) and **wild cherry**, **crab apple, sycamore** or **sweet chestnut** (drier sites). Seedlings of all typical species present but only **oak, beech, birch** and **sycamore** establish.	**No ash trees, saplings or coppice (living or dead).** A full canopy composed of the **sycamore** and large amounts of **bird cherry** or **downy birch** (wet sites), **wild cherry, crab apple, sycamore** or **sweet chestnut** (free draining sites). Understorey well developed and composed of a range of **typical** species. A diverse shrub layer composed of the **typical** species. Seedlings of potentially all **typical** species occur but very few establish. Sparse vegetation cover but with some species (e.g. **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle.**).

	Early successional species (e.g. **primrose** and **violets**) establish, but ground disturbance leads to **tufted hair-grass, false oat-grass, creeping bent, cocksfoot, creeping thistle**, and **bramble** establishing. These are controlled to favour a field layer of **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle.**	
5	Canopy composed of some **dying/dead but no living ash trees,** and **sycamore, beech, birch,** and **oak,** mixed with a few other **typical** species. Some gaps in canopy. Positive growth of understorey of young **sycamore**, **beech, holly** and **bird cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs e.g. **hazel** present but **ash coppice is cut.** Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore** and **beech** (**birch** in gaps) thrive and grow. Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **false brome** and **red campion)** become abundant.	Canopy composed of **sycamore** and **beech** with a few other **typical** species present. **No ash trees, saplings or coppice (living or dead).** Some large gaps in the canopy. Understorey depleted and composed mainly of **sycamore** and **beech.** A mixture of the **typical** shrubs e.g. **hazel** present. Seedlings of all the **typical** canopy tree species present in gaps. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.
6	Canopy composed of **sycamore, beech, field maple,** and **oak,** mixed with a few other **typical** species. **No ash trees (living or dead).** Some large gaps in canopy. Positive growth of understorey of young **sycamore**, **beech, holly** and **bird cherry. Typical** shrubs are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow. Early successional species (e.g. **primrose** and **violets**) establish, but ground disturbance leads to **tufted hair-grass, false oat-grass, creeping bent,**	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: -a full canopy composed of **sycamore, beech, field maple** and **oak,** mixed with a few other **typical** species. -an understorey of a mixture of young **beech, sycamore**, **yew, field maple** and **holly**. A mixture of the **typical** shrubs present. Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore** and **beech** establish. Sparse vegetation cover but with some species (e.g. **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle**).

	cocksfoot, creeping thistle, and **bramble** establishing. These are controlled to favour a field layer of **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle.**	

Table 7.6 Upland Wales (sub-region 5)

<table>
<tr><td>Current ash dominance</td><td colspan="3">Woodlands where main canopy has >40% ash</td></tr>
<tr><td>Typical species</td><td>Typical canopy tree species:
sycamore, poplars, sessile oak, pedunculate oak, holly, downy birch, silver birch, rowan, goat willow, bird cherry and alder.</td><td>Typical shrub species:
blackthorn, elder, grey willow, guelder rose, hawthorn, hazel.</td><td>Field layer of composed of species typical of NVC community:
W8, W9</td></tr>
<tr><td>Management Scenario</td><td colspan="2">After 1–10 years</td><td>After 50–100 years</td></tr>
<tr><td>1</td><td colspan="2">**Ash trees die back – some live mature and veteran ash trees remain.**
Standing deadwood (mainly **ash**) will start to become a dominant feature.
In the canopy, **birch, sycamore** and other **typical** canopy species show canopy growth.
Understorey **sycamore, alder, oak** and **bird cherry** show rapid growth but **ash saplings dying back.**
Rapid growth of **hazel** and other **typical** shrubs.
Seedlings of all typical species present but only **alder** and **sycamore** establish.
Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **false brome** and **red campion)** become abundant.</td><td>**No ash trees, saplings or coppice (living or dead).**
No living ash trees.
Significant quantities of deadwood (mainly ash) – most on ground.
Large gaps in canopy.
Canopy composed mainly of **sycamore**, **alder**, **oak** with a few other **typical** species.
Canopy of simple structure with no understorey.
Good shrub cover composed of **typical** species.
Seedlings of all **typical** species present but only **alder** and **sycamore** and possibly **beech** establish.
Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.</td></tr>
<tr><td>2</td><td colspan="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.
In the canopy, **birch, sycamore** and other **typical** canopy species show canopy growth.
Understorey **sycamore, alder, oak** and **bird cherry** show rapid growth but **ash saplings dying back.**
Growth of **hazel** and other **typical** shrubs is kept in check and their cover is reduced.
Seedlings of all typical species present but only **alder** and</td><td>**No ash trees, saplings or coppice (living or dead).**
No living ash trees.
Significant quantities of deadwood (mainly ash) – most on ground.
Large gaps in canopy.
Canopy composed mainly of **sycamore**, **alder**, **oak** with a few other **typical** species.
Canopy of simple structure with no understorey.
Good shrub cover composed of **typical** species.
Seedlings of all **typical** species present but only **alder** and **sycamore** and possibly **beech** establish.
Field layer a mosaic of sparse</td></tr>
</table>

	sycamore (and **birch** in gaps) establish. Field layer well developed and of typical species e.g. **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle.**	vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.
3	**No ash trees (living or dead).** In the canopy, **sycamore, birch, oak, alder** and other **typical** canopy species show growth. Some understorey trees e.g. **sycamore, sessile oak, alder** and **holly** grow up to fill canopy gaps. Gaps in canopy. Rapid growth of **hazel** and other **typical** shrubs. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **alder** may survive. Field layer contains **dog's mercury** and **wild garlic** below canopy but in gaps 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**).	**No ash trees (living or dead).** Few gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **sycamore, alder, oak** and a few other **typical** species. Limited shrub cover of **typical** species in gaps. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **alder** may survive. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.
4	**No ash trees (living or dead).** In the canopy, **sycamore, birch, oak, alder** and other **typical** canopy species show growth. Some understorey trees e.g. **sycamore, sessile oak, alder** and **holly** grow up to fill canopy gaps. Gaps are planted with **common alder** or **pedunculate oak** (wetter sites) and **sessile oak, rowan** or **sycamore** (drier sites). Rapid growth of **hazel** and other **typical** shrubs. Seedlings of potentially all **typical** species occur and establishment is of species favoured by management e.g. **alder, oak, birch** are promoted. Early successional species (e.g.	**No ash trees, saplings or coppice (living or dead).** A full canopy composed of the **sycamore** and possibly **beech** but with large amounts of **pedunculate oak** or **common alder** (wet sites), and **sycamore**, **sessile oak** or **rowan** (free draining sites). An Undersorey well developed and composed of a range of **typical** species. Diverse shrub layer composed of the **typical** species. Seedlings of potentially all **typical** species occur but very few establish. Sparse vegetation cover but with some species (e.g. **dog's mercury**, **wild garlic** and **wood avens**).

	primrose and **violets**) establish, but ground disturbance leads to **tufted hair-grass, false oat-grass, creeping bent, cocksfoot, creeping soft-grass**, and **bramble** establishing. These are controlled to favour a field layer of **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle.**	
5	Canopy composed of some **dying/dead but no living ash trees,** and **sycamore, birch, alder, poplar** and **oak,** mixed with a few other **typical** species. Some gaps in canopy. Positive growth of understorey of young **sycamore**, **alder**, **sessile oak** and **bird cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs including **hazel** present but **ash coppice is cut.** Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore** (**birch** in gaps) thrive and grow. Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **false brome** and **red campion)** become abundant.	Canopy composed of **sycamore** and possibly some **beech** and **hornbeam** with a few other **typical** species present. **No ash trees (living or dead).** Some large gaps in the canopy. Understorey depleted and composed of mainly **sycamore** and possibly some **beech.** A mixture of the **typical** shrubs including **hazel** present Seedlings of the **typical** canopy tree species occur occasionally in gaps. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **wild garlic** and denser cover of **tufted hair-grass**, **stinging nettle** and **red campion** in gaps.
6	Canopy composed of **sycamore, birch, alder, poplar** and **oak,** mixed with a few other **typical** species. **No ash trees (living or dead).** Large gaps in canopy. Positive growth of understorey of young **sycamore**, **alder**, **sessile oak** and **bird cherry**. **Typical** shrubs are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some e.g. **birch** and **sycamore** thrive and grow. Early successional species (e.g. **primrose** and **violets**) establish, but ground disturbance leads to **tufted hair-grass, false oat-grass, creeping bent,**	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: - a full canopy composed of the **typical** species but with large amounts **sycamore, sessile oak** and **alder,** with possibly some **beech.** -an understorey of a mixture of young **sycamore**, **sessile oak, alder, holly** and **bird cherry**. -a mixture of the **typical** shrubs including **hazel** present Seedlings of the **typical** canopy tree species occur occasionally but only a few e.g. **sycamore** are likely to establish. Sparse vegetation cover but with some species (e.g. **dog's mercury**, **wild garlic** and **wood avens**).

	cocksfoot, creeping soft-grass, and **bramble** establishing. These are controlled to favour a field layer of **dog's mercury**, **wild garlic**, **wood avens, false brome, stinging nettle.**	

Table 7.7 Lowland Wales (sub-region 6)

<table>
<tr><td>Current ash dominance</td><td colspan="4">Woodlands where main canopy has >60% ash.</td></tr>
<tr><td>Typical species</td><td colspan="2">Typical canopy tree species:
beech, birch, goat willow, holly, oak, rowan, field maple, wild cherry, yew, poplars, crab apple and sycamore.</td><td colspan="1">Typical shrub species:
hawthorn, hazel, blackthorn, elder, guelder rose, privet and grey willow.</td><td>Field layer of composed of species typical of NVC community:
W8, W9a.</td></tr>
<tr><td>Management Scenario</td><td colspan="2">After 1–10 years</td><td colspan="2">After 50–100 years</td></tr>
<tr><td>1</td><td colspan="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.
In the canopy, beech, sycamore, oak, birch and other typical canopy species show canopy growth.
Understorey sycamore, beech, yew and wild cherry show rapid growth but ash saplings dying back.
Rapid growth of hazel and other typical shrubs.
Seedlings of all typical species present but only beech and sycamore establish
Field layer of partially shade-tolerant species (e.g. tufted hair-grass, stinging nettle, creeping thistle, bramble and rough meadow-grass) become abundant.</td><td colspan="2">No ash trees, saplings or coppice (living or dead).
No living ash trees.
Significant quantities of deadwood (mainly ash) – most on ground.
Large gaps in canopy.
Canopy composed mainly of beech, sycamore, oak, wild cherry with a few other typical species.
Canopy of simple structure with no understorey.
Good shrub cover composed of typical species e.g. blackthorn and hawthorn.
Seedlings of all typical species present but only beech and sycamore establish.
Field layer 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).</td></tr>
<tr><td>2</td><td colspan="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.
In the canopy, beech, sycamore, oak, birch and other typical canopy species show canopy growth.
Understorey sycamore, beech, yew and wild cherry show rapid growth but ash saplings dying back.
Growth of hazel and other typical shrubs is kept in check</td><td colspan="2">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 mainly of beech, sycamore, oak, wild cherry with a few other typical species.
Good shrub cover composed of typical species e.g. blackthorn and hawthorn.
Seedlings of all typical species present but only beech and sycamore establish.
Field layer a mosaic of browse-</td></tr>
</table>

	and their cover is reduced. Seedlings of all typical species present but only **beech** and **sycamore** (**birch** and **oak** in gaps) establish. Field layer dominated by **dog's mercury**, **wild garlic**, **bluebell**, **ivy** and **bramble**.	resistant vernal species (e.g. **bluebell**, **wild garlic**) and partially shade-tolerant species (e.g. **bramble**, **tufted hair-grass** and **Yorkshire fog**).
3	**No ash trees (living or dead).** In the canopy, **beech, sycamore, birch, oak** and other **typical** canopy species show growth. Some understorey trees e.g. **beech, sycamore, oak, yew, wild cherry** and **holly** grow up to fill canopy gaps. Gaps in canopy. Rapid growth of **hazel,** and other **typical** shrubs. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **goat willow** may survive. Field layer contains 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**).	**No ash trees, saplings or coppice (living or dead).** **No ash trees (living or dead).** Few gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **sycamore, beech, yew**, **oak, wild cherry** and a few other **typical** species. Limited shrub cover of **typical** species in gaps. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **beech** may survive. Field layer 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**).
4	**No ash trees (living or dead).** In the canopy, **beech, sycamore, birch, oak** and other **typical** canopy species show growth. Some understorey trees e.g. **beech, sycamore, oak, yew, wild cherry** and **holly** grow up to fill canopy gaps. Rapid growth of hazel, and other typical shrubs. Gaps are planted with **hazel, large-leaved lime, sweet chestnut** or **black walnut** (drier sites) and **pedunculate oak, common alder** or **black poplar** (wetter sites). Seedlings of potentially all **typical** species occur and establishment is of species	**No ash trees, saplings or coppice (living or dead).** **No ash trees (living or dead).** A full canopy composed of the **sycamore, beech, birch, yew, holly, wild cherry** and **field maple** but with large amounts of **pedunculate oak, common alder** or **black poplar** (wet sites), **large-leaved lime, sweet chestnut** or **black walnut** (free draining sites). Understorey well developed and composed of a range of **typical** species. A diverse shrub layer composed of the **typical** species. Seedlings of potentially all **typical** species occur but very few establish. Field layer of sparse vegetation cover but with some species (e.g.

	favoured by management e.g. **beech, oak** is promoted. Field layer of 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.	**bluebell**, **wild garlic**, **false brome** and **male fern**).
5	Canopy composed of many **dying/dead but no living ash trees,** and **beech, birch, oak, yew** and **poplar,** mixed with a few other **typical** species. Some gaps in canopy. Positive growth of understorey of young **sycamore**, **beech**, **oak** and **wild cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs e.g. **hazel** present but ash coppice is cut. Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, beech** thrive and grow. Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **creeping thistle**, **bramble** and **rough meadow-grass**) become abundant.	Canopy composed of **sycamore** and **beech** with a few other **typical** species e.g. **wild cherry** present. **No ash trees (living or dead).** Some large gaps in the canopy. Understorey depleted and composed of **yew**, **sycamore**, **beech** and **wild cherry** A mixture of the **typical** shrubs present. Seedlings of all the **typical** canopy tree species present in gaps. Field layer is 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**).
6	Canopy composed of **beech, birch, oak** and **poplar,** mixed with a few other **typical** species. **No ash trees (living or dead).** Large gaps in canopy. Understorey of young **sycamore**, **beech**, **oak** and **wild cherry** show positive growth in gaps but **ash** absent. **Typical** shrubs (and **ash**) are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow. Field layer has early successional species (e.g. **primrose** and **violets**) establish,	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: - a full canopy composed of the **typical** species but with large amounts **sycamore, beech, oak** and **birch. No ash trees (living or dead).** -an understorey of a mixture of young, **sycamore**, **beech**, **oak, field maple, wild cherry** and **holly.**. -a range of **typical** shrubs are well developed. Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore** and **beech** establish. Field layer has sparse vegetation cover but with some species (e.g. **bluebell**, **wild garlic**, **false brome**

	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.	and **male fern**).

Table 7.8 Southern England Clay (sub-region 7)

<table>
<tr><td>Current ash dominance</td><td colspan="3">Woodlands where main canopy is dominated by ash (>40%).</td></tr>
<tr><td>Typical species</td><td>Typical canopy tree species:
beech, **crab apple**, **birch**, **oak**, **sweet chestnut**, **whitebeam**, **hornbeam**, **rowan**, **goat willow**, **holly**, **field maple**, **wild cherry**, **yew**, **poplar** and **sycamore**.</td><td>Typical shrub species:
hawthorn, **hazel**, **grey willow**, **blackthorn**, **elder**, **guelder rose**, **dogwood**, **spindle** and **privet**.</td><td>Field layer of composed of species typical of NVC community: **W12a, W8.**</td></tr>
<tr><td>Management Scenario</td><td colspan="2">After 1–10 years</td><td>After 50–100 years</td></tr>
<tr><td>1</td><td colspan="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.
In the canopy, **beech, sycamore, oak, birch** and other **typical** canopy species show canopy growth.
Understorey **sycamore, beech, hornbeam** and **wild cherry** show rapid growth but **ash saplings dying back.**
Rapid growth of **hazel** and other **typical** shrubs.
Seedlings of all typical species present but only **beech** and **sycamore** establish
Partially shade-tolerant species (e.g. **bramble**, **ivy** and **false brome**) become abundant.</td><td>**No ash trees, saplings or coppice (living or dead).**
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 mainly of **beech**, **sycamore**, **oak**, **wild cherry** with a few other **typical** species.
Canopy of simple structure with no understorey.
Good shrub cover composed of **typical** species.
Seedlings of all **typical** species present but only **beech** and **sycamore** establish.
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**).</td></tr>
<tr><td>2</td><td colspan="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.
In the canopy, **beech, sycamore, oak, birch** and other **typical** canopy species show canopy growth.
Growth of **hazel** and other **typical** shrub species is kept in check and their cover is reduced.
Regeneration is sparse and only **sycamore** regeneration survives.
Ground flora dominated by **dog's mercury**, **bluebell**, **ivy**, **enchanter's**</td><td>**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 mainly of **beech**, **sycamore**, **oak**, **wild cherry** with a few other **typical** species.
Good shrub cover composed of **typical** species e.g. **hazel**.
Regeneration is likely to be sparse.
Ground flora a mosaic of browse-</td></tr>
</table>

	nightshade and **false brome**.	resistant vernal species (e.g. **bluebell**, **ivy**) and partially shade-tolerant species (e.g. **false oat-grass**, **tor-grass**, **false brome**).
3	**No ash trees (living or dead).** In the canopy, **beech, sycamore, birch, oak** and other **typical** canopy species show growth. Understorey **sycamore, beech, hornbeam** and **wild cherry** grow up to fill canopy gaps. Rapid growth of **typical** shrubs e.g. **hazel** Gaps in canopy. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **grey willow** may survive. 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**).	**No ash trees, saplings or coppice (living or dead).** **No ash trees (living or dead).** Canopy of simple structure with no understorey. Canopy composed of **sycamore, beech, hornbeam, wild cherry** and a few other **typical** species. Limited shrub cover of **typical** species in gaps. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **beech** may survive. 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**).
4	**No ash trees (living or dead).** In the canopy, **beech, sycamore, oak, birch** and other **typical** canopy species show canopy growth. Understorey **sycamore, beech, hornbeam** and **wild cherry** grow up to fill canopy gaps. Rapid growth of **hazel**, and other typical shrubs. Gaps are planted with **hornbeam, large-leaved lime, sycamore** or **black walnut** (drier sites) and **pedunculate oak** or **black poplar** (wetter sites). Seedlings of potentially all **typical** species occur and establishment is of species favoured by management e.g. **beech, oak** is promoted. 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**	**No ash trees, saplings or coppice (living or dead).** **No ash trees (living or dead).** A full canopy composed of the **beech** and other **typical** species but with more **pedunculate oak** and **black poplar** (wet sites), **hornbeam, large-leaved lime, sycamore** or **black walnut** (free draining sites). A diverse shrub layer composed of **typical** species. Seedlings of potentially all **typical** species occur but very few establish. Sparse ground flora a mosaic of browse-resistant vernal species (e.g. **bluebell**, **ivy** and **false brome**).

	fir (free draining sites).	
5	Canopy composed of many **dying/dead but no living ash trees,** and **beech, sycamore, birch, oak** and **holly**, mixed with a few other **typical** species**.** Some gaps in canopy. Positive growth of understorey of young **sycamore**, **beech**, **sweet chestnut**, **field maple** and **wild cherry** but **ash saplings dying back**. A mixture of the **typical** shrubs e.g. **hazel** present but ash coppice is cut. Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore**, **beech** thrive and grow. Field layer of partially shade-tolerant species (e.g. **bramble, ivy** and **false brome**) become abundant.	**No ash trees, saplings or coppice (living or dead).** Canopy composed of **sycamore** and **beech** with a few other **typical** species e.g. **wild cherry** present**.** Some large gaps in the canopy. Understorey depleted and composed of **hornbeam, yew, sycamore, beech** and **wild cherry.** A mixture of the typical shrubs present**.** Seedlings of all the typical canopy tree species present in gaps. Field layer 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**).
6	Canopy composed of **beech, sycamore, birch, oak** and **holly**, mixed with a few other **typical** species**.** **No ash trees (living or dead).** **Some gaps in canopy.** Positive growth of understorey of young **sycamore, beech, sweet chestnut, field maple** and **wild cherry** but **ash** absent**.** Typical shrubs **(and ash)** are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow. Field layer of 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.	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: -a full canopy composed of **sycamore, oak, beech** and **sweet chestnut** with a few other **typical** species e.g. **wild cherry** present. Some large gaps in the canopy. -an understorey well developed and a mixture of young, **sycamore, beech, field maple, wild cherry, sweet chestnut** and **holly.** -a mixture of the typical shrubs present. Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore** and **beech** establish. Field layer has sparse cover of browse-resistant vernal species (e.g. **bluebell, ivy** and **false brome**).

Table 7.9 Southern England Calcareous (sub-region 8)

Current ash dominance	Woodlands where main canopy has >60% ash.		
Typical species	Typical canopy tree species: **beech**, **crab apple**, **birch**, **oak**, **sweet chestnut**, **whitebeam**, **hornbeam**, **rowan**, **goat willow**, **holly**, **field maple**, **wild cherry**, **yew**, **poplar**, **small leaved lime** and **sycamore**.	Typical shrub species: **hawthorn**, **hazel**, **grey willow**, **blackthorn**, **elder**, **guelder rose**, **dogwood**, **spindle** and **privet**	Field layer of composed of species typical of NVC community: **W8**
Management 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. In the canopy, **beech, oak, sycamore, field maple, small leaved lime** and other **typical** canopy species show canopy growth. Understorey **sycamore, beech, yew, field maple** and **small leaved lime** show rapid growth but **ash saplings dying back.** Rapid growth of **hazel** and other **typical** shrubs. Seedlings of all typical species present but only **beech** and **sycamore** establish Field layer- partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **creeping thistle**, **bramble** and **rough meadow-grass**) become abundant.	**No ash trees, saplings or coppice (living or dead).** Significant quantities of deadwood (mainly ash) – most on ground. Large gaps in canopy. Canopy composed mainly of **beech**, **sycamore**, **oak**, **field maple**, **hornbeam, small leaved lime** with a few other **typical** species. Canopy of simple structure with no understorey. Good shrub cover composed of **typical** species e.g. **blackthorn** and **hawthorn**. Seedlings of all **typical** species present but only **beech** and **sycamore** establish. Field layer 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. In the canopy, **beech, oak, sycamore, field maple, small leaved lime** and other **typical** canopy species show canopy growth. Understorey **sycamore, beech, yew, field maple** and **small**	**No ash trees, saplings or coppice (living or dead).** Significant quantities of deadwood (mainly ash) – most on ground. Large gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed mainly of **beech**, **sycamore**, **oak**, **field maple**, **hornbeam, small leaved lime** with a few other **typical** species. Good shrub cover composed of **typical** species e.g. **blackthorn** and	

	leaved lime show rapid growth but **ash saplings dying back.** Growth of **hazel** and other **typical** shrubs is kept in check and their cover is reduced. Seedlings of all typical species present but only **beech** and **sycamore** establish. Field layer dominated by **dog's mercury**, **wild garlic**, **bluebell**, **ivy** and **bramble**.	**hawthorn**. Seedlings of all **typical** species present but only **beech** and **sycamore** establish. Field layer 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**).
3	**No ash trees (living or dead).** In the canopy, **beech, sycamore, oak** and other **typical** canopy species show growth. Some understorey trees e.g. **beech, sycamore, hornbeam, yew, field maple** and **small leaved lime** grow up to fill canopy gaps. Gaps in canopy. Rapid growth of **hazel,** and other **typical** shrubs. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **goat willow** may survive. Field layer contains early successional species (e.g. **primrose** and **violets**) which establish but are replaced by vigorous competitive species like **bramble** and grasses (e.g. **tufted hair-grass**, **false oat-grass**, **Yorkshire fog**, **cocksfoot**).	**No ash trees, saplings or coppice (living or dead).** Few gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **sycamore, beech, field maple**, **hornbeam, small leaved lime** and a few other **typical** species. Limited shrub cover of **typical** species in gaps. Seedlings of potentially all **typical** species occur but establishment is sparse even in large gaps but some **birch** and **goat willow** may survive. Field layer 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**).
4	**No ash trees (living or dead).** In the canopy, **beech, sycamore, oak** and other **typical** canopy species show growth. Some understorey trees e.g. **beech, sycamore, hornbeam, yew, field maple** and **small leaved lime** grow up to fill canopy gaps. Gaps are planted with **small leaved lime, wild service** or **black walnut** (drier sites), and **pedunculate oak** or **black poplar** (wetter sites). Rapid growth of **hazel** and other	**No ash trees, saplings or coppice (living or dead).** A full canopy composed of the **sycamore, beech, hornbeam** and **field maple** but with large amounts of **pedunculate oak** or **black poplar** (wet sites), **small leaved lime, wild service** or **black walnut** (free draining sites). Undersorey well developed and composed of a range of **typical** species. A diverse shrub layer composed of the **typical** species. Seedlings of potentially all **typical** species occur but very few

	typical shrubs. Seedlings of potentially all **typical** species occur and establishment is of species favoured by management e.g. **beech, oak, hornbeam** is promoted. 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.	establish. Sparse vegetation cover but with some species (e.g. **bluebell**, **wild garlic**, **false brome**, **ivy**, **dog's mercury** and **male fern**).
5	Canopy composed of many **dying/dead but no living ash trees,** and **beech, oak,** and **sycamore** mixed with a few other **typical** species. Some gaps in canopy. Positive growth of understorey of young **sycamore**, **beech**, **hornbeam, field maple** and **small leaved lime** but **ash saplings dying back.** A mixture of the **typical** shrubs e.g. **hazel** present but ash coppice is cut. Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore, beech** and **hornbeam** thrive and grow. Field layer of partially shade-tolerant species (e.g. **tufted hair-grass**, **stinging nettle**, **creeping thistle**, **bramble** and **rough meadow-grass**) become abundant.	**No ash trees, saplings or coppice (living or dead).** A canopy of **beech, oak, sycamore, field maple, hornbeam** and **small leaved lime,** mixed with a few other **typical** species. **No ash trees (living or dead).** Some large gaps in the canopy. Understorey depleted and composed of **hornbeam**, **yew**, **sycamore**, and **beech.** A mixture of the **typical** shrubs present. Seedlings of all the **typical** canopy tree species present in gaps. Field layer 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**).
6	Canopy composed of **beech, oak** and **sycamore,** mixed with a few other **typical** species. **No ash trees (living or dead).** Some gaps in canopy. Positive growth of understorey of young **sycamore**, **beech**, **hornbeam**, **field maple** and **small leaved lime** but **ash** absent. **Typical** shrubs (and **ash**) are infrequent as removed by management.	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: -a full canopy composed of **sycamore, oak, beech** and **small leaved lime** with a few other **typical** species e.g. **field maple** present. **No ash trees (living or dead).** Some large gaps in the canopy. -an understorey well developed and a mixture of young, **sycamore**, **beech**, **field maple, hornbeam, wild cherry, yew, sweet chestnut,**

	Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow. Field layer of 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.	and **holly.** -a mixture of the **typical** shrubs present. Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore, beech** and **hornbeam** establish. Field layer has sparse cover but with some species (e.g. **bluebell**, **wild garlic**, **false brome**, **ivy**, **dog's mercury** and **male fern**).

Table 7.10 Northern Ireland (sub-region 9)

Current ash dominance	Woodlands where main canopy has >40% ash		
Typical species	Typical canopy tree species: **sycamore, poplars, sessile oak, pedunculate oak, holly, downy birch, silver birch, rowan, goat willow, bird cherry and alder.**	Typical shrub species: **blackthorn, elder, grey willow, guelder rose, hawthorn, hazel.**	Field layer of composed of species typical of NVC community: **W9, W8**
Management 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**) will start to become a dominant feature. In the canopy, **birch**, **sycamore** and **oak** other **typical** canopy species show canopy growth. Understorey **sycamore, sessile oak** and **alder** show rapid growth but **ash saplings dying back.** Rapid growth of **hazel** and **grey willow** and other **typical** shrubs. Seedlings of all typical species present but only **alder** and **sycamore** establish. Field layer of partially shade-tolerant species (e.g. **bluebell, lady fern, wood avens, yellow pimpernel** and **wood sorrel)** become abundant.	**No ash trees, saplings or coppice (living or dead).** Significant quantities of deadwood (**mainly ash**) – most on ground. Large gaps in canopy. Canopy composed mainly of **alder**, **sycamore, sessile oak, holly** and **bird cherry** with a few other **typical** species. Canopy of simple structure with no understorey. Good shrub cover composed of **typical** species. Seedlings of all **typical** species present but only **sycamore** establish. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **cocksfoot**, **tufted hair-grass**, **male fern** and **meadowsweet** in gaps.	
2	**Ash trees die back – some live mature and veteran ash trees remain.** Standing deadwood (**mainly ash**) will start to become a dominant feature. In the canopy, **birch**, **sycamore** and **oak** other **typical** canopy species show canopy growth. Understorey **sycamore, sessile oak** and **alder,** and show rapid growth but **ash saplings dying back.** Rapid growth of **hazel** and **grey willow** and other **typical** shrubs. Seedlings of all typical species present but only **alder** and **sycamore** establish.	**No ash trees, saplings or coppice (living or dead).** Significant quantities of deadwood (**mainly ash**) – most on ground. Large gaps in canopy. Canopy composed mainly of **alder**, **sycamore, sessile oak, holly** and **bird cherry** with a few other **typical** species. Canopy of simple structure with no understorey. Good shrub cover composed of **typical** species. Seedlings of all **typical** species present but only **sycamore** establish. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's**	

	Field layer shows an increase in **dog's mercury, bluebell, wood sorrel** and **lady fern.**	**mercury** and **bluebell** and denser cover of **cocksfoot**, **tufted hair-grass**, **male fern** and **meadowsweet** in gaps.
3	**No ash trees (living or dead).** In the canopy, **sycamore, birch, oak, alder, poplars** and other **typical** canopy species show growth. Some understorey trees e.g. **sycamore, sessile oak, alder** and **holly** grow up to fill canopy gaps. Rapid growth of **hazel** and **grey willow** and other **typical** shrubs. Seedlings of all typical species present but only **alder** and **sycamore** establish. Field layer contains **dog's mercury, bluebell** and **wood sorrel** below canopy but in gaps early successional species (e.g. **primrose** and **violets**) establish but are replaced by vigorous competitive species **tufted hair-grass**, **false oat grass**, **Yorkshire fog** and **cocksfoot**).	**No ash trees, saplings or coppice (living or dead).** Few gaps in tree canopy. Canopy of simple structure with no understorey. Canopy composed of **sycamore, alder, oak** and a few other **typical** species. Limited shrub cover of **typical species** in gaps. Seedlings of all **typical** species present but only **alder** and **sycamore** establish. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **cocksfoot**, **tufted hair-grass**, **male fern** and **meadowsweet** in gaps.
4	**No ash trees (living or dead).** In the canopy, **sycamore, birch, oak, alder, poplars** and other **typical** canopy species show growth. Some understorey trees e.g. **sycamore, sessile oak, alder** and **holly** grow up to fill canopy gaps. Gaps are planted with **common alder**, **black poplar** or **pedunculate oak** (wetter sites) and **wild cherry**, **wych elm** or **sycamore** (drier sites). Rapid growth of **hazel** and **grey willow** and other **typical** shrubs. Seedlings of all typical species present but only **oak, birch** and **sycamore** establish. Field layer contains **dog's mercury, bluebell** and **wood sorrel** and **lady fern,** and some early successional species (e.g. **primrose** and **violets**).	**No ash trees, saplings or coppice (living or dead).** A full canopy composed of **sycamore** and large amounts of **common alder, black poplar**' or **pedunculate oak** (wet sites), **wild cherry**, **wych elm** or **sycamore** (free draining sites). Understorey well developed and composed of a range of **typical** species. A diverse shrub layer composed of the **typical** species. Seedlings of potentially all **typical** species occur but very few establish. Sparse vegetation cover but with some species e.g. **dog's mercury**, **wood sorrel, bluebell, wood avens** and **lady fern**.
5	Canopy composed of some **dying/dead but no living ash**	Canopy composed of **sycamore** with a few other **typical** species

	trees, and **sycamore, birch, alder** and **oak,** mixed with a few other **typical** species. Some gaps in canopy. Positive growth of understorey of young **sycamore**, **alder, sessile oak** and **bird cherry** but **ash saplings dying back.** A mixture of the **typical** shrubs e.g., **hazel** and **grey willow** present but **ash coppice is cut.** Seedlings of a mixture of the **typical** canopy tree species frequent; some seedlings e.g. **sycamore,** (**birch** in gaps) thrive and grow. Field layer shows an increase in **dog's mercury, bluebell, wood sorrel** and **lady fern.**	present. **No ash trees, saplings or coppice (living or dead).** Some large gaps in the canopy. Understorey depleted and composed mainly of **sycamore.** A mixture of the **typical** shrubs e.g. **hazel** and **grey willow** present. Seedlings of all the **typical** canopy tree species present in gaps. Field layer a mosaic of sparse vegetation under canopy e.g. **dog's mercury** and **bluebell** and denser cover of **cocksfoot**, **tufted hair-grass**, **male fern** and **meadowsweet** in gaps.
6	Canopy composed of **sycamore, birch, alder** and **oak,** mixed with a few other **typical** species. **No ash trees (living or dead).** Some large gaps in canopy. Positive growth of understorey of young **sycamore**, **alder, sessile oak** and **bird cherry** **Typical** shrubs are infrequent as removed by management. Seedlings of the **typical** canopy tree species frequent; some of potentially each **typical** species thrive and grow. Field layer contains **dog's mercury, bluebell** and **wood sorrel** and **lady fern,** and some early successional species (e.g. **primrose** and **violets**).	**No ash trees, saplings or coppice (living or dead).** Multi-strata woodland with: -a full canopy composed of **sycamore, alder, birch** and **oak,** mixed with a few other **typical** species. -an understorey of a mixture of young, **sycamore**, **alder**, **sessile oak, bird cherry** and **holly**. A mixture of the **typical** shrubs e.g. **hazel** and **grey willow** present. Seedlings of the canopy tree species occur occasionally but few e.g. **sycamore** establish. Sparse vegetation cover but with some species e.g. **dog's mercury**, **wood sorrel, bluebell, wood avens** and **lady fern**.

8 Impact of management scenarios on partially associated species for woodlands with a high cover of ash.

Chapter summary

1. *An assessment of the likely impact of all the management scenarios on partially associated ash species was carried out for woodlands with greater than 20% ash canopy. The assessment was done for all partially associated species in Region 8 (calcareous Southern England) and for bryophytes, birds, fungi, invertebrates and mammals in regions 1 and 6 (lowland Scotland and lowland Wales).*
2. *Partially associated species are predicted to decline initially following the arrival of ash dieback but after 50-100 years over 200 of the 226 species present in region 8 are predicted to be unchanged in abundance compared to current population levels. This is due to an increase in the abundance of other tree species which they use instead of ash.*
3. *There is a clear difference between the response of highly associated species (which are predicted to either decline or go extinct) and the majority of partially associated species which although they may decrease in abundance initially, are predicted to remain unchanged in abundance after 50-100 years.*
4. *In region 8 after 50-100 years up to 28 partially associated ash species may have greater abundance than at present as ash dies out and is replaced with alternative tree species that the partially associated species are more highly associated with.*
5. *Responses by partially associated species show some very species specific responses illustrating the importance of knowing which ash-associated species are present and which alternative tree species they will use if partially associated ash specie are to be conserved.*
6. *The results suggest that for the majority of partially associated ash species if the correct management is undertaken the impacts of ash dieback on partially associated species can be mitigated.*

8.1 Introduction

Obligate and highly associated species populations are generally predicted to either decline or go extinct under the six management scenarios assessed. This is because they either never or rarely use any of the alternative trees that are predicted to establish instead of ash. Thus an assessment of the impact on obligate and highly associated ash species for the management scenarios developed for woodlands with greater than 20% ash canopy are likely to yield similar results to those shown in Chapter 6 and Phase 1 where the majority of assessments were for woods with less than 20% ash canopy.

In order to understand whether the management scenarios and replacement tree species may benefit partially associated species, the impact of a change to the vegetation composition described in the ‘pen pictures’ developed in Chapter 7 was assessed for partially associated species.

As there were a lot more partially associated species than obligate and highly associated species, particularly lichens, the assessment was only carried out for region 8 (calcareous southern England) for all species. In order to provide a broader coverage for some species the assessment was also repeated in regions 1 and 6 (lowland Scotland and lowland Wales) for all groups except lichens. This resulted in the following assessments being made:

- In region 8 a total of 4128 impact assessments were made for partially associated species: 12 assessments for each of 344 partially associated species.
- In regions 1 and 6 a total of 1356 assessments were made to cover 113 partially associated birds, bryophytes, fungi, invertebrates and mammals.
- The results for the partially associated species were compared to the results for highly associated species. The impact of these management scenarios in woods with >20% ash canopy cover on highly associated species had already been assessed for Regions 6 and 8 (Phase 1) but not for Region 1. (In Phase 1 Region 1 had been assessed for woods with <20% ash canopy). Therefore a new assessment of the impact of the management scenarios on the 62 highly associated species was carried out for woods with >20% ash canopy.

The assessment methods were the same as those described in Chapter 6, with particular attention being paid to whether the ash-associated species would use any of the alternative tree species.

8.2 Results

Similar assumptions and caveats to those listed in Chapter 6 are appropriate when interpreting the results presented here. Again, results from scenarios (1), (2) and (5) are based on the assumption that ash dieback causes large-scale loss of ash (95% or more), in scenarios (3), (4) and (6) all ash is felled so the scale of ash dieback is irrelevant. Large scale loss of ash may not happen. Predicted increases or 'no-change' impacts on partially associated species are based on the descriptions of the vegetation provided in 'pen pictures' in Chapter 7. There is no guarantee that if the management scenarios are carried out in any given ash wood the vegetation changes described will occur and hence the impact on the partially associated species. The vegetation composition resulting from any management will be impacted by a range of site conditions such as seed source and grazing pressure in addition to the management. These additional factors will also influence the final impact on any partially associated species. However these assessments do show the potential for mitigating some of the impacts of ash dieback on partially associated species.

8.2.1 Region 8 (calcareous Southern England) – all partially associated species

In region 8 in the first 10 years 162-255 partially associated species are predicted to decline compared to current population levels. However after 50-100 years only 29-69 species are predicted to decline with over 200 of the 286 partially associated ash species present in the region predicted to be unchanged in abundance compared to current population levels (Figure 8.1). Thus populations of the majority of partially-associated species are predicted to initially decline and then increase in abundance as the abundance of other tree species which they will use instead of ash increases with time.

After 50-100 years up to 28 partially associated ash species may have greater abundance than at present as ash dies out and is replaced with alternative tree species that the partially associated species are more highly associated with.

There is some indication that in years 1-10 partially associated species decline more in scenarios (2) - no felling with natural regeneration promoted, (5) - thinning, and (6) – felling with natural regeneration promoted, than in scenarios (3) - felling and (4) – felling and replanting. Scenarios (2) and (6) encouraged natural regeneration and scenario (4) included planting of alternative trees. It is these scenarios which one would predict should reduce the decline in partially associated species. The lack of predicted response after 10 years may be due to the time taken for these alternative tree species to establish. This is confirmed by the predicted results after 50-100 years; management scenario (3) – felling, which did not actively encourage the growth of alternative species, is predicted to have the longest lasting negative impact on partially associated ash species: 69 species predicted to have declined compared to 35 or fewer species in the other scenarios after 50-100 years.

Only one partially associated species (an invertebrate) is predicted to go extinct in region 8, this is because none of the alternative species it will use were predicted to be present within the 'pen pictures'.

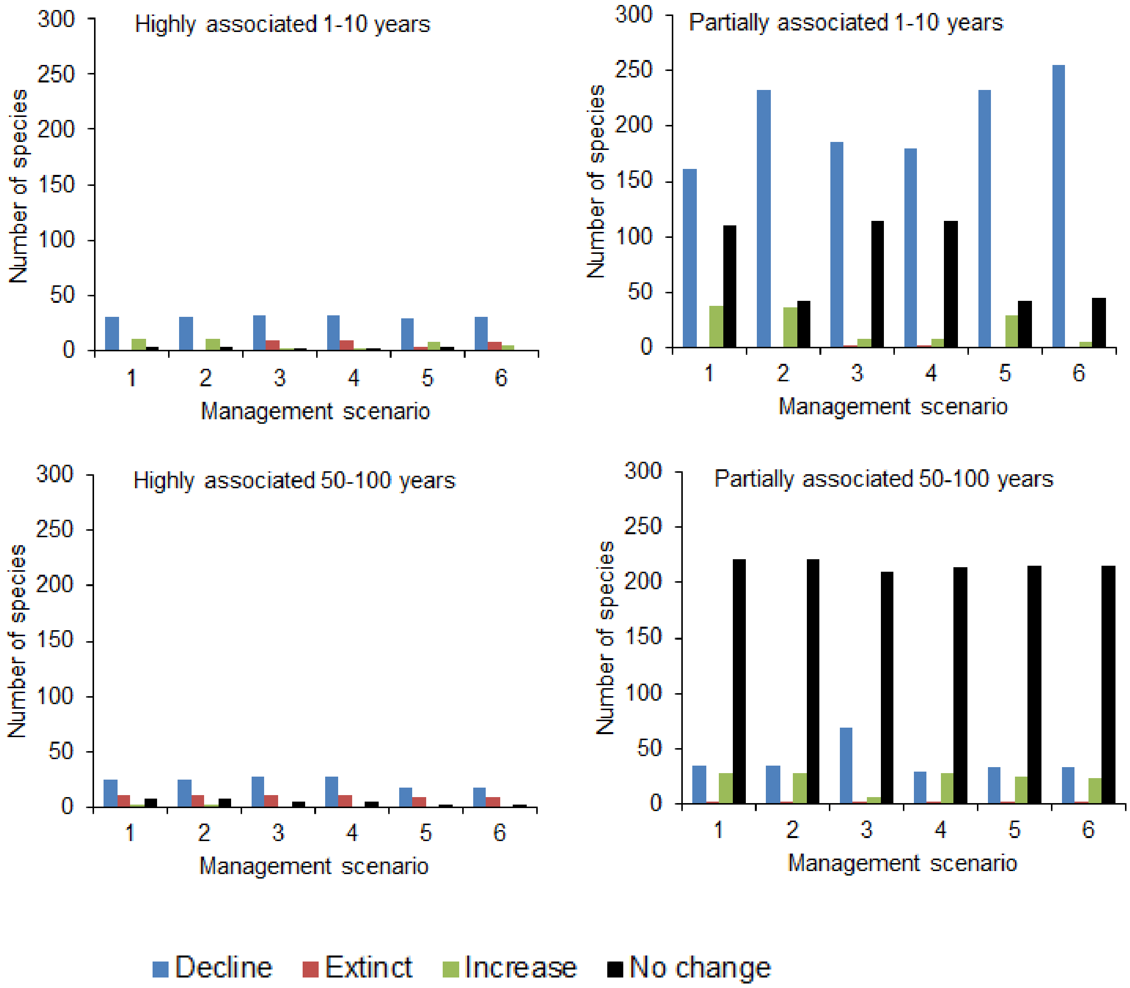

Figure 8.1 Predicted impact on high and partially associated ash species of 6 management scenarios in region 8 (calcareous Southern England) over two time periods

Figure 8.1 shows the impact of the six scenarios on highly associated species (includes data taken from Phase 1) as a comparison with the partially associated species. This shows that despite an initial decline in abundance the majority of partially associated species are predicted to recover in abundance to current population levels after 50-100 years but highly associated species are not predicted to recover.

8.2.2 Impact on partially associated lichens

There were 231 partially associated lichens for which an assessment was made in region 8 of which 204 were found to occur in that region. In the first 10 years between 135 and 204 partially associated lichens are predicted to decline in abundance and up to 68 species may not change in their abundance. However after 50-100 years the number of partially associated lichens predicted to decline decreased to 13 with up to 171 species showing no change in abundance from current population levels (Figure 8.2). This is due to the increase in abundance of alternative tree species, often hazel, which these partially associated species will use.

In the first ten years one partially associated lichen species may increase in abundance under scenarios (1), (3) and (4) and after 50-100 years up to 20 partially associated lichen species may occur at greater abundance than at present due to increases in the abundance of tree species which they use to a greater extent than ash.

No partially associated lichen species are predicted to go extinct (if ash dieback causes large scale loss of ash) compared to two highly associated species (Figure 8.2). Generally the impact of the management scenarios on partially associated lichens was much more variable than on highly associated lichens, with the species response depending on the alternative tree species establishing in the woods following the loss of ash.

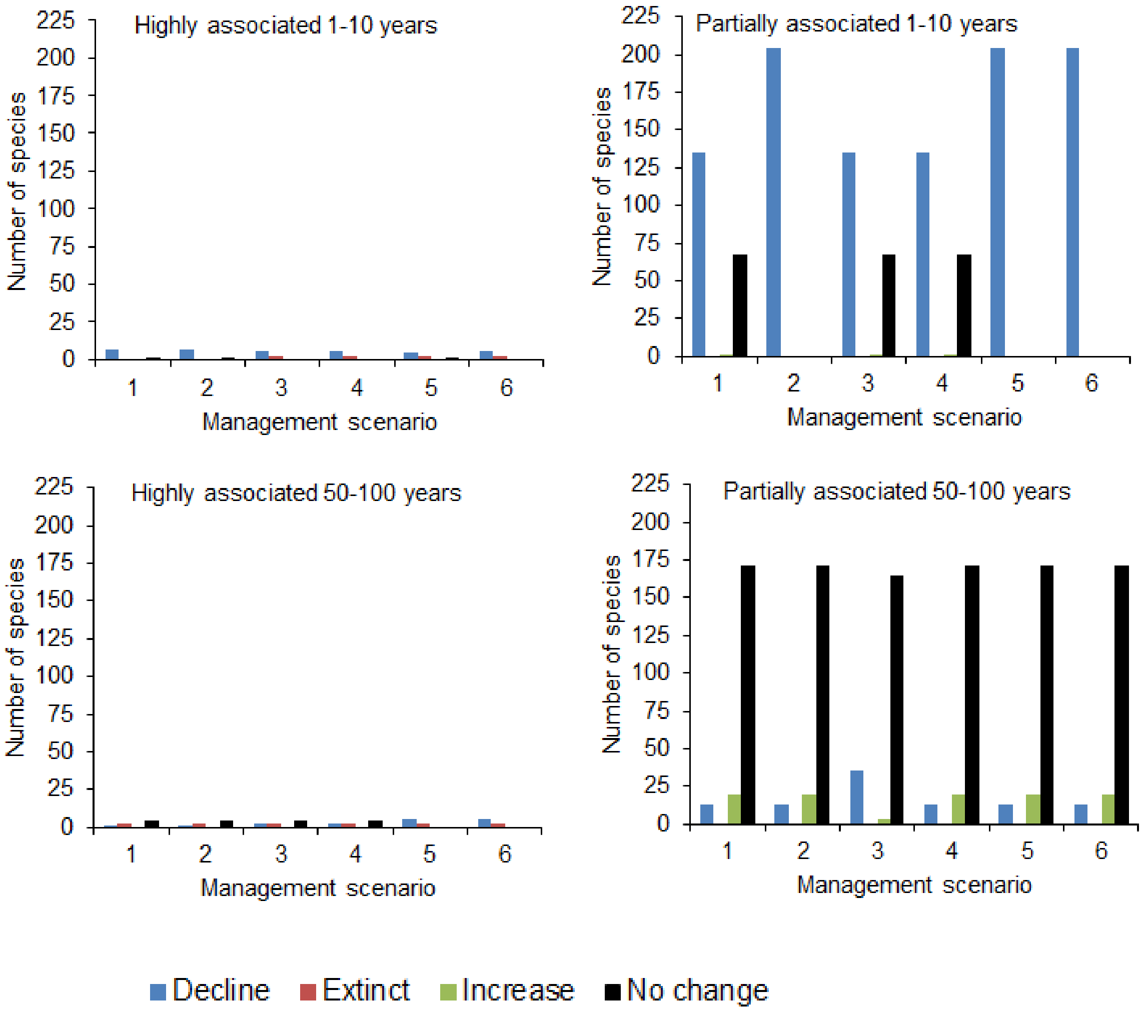

Figure 8.2 Predicted impact on high and partially associated lichen species of 6 management scenarios in region 8 over two time periods

8.2.3 Difference between species groups and regions

Partially associated species for all groups except lichens were also assessed for region 1 (lowland Scotland) and region 6 (lowland Wales) in addition to region 8. The results are compared to the results for highly associated species. Different numbers of partially associated species are present in different regions resulting in the numbers of species increasing/decreasing differing between regions, therefore the number of species impacted are reported as a range across regions.

There were no highly associated bird species with which to compare the impact of the management scenarios on the partially associated bird species. The response of the partially associated bird species is predicted to be very mixed (Figure 8.3). Up to four species are predicted to either remain unchanged in abundance or increase in abundance in the first 10 years due to the increase in understorey species following the loss of ash. After 50-100 years four partially associated bird species may occur in greater abundance than at present and up to five bird species may be unchanged in abundance; however there are regional variations and differences between management scenarios. After 50-100 years management scenarios (3) and (4) are predicted to have the greatest negative impact on partially associated birds with no species increasing in abundance compared to other scenarios where some bird species are predicted to increase in abundance. It should be noted that woodland structure is as important as woodland composition in predicting bird abundances (Section 10.3).

Assessments were made for 30 partially associated bryophyte species. In the first ten years up to 20 partially associated bryophytes may decline in abundance but none are predicted to go extinct (Figure 8.4). Up to seven partially associated bryophytes are predicted to remain unchanged in abundance and up to two bryophytes are predicted to increase in abundance, depending on region and management scenario. The impact on partially associated bryophytes was largely assessed as unknown after 50-100 years but 2 species are predicted to increase in abundance and two species to remain unchanged with up to 14 species showing a decline in abundance. There is no consistent pattern between the different management scenarios on the predicted impact on partially associated bryophytes, with responses being species-specific.

There were 38 partially associated fungi for which an assessment was made. In region 8, where the greatest number of partially associated fungi occur, there are clear differences between management scenarios in the first 10 years: under scenarios (1) and (2) 21 fungi may increase in abundance but in scenarios (3) and (4) (where all dead wood is removed) these species are predicted to decline in abundance (Figure 8.5). Similarly there are differences between scenarios (5) where 20 species are predicted to increase and one decline compared to scenario (6) where 21 partially associated fungi species are predicted to decline in abundance. There are 13 partially associated fungi in region 8 that are predicted to not to change in their abundance under all management scenarios. After 50-100 years few partially associated fungi are still predicted show an increase in abundance although five species are predicted to increase in region 8 under management scenario (4). Up to 22 partially associated fungi are predicted to be unchanged in abundance after 50-100 years (region 8, scenarios (1) and (2)); seven partially associated fungi are predicted to decline in abundance (region 8, scenario (3)). However there are up to 12 species for which the impact of the management after 50-100 years is unknown.

There were 37 partially associated invertebrate species for which an assessment was made. The predicted difference in response to the management scenarios between highly and partially associated species is clearly seen for the invertebrates (Figure 8.6). Most highly associated invertebrate species are predicted to either decline or go extinct whereas the majority of partially associated invertebrate species are predicted to remain unchanged in their abundance. However up to eight partially associated invertebrates are predicted to decline (region 6, management scenarios (5) and (6)) in the first 10 years and 11 species after 50-100 years (region 8, management scenario (5)). The maximum number of partially associated invertebrate species that are predicted to increase in abundance in the first 10 years is in region 8 under management scenarios (1) and (2) (22 species). After 50-100 years the number of species predicted to increase in abundance declines but the number of species whose abundance is predicted to be unchanged is greater in years 50-100 than in years 1-10, suggesting that after an initial increase in abundance the population of these species returns to current levels. Two partially associated invertebrate species are predicted to have gone extinct in regions 6 and 8 after 50-100 years (this is based entirely on the vegetation composition described by the ‘pen pictures’, in reality some of the alternative trees these species use are likely to still occur in the region but they were not mentioned in the ‘pen pictures’ and were hence assessed as at risk of extinction).

There is only one partially associated mammal species (wood mouse) and its abundance is not predicted to change under any of the scenarios at any time or in any region (data not presented).

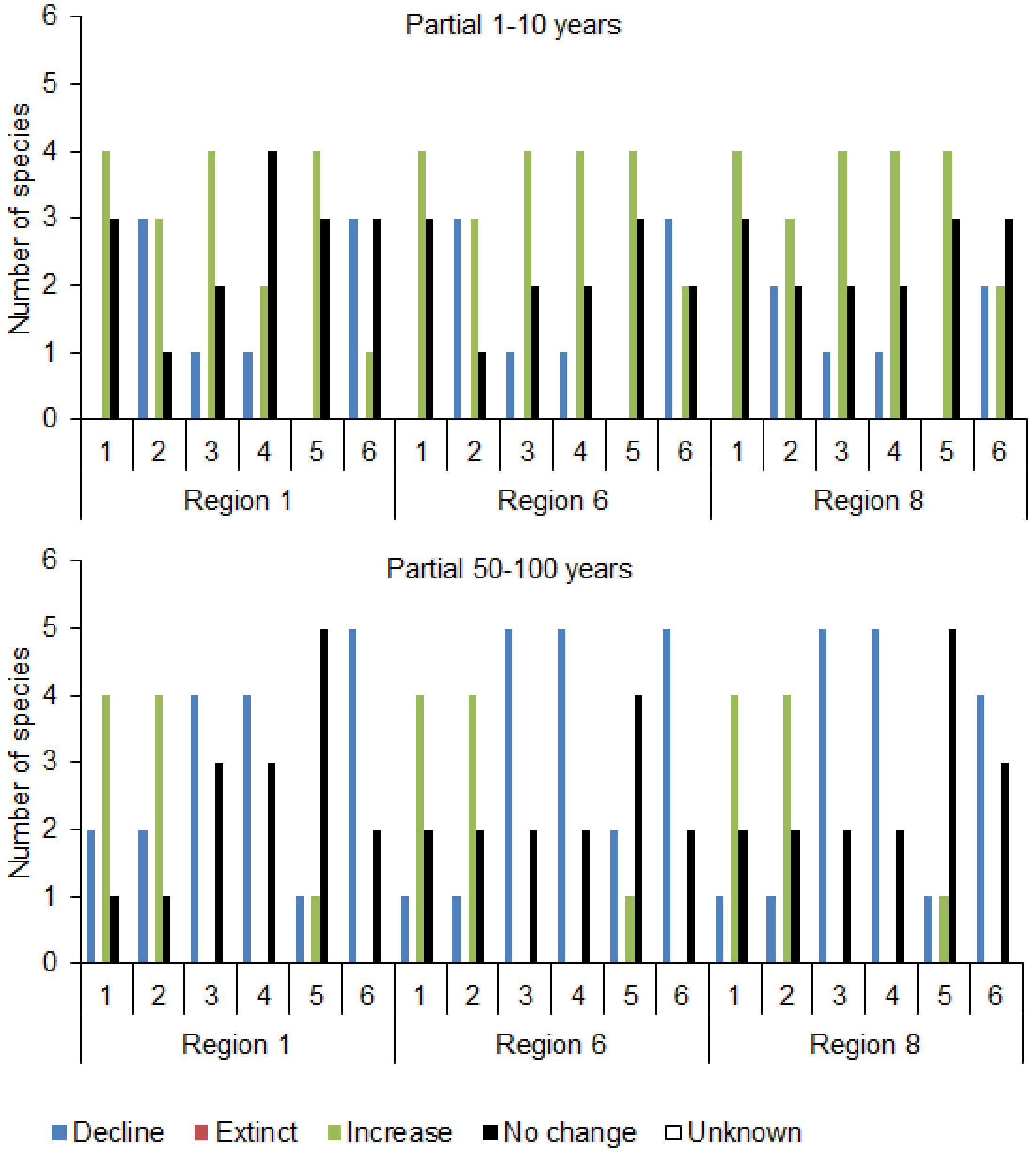

Figure 8.3 Predicted impact of management scenarios on partially associated bird species for three regions

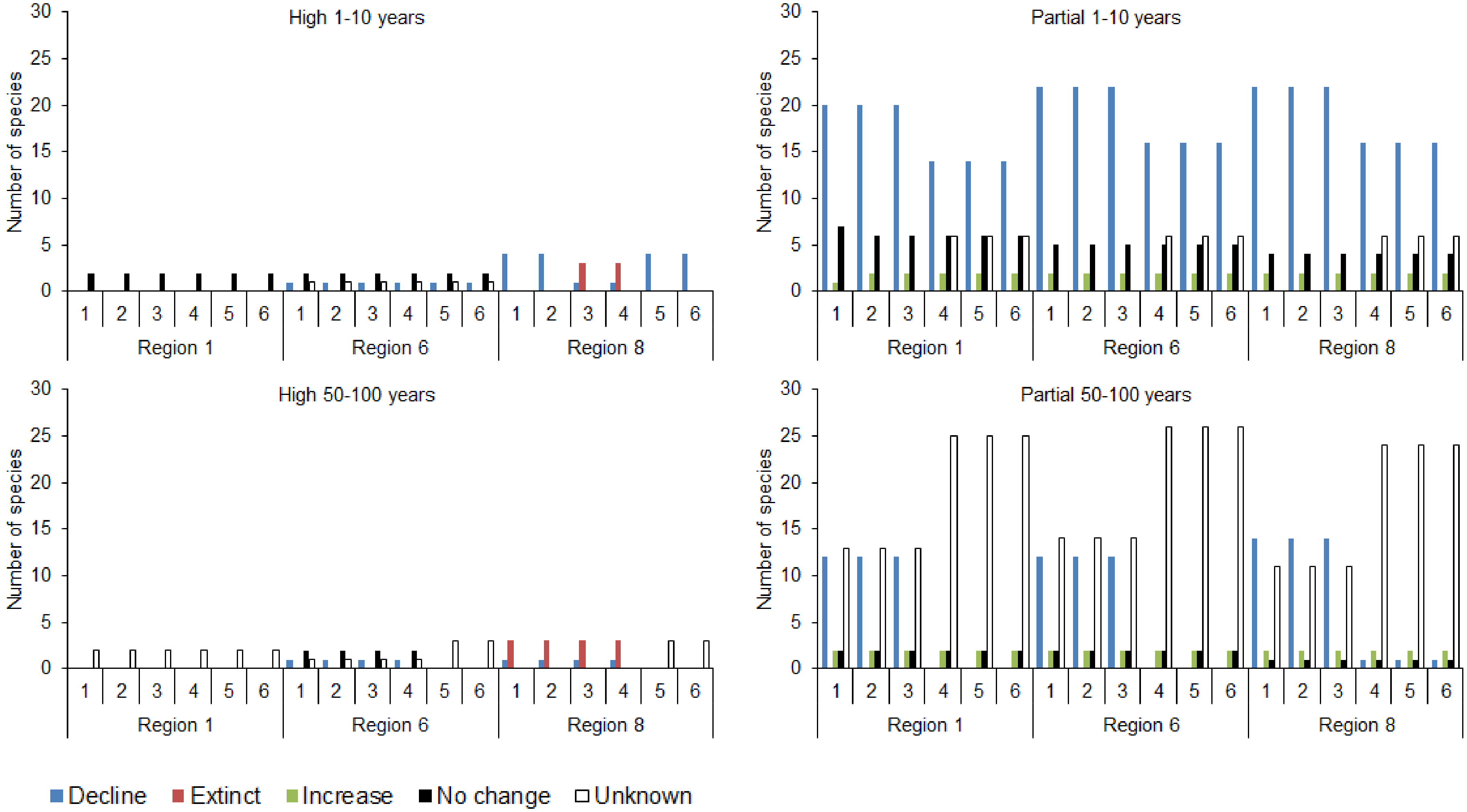

Figure 8.4 Predicted impact of management scenarios on high and partially associated bryophyte species for three regions

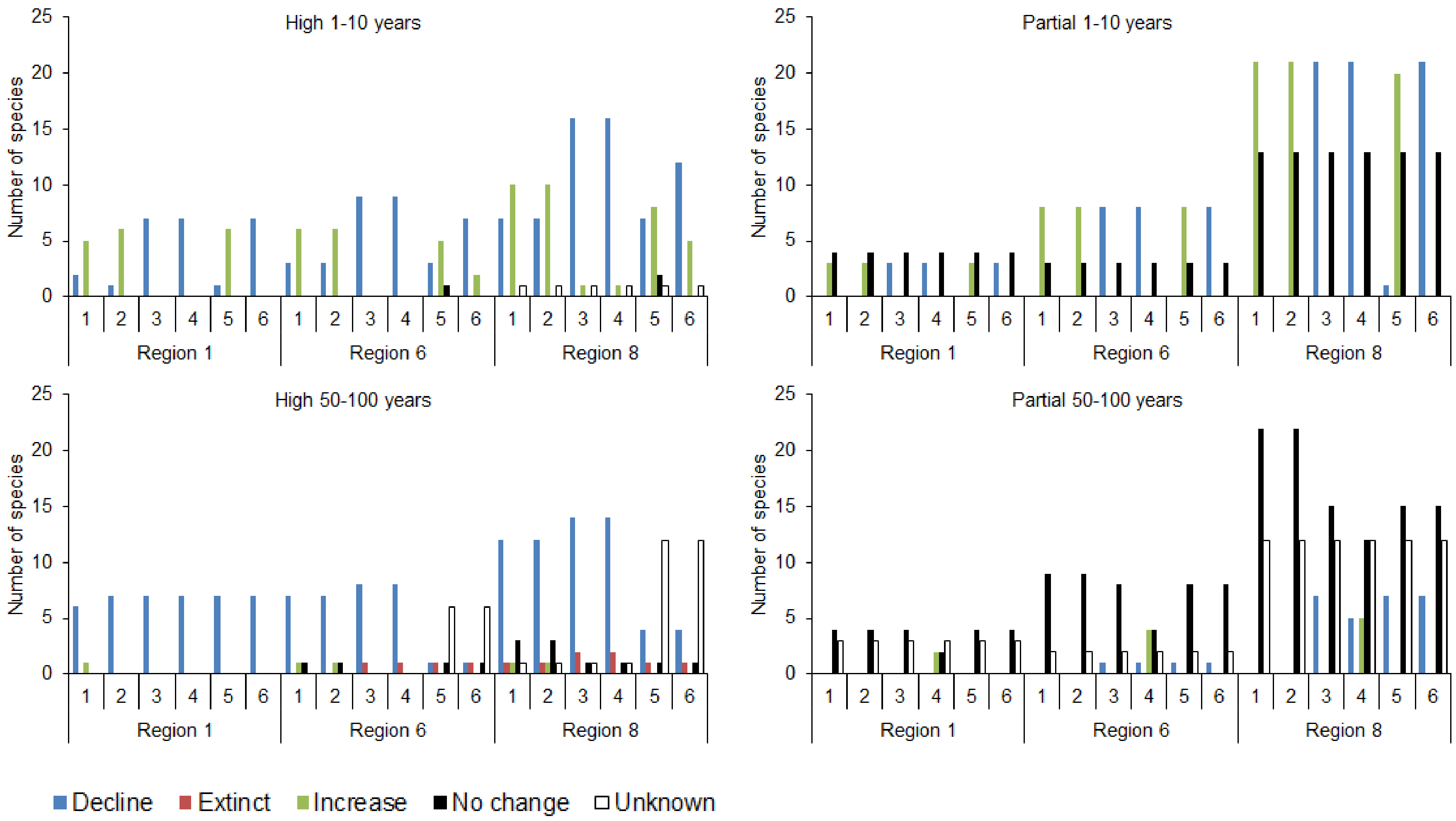

Figure 8.5 Predicted impact of management scenarios on high and partially associated fungi species for three regions

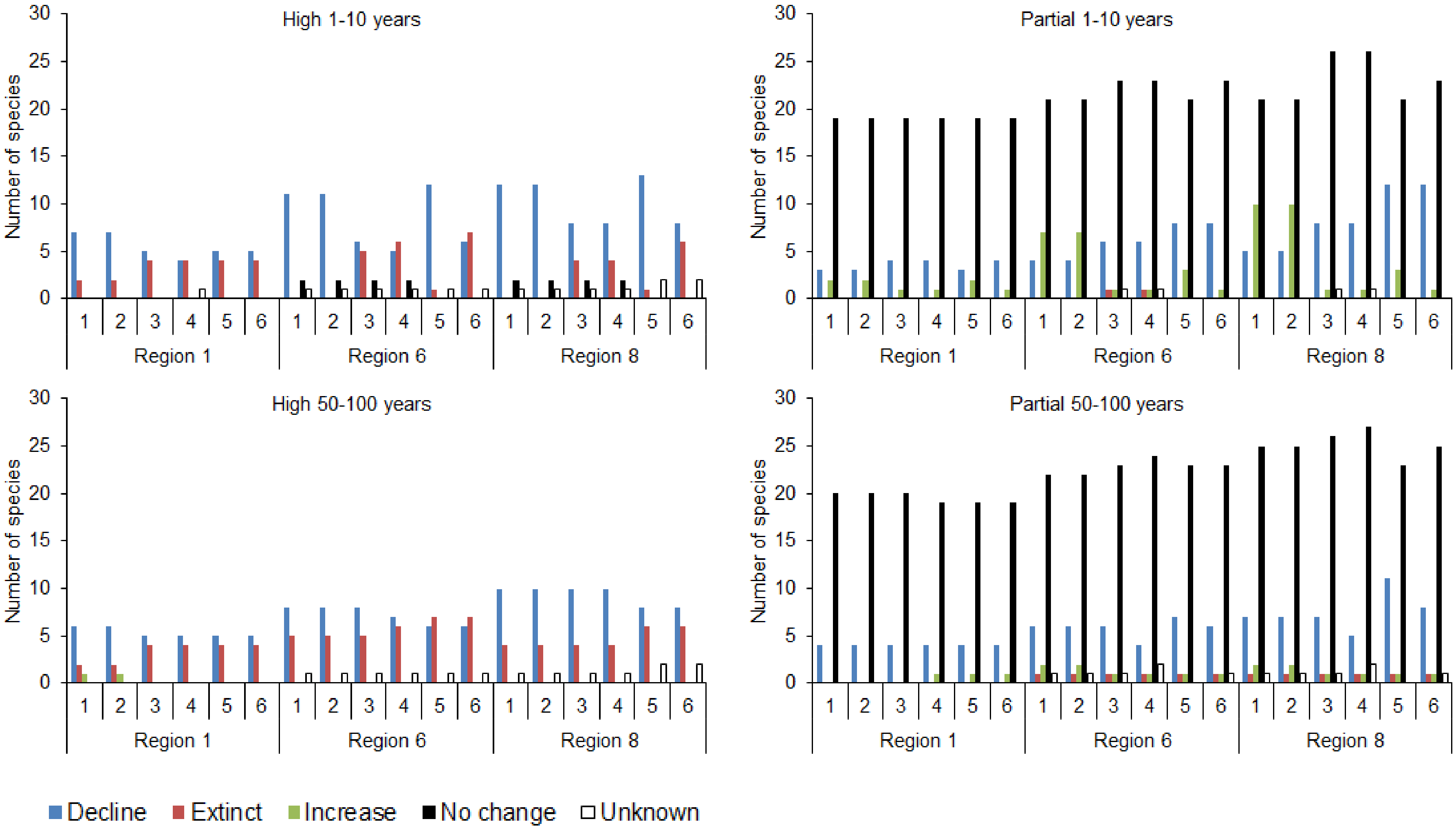

Figure 8.6 Predicted impact of management scenarios on high and partially associated invertebrate species for three regions

9 Tools for woodland managers

Chapter summary

1. *This report provides information for advisors and policy makers to aid woodland managers in conserving ash-associated biodiversity. This report does not provide a complete woodland planning tool - it is intended for use alongside other resources (eg ESC) to develop appropriate woodland management plans.*

2. A five-step procedure to develop management recommendations for ash associated species is provided.

3. *Information on ash-associated species and which alternative tree species they will use is provided in the Excel file AshEcol.*

4. *This project has undertaken 15 cases studies, providing a range of examples of how current management plans may be adapted to manage for ash-associated biodiversity if ash dieback affects these sites, and examples of how to use the information provided in this and the Phase 1 report.*

9.1 AshEcol: A spreadsheet of Ash-associated biodiversity

The information on ash-associated species gathered during this project is collated in a Microsoft Excel file called AshEcol. The AshEcol spreadsheets aim to help woodland managers identify if they have ash-associated species on their sites and to provide advice on which alternative trees may be suitable replacements if the management objective is to maintain ash-associated biodiversity.

The spreadsheets are available at weblink together with instructions on how to use them. Examples of how to use these spreadsheets are provided below.

9.1.1 Spreadsheets

The AshEcol file contains three data spreadsheets:

1. **Ash associated sp** - allows managers to identify which species present at the site are ash-associated and their level of association with ash.
2. **Assessment_alternative trees** - allows managers to identify which alternative trees the ash-associated species will also use.
3. **Traits** - provides all the data collected on the traits of ash and the alternative trees.

At the front of each of these spreadsheets is a notes page describing the columns within each spreadsheet. These should be referred to in order to ensure correct interpretation of the data.

9.1.2 Ash-associated species - spreadsheet

This spreadsheet lists all the species identified by Phase 1 and 2 as using ash trees. The level of association with ash is shown as 'obligate', 'high', 'partial', 'cosmopolitan' and 'uses' (Table 9.1). Other species, eg vascular plants, will also use the ash woodland habitat (see Phase 1) but these are not included in this spreadsheet as they are not specifically using the ash trees.

Table 9.1 Definitions of association with ash used in AshEcol (see Phase 1 for details of how these levels were assigned for each species group)

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

9.1.3 Assessment of alternative tree species spreadsheet

As discussed in Chapter 3, one 'solution' to the potential loss of ash trees is to plant/encourage regeneration of alternative tree species which could support ash-associated biodiversity. For each of 48 tree species we provide an assessment of their ability to support each of the 955 ash-associated species. The tree species are colour coded according to whether they are native or non-native to the UK. If woodland managers are managing for a particular ash-associated species or group of ash-associated species, this spreadsheet allows identification of which alternative trees they may use. Not all alternative trees listed here will be suitable on any site, and site suitability (environmental conditions) and compatibility with other management objects (e.g. silvicultural objectives) should also be checked.

The use of the 48 alternative trees by ash-associated species is classified as:

- Yes: known to use this tree species.
- No: known not to use this tree species.
- Likely: the ash-associated species is thought likely to use this tree species but no specific information is available for this particular tree species. For example, some ash-associated species are known to use most deciduous trees. Site managers should be cautious when using this category as the level of confidence associated with it is lower than for the 'Yes' category.
- Rare: the ash-associated species has very occasionally been recorded on this tree species but we advise that a precautionary approach is taken and that this tree species is not planted as an alternative to ash for this species as it is likely to do little to aid the survival of the species
- Unknown: the use (or otherwise) of this tree is unknown.

9.1.4 Traits

This spreadsheet contains all the data gathered in Chapter 4 to assess the similarity of the alternative trees to ash by their traits. A summary of how different tree traits may influence the species that use the tree and ecosystem functioning is shown in Table 1 in the spreadsheet called 'Notes_traits'. The sources from which this data is taken are acknowledged in the spreadsheet 'Traits_data sources'.

9.1.5 How to use AshEcol

Detailed instructions on how to use AshEcol are provided in the accompanying AshEcol PDF document. The main steps are shown below.

1. Obtain a list of species present at the site (one source of such a list is the National Biodiversity Network http://www.nbn.org.uk/)
2. The spreadsheets make use of the filter tool within Excel (exactly how this works differs between versions of excel).

3. In the ‘Ash associated sp’ spreadsheet select those species that are present at the site (using the filter).
4. Use the column ‘Level association with ash’ within the ‘Ash associated sp’ spreadsheet to see how highly associated with ash the species present on the site are.
5. Decide which ash-associated species you wish to conserve (this may be based on conservation status and/or level of association with ash).
6. In the ‘Assessment of alternative trees’ spreadsheet use the filters to select the species identified in Step 5. Then filter on the ‘Association’ column to show ‘Yes’ and this will then list only those tree species that the species you have selected are known to use. If you filter on ‘Yes’ and ‘Likely’ this will show all trees which the species selected are likely to use but there is a lower level of confidence in the data associated with the ‘Likely’ category.

9.2 Case studies

Fifteen case studies have been developed as part of this project. The case studies illustrate how appropriate management responses that will maximise the survival opportunities of ash-associated biodiversity can be developed by combining knowledge of the site with the resources developed by both Phases 1 and 2 of this research (AshEcol, Section 9.1). These case studies have been produced as separate downloadable PDFs and are available at weblink. The locations of the case study sites are shown in Figure 9.1.

Case studies have been selected to be representative of ash-dominated woodlands in the 9 ash-relevant regions of the UK, where conservation of biodiversity is a management priority. Sites therefore are primarily nature reserves or SSSIs for which objectives and management plans have been developed, and for which records of species supported by the woodland are more likely to be available. Information on each site was collated and analysed following a five-step procedure; this is described below using one of the case study sites (Roudsea Wood) as an example.

Management recommended for each site is considered in the context of six generic methods of management (Section 5.1), discussed in the wider project. Case studies also include a consideration of the consequences for ash-associated biodiversity if management continues as planned.

9.2.1 Five-step procedure used to analyse case study sites and develop management recommendations - Roudsea Wood is used as an example

Step 1 Gather information on biodiversity recorded for the site

- Using the National Biodiversity Network (www.nbn.org.uk/), extract species records for the site /or the 10km square that the site lies within. Select surveys of all taxa groups.

- Use any other survey data available to fill any obvious gaps.

For Roudsea Wood, the Natural England level of access to the NBN returned 3720 species records contained in 17 datasets. The search resolution was 100m, the years covered were 1980 – 2014 and taxa with designation status ‘All’ were returned. This resulted in a species list of 579 species being compiled from the NBN. No records were available for vascular plants, birds or herptiles, and the survey data for bryophytes contained only one species. Data from a recent survey of bryophytes was provided by the site manager to supplement the latter.

Step 2 Identify ash-associated species present on the site and short-list those for site management to target

- Using the ash-associated spreadsheet in the Excel file AshEcol, identify which of the site's species are associated with ash.

- Short-list those that are a priority for management action, i.e. the higher conservation priority species which are also vulnerable to ash dieback. Species considered vulnerable to ash dieback at each site are generally those ash-associated species where the association (definitions in Table 9.1) is classed as either ' high' , 'partial' or 'obligate'; species that are classed as 'cosmopolitan' or 'uses', are excluded.

Fifteen of the species recorded at Roudsea Wood were identified in the database as being vulnerable to ash dieback. One, the moth centre-barred sallow (*Atethmia centrago*) is classed as obligate, three others are classed as highly associated with ash and the remainder are classed as having a partial association with ash. Four of the 15 species had a Red Data Book or IUCN listing.

Step 3 Identify tree and shrub species that could act as alternatives to ash to provide habitat for the ash-associated species

- Using the assessment of alternative trees spreadsheet in the Excel file AshEcol, identify the alternative tree and shrub species that would support the short-listed ash-associated species identified in step 2.

Half of the vulnerable species at Roudsea Wood also use a wide range of alternative tree species which are expected to occur on the site. However, seven of the vulnerable ash-associated species, all of which are Lepidoptera, may be badly affected by loss of ash as the number of alternative tree and shrub species they use is small and may be absent from the site. The six non-obligate species use between one and five alternative trees or shrubs, with the majority using privet (Table 9.2).

Table 9.2 Alternative trees and shrubs used (x) by the ash-associated vulnerable species identified at Roudsea Wood

Ash-associated vulnerable species		Alternative trees and shrubs								
		Alder	Hazel	Aspen	Goat willow	Grey willow	Horse chestnut	Privet	Black poplar	Wych & English Elm
The Coronet	*Craniophora ligustri*	X	X					X		
Dusky Thorn	*Ennomos fuscantaria*						X	X		
Yellow-spot Twist	*Pseudargyrotoza conwagana*							X		
The Brick	*Agrochola circellaris*			X	X	X			X	X
Lilac Beauty	*Apeira syringaria*							X		
Barred Tooth-striped	*Trichopteryx polycommata*							X		
Centre-barred Sallow	*Atethmia centrago*									

Step 4 Assess the site

- Determine the amount and distribution of each tree and shrub species present and how they are likely to respond to management.
- Assess the factors at the site which are likely to have a significant influence on the choice of methods to manage the site.
- Identify the range of tree and shrub species with the potential to grow at the site (e.g. from NVC and the ESC tools) and cross-reference this with your list of alternative tree and shrub species (from step 3 above) to select those which should be encouraged by natural regeneration or planting.

Roudsea Wood is developing into coppice with standards with many small coupes of varying age mixed with patches of stored coppice awaiting a restoration cut. It is being managed primarily for hazel dormouse which is a European Protected Species. The overstorey is generally dominated by oak and small-leaved lime; there are some areas where ash dominates but over a majority of the site the percentage canopy cover of ash is 5 – 10%. Other trees present include birch and hawthorn (which are common), rowan, crab apple, wild service tree and scattered conifers: a small amount of sycamore is present in the overstorey at the southern end of the wood. The understorey is predominantly hazel but other species such as spindle, blackthorn and purging buckthorn are present. Whilst regrowth from coppice stools is vigorous and will ensure continuity of many of the existing trees and shrubs, the absence of substantial natural regeneration of any species during the last 20-30 years of coppice management suggests that changing the relative abundance of different species through natural regeneration may be difficult.

The adverse effects of deer are obvious, including browsing damage to small trees, a browse line and significantly less cover of bramble outside exclosures.

Step 5 Select the most appropriate management method

- Considering the constraints identified in step 4, assess the potential of the site for management when silviculture best practice is followed

- Identify the most appropriate method of management (also consider six generic procedures-Section 5.1) according to the site's objectives and potential for management and aim to maximise the ash-associated biodiversity.

At Roudsea Wood, provision of habitat for hazel dormouse has a significant effect on the choice of stand management. Continued use of coppice with standards with some minor changes to existing procedures is probably the most appropriate method of future management.

Although alternative trees and shrubs for the six species of Lepidoptera species are present on site, they are not common. The spread of species such as wych elm and aspen is unlikely to take place by natural processes. Privet has intermediate shade tolerance and should survive the coppice regime being used; however it has not been seen recently.

The most reliable method to increase the amounts of these species is by planting small numbers of transplants at appropriate locations. Planting should therefore take place within a coppiced area immediately after the fence has been erected and subsequent management should follow best practice to ensure establishment. The control of competitive vegetation within the fenced areas will be important.

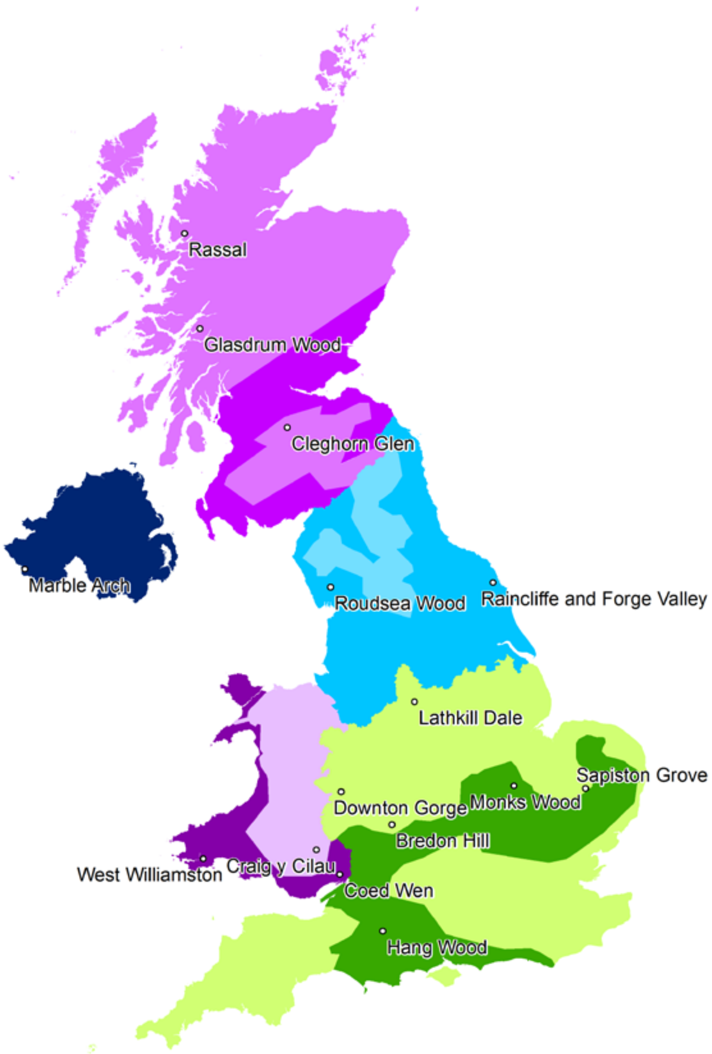

Figure 9.1 Location of 15 case study sites in relation to the 9 ash-relevant regions

9.2.2 Summary findings for the 15 case study sites

The key findings from the 15 case studies are summarised in Table 9.3. The majority of sites had a high forest woodland structure but several were neglected coppice sites, and others had abundant scrub but patchy canopy cover. Current % cover of ash in the canopy varied but was generally high. The number of vulnerable ash-associated species identified for individual sites varied between 2 and 150 species.

For all but one site (Coed Wen), the alternative tree and shrubs required by the sites' vulnerable ash-associated species were already growing at the site, albeit in many cases at low abundance. Privet appeared as a key alternative species that needed to be introduced (at half of the case study sites) to support the vulnerable ash-associated species. Aspen, elder and blackthorn were the other alternative species recommended for introduction at two further sites.

The recommended management actions are not radical. On the whole they focus on maintaining woodland cover and adjusting the relative mix and abundance of species already growing on the site. In some cases this means carrying out relatively intense management interventions (as recommended for Hang Wood), or continuing the current management regime but with slight changes (as recommended for Roudsea Wood). However, for most sites local site factors mean that interventions, different from those currently applied, are needed to achieve these relatively small changes in species composition/abundance. For example interventions such as preventing browsing, thinning, and planting, rather than relying on natural regeneration are needed. For some sites, however, carrying out these interventions may not be practical, e.g. Coed y Cilau, and non-intervention may still be the best option.

Analysis for the case studies has focused on producing recommendations to secure the majority of the mostly closely ash-associated species with the highest conservation status at each site. In general this has meant that only obligate and highly associated species were considered. However, the species records available and the number of ash associated species in each category vary between sites, and at some sites partially associated species were also included. For example, at Roudsea Wood where there were 15 species with high/obligate/partial association with ash, all were considered but at Downton Gorge where there were 115 ash-associated species, only those highly associated were considered. At some sites (eg Hang Wood) the analysis was based entirely on partially associated species as this was the only type present. Where there was a large number of partially associated species present a sub-set of these were selected using other conservation criteria (eg BAP status).

Recommendations made in the case studies are therefore highly dependent on the quality of the species records available for the site. A site that has been comprehensively surveyed for the full range of taxa, relatively recently is likely to have a better diagnosis of the appropriate management responses than those sites where species data are poor. It should also be noted that the alternative tree species considered in the project have been selected as they are likely to establish on site types that support ash; however, they may be only a subset of the range of trees and shrubs used by ash-associated species.

Table 9.3 Summary findings for 15 case studies ([1]Sites vary in size between 12 and 160 hectares; Fig. 9.1 gives locations; [2]vulnerable ash-associated species)

Site[1]	**% ash in canopy**	**Woodland structure**	**Number of species[2]**	**Alternative trees and shrubs**	**Management**
Rassal	85	High forest / wood pasture	125	Several present but abundance low; could introduce aspen	Establish new plants by natural regeneration or planting; prevent browsing damage by herbivores
Glasdrum Wood	40	High forest	150	Several present but abundance low; could introduce blackthorn and elder	Establish new plants by natural regeneration or planting; prevent browsing by herbivores
Cleghorn Glen	30	High forest	55	A variety present but privet should be introduced	Establish transplants in gaps after group felling; protect from browsing damage
Marble Arch	80	High forest	87	A variety present but abundance of some is low	Create gaps of suitable size for natural regeneration or planting
Craig y Cilau	50	Scattered patches of trees amongst large areas of scrub	2	Present but abundance low; will be difficult to increase	Establish transplants in areas fenced to exclude herbivores
West Williamston	80	High forest	5	Common	Create gaps of suitable size for natural regeneration or planting
Coed Wen	90	Neglected coppice with standards	2	None; privet should be introduced	Establish transplants in recently felled coppice coupes
Roudsea Wood	5-10	Coppice with standards and stored coppice	27	Many present but privet should be introduced	Plant privet in fenced, recently felled, coppice coupes
Raincliffe and Forge Valley	45	High forest	9	Present but privet should be introduced	Plant privet in gaps created by group felling
Lathkilll Dale	95	High forest	9	Some present but abundance low; diversity should be increased	Introduce new species by planting in gaps
Downton Gorge	50	High forest	115	Present but privet could be planted	Establish new plants within fenced, recently felled, coppice coupes
Monks Wood	60	High forest	100	Present but abundance low	Felling to reduce overstorey cover; prevent browsing damage by deer
Bredon Hill	45	Wood pasture and scrubby woodland	80	Present but abundance low; could be introduced	Establish trees by planting; prevent browsing damage
Sapiston Grove	75	High forest	61	Present but at low abundance; introduce privet	Establish privet using transplants; prevent deer browsing
Hang Wood	70	Neglected coppice with standards	6	Present	Reduce overstorey cover and prevent deer browsing

10 Discussion

<u>Chapter summary</u>

1. *Potential solutions to ash dieback should consider*
   - *The ecological functioning of ash and how any replacement tree species will alter this*
   - *The impact of any management on ash-associated species*
   - *The impact of any management on the woodland community and woodland structure.*

2. *There is a tension between the ecologically 'most suitable' alternative tree species when assessed by species use and when assessed by ecological function. The alternative tree species that support the greatest number of ash-associated species are very dissimilar to ash when assessed by traits and ecological function. Sessile and pedunculate oak (combined as one assessment) support 640 of the 955 ash-associated species and beech supports 505 ash associated species. However, oak and beech have much slower rates of litter decomposition and nutrient cycling than ash and their canopies cast a much darker shade which will influence the ground flora species present. Alder is similar to ash with respect to decomposition rates, litter quality and nutrient cycling but supports fewer ash-associated species (389 out of 955).*

3. *In addition to considering the number of ash-associated species supported, woodland managers should consider other factors which will influence the occurrence of ash-associated species:*
   - *Woodland structure*
   - *Food supply – eg invertebrates*
   - *The size, shape and number of holes in trees for roosting bats and hole nesting birds*
   - *Interactions between species*
   - *Changes in woodland ground flora composition.*

4. *Ash dieback is just one of many potential drivers of change within woodlands within the UK. Other drivers should be considered alongside ash dieback when considering how to manage for ash-associated species.*

5. *Ash woodlands may also support non-ash-associated species of conservation concern and these should be considered and may over-ride any management for ash-associated species.*

6. *This report aims to provide advice to woodland managers, advisers and policy makers but there is no "straightforward" or "one size fits all" method to conserve ash-associated biodiversity. This report should be used alongside other resources to develop appropriate woodland management plans.*

7. *This report has identified the unknowns with respect to the use made of alternative trees by ash-associated species and provides clear evidence that if those tree species with a low percentage of known data are planted then we do not know what the ecological impact on ash-associated species will be.*

8. *Suggestions for future work are presented.*

10.1 Missing data

Missing data has impacted on the confidence of the some of the analyses presented in this report and in other cases limited the analyses that could be done. However this has been clearly stated and we now know the 'unknowns'.

10.1.1 Missing data on species use of alternative trees

Information on the use made of some non-native tree species by ash-associated species was not available. This should not be seen as a limitation of the report but rather an identification of the unknowns. It provides clear evidence that if those tree species with a low percentage of known data are planted (Figure 3.1) then we do not know what the ecological impact on ash-associated species will be. If the aim is to conserve ash-associated biodiversity and a precautionary approach is required then this identification of unknowns allows this to be done.

10.1.2 Missing trait data

Missing trait data for some alternative tree species prevented a similarity index being calculated to provide one over-arching measure of similarity to ash. However, traits are becoming an increasingly popular research topic with a growing number of trait databases being established. It is possible that in the future this missing data may become available.

Ideally trait data would be linked to ecological function and the use made of the tree by the ash-associated species. The former is a popular research area and these linkages maybe come more apparent with further research.

10.1.3 Missing data on the species present at a site

The use of the tools developed as part of this project requires site managers to know which species are present at their site. Rarely will a complete species list be present for any site. While additional surveys may be considered desirable the resources to undertake them are often lacking.

Lack of a complete species list for a site should not stop managers from using the tools developed. The woodland will almost certainly have been managed to date based on an incomplete knowledge of the species present.

10.2 The impacts of ash dieback and potential ecological solutions

Phase 1 identified the following potential ecological impacts of ash dieback:

1. The ecological functioning of ash (decomposition, nutrient cycling, litter quality, successional processes) is very different from most other tree species within the UK. The loss of ash from ash dominant woodlands will alter the ecological functioning of these woodlands.

2. 955 species are associated with the ash trees, species that are obligate or highly associated with ash are predicted to be most affected if ash-dieback causes large scale (90%) loss of ash trees.

3. The eight NVC woodland communities that ash is dominant in (i.e. W8a, W8b, W8c, W8d, W8e, W8g, W9a and W12a) will change as a result of the loss of ash. These changes will be driven by changes in light: either an increase caused by the loss of ash from the canopy or a decrease caused by the replacement of ash with a tree species that casts more shade. Changes in community composition will lead to

changes in woodland structure which will affect all those species associated with the ash woodland habitat, not just those using the ash trees themselves.

Potential solutions to ash dieback and tools to aid woodland managers to manage for ash associated biodiversity need to consider all of these three potential major ecological impacts.

10.3 The most suitable alternative tree species?

One solution to ash dieback is to replace ash with alternative trees. Phases 1 and 2 of this research have assessed 48 alternative tree species. This does not mean that these 48 tree species are the only alternative trees that support ash-associated species, nor that they are necessarily the most suitable alternatives. Mixtures of tree species have also been shown to support a greater number of ash-associated species than single alternative tree species.

If an alternative tree is to ‘replace’ the ecological role of ash then it should be as similar to ash as possible. The similarity of an alternative tree to ash may be assessed by:

1. Use made of the tree by ash-associated species
2. Tree traits
3. Ecological function

Oak (sessile and pedunculate), beech, elm, sycamore, hazel and birch all support more than 400 ash-associated species, with elm supporting many ash-associated species that are at high risk from ash-dieback. However, identifying the ecologically most suitable alternative tree cannot simply be assessed as which tree species supports the greatest number of ash-associated species; ideally the traits and ecological functioning of the tree should be similar too.

The non-native trees such as American ash, common walnut, green ash, black walnut, and Manchurian ash had a number of traits similar to ash. When assessed by traits these species might be considered good alternatives to ash but data was missing for some traits leading to low confidence in this assessment. In addition there is little information available on the use made of these trees by ash-associated species so a precautionary approach suggests that they should not be considered as ‘good’ ecological alternatives to ash for this reason. This could be reassessed if more data on usage of these species becomes available in future.

The ecological functioning of oak and beech is very different from ash. Thus although these tree species support many of the ash-associated species, they will not maintain the ecological functioning (decomposition rates, nutrient cycling, low levels of shade, etc) associated with ash woodlands. There is thus a tension between the ecologically ‘most suitable’ alternative tree species when assessed by species use and when assessed by ecological function (Table 10.1).

Table 10.1 The suitability of 11 alternative tree species (those assessed in Chapter 2) when ranked by number of ash-associated species supported, traits and ecological function. Those shaded green are classed as 'good' alternative to ash, those shaded red as ecologically 'bad' alternatives to ash

No. of species[1]	Traits[2]	Decomposition[3]	Litter quality[3]	Nutrient cycling[3]
Oak	Alder	Alder	Walnut	Alder
Beech	Aspen	Lime	Alder	Lime
Sycamore	Sycamore	Rowan	Lime	Field maple
Birch	Beech	Sycamore	Aspen	Sycamore
Alder	Wild cherry	Field maple	Field maple	
Rowan		Aspen	Sycamore	
Aspen			Oak	
Field maple			Rowan	
Walnut	Oak		Birch	Oak
Wild cherry	Birch	Oak	Beech	Birch
Lime	Lime	Beech	Wild cherry	Beech

[1]Green = supports >450 ash-associated species, amber = supports 300-450 ash associated species, red = supports < 300 ash-associated species.
[2]Ranking of traits taken from Phase 1 report where a similarity index was calculated. It was not possible to do this in Phase 2 due to missing data for many species.
[3]Ranking taken from Chapter 2.

10.4 Management scenarios

The management scenario analyses show the difficulties of managing for obligate and highly associated ash species but also the potential to mitigate the impacts of ash-dieback for many partially associated species. The response of the partially associated species to the management scenarios was often species-specific, even within a species group. Thus although the impacts of ash dieback on partially associated species can be mitigated, there is a clear need to: a) identify which species are partially associated with ash; and b) assess which alternative trees these species will use. The development of AshEcol allows woodland managers to do this by providing a list of all species known to use ash in the UK and their level of association with ash, and providing information on which alternative trees they will also use.

10.5 The importance of woodland structure and community composition

In order to make assessments and comparisons between different alternative tree species the tree species have often been ranked, with 'good' alternatives simply defined by the number of ash-associated species supported. In addition, whether an ash-associated species will or will not use an alternative tree species has been simplified to 'yes' or 'no'. These simplifications provide useful information for woodland managers but should not be taken in isolation. For many ash-associated species it is not just the species of tree present that is important but also the woodland structure and the presence of other species. These caveats have been noted by the species experts in making their assessments of alternative tree species and the impact of the management scenarios on ash-associated species (Appendix 4 and the AshEcol excel spreadsheets).

Some of the key considerations with regard to woodland structure and community composition that should be considered alongside information on the use made of alternative tree species are:

- For ash-associated birds such as blackcap, chiffchaff, wren and spotted flycatcher the structure of the wood is more important than the tree species and any tree species providing light or open canopy and allowing a dense low shrub layer to develop may be suitable.

- The invertebrate community supported by the woodland will also be important when assessing the suitability of alternative trees for many bird species.

- For bat species that use trees for roosting, the species of tree is less important than the size and shape of the holes (used for roosting) within the tree. Thus it is the likelihood of old trees forming suitable holes that is important rather than the tree species as such. Thus small trees and shrubs that rarely yield tree holes are unlikely to be suitable alternatives for bats.

- For many lichens and some bryophytes the age of tree is important in addition to the tree species, with older trees generally supporting more lichens in particular.

- The interaction between species needs to be taken into account when considering suitable alternative trees. For example, whilst red squirrels may utilise and benefit from presence of medium/large-seeded deciduous trees in the absence of grey squirrels, the planting of such trees where greys are present would have significant negative impacts for red squirrels.

- Changes in the canopy composition (ie which alternative trees are encouraged or planted) will influence the ground flora due to changes in light levels and nutrient cycling. This report has focused on the species that use ash trees but the impacts on the ground flora (often the reason for the conservation designation of many ash woodlands) should also be considered – see Phase 1 report.

10.6 Other drivers of change

Ash dieback is just one of many potential drivers of change within woodlands within the UK. Other drivers include:

- Other tree diseases
- Grazing
- Climate change
- Land management e.g. coppicing
- Pollution

These drivers need to be considered alongside the impacts caused by ash dieback.

10.7 Other conservation concerns

These reports (Phase 1 & 2) and the related case studies have highlighted the potential ecological impacts of ash dieback and suggested ways to manage for ash-associated species should ash dieback cause the death of a large percentage of ash trees in the UK. However if the aim at a site is to manage for wider conservation aims, not just ash-associated biodiversity, then there may be other conservation concerns that will need to be taken into consideration. For example; there may be species present that are not associated with ash that are of greater conservation concern than any of the ash-associated species. If the management to conserve ash-associated species is to the detriment of other species of conservation concern then these non-ash-associated species may have to be prioritized. Such decisions have to be made on a site by site basis depending on the objectives of the site management.

10.8 Tools for managers

A five-step procedure to develop management recommendations for ash-associated species has been developed. Information on 955 ash-associated species and their use of 48 alternative tree species has been collated into the AshEcol spreadsheets. The use of these two tools will allow woodland managers to assess how they can adapt their management to aid ash-associated biodiversity in face of ash dieback. Examples of how this has been done for 15 case studies are provided.

However it should be stressed that these resources are tools not answers. There is no “straightforward” or “one size fits all” method to conserve ash-associated biodiversity. Each woodland manager should use these resources taking into consideration the limitations outlined in sections 9.2-9.6 to develop suitable management plans that meet the objectives for the wood they are managing.

10.9 Future work

The following future work would develop further our knowledge of the suitability of alternative tree species to ash:

1. A more sophisticated analysis of which mixtures of tree species support the greatest number of ash-associated species would be useful. This analysis should pick tree species which require similar growing conditions and are suitable to be grown together and then assess the mixtures of those species that support the greatest number of ash-associated species.

2. A comparative study of bird communities in mature non-native plantations could fill some of the gaps in our knowledge.

3. While bark pH is known to be important for lichens and bryophytes and many papers report such findings, the actual data (bark pH) is rarely published. Collecting information on the bark pH of tree species being considered to replace ash would aid the assessment of their suitability as a replacement.

4. The shade cast by trees is known to influence the ground flora beneath them but there is no consistent data on the relative shade cast by different tree species.

5. Work on how mixtures of tree species might influence ecological function would be beneficial.

6. More recording of species use of non-native tree species. For example surveys of bryophytes and lichens in parks and botanic gardens were some of the non-native trees considered as alternative tree species grown. This will allow us to start to accumulate data on the use of these tree species in a UK environment.

11 Conclusion

With regard to the alternative tree species considered within this report the following conclusions may be made:

- Those species that may support the greatest number of ash-associated species (oak and beech) will not replace the ecological functioning of ash within woodlands. They will cause a major change in the functioning of the woodland, for example increasing shade and slowing down nutrient cycling.

- With regard to ecological functioning, alder, lime and rowan are most similar to ash with oak and beech most dissimilar and sycamore, field maple and aspen intermediate. The exception to this is for successional processes where beech and oak are more similar to ash in being late successional species of similar height and with similar gap colonisation strategies (particularly beech).

- Elm is able to support a large number of ash-associated species but has already declined in distribution due to Dutch elm disease. Alder is currently being affected by *Phytophthora alni* and may decline. These tree diseases may limit the suitability of these two species as alternative tree species to ash. Other tree species may of course also be affected by diseases not yet known to be a problem.

- Native species generally support more ash-associated species than non-native tree species, with the exception of sycamore which supports as many ash-associated species as some native tree species. Some of this difference may be due to poorer data availability for many non-native species.

- Non-native ash species may support some ash-associated species, but this is largely based on expert judgement rather than known records of ash-associated species using these tree species. Some of the non-native ash species, particularly Manchurian ash, are also susceptible to ash dieback, limiting their suitability as replacements for ash.

- Elm, oak, hazel, aspen and sycamore support the greatest number of ash-associated species that are most at risk (those with a high level of association with ash and a high level of conservation concern).

- For the alternative tree species assessed in this project we have identified those which have little data on the use made of them by ash-associated species. If these tree species are planted to replace ash then it should be done in the knowledge that we do not know the potential ecological impact of such plantings.

With regard to the management scenarios considered within this report the following conclusions may be made:

- In the first ten years thinning (management scenario (5)) is predicted to be better than felling with natural regeneration promoted for obligate and highly associated ash species.

- In the short-term (1-10 years) management scenarios (5) thinning; (6) felling with natural regeneration were predicted to be intermediate in their impact on obligate and highly associated ash species compared to scenarios (1) non-intervention and (2) no felling with natural regeneration promoted which are predicted to be best for ash-associated biodiversity and scenarios (3) felling and (4) felling and replanting which are predicted to be worst for ash-associated biodiversity.

- In the long-term (50-100 years) there is predicted to be little difference between the six management scenarios in their impact on obligate and highly associated species.

- Under the management scenarios tested partially associated ash species are predicted to decline initially following the arrival of ash dieback but after 50-100 years the majority of partially associated species are predicted to be unchanged in abundance compared to current population levels due to an increase in the abundance of other tree species which they utilise.

- After 50-100 years some partially associated ash species are predicted to have greater abundance than at present, as ash dies out and is replaced with alternative tree species that the partially associated species are more highly associated with.

- Partially associated species show some very species specific responses to the management scenarios, illustrating the importance of knowing which ash-associated species are present on a site and which alternative tree species they will use if partially associated ash species are to be conserved.

- The results suggest that for the majority of partially associated ash species, if the correct management is undertaken the impacts of ash dieback on partially associated species can be mitigated.

12 References

ATKINSON, M.D. 1992. *Betula-pendula* Roth (*B-verrucosa* Ehrh) and *B-pubescens* Ehrh. *Journal of Ecology*, 80, 837-870.

AVERILL, C., TURNER, B.L. FINZI, A.C. 2014. Mycorrhiza-mediate competition between plants and decomposers drivers soil carbon storage. *Nature*, 505, 7484.

AUGUSTO, L., RANGER, J., BINKLEY, D., ROTHE, A. 2002. Impact of several common tree species of European temperate forests on soil fertility. *Annals of Forest Science*, 59, 233-253.

AYRES, E., DROMPH, K.M., BARDGETT, R.D. 2006. Do plant species encourage soil biota that specialise in the rapid decomposition of their litter? *Soil Biology & Biochemistry*, 38, 183-186.

BARKMAN, J.J. 1958. *Phytosociology and Ecology of Cryptogamic Epiphytes*. Netherlands: Van Gorcum & Co., 628 pp.

BJORNLUND, L., CHRISTENSEN, S. 2005. How does litter quality and site heterogeneity interact on decomposer food webs of a semi-natural forest? *Soil Biology & Biochemistry*, 37, 203-213.

BOBIEC, A. 2007. The influence of gaps on tree regeneration: A case study of the mixed lime-hornbeam (*Tilio-Carpinetum* Tracz. 1962) communities in the Bialowieza primeval forest. *Polish Journal of Ecology*, 55, 441-455.

BREZINA, I., DOBROVOLNY, L. 2011. Natural regeneration of sessile oak under different light conditions. *Journal of Forest Science*, 57, 359-368.

CALLESEN, I., NILSSON, L.O., SCHMIDT, I.K., VESTERDAL, L., AMBUS, P., CHRISTIANSEN, J.R., HOGBERG, P., GUNDERSEN, P. 2013. The natural abundance of N-15 in litter and soil profiles under six temperate tree species: N cycling depends on tree species traits and site fertility. *Plant and Soil*, 368, 375-392.

CAQUET, B., MONTPIED, P., DREYER, E., EPRON, D., COLLET, C. 2010. Response to canopy opening does not act as a filter to *Fagus sylvatica* and *Acer* sp advance regeneration in a mixed temperate forest. *Annals of Forest Science*, 67, 105.

CARNOL, M., BAZGIR, M. 2013. Nutrient return to the forest floor through litter and throughfall under 7 forest species after conversion from norway spruce. *Forest Ecology and Management*, 309, 66-75.

CESARZ, S., FENDER, A.C., BEYER, F., VALTANEN, K., PFEIFFER, B., GANSERT, D., HERTEL, D., POLLE, A., DANIEL, R., LEUSCHNER, C., SCHEU, S. 2013. Roots from beech (*Fagus sylvatica* L.) and ash (*Fraxinus excelsior* L.) differentially affect soil microorganisms and carbon dynamics. *Soil Biology & Biochemistry*, 61, 23-32.

Cheffings, C., Farrell, L. 2006. The Vascular Plant Red Data List for Great Britain. http://jncc.defra.gov.uk/page-3354.

CLUZEAU, C. 1992. Colonization dynamics of alder (*Alnus-glutinosa*) in an eutrophic swamp of the floodplain of the upper rhone. *Annales des Sciences Forestieres*, 49, 539-548.

COLLET, C., PIBOULE, A., LEROY, O., FROCHOT, H. 2008. Advance *Fagus sylvatica* and *Acer pseudoplatanus* seedlings dominate tree regeneration in a mixed broadleaved former coppice-with-standards forest. *Forestry*, 81, 135-150.

Conrad, K.F., Warren, M.S., Fox, R., Parsons, M.S., Woiwod, I.P. 2006. Rapid declines of common, widespread British moths provide evidence of an insect biodiversity crisis. *Biological Conservation,* 132, 279–291.

COOLS, N., VESTERDAL, L., VOS, B., VANGUELOVA, E., HANSEN, K. 2014. Tree species is the major factor explaining C:N ratios in european forest soils. *Forest Ecology and Management*, 311, 3-16.

Cornelissen, J.H.C., Thompson, K. 1997. Functional leaf attributes predict litter decomposition rate in herbaceous plants. *New Phytologist*, 135, 109-114.

CORTEZ, J. 1998. Field decomposition of leaf litters: Relationships between decomposition rates and soil moisture, soil temperature and earthworm activity. *Soil Biology & Biochemistry*, 30, 783-793.

CORTEZ, J., DEMARD, J.M., BOTTNER, P., MONROZIER, L.J. 1996. Decomposition of mediterranean leaf litters: A microcosm experiment investigating relationships between decomposition rates and litter quality. *Soil Biology & Biochemistry*, 28, 443-452.

COTRUFO, M.F., BRIONES, M.J.I., INESON, P. 1998. Elevated CO_2 affects field decomposition rate and palatability of tree leaf litter: Importance of changes in substrate quality. *Soil Biology & Biochemistry*, 30, 1565-1571.

COTRUFO, M.F., INESON, P., ROWLAND, A.P. 1994. Decomposition of tree leaf litters grown under elevated CO_2 - effect of litter quality. *Plant and Soil*, 163, 121-130.

Davis, T. 2012. *A Review of the Status of Microlepidoptera in Britain*. Wareham.

DE SANTO, A.V., DE MARCO, A., FIERRO, A., BERG, B., RUTIGLIANO, F.A. 2009. Factors regulating litter mass loss and lignin degradation in late decomposition stages. *Plant and Soil*, 318, 217-228.

DIACI, J., ADAMIC, T., ROZMAN, A. 2012. Gap recruitment and partitioning in an old-growth beech forest of the dinaric mountains: Influences of light regime, herb competition and browsing. *Forest Ecology and Management*, 285, 20-28.

DON, A., KALBITZ, K. 2005. Amounts and degradability of dissolved organic carbon from foliar litter at different decomposition stages. *Soil Biology & Biochemistry*, 37, 2171-2179.

EATON M.A., BROWN A.F., NOBLE D.G., MUSGROVE A.J., HEARN, R., AEBISCHER, N.J., GIBBONS D.W., EVANS, A., GREGORY, R.D. 2009. Birds of Conservation Concern 3: the population status of birds in the United Kingdom, Channel Islands and the Isle of Man. *British Birds,* 102, 296–341.

EMBERLIN, J., BAILLIE, I. 1980. Aspects of birch regeneration in two woods at Inverpolly national nature reserve, wester ross. *Scottish Forestry*, 34, 13-34.

EMBORG, J. 1998. Understorey light conditions and regeneration with respect to the structural dynamics of a near-natural temperate deciduous forest in Denmark. *Forest Ecology and Management*, 106, 83-95.

EMMER, I. 1999. Litter decomposition and soil nitrogen dynamics (1995-1996) in the Krkonose national park. *Journal of Forest Science*, 45, 316-327.

EVANS, S., HENRICI A., ING, B. 2006. The Red Data List Of Threatened British Fungi. http://www.fieldmycology.net/Download/RDL_of_Threatened_British_Fungi.pdf.

FELTON, A., BOBERG, J., BJORKMAN, C., WIDENFALK, O. 2013. Identifying and managing the ecological risks of using introduced tree species in Sweden's production forestry. *Forest Ecology and Management*, 307, 165–177.

FREMSTAD, E. 1983. Role of black alder (*Alnus glutinosa*) in vegetation dynamics in west norway. *Nordic Journal of Botany*, 3, 393-410.

GAUTHIER, M.M., JACOBS, D.F. 2010. Ecophysiological responses of black walnut (*Juglans nigra*) to plantation thinning along a vertical canopy gradient. *Forest Ecology and Management*, 259, 867-874.

GOEBEL, M., HOBBIE, S.E., BULAJ, B., ZADWORNY, M., ARCHIBALD, D.D., OLEKSYN, J., REICH, P.B., EISSENSTAT, D.M. 2011. Decomposition of the finest root branching orders: Linking belowground dynamics to fine-root function and structure. *Ecological Monographs*, 81, 89-102.

GURMESA, G., SCHMIDT, I., GUNDERSEN, P., VESTERDAL, L. 2013. Soil carbon accumulation and nitrogen retention traits of four tree species grown in common gardens. *Forest Ecology and Management*, 309, 47-57.

HAGEN-THORN, A., CALLESEN, I., ARMOLAITIS, K., NIHLGARD, B. 2004. The impact of six European tree species on the chemistry of mineral topsoil in forest plantations on former agricultural land. *Forest Ecology and Management*, 195, 373-384.

HAGEN-THORN, A., VARNAGIRYTE, I., NIHLGARD, B., ARMOLAITIS, K. 2006. Autumn nutrient resorption and losses in four deciduous forest tree species. *Forest Ecology and Management*, 228, 33-39.

HANSEN, K., VESTERDAL, L., SCHMIDT, I.K., GUNDERSEN, P., SEVEL, L., BASTRUP-BIRK, A., PEDERSEN, L.B., BILLE-HANSEN, J. 2009. Litterfall and nutrient return in five tree species in a common garden experiment. *Forest Ecology and Management*, 257, 2133-2144.

HEIN, S., COLLET, C., AMMER, C., LE GOFF, N., SKOVSGAARD, J.P., SAVILL, P. 2009. A review of growth and stand dynamics of *Acer pseudoplatanus* L. In Europe: Implications for silviculture. *Forestry*, 82, 361-385.

HOBBIE, S.E., OLEKSYN, J., EISSENSTAT, D.M., REICH, P.B. 2010. Fine root decomposition rates do not mirror those of leaf litter among temperate tree species. *Oecologia*, 162, 505-513.

HOBBIE, S.E., REICH, P.B., OLEKSYN, J., OGDAHL, M., ZYTKOWIAK, R., HALE, C., KAROLEWSKI, P. 2006. Tree species effects on decomposition and forest floor dynamics in a common garden. *Ecology*, 87, 2288-2297.

Hodgetts, N.G. 2011. A revised Red List of bryophytes in Britain. Field Bryology,103, 40-49.

HOLZWARTH, F.M., DAENNER, M., FLESSA, H. 2011. Effects of beech and ash on small-scale variation of soil acidity and nutrient stocks in a mixed deciduous forest. *Journal of Plant Nutrition and Soil Science*, 174, 799-808.

HOWARD, P.J.A., HOWARD, D.M. 1974. Microbial decomposition of tree and shrub leaf litter .1. Weight-loss and chemical composition of decomposing litter. *Oikos*, 25, 341-352.

JACOB, M., VIEDENZ, K., POLLE, A., THOMAS, F.M. 2010. Leaf litter decomposition in temperate deciduous forest stands with a decreasing fraction of beech (*Fagus sylvatica*). *Oecologia*, 164, 1083-1094.

JACOB, M., WELAND, N., PLATNER, C., SCHAEFER, M., LEUSCHNER, C., THOMAS, F.M. 2009. Nutrient release from decomposing leaf litter of temperate deciduous forest trees along a gradient of increasing tree species diversity. *Soil Biology & Biochemistry*, 41, 2122-2130.

JARCUSKA, B. 2009. Growth, survival, density, biomass partitioning and morphological adaptations of natural regeneration in fagus sylvatica. A review. *Dendrobiology*, 61, 3-11.

JONARD, M., ANDRE, F., PONETTE, Q. 2008. Tree species mediated effects on leaf litter dynamics in pure and mixed stands of oak and beech. *Canadian Journal of Forest Research-Revue Canadienne de Recherche Forestiere*, 38, 528-538.

JONES, E.W. 1945a. *Acer campestre* L. *Journal of Ecology*, 32, 239-252.

JONES, E.W. 1945b. *Acer pseudo-platanus* L. *Journal of Ecology*, 32, 220-237.

JONES, E.W. 1959. Biological flora of the British-Isles *Quercus* L. *Journal of Ecology*, 47, 169-222.

JONSSON, M.T. & THOR, G. 2012. Estimating coextinction risks from epidemic tree death: affiliate lichen communities among diseased host tree populations of *Fraxinus excelsior*. *Plos One*, *7*. Available from: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0045701 [Accessed March 2013].

KALYONCU, I.H., ERSOY, N., YILMAZ, M. 2009. Some physico-chemical properties and mineral contents of sweet cherry (*Prunus avium* L.) type grown in Konya. *African Journal of Biotechnology*, 8, 2744-2749.

KATTGE, J., S. DÍAZ, S. LAVOREL, I. C. PRENTICE, P. LEADLEY, G. BÖNISCH, E. GARNIER, M. WESTOBY, P. B. REICH, I. J. WRIGHT, J. H. C. CORNELISSEN, C. VIOLLE, S. P. HARRISON, P. M. V. BODEGOM, M. REICHSTEIN, B. J. ENQUIST, N. A. SOUDZILOVSKAIA, D. D. ACKERLY, M. ANAND, O. ATKIN, M. BAHN, T. R. BAKER, D. BALDOCCHI, R. BEKKER, C. BLANCO, B., BLONDER, W. J. BOND, R. BRADSTOCK, D. E. BUNKER, F. CASANOVES, J. CAVENDER-BARES, J. Q. CHAMBERS, F. S. CHAPIN, J. CHAVE, D. COOMES, W. K. CORNWELL, J. M. CRAINE, B. H. DOBRIN, L. DUARTE, W. DURKA, J. ELSER, G. ESSER, M. ESTIARTE, W. F. FAGAN, J., FANG, F. FERNÁNDEZ-MÉNDEZ, A. FIDELIS, B. FINEGAN, O. FLORES, H. FORD, D. FRANK, G., T. FRESCHET, N. M. FYLLAS, R. V. GALLAGHER, W. A. GREEN, A. G. GUTIERREZ, T. HICKLER, S. HIGGINS, J. G. HODGSON, A. JALILI, S. JANSEN, C. JOLY, A. J. KERKHOFF, D. KIRKUP, K., KITAJIMA, M. KLEYER, S. KLOTZ, J. M. H. KNOPS, K. KRAMER, I. KÜHN, H. KUROKAWA, D., LAUGHLIN, T. D. LEE, M. LEISHMAN, F. LENS, T. LENZ, S. L. LEWIS, J. LLOYD, J. LLUSIÀ, F., LOUAULT, S. MA, M. D. MAHECHA, P. MANNING, T. MASSAD, B. MEDLYN, J. MESSIER, A. T., MOLES, S. C. MÜLLER, K. NADROWSKI, S. NAEEM, Ü. NIINEMETS, S. NÖLLERT, A. NÜSKE, R., OGAYA, J. OLEKSYN, V. G. ONIPCHENKO, Y. ONODA, J. ORDOÑEZ, G. OVERBECK, W. A., OZINGA, S. PATIÑO, S. PAULA, J. G. PAUSAS, J. PEÑUELAS, O. L. PHILLIPS, V. PILLAR, H., POORTER, L. POORTER, P. POSCHLOD, A. PRINZING, R. PROULX, A. RAMMIG, S. REINSCH, B., REU, L. SACK, B. SALGADO-NEGRET, J. SARDANS, S. SHIODERA, B. SHIPLEY, A. SIEFERT, E., SOSINSKI, J.-F. SOUSSANA, E. SWAINE, N. SWENSON, K. THOMPSON, P. THORNTON, M., WALDRAM, E. WEIHER, M. WHITE, S. WHITE, S. J. WRIGHT, B. YGUEL, S. ZAEHLE, A. E., ZANNE, C. WIRTH. 2011. TRY – a global database of plant traits. *Global Change Biology*, 17, 2905–2935.

KAZDA, M., SALZERL, J., SCHMID, I., VON WRANGELL, P. 2004. Importance of mineral nutrition for photosynthesis and growth of *Quercus petraea, Fagus sylvatica* and *Acer pseudoplatanus* planted under norway spruce canopy. *Plant and Soil*, 264, 25-34.

KING, R.F., DROMPH, K.M., BARDGETT, R.D. 2002. Changes in species evenness of litter have no effect on decomposition processes. *Soil Biology & Biochemistry*, 34, 1959-1963.

Kirby, P. 1992. *A review of the scarce and threatened Hemiptera of Great Britain*. Joint Nature Conservation Committee.

KJÆR, E.D., MCKINNEY, L.V., NIELSEN, L.R., HANSEN, L.N. & HANSEN, J.K. 2012. Adaptive potential of ash (*Fraxinus excelsior*) populations against the novel emerging pathogen Hymenoscyphus pseudoalbidus. *Evolutionary Applications*, 5, 219-228.

KLEYER, M., BEKKER, R.M., KNEVEL, I.C., BAKKER, J.P, THOMPSON, K., SONNENSCHEIN, M., POSCHLOD, P., VAN GROENENDAEL, J.M., KLIMES, L., KLIMESOVÁ, J., KLOTZ, S., RUSCH, G.M., HERMY, M., ADRIAENS, D., BOEDELTJE, G., BOSSUYT, B., DANNEMANN, A., ENDELS, P., GÖTZENBERGER, L., HODGSON, J.G., JACKEL, A-K., KÜHN, I., KUNZMANN, D., OZINGA, W.A., RÖMERMANN, C., STADLER, M., SCHLEGELMILCH, J., STEENDAM, H.J., TACKENBERG, O., WILMANN, B., CORNELISSEN, J.H.C., ERIKSSON, O., GARNIER, E., PECO, B. 2008: The LEDA Traitbase: A database of life-history traits of Northwest European flora. *Journal of Ecology*, 96, 1266-1274.

KULL, O., TULVA, I. 2002. Shoot structure and growth along a vertical profile within a populus-tilia canopy. *Tree Physiology*, 22, 1167-1175.

KUROKAWA, H., PELTZER, D.A. AND WARDLE, D.A. 2010. Plant traits, leaf palatability and litter decomposability for co-occurring woody species differing in invasion status and nitrogen fixation ability. *Functional Ecology*, 24, 513–523.

LADEGAARD-PEDERSEN, P., ELBERLING, B., VESTERDAL, L. 2005. Soil carbon stocks, mineralization rates, and CO_2 effluxes under 10 tree species on contrasting soil types. *Canadian Journal of Forest Research-Revue Canadienne de Recherche Forestiere*, 35, 1277-1284.

LANGENBRUCH, C., HELFRICH, M., FLESSA, H. 2012. Effects of beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*) and lime (*Tilia* spec.) on soil chemical properties in a mixed deciduous forest. *Plant and Soil*, 352, 389-403.

LEITGEB E., GARTNER K., NADEZHDINA N., ENGLISCH M., CERMAK J. 2002. Ecological effects of pioneer species on soil moisture regime in an early successional stage, following wind-throw in a spruce stand. *Proceedings of the IUFRO Conference on Restoration of Boreal and Temperate Forests / Gardiner E.S., Breland L.J. [Comp.] Reports / Skov & Landskab,* (11): 193-194. http://bfw.ac.at/300/2019.html.

LIGOT, G., BALANDIER, P., FAYOLLE, A., LEJEUNE, P., CLAESSENS, H. 2013. Height competition between *Quercus petraea* and *Fagus sylvatica* natural regeneration in mixed and uneven-aged stands. *Forest Ecology and Management*, 304, 391-398.

LORENZ, K., PRESTON, C.M., KRUMREI, S., FEGER, K.H. 2004. Decomposition of needle/leaf litter from scots pine, black cherry, common oak and European beech at a conurbation forest site. *European Journal of Forest Research*, 123, 177-188.

LOSING, H. 2013. Eschentriebsterben:symptome und Toleranz von Arten und sorten gegenuber dem Erreger. *Eschentriebsterben.*

LUMMER, D., SCHEU, S., BUTENSCHOEN, O. 2012. Connecting litter quality, microbial community and nitrogen transfer mechanisms in decomposing litter mixtures. *Oikos*, 121, 1649-1655.

MADSEN, P., HAHN, K. 2008. Natural regeneration in a beech-dominated forest managed by close-to-nature principles - a gap cutting based experiment. *Canadian Journal of Forest Research-Revue Canadienne de Recherche Forestiere*, 38, 1716-1729.

MARCOS, E., CALVO, L., ANTONIO MARCOS, J., TABOADA, A., TARREGA, R. 2010. Tree effects on the chemical topsoil features of oak, beech and pine forests. *European Journal of Forest Research*, 129, 25-30.

MCVEAN, D.N. 1953. *Alnus-glutinosa* (l) gaertn (a rotundifolia stokes). *Journal of Ecology*, 41, 447-466.

MICHAELS, H.J., BENNER, B., HARTGERINK, A.P., LEE, T.D., RICE, S., WILLSON, M.F., BERTIN, R.I. 1988. Seed size variation: magnitude, distribution, and ecological correlates. *Evolutionary Ecology*, 2, 157-166.

MOUNTFORD, E., PETERKEN, G., EDWARDS, P., MANNERS, J. 1999. Long-term change in growth, mortality and regeneration of trees in denny wood, an old-growth wood-pasture in the new forest (UK). *Perspectives in Plant Ecology, Evolution and Systematics*, 2, 223-272.

MUYS, B., BERGE, K., ROSKAMS, P., MADDELEIN, D., MEYEN, S. 1988. Analysis of natural regeneration in a 200 years old beech stand. *Silva Gandavensis*, 61-81.

MYKING, T., BOHLER, F., AUSTRHEIM, G., SOLBERG, E.J. 2011. Life history strategies of aspen *(Populus tremula* L.) and browsing effects: A literature review. *Forestry*, 84, 61-71.

NAGEL, T.A., SVOBODA, M., RUGANI, T., DIACI, J. 2010. Gap regeneration and replacement patterns in an old-growth *Fagus-abies* forest of Bosnia-Herzegovina. *Plant Ecology*, 208, 307-318.

NEIRYNCK, J., MIRTCHEVA, S., SIOEN, G., LUST, N. 2000. Impact of *Tilia platyphyllos* scop., *Fraxinus excelsior* L., *Acer pseudoplatanus* L., *Quercus robur* L. and *Fagus sylvatica* L. On earthworm biomass and physico-chemical properties of a loamy topsoil. *Forest Ecology and Management*, 133, 275-286.

NORDEN, U. 1994. Leaf litterfall concentrations and fluxes of elements in deciduous tree species. *Scandinavian Journal of Forest Research*, 9, 9-16.

OGILVY, T.K., LEGG, C.J., HUMPHREY, J.W. 2006. Diversifying native pinewoods using artificial regeneration. *Forestry*, 79, 309-317.

OOSTRA, S., MAJDI, H., OLSSON, M. 2006. Impact of tree species on soil carbon stocks and soil acidity in southern sweden. *Scandinavian Journal of Forest Research*, 21, 364-371.

PACKHAM, J.R., THOMAS, P.A., ATKINSON, M.D., DEGEN, T. 2012. Biological flora of the British Isles: *Fagus sylvatica*. *Journal of Ecology*, 100, 1557-1608.

PAUTASSO, M., GREGOR, A., QUELOZ, V. & HOLDENRIEDER, O. 2013. European ash (*Fraxinus excelsior*) dieback – A conservation biology challenage. *Biological Conservation*, 158, 37–49.

PEICHL, M., LEAVA, N.A., KIELY, G. 2012. Above- and belowground ecosystem biomass, carbon and nitrogen allocation in recently afforested grassland and adjacent intensively managed grassland. *Plant and Soil*, 350, 281-296.

PELTIER, A., TOUZET, M.C., ARMENGAUD, C., PONGE, J.F. 1997. Establishment of *Fagus sylvatica* and *Fraxinus excelsior* in an old-growth beech forest. *Journal of Vegetation Science*, 8, 13-20.

PETRITAN, A., NUSKE, R., PETRITAN, I., TUDOSE, N. 2013. Gap disturbance patterns in an old-growth sessile oak (*Quercus petraea* L.) - European beech (*Fagus sylvatica* L.) forest remnant in the carpathian mountains, Romania. *Forest Ecology and Management*, 308, 67-75.

PETRITAN, A.M., VON LUEPKE, B., PETRITAN, I.C. 2007. Effects of shade on growth and mortality of maple (*Acer pseudoplatanus*), ash (*Fraxinus excelsior*) and beech (*Fagus sylvatica*) saplings. *Forestry*, 80, 397-412.

PETRITAN, A.M., VON LUEPKE, B., PETRITAN, I.C. 2010. A comparative analysis of foliar chemical composition and leaf construction costs of beech (*Fagus sylvatica* L.), sycamore maple (*Acer pseudoplatanus* L.) and ash (*Fraxinus excelsior* L.) saplings along a light gradient. *Annals of Forest Science*, 67.

PETROKAS, R. 2010. Prerequisites for the reproduction of wild cherry (*Prunus avium* L.). *Baltic Forestry*, 16, 139-153.

PIGOTT, C.D. 1991. *Tilia-cordata* miller. *Journal of Ecology*, 79, 1147-1207.

PORTSMUTH, A., NIINEMETS, U. 2007. Structural and physiological plasticity in response to light and nutrients in five temperate deciduous woody species of contrasting shade tolerance. *Functional Ecology*, 21, 61-77.

RAJAPAKSHA, N., BUTT, K., VANGUELOVA, E., I, MOFFAT, A. 2013. Earthworm selection of short rotation forestry leaf litter assessed through preference testing and direct observation. *Soil Biology & Biochemistry*, 67, 12-19.

RASPE, O., FINDLAY, C., JACQUEMART, A.L. 2000. *Sorbus aucuparia* L. *Journal of Ecology*, 88, 910-930.

RIUTTA, T., SLADE, E.M., BEBBER, D.P., TAYLOR, M.E., MALHI, Y., RIORDAN, P., MACDONALD, D.W., MORECROFT, M.D. 2012. Experimental evidence for the interacting effects of forest edge, moisture and soil macrofauna on leaf litter decomposition. *Soil Biology & Biochemistry*, 49, 124-131.

ROZAS, V. 2003. Regeneration patterns, dendroecology, and forest-use history in an old-growth beech-oak lowland forest in northern spain. *Forest Ecology and Management*, 182, 175-194.

SARIYILDIZ, T., ANDERSON, J.M. 2003a. Decomposition of sun and shade leaves from three deciduous tree species, as affected by their chemical composition. *Biology and Fertility of Soils*, 37, 137-146.

SARIYILDIZ, T., ANDERSON, J.M. 2003b. Interactions between litter quality, decomposition and soil fertility: A laboratory study. *Soil Biology & Biochemistry*, 35, 391-399.

SARIYILDIZ, T., ANDERSON, J.M. 2005. Variation in the chemical composition of green leaves and leaf litters from three deciduous tree species growing on different soil types. *Forest Ecology and Management*, 210, 303-319.

SCHADLER, M., BRANDL, R. 2005. Do invertebrate decomposers affect the disappearance rate of litter mixtures? *Soil Biology & Biochemistry*, 37, 329-337.

SHILENKOVA, O.L., TIUNOV, A.V. 2013. Soil-litter nitrogen transfer and changes in delta C-13 and delta N-15 values in decomposing leaf litter during laboratory incubation. *Pedobiologia*, 56, 147-152.

SLADE, E.M., RIUTTA, T. 2012. Interacting effects of leaf litter species and macrofauna on decomposition in different litter environments. *Basic and Applied Ecology*, 13, 423-431.

STRAIGYTE, L., JURKSIENE, G., ARMOLAITIS, K. 2009. Decomposition of oak and maple leaf litters: Comparative study of native and alien species. *Rural Development 2009 Proceedings, Vol 4, Book 2, Proceedings*, 196-200.

SURMEN, B., KUTBAY, H., KLC, D. 2012. Foliar resorption in a nitrogen-fixing *Alnus glutinosa* L. and non-fixing *Acer campestre* L. In swamp forest of Hacosman nature protection area (Samsun/Turkey). *BIBAD, Biyoloji Bilimleri Arastrma Dergisi*, 5, 13-19.

SZWAGRZYK, J., SZEWCZYK, J., BODZIARCZYK, J. 2001. Dynamics of seedling banks in beech forest: Results of a 10-year study on germination, growth and survival. *Forest Ecology and Management*, 141, 237-250.

TAUGOURDEAU, O., SABATIER, S. 2010. Limited plasticity of shoot preformation in response to light by understorey saplings of common walnut (*Juglans regia*). *Aob Plants*, 110, 1-8. doi:10.1093/aobpla/plq022.

TIUNOV, A.V. 2009. Particle size alters litter diversity effects on decomposition. *Soil Biology & Biochemistry*, 41, 176-178.

VAN COUWENBERGHE, R., COLLET, C., LACOMBE, E., PIERRAT, J.C., GEGOUT, J.C. 2010. Gap partitioning among temperate tree species across a regional soil gradient in windstorm-disturbed forests. *Forest Ecology and Management*, 260, 146-154.

VARNAGIRYTE, I., HAGEN-THORN, A., ARMOLAITIS, K. 2005. Comparative study of litterfall in deciduous species plantations. *Miskininkyste*, 30-36.

VEHMAS, M., KOUKI, J., EERIKAINEN, K. 2009. Long-term spatio-temporal dynamics and historical continuity of European aspen (*Populus tremula* L.) stands in the Koli national park, Eastern Finland. *Forestry*, 82, 135-148.

VESTERDAL, L., SCHMIDT, I.K., CALLESEN, I., NILSSON, L.O., GUNDERSEN, P. 2008. Carbon and nitrogen in forest floor and mineral soil under six common European tree species. *Forest Ecology and Management*, 255, 35-48.

VON LUPKE, B. 1998. Silvicultural methods of oak regeneration with special respect to shade tolerant mixed species. *Forest Ecology and Management*, 106, 19-26.

Wardle, D.A., Bonner, K.I. & Barker, G.M. 2002. Linkages between plant litter decomposition, litter quality, and vegetation responses to herbivores. *Functional Ecology*, 16, 585-595.

WARDLE, P. 1959. The regeneration of *Fraxinus-excelsior* in woods with a field layer of *Mercurialis-perennis*. *Journal of Ecology*, 47, 483-497.

WARDLE, P. 1961. Biological flora of the British Isles: *Fraxinus excelsior* L. *Journal of Ecology*, 49, 739–751.

WELANDER, N.T., OTTOSSON, B. 1998. The influence of shading on growth and morphology in seedlings of *Quercus robur* L. and *Fagus sylvatica* L. *Forest Ecology and Management*, 107, 117-126.

WITTMANN, C., ASCHAN, G., PFANZ, H. 2001. Leaf and twig photosynthesis of young beech (*Fagus sylvatica*) and aspen (*Populus tremula*) trees grown under different light regime. *Basic and Applied Ecology*, 2, 145-154.

Woods, R.G., Coppins, B.J. 2012. *A Conservation Evaluation of British Lichens and Lichenicolous Fungi.* Peterborough: Joint Nature Conservation Committee.

ZYWIEC, M., LEDWON, M. 2008. Spatial and temporal patterns of rowan (*Sorbus aucuparia* L.) regeneration in west Carpathian subalpine spruce forest. *Plant Ecology*, 194, 283-291.

13 Appendix 1: Glossary

Table 13.1 Latin names of tree species

English name	**Latin name**
Alder	*Alnus glutinosa*
American Ash	*Fraxinus americana*
Ash	*Fraxinus excelsior*
Aspen	*Populus tremula*
Beech	*Fagus sylvatica*
Bird cherry	*Prunus padus*
Black poplar	*Populus nigra*
Black walnut	*Juglans nigra*
Blackthorn	*Prunus spinosa*
Caucasian wingnut	*Pterocarya fraxinifolia*
Common walnut	*Juglans regia*
Crab apple	*Malus sylvestris*
Douglas fir	*Pseudotsuga menziesii*
Downy birch	*Betula pubescens*
Elder	*Sambucus nigra*
English Elm	*Ulmus procera*
European larch	*Larix decidua*
Field maple	*Acer campestre*
Goat willow	*Salix caprea*
Green Ash or Red Ash	*Fraxinus pennsylvanica*
Grey willow	*Salix cinerea*
Hawthorn	*Crataegus monogyna*
Hazel	*Corylus avellana*
Holly	*Ilex aquifolium*
Hop-hornbeam	*Ostrya carpinifolia*
Hornbeam	*Carpinus betulus*
Horse-chestnut	*Aesculus hippocastanum*
Italian alder	*Alnus cordata*
Large-leaved lime	*Tilia platyphyllos*
Manchurian Ash	*Fraxinus mandschurica*
Manna Ash or South European Flowering Ash	*Fraxinus ornus*
Norway maple	*Acer platanoides*
Pedunculate oak	*Quercus robur*
Plane	Platanus x hybrid*
Privet	*Ligustrum vulgare*
Red oak	*Quercus rubra*
Rowan	*Sorbus aucuparia*
Scots pine	*Pinus sylvestris*
Sessile oak	*Quercus petraea*
Shagbark hickory	*Carya* ovata
Silver birch	*Betula pendula*

English name	**Latin name**
Silver fir	*Abies alba*
Small-leaved lime	*Tilia cordata*
Sweet chestnut	*Castanea sativa*
Sycamore	*Acer pseudoplatanus*
Turkey oak	Quercus cerris
Western red cedar	*Thuja plicata*
Whitebeam	*Sorbus aria*
Wild cherry	*Prunus avium*
Wild service	*Sorbus torminalis*
Wych Elm	*Ulmus glabra*
Yew	*Taxus baccata*

Table 13.2 Glossary

Word	**Definition as used in this report**
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.
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.
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
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.
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 when there was no specific information on the use of the tree species by the taxon but expert judgement suggested that the taxon was likely to use that tree species. For example the taxon was known to use other tree species in the same genera or known to use a wide range of deciduous tree species but no information is available on whether it actually uses this particular tree species.
NNR	National Nature Reserve
No	In relation to the use of a tree by a taxon: the taxon does not use this tree species, or where information is lacking on the use of the tree species by the taxon it is thought unlikely that the taxon uses this tree species.

Word	**Definition as used in this report**
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
Phase 1	The report on ash dieback produced as phase one of this work http://jncc.defra.gov.uk/page-6322
Phase 2	The current report
Rare	In relation to the use of a tree by a taxon: the taxon has been recorded on this tree species but only rarely.
Similarity index	A statistical method to compare how similar two things are using more than one measure
SSSI	Site of special scientific interest, a conservation designation denoting a protected area in the United Kingdom.
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

14 Appendix 2: Rankings of ecological function

Table 14.1 Species names and codes used in Appendix 2

Latin	English	Code for species
Fraxinus excelsior	Ash	Fe
Sorbus aucuparia	Rowan	Sau
Betula pubescens /pendula	Birch, silver or downy.	Bp/p
Acer campestre	Field Maple	Aca
Acer pseudoplatanus	Sycamore	Aps
Populus tremula	Aspen	Ptr
Quercus petraea/robur	Oak, pedunculate or sessile	Qr/p
Fagus sylvatica	Beech	Fsy
Tilia cordata	Lime	Tco
Alnus glutinosa	Alder	Agl
Juglans nigra/regia	Walnut, black or common	Jn/r
Prunus avium	Wild cherry	Pav

Table 14.2 Hierarchy of litter fall (amount) of alternative tree species. Tree species aligned between studies where possible

High								Low	Reference	Function measured
	Sau>=		Bp/p>=	Agl>	Qp/r =	Fsy			Carnol & Bazgir 2013	Total annual litterfall biomass
Agl =	Sau =		Bp/p =		Qp/r =	Fsy			Carnol & Bazgir 2013	Yearly throughfall volume
					Qp/r =	Fsy			Hansen et al 2009	Foliar litterfall
					Qp/r =	Fsy			Hansen et al 2009	Total litterfall
					Qp/r =	Fsy			Jonard et al 2008	Mean litter fall in mature woodland (mass per unit area)
		Aps =			Qp/r				Straigyte et al 2009	Litterfall mass per unit area
					Qp/r >=	Bp>	Tco >	Fe	Varnagiryte et al 2005	Litterfall mass - trap technique

Species codes are shown in Table 14.1
Highlighted species are those that do not fit in a clear hierarchy shown by other studies or where confidence is low due to low number of studies.

Table 14.3 Hierarchy of litter mass loss rates of alternative tree species. Tree species aligned between studies where possible

Fast								Slow			Reference	Function measured
	Fe>									Fsy	Bjornlund et al 2005	Mass loss at 4 months
								Fsy>	Qp/r		Cortez et al 1998	Mass loss over 2 years
									Qp/r>=	Fsy	Cortez et al 1996	Mass loss over 90 days - fresh litter
									Qp/r =	Fsy	Cortez et al 1996	Mass loss over 90 days - 1 year old litter
Bp>	Fe=				Aps						Cotrufo et al 1998	Mass loss
Bp>	Fe>				Aps						Cotrufo et al 1998	Mass loss
						Ptr >	Bp				De Santo et al 2009	Mass loss - productive temperate site; green leaves only
						Ptr =	Bp				De Santo et al 2009	Mass loss - unproductive boreal site; green leaves only
				Sau >	Aps >					Fsy	Don et al 2005	Mass loss at 12 months - forest stand
				Sau >=	Aps >					Fsy	Don et al 2005	Mass loss at 12 months - clear cut area
		Tco =			Aps						Goebel et al 2011	Under own species canopy, mass loss at 36 months 1st and 2nd order roots
		Tco >			Aps						Goebel et al 2011	Under own species canopy, mass loss at 36 months 3rd and 4th order roots
		Tco >			Aps						Goebel et al 2011	Under common-species canopy, mass loss at 14 months 1st and 2nd order roots
		Tco >			Aps						Goebel et al 2011	Under common-species canopy, mass loss at 14 months 3rd and 4th order roots
		Tco >	Fsy >Qr >		Aps						Hobbie et al 2010	Proportion initial mass lost, asymptotic models
	Fe >	Tco =					Bp/p=		Qp/r =		Howard et al 1974	Comparison of asymptotic regressions of mass loss against time.
	Fe >	Tco >								Fsy	Jacob et al 2010	Litter % of initial mass lost - 5.5 months (approx.)
	Fe >	Tco >								Fsy	Jacob et al 2010	Litter % of initial mass lost - 7.5 months (approx.)

Fast							Slow		Reference	Function measured
							Qp/r >	Fsy	Jonard et al 2008	% mass lost (all sampling dates up to 36 months) from litter bags
		Sau =				Bp/p			King et al 2002	Percentage weight loss of litter
							Qp/r >	Fsy	Lorenz et al 2004	Mass loss over 2 years
	Fe >							Fsy	Lummer et al 2012	Mass loss over 104 days
	Fe >						Qp/r		Riutta et al 2012	Mass loss at 3 and 12 months
							Qp/r	Fsy	Sariyildiz et al 2003	Mass loss after 24 months
							Qp/r >	Fsy	Sariyildiz et al 2003	Mass loss at 12 months, high nutr. soils
							Qp/r>=	Fsy	Sariyildiz et al 2003	Mass loss at 12 months, low nutr. soils
							Qp/r >	Ptr	Shilenkova et al 2013	Mass loss for 260 days
	Fe =		Aps >	Aca >			Qp/r =	Fsy	Slade et al 2012	Mass loss
Agl >					Ptr >		Qp/r		Tiunov et al 2009	Percentage mass loss by 142 days - large fragments
Agl >					Ptr >		Qp/r		Tiunov et al 2009	Percentage mass loss by 142 days - small fragments

Species codes are shown in Table 14.1
Highlighted species are those that do not fit in a clear hierarchy shown by other studies or where confidence is low due to low number of studies.

Table 14.4 Hierarchy of decomposition rate of alternative tree species. Tree species aligned between studies where possible

Fast							Slow					Reference	Function measured
					Aps>					Fsy		Ayres et al 2006	Litter decomposition rate (mass loss)
Bp>	Fe >				Aps							Cotrufo et al 1998	Decomposition rate constant *k*
					Aps >			Tco =	Qp/r >	Fsy =	Bp	Hobbie et al 2006	Litter bag decay constant - common plot
					Aps >=		Bp >=	Tco >	Qp/r=	Fsy		Hobbie et al 2006	Litter bag decay constant - home plot
		Tco >	Fsy >	Qp/r >	Aps							Hobbie et al 2010	Decomposition rate constant from single exponential model
		Tco >			Aps >				Qp/r >	Fsy		Hobbie et al 2010	Decomposition rate constant from asymptotic models
									Qp/r >	Fsy		Jonard et al 2008	"Mass balance" derived decomposition rates
	Fe >								Qp/r >	Fsy		Schadler et al 2005	Disappearance rate, 4 months, coarse mesh litter bags
	Fe >								Qp/r >	Fsy		Schadler et al 2005	Disappearance rate, 4 months, fine mesh litter bags
	Fe >								Qp/r >	Fsy		Schadler et al 2005	Disappearance rate, 8 months, coarse mesh litter bags
	Fe >								Qp/r >	Fsy		Schadler et al 2005	Disappearance rate, 8 months, fine mesh litter bags
	Fe =				Aps >	Aca >			Qp/r >	Fsy		Slade et al 2012	Decomposition coefficient - large mesh
	Fe >				Aps >	Aca >			Qp/r >	Fsy		Slade et al 2012	Decomposition coefficient - small mesh
					Aps >				Qp/r			Straigyte et al 2009	Decomposition rate constant k from exponential models

Species codes are shown in Table 14.1
Highlighted species are those that do not fit in a clear hierarchy shown by other studies or where confidence is low due to low number of studies.

Table 14.5 Hierarchy of litter quality of alternative tree species. Tree species aligned between studies where possible

High						Low			Reference	Function measured
					Qr/p=		Fsy		Augusto et al 1988	Litter C:N
Agl>		Fe=			Qr/p=	Bp/p=	Fsy		Cools et al 2014	Litter C:N
					Qr/p=		Fsy		Gurmesa et al 2013	Litter C:N
		Fe<	Tco=	Aps<			Fsy		Jacob et al 2009	Litter C:N
		Fe=	Tco=				Fsy		Lagenbruch et al 2012	Litter C:N
		Fe=	Tco<				Fsy		Lagenbruch et al 2012	Litter C:N
					Qr/p<		Fsy<	Pav	Lorenz et al 2004	Litter C:N
Agl<		Fe							Peichl et al 2012	Litter C:N
Agl>		Fe=		Aps=		Bp/p			Rajapaksha et al 2013	Litter C:N
					Qr/p<		Fsy		Sariyildiz et al 2005	Litter C:N
		Fe>	Tco=	Aca>	Qr/p>		Fsy		Vesterdal et al 2008	Litter C:N
		Fe=	Tco<				Fsy		Lagenbruch et al 2012	Litter Lignin:N
					Qr/p<		Fsy		Sariyildiz et al 2005	Litter Lignin:N
		Fe=	Aca<	Tco<	Qr/p<		Fsy		Vesterdal et al 2008	Litter Lignin:N
		Fe>	Tco>	Bp/p>	Qr/p				Hagen-Thom et al 2006	Litter Ca
	Aps>	Fe>	Tco>				Fsy		Jacob et al 2009	Litter Ca
		Fe=	Tco>				Fsy		Lagenbruch et al 2012	Litter Ca
		Fe>		Aps>	Agl>	Bp/p			Rajapaksha et al 2013	Litter Ca
					Qr/p=		Fsy		Sariyildiz et al 2005	Litter Ca
	Tco>	Fe>		Bp/p>	Qr/p				Varnagiryte et al 2005	Litter Ca
		Fe=	Aca>	Tco>	Qr/p=		Fsy		Vesterdal et al 2005	Litter Ca
			Tco=	Aca>	Qr/p=		Fsy		Norde et al 1994	Litter Ca
					Sau>	Bp/p>	Fsy		Emmer et al 1999	Litter Ca
			Tco=		Qr/p=	Bp/p			Hagen-Thom et al 2006	Litter K

High							Low			Reference	Function measured
		Qr/p>	Fe							Hagen-Thom et al 2006	Litter K
			Fe>	Tco>	Aps>			Fsy		Jacob et al 2009	Litter K
						Qr/p=		Fsy		Sariyildiz et al 2005	Litter K
Qr/p>	Tco>	Bp/p>	Fe							Varnagiryte et al 2005	Litter K
		Tco>	Fe=		Aca>	Qr/p>		Fsy		Vesterdal et al 2008	Litter K
				Tco>	Aca=	Qr/p=		Fsy		Norde et al 1994	Litter K
						Bp/p>	Sau=	Fsy		Emmer et al 1999	Litter K
			Fe=	Bp/p>	Tco=	Qr/p=				Hagen-Thom et al 2006	Litter Mg
		Aps>	Fe>	Tco>				Fsy		Jacob et al 2009	Litter Mg
			Fe>	Tco>				Fsy		Lagenbruch et al 2012	Litter Mg
						Qr/p=		Fsy		Sariyildiz et al 2005	Litter Mg
			Fe=	Bp/p>	Tco=	Qr/p				Varnagiryte et al 2005	Litter Mg
			Fe>	Tco=	Aca>	Qr/p>		Fsy		Vesterdal et al 2008	Litter Mg
				Tco>	Aca=	Qr/p=		Fsy		Norde et al 1994S	Litter Mg
						Sau>	Bp/p>	Fsy		Emmer et al 1999	Litter Mg
					Aps>			Fsy		Callesen et al 2013	Litter N
			Fe>	Qr/p>	Tco=		Bp/p			Hagen-Thom et al 2006	Litter N
			Fe>	Tco=	Aps>			Fsy		Jacob et al 2009S	Litter N
			Fe=	Tco>				Fsy		Lagenbruch et al 2012	Litter N
						Qr/p>		Fsy>	Pav	Lorenz et al 2004	Litter N
			Fe>		Aps=			Fsy		Petritan et al 2010	Litter N
	Agl>		Fe=		Aps=		Bp/p			Rajapaksha et al 2013	Litter N
						Qr/p>		Fsy		Sariyildiz et al 2005	Litter N
					Ptr=	Qr/p				Shilenkova et al 2013	Litter N
	Agl>				Aca					Surmen et al 2012	Litter N

High						Low			Reference	Function measured
		Fe>	Tco=		Qr/p>	Bp/p			Varnagiryte et al 2005	Litter N
		Fe>	Tco=	Aca>	Qr/p>		Fsy		Vesterdal et al 2008	Litter N
			Tco>	Aca=	Qr/p>		Fsy		Norde et al 1994	Litter N
					Sau=	Bp/p>	Fsy		Emmer et al 1999	Litter N
	Bp/p>	Fe=	Tco=		Qr/p				Hagen-Thom et al 2006	Litter P
		Fe=	Tco>	Aps>			Fsy		Jacob et al 2009	Litter P
					Qr/p=		Fsy>	Pav	Lorenz et al 2004	Litter P
		Fe>	Agl>	Aps=		Bp/p			Rajapaksha et al 2013	Litter P
					Qr/p=		Fsy		Sariyildiz et al 2005	Litter P
Bp/p>	Qr/p>	Fe>	Tco						Varnagiryte et al 2005	Litter P
		Fe>	Tco=		Qr/p>	Aca>	Fsy		Vesterdal et al 2008	Litter P
					Sau>	Bp/p=	Fsy		Emmer et al 1999	Litter P

Species codes are shown in Table 14.1

Table 14.6 Hierarchy of soil fertility indicators of alternative tree species. Tree species aligned between studies where possible

High							Low	Reference	Function measured
	Fsy<	Fe						Cezarz et al 2013	Soil C
					Qr/p=		Fsy	Gurmesa et al 2013	Soil C
		Fe=	Tco=		Qr/p=	Bp/p=	Fsy	Hagen-Thom et al 2004	Soil C
		Fe<					Fsy	Holzwarth et al 2011	Soil C
					Qp/p=		Fsy	Ladegaard-Pedersen et al 2005	Soil C
Tco=	Fsy<	Fe						Lagenbruch et al 2012	Soil C
					Qr/p<		Fsy	Marcos et al 2010	Soil C
			Tco<				Fsy	Neirynck et al 2000	Soil C
		Fe<			Qr/p			Neirynck et al 2000	Soil C
				Aps=	Qr/p<		Fsy	Neirynck et al 2000	Soil C
		Fe<		Fsy<	Qr/p			Oostra et al 2006	Soil C
	Agl=	Fe<			Qr/p=	Bp/p=	Fsy	Cools et al 2014	Soil C:N
					Qr/p=		Fsy	Gurmesa et al 2013	Soil C:N
					Qp/p=		Fsy	Ladegaard & Pedersen 2005	Soil C:N
		Fe=	Tco=				Fsy	Lagenbruch et al 2012	Soil C:N
			Tco<				Fsy	Neirynck et al 2000	Soil C:N
		Fe<			Qr/p			Neirynck et al 2000	Soil C:N
				Aps<	Qr/p<		Fsy	Neirynck et al 2000	Soil C:N
		Fe<			Qr/p=		Fsy	Oostra et al 2006	Soil C:N
		Fe>	Tco=	Aca>	Qr/p=		Fsy	Vesterdal et al 2008	Soil C:N
	Tco>	Fe=			Qr/p=	Bp/p=	Fsy	Hagen-Thom et al 2004	Soil Ca
		Fe>					Fsy	Holzwarth et al 2011	Soil Ca
		Fe=	Tco=				Fsy	Lagenbruch et al 2012	Soil Ca
					Qr/p=		Fsy	Marcos et al 2010	Soil Ca

High						Low	Reference	Function measured
		Fe=	Tco=	Qr/p=	Bp/p=	Fsy	Hagen-Thom et al 2004	Soil K
				Qr/p=		Fsy	Marcos et al 2010	Soil K
		Fe=	Tco=	Qr/p=	Bp/p=	Fsy	Hagen-Thom et al 2004	Soil Mg
		Fe>				Fsy	Holzwarth et al 2011	Soil Mg
		Fe>	Tco>			Fsy	Lagenbruch et al 2012	Soil Mg
				Qr/p=		Fsy	Marcos et al 2010	Soil Mg
		Fe>				Fsy	Callesen et al 2013	Soil N
				Qr/p=		Fsy	Gurmesa et al 2013	Soil N
		Fe=	Tco=	Qr/p=	Bp/p=	Fsy	Hagen-Thom et al 2004	Soil N
		Fe>				Fsy	Cezarz et al 2013	soil pH
	Tco>	Fe=		Qr/p=	Bp/p=	Fsy	Hagen-Thom et al 2004	Soil pH
		Fe=	Tco=	Qr/p=	Bp/p=	Fsy	Hagen-Thom et al 2004	soil pH
		Fe>				Fsy	Holzwarth et al 2011	Soil pH
		Fe>	Tco=			Fsy	Lagenbruch et al 2012	Soil pH
				Qr/p>		Fsy	Marcos et al 2010	Soil pH
		Fe>		Qr/p=		Fsy	Oostra et al 2006	Soil pH

Species codes are shown in Table 14.1

Table 14.7 Hierarchy of successional stage of alternative tree species. Tree species aligned between studies where possible

Early		Med		Late	Reference
Ptr=Bp/p					Leitget et al 2002
Ptr*				Ptr*	Vehmas et al 2009 and Myking et al 2011
Pav					Petrokas 2010
Agl					McVean 1953
Agl					Cluzeau 1992
Bp/p					Atkinson 1992
Bp=Agl					Fremstad 1983
Sau=Agl		Sau			Raspe et al 2000
Bp/p			Sau		Emberlin & Baillie 1980
				Aca=Fsy=Fe	Jones 1945
				Aps	Jones 1945
				Fsy=Aps=Fe=Qr=Pav	Packham et al 2012
	Qr			Qp/r=Aca=Fe=Fsy	Jones 1959
				Tco=Fsy=Qr=Fe	Pigott 1991

Species codes are shown in Table 14.1

Table 14.8 Hierarchy of seed dry weights of alternative tree species. Tree species aligned between studies where possible

Lowest			Med			Highest	Reference
Ptr 0.06-0.12mg							Myking et al 2011
	Agl						McVean 1953
	Bp/p 0.2mg*						Atkinson 1992
		Sau 1-4mg					Raspe et al 2000
			Tco 25mg				Pigott 1991
				Aca 80mg*			Jones 1945
				Aps 80mg*			Jones 1945
					Pav 200mg		Kalyoncu et al 2009
					Fsy 225mg*		Packham et al 2012
						Qp/r 2000-4000mg	Jones 1959
						Jn 2200mg	Michaels et al 1988

Species codes are shown in Table 14.1

Table 14.9 Hierarchy of the ability of the alternataive tress to germinate in shade. Tree species aligned between studies where possible

Poor					Good	Reference
Bp/p						Atkinson 1992
Bp/p					Fsy	Muys et al 1988
Bp=Ptr=Sau=Agl		Qr		Tco		Bobiec 2007
				Sau		Raspe et al 2000
Ptr						Vehmas et al 2009
Ptr						Myking et al 2011
	Aca1			Aca2		1.Mathey 1924 (in Jones 1945); 2. Jones 1945
		Sau				Raspe et al 2000
		Agl				Mcvean 1953
			Pav			Petrokas 2010
			Jr			Taugourdeau et al 2010
			Aps		Fsy	Nagel et al 2010
			Fsy	Fe	Aps	Jones 1945
					Tco	Pigott 1991
					Fsy=Aps	Collet et al 2008
					Qp	Brezina & Dobrovolny 2011
				Qp/r	Fsy	Packham et al 2012
					Qp/r	Jones 1959
					Fe=Fsy	Peltier et al 1997
					Fsy	Szwagrzyk et al 2001
					Fe=Fsy	Emborg 1998
					Fsy	Jarcuska 2009

Species codes are shown in Table 14.1

Table 14.10 Hierarchy of the ability of the alternative trees to create seedling bank (no/yes). Tree species aligned between studies where possible

No	Yes	Reference
Sau		Zywiec & Ledwon 2008
Fsy	Aca	Diaci et al 2012
	Aps	Hein et al 2009
	Fsy=Fe=Aps	Madsen & Hahn 2008; + many references in Phase 1
	Fsy=Aps=Aca	Caquet et al 2010
	Fe=Fsy	Emborg 1998

Species codes are shown in Table 14.1

Table 14.11 Hierarchy of ability of seedlings/saplings of alternative trees to grow in shade. Tree species aligned between studies where possible

Low						High	Reference
Agl							McVean 1953
Agl							Ogilvy et al 2006
Bp/p							Atkinson 1992
Pav				Pav*			Petrokas 2010 * may persist into older forest due to its suckering abilities.
Bp			Aca=Aps=Fe		Qp/r=Fsy		Van Couwenberghe et al 2010
Bp		Ptr		Qr			Portsmuth & Niinemets 2007
	Ptr*						Raspe et al 2000. *But evidence of regeneration in old growth forest so must manage with small gaps… not well studied (Vehmas et al 2009)
		Ptr					Myking et al 2011
		Ptr				Fsy	Wittmann et al 2001
		Jr					Taugourdeau et al 2010
			Sau				Raspe et al 2000
			Aca			Fsy	Diaci et al 2012
				Aps			Hein et al 2009
					Aca		Jones 1945
					Aps		Jones 1945
						Aps	Hein et al 2009
				Aps	Qp	Fsy	Kazda et al 2004
				Aps	Fe	Fsy	Petritan et al 2007
				Qp	Tco	Fsy	Pigott 1991
				Qp/r			Jones 1959
				Qp		Fsy	Ligot et al 2013
				Qr		Fsy	Mountford et al 1999

Low			High	Reference
	Qp			Brezina & Dobrovolny 2011
	Qr		Fsy	Rozas 2003
	Qp		Fsy	Petritan et al 2013
		Qp/r		Von Lupke 1998
		Qr	Fsy	Welander & Otterson 1998
	Fe=Fsy			Peltier et al 1997
	Fsy			Szwagrzyk et al 2001
			Fsy	Packham et al 2012
			Fsy	Jarcuska 2009

Species codes are shown in Table 14.1

Table 14.12 Hierarchy of shade tolerance of alternative tree species as mature trees. Tree species aligned between studies where possible

Low					High	Reference
Bp/p						Atkinson 1992
Agl						Mcvean 1953
Pav						Petrokas 2010
Jr						http://www.treeseedonline.com/english-walnut-juglans-regia.html
		Jr				Gauthier & Jacobs 2010
Ptr				Tco		Kull & Tulva 2002
Bp/p	Ps		Qr	Tco	Fsy	Pigott 1991
		Sau				Raspe et al 2000
		Qp/r				Jones 1959
				Aca=Fe		Jones 1945
				Aps	Fsy	Jones 1945
					Fsy	Packham et al 2012

Species codes are shown in Table 14.1

Table 14.13 Hierarchy of height of alternative tree species. Tree species aligned between studies where possible

Low					High	Reference
Agl 3-24m						Mcvean 1953
	Aca 12-16m	Aps 18-24m				Jones 1945a&b
		Fe 12-20 (-48)m				Wardle 1961
		Sau 25m				Raspe et al 2000
		Ptr 25-30m				Myking et al 2011
		Pav 23-35m				Petrokas 2010
			Bp/p 25-30m			Atkinson 1992
			Jr 25-35m			http://www.treeseedonline.com/english-walnut-juglans-regia.html
				Qp/p 30m		Jones 1959
				Tco 30m		Pigott 1991
				Jn 30-40m		http://apps.kew.org/trees/?page_id=102
					Fsy 30-50m	Packham et al 2012

Species codes are shown in Table 14.1

Table 14.14 Hierarchy of longevity of alternative tree species. Tree species aligned between studies where possible

Low					High	Reference
Pav 100(-200) yrs						Petrokas 2010
	Agl 120yrs					Mcvean 1953
	Bp/p 60-180yrs					Atkinson 1992
	Sau 150yrs					Raspe et al 2000
		Ptr 150-200 yrs				Vehmas et al 2009
		Ptr 100-200 yrs				Myking et al 2011
			Fe 200-300 yrs			Wardle 1958
			Aca 200-300yrs		Aps 400-600yrs	Jones 1945a&b
				Fsy 150-500yrs		Packham et al 2012
					Qp/p 500yrs	Jones 1959
					Tco 400-600+ yrs	Pigott 1991

Species codes are shown in Table 14.1

15 Appendix 3: Alternative tree species mixtures

The tables in this appendix show the number of ash-associated species supported for the mixtures of different alternative tree species. The best mixture of alternative tree species is shown for 1-20 tree species or until no improvement in the number of ash-associated species supported is reached. Trees were assessed as supporting the ash-associated species if they were classed as 'yes' (known to support the species) or 'likely' thought likely to support the species based on ecological knowledge of the species.

AND means all species

OR means alternatives exist (different groups of alternative tree species may support the same number of ash-associated species)

() Means that the species is not definitely selected at this point. In some of the taxa a tree species comes in and drops out later.

Tables are shown for all ash-associated species and then separate tables for ash-associated invertebrates and lichens. Tables are not shown for ash-associated birds, bryophytes and mammals as the maximum possible number of species supported for these groups is quickly reached with only a few species and the results are described in Chapter 3.

Table 15.1 Codes used in tables 14.2-14.4

Code[1]	Latin	English
Aal	Abies alba	Silver fir
Aca	Acer campestre	Field maple
Aco	Alnus cordata	Italian alder
Agl	Alnus glutinosa	Alder
Ahi	Aesculus hippocastanum	Horse chestnut
Apl	Acer platanoides	Norway maple
Aps	Acer pseudoplatanus	Sycamore
Bpe	Betula pendula	Silver birch
Bpu	Betula pubescens	Downy birch
Cav	Corylus avellana	Hazel
Cbe	Carpinus betulus	Hornbeam
Cmo	Crataegus monogyna	Hawthorn
Cov	Carya ovata	Shagbark hickory
Csa	Castanea sativa	Sweet chestnut
Fam	Fraxinus americana	American ash
Fex	Fraxinus excelsior	Common ash
Fma	Fraxinus mandschurica	Manchurian ash
For	Fraxinus ornus	Manna ash
Fpe	Fraxinus pennsylvanica	Green ash or red ash
Fsy	Fagus sylvatica	Beech
Iaq	Ilex aquifolium	Holly
Jni	Juglans nigra	Black walnut
Jre	Juglans regia	Common walnut
Lde	Larix decidua	European larch

Code[1]	Latin	English
Lvu	Ligustrum vulgare	Privet
Msy	Malus sylvestris	Crab apple
Oca	Ostrya carpinifolia	Hop-hornbeam
Pav	Prunus avium	Wild cherry
Pfr	Pterocarya fraxinifolia	Caucasian wingnut
Phy	Platanus x hybrid	Plane sp
Pme	Pseudotsuga menziesii	Douglas fir
Pni	Populus nigra	Black poplar
Ppa	Prunus padus	Bird cherry
Psp	Prunus spinosa	Blackthorn
Psy	Pinus sylvestris	Scots pine
Ptr	Populus tremula	Aspen
Qce	Quercus cerris	Turkey oak
Qpe	Quercus petraea	Sessile oak
Qro	Quercus robur	Pedunculate oak
Qru	Quercus rubra	Red oak
Sar	Sorbus aria	Whitebeam
Sau	Sorbus aucuparia	Rowan
Sca	Salix caprea	Goat willow
Sci	Salix cinerea	Grey willow
Sni	Sambucus nigra	Elder
Sto	Sorbus torminalis	Wild service tree
Tba	Taxus baccata	Yew
Tco	Tilia cordata	Small leaved lime
Tpi	Thuja plicata	Western red cedar
Tpl	Tilia platyphyllos	Large leaved lime
Upg	Ulmus procera/glabra	Wych & English Elm

[1] Code used in Tables 4.5 & 4.6

Table 15.2 Number of ash-associated species supported by mixtures of different alternative tree species

Number of tree species added	Tree species added	Associated species added by adding that tree (or combination of trees)	Cumulative associated species	% of species supported	Commentary
1	Qrp	654	654	0.68	Oak adds loads
2	Upg	97	751	0.79	Next best species is Upg
3	For	48	799	0.84	Next is For
4	Cav	22	821	0.86	Next is Cav
5	(Fsy OR Psy)	13	834	0.87	At this level two species, Fsy and Psy, add the same number.
6	(Psy AND Fsy) OR (Fsy AND Lvu)	9	843	0.88	At this level there are two combinations of two species that support the same number of species
7	Psy AND Fsy AND Lvu	9	852	0.89	Now all three species in the previous row are added
8	Psp	4	856	0.90	Simple addition of one species
9	(Ptr OR Qru OR Iaq)	3	859	0.90	Perm one of three
10	(Ptr AND Qru) OR (Iaq AND Ptr) OR (Qru AND Iaq)	3	862	0.90	Perm two of three
11	Ptr AND Qru AND Iaq	3	865	0.91	All three
12	Pni OR Ahi OR Tpl	2	867	0.91	Perm one of three
13	(Pni AND Ahi) OR (Tpl AND Pni) OR (Ahi AND Tpl)	2	869	0.91	Perm two of three
14	Chaotic	1	870	0.91	Here on in all remaining tree species can add an extra associated species

Table 15.3 Number of ash-associated invertebrate species supported by mixtures of different alternative tree species

Number of tree species added	Tree species added	Associated species added by adding that tree (or combination of trees)	Cumulative associated species	% of species supported	Commentary
1	For	100	100	41.5	
2	Qrp	32	132	54.8	
3	Upg	14	146	60.6	
4	(Lvu OR Fsy OR Bp)	10	156	64.7	Lvu, Fsy and BP all add the same number of inverts
5	Lvu AND (Fsy OR Bp)	10	166	68.9	Lvu and either Bp or Fsy add the same number of species
6	Fsy AND (Bp OR Cav)	6	172	71.4	Fsy and either Bp or Cav add the same number of species
7	(Bp AND Psp) OR (Psp AND Cav) OR (Psy AND Cav)	4	176	73.0	3 combinations of 2 species
8	Psp AND Psy AND Cav	4	180	74.7	
9	(Pni OR Qru)	2	182	75.5	
10	Pni AND Qru	2	184	76.3	Both species from the previous line added
11	Chaotic	1	185	76.8	Here on in all remaining tree species can add an extra associated species

Table 15.4 Number of ash-associated lichen species supported by mixtures of different alternative tree species

Number of tree species added	Tree species added	Associated species added by adding that tree (or combination of trees)	Cumulative associated species	% of species supported	Commentary
1	Qrp	467	467	85.2	Oak the best species
2	Upg	33	500	91.2	Elm added
3	(Cav)	12	512	93.4	Hazel added
4	Psy	7	519	94.7	Pine added
5	(Iaq AND Cav) OR (Iaq AND Ptr) OR (Cav AND Ptr)	3	522	95.3	3 combinations of 2 species
6	Iaq AND Cav AND Ptr	3	525	95.8	All three species added
7	Chaotic	1	526	96.0	Here on in all remaining tree species can add an extra associated species

16 Appendix 4: Species use of alternative trees - limitations of approach

These reports (Phase 1 and 2) have for the first time collated the use made by ash-associated species of a range of alternative tree species. This provides useful summary information for woodland managers when considering alternative tree species within ash woodlands. However there are a number of limitations with this approach which are highlighted below for each species group.

16.1 Birds

There are clear gaps in evidence for many of the non native trees. For some birds which also occur in Mediterranean or oriental woods some of these gaps are reduced, e.g. for *Fraxinus mandshuria*, *Quercus cerris*. No useful information was found for American tree species even *Quercus rubra* and *Thuja plicata* which are commonly planted in the UK. Any American references found were mainly descriptions of bird communities with tree species composition for the woods studied also given. However, they didn't allow any informed assessment about likely associations or possible use for particular tree species. Most studies are from native woodland across northern Europe. There was little information from plantations of non-native trees grown for forestry except Sitka spruce. There are also biases in which bird species were studied. Hole nesting species (blue tit, marsh tit, nuthatch, pied flycatcher, great and lesser spotted woodpecker) are well studied providing quantitative assessments of tree species use compared with availability. Seed eating birds (bullfinch, hawfinch) are also well studied with quantitative data on diets. Data from other bird species (blackcap, chiffchaff, wren, spotted flycatcher) which have a less direct link with tree species are sketchier. For these species the structure of the wood is more important and any tree species providing light or open canopy and allowing a dense low shrub layer to develop may be suitable.

16.2 Bryophytes

It is striking how infrequently the species of tree is recorded when epiphytes are being recorded, except in specific epiphyte studies. For the most part, it is very difficult or impossible to associate particular species of bryophyte with particular species of non-native trees. When 'apple' or 'privet' is recorded, there is often no attempt to specify whether these are wild or domestic species. Where 'plane', 'lime' or 'poplar' have been recorded, it has been assumed that these refer to the hybrid trees, as they are much more frequent than the true species. This might, of course, mean that some records of epiphytes on the true species could have been overlooked.

Data is very sparse or lacking for all the non-native trees. It is also remarkably sparse for several of the native species (e.g. holly, large-leaved lime, black poplar).

Data from non-UK sources should be used with extreme caution, as epiphytic bryophytes might behave quite differently in the UK from how they behave in eastern Europe, for example. It is assumed that exotic ash species are 'likely' to be able to support a wide range of bryophytes, as *Fraxinus excelsior* does, but this is largely based on anecdotal evidence. The rarity of some of these trees in the UK means that, while they may be likely to support epiphytes if the opportunity arises, the reality is that they are unlikely to support significant populations at present. While any widespread planting of exotic species *might* result in an increase in substrate for some epiphytic bryophytes, this can by no means be guaranteed, and any such initiative should take place only after extensive trials and with due regard to possible deleterious effects on native British wildlife in general.

16.3 Fungi

The alternative tree hosts represent a mix of native and non-native broad-leafed and coniferous trees and shrubs. In order to facilitate evaluating the level of association with these plant species for the 68 species of fungi include in the first phase of the assessment, categories of association were established using available literature. However, for most of the non-native species it was difficult to obtain direct data relating to the fungi. The main reasons for this are the lack of assessments where these trees are native and the likelihood that the fungi do not occur is these areas. The categories (see below) were broadly determined by the host ranges found in the literatures and served as a proxy for inferring associations when data was unavailable.

A total of nine categories were established for the partially and highly associated fungal taxa.

Categories:

1) Deciduous host wood, narrow range, partially associated
2) Deciduous host wood, narrow range, highly associated
3) Deciduous host wood, broad range, partially associated
    - This was further split into two subgroups: taxa with less than or more than 40% of records with Ash
4) Deciduous host wood, broad range, highly associated
5) Deciduous host wood, general
6) Wood, general
7) Leaves, general
8) Leaves, restricted range
9) Litter fungi, general

The use of the categories sustained consistency when assessing associations but each case was considered separately and was influenced by the individual hosts recorded for each taxon.

The most general category was that of the litter fungi. In most cases it seems likely that there would be little change in the immediate term but how these fungi will respond in the long term to changes in litter chemistry and habitat with shifts in tree species composition is largely unknown.

In addition to using the categories, a number of simple rules were followed:

- Where literature indicated that a fungus was associated with deciduous trees then ‘no’ was returned for each of the 4 conifers and unknown for Holly and Privet
- Where Salix was recorded as a host in the literature, then a likely was returned for Populus as taxa are often shared between these two genera – and *vice versa*
- Where a taxon was recorded in the literature on a particular species within a genus, then any alternative host within that genius was recorded as a likely host.

Cautionary Comment – ‘Likely’ is not a good category – ‘possible’ would have been better as likely infers that it has a good chance of happening; whereas possible simply means that it could happen. This should be borne in mind when utilising the data on association.

16.4 Invertebrates

There were lots of cases of trees being recorded by genus. Where an insect species had a wide range of foodplants, (and there was no more specific information as to species of trees used) the association was assessed as likely. Where there is a narrow range of food plants the association was recorded as unknown.

Some species are rather polyphagous though with some foodplants specifically mentioned in literature. In such cases, the use of known foodplants was recorded and other species listed as unknown (though if recorded as "polyphagous on deciduous trees and shrubs" the species was listed as 'no' for the conifers (and holly).

Some species have a narrow foodplant range, and in such cases foodplants not specifically recorded have been assessed as 'no'.

16.5 Lichens

Of the 28 alternative tree species listed, it was not possible to make an assessment for 10 of these. In 4 cases the alternative tree species has no associated lichen records in the database (*unknown*): *Carya ovata*, *Ostrya carpinifolia*, *Pterocarya frazinifolia*, and *Sorbus torminalis*. In a further 6 cases, the tree species is recorded within a generic classification, for which the vast majority of records can be referred to the native species (also *unknown*): *Alnus cordata*, *Fraxinus americana*, *Fraxinus mandschurica*, *Fraxinus ornus*, *Fraxinus pennsylvanica*, and *Quercus rubra*.

A further 5 species had associated lichen records in the database, but the recording effort was considered too low (< 100 records) to make a valuable assessment of association: *Abies alba* (*n* = 74), *Populus nigra* (*n* = 58), *Quercus cerris* (*n* = 24), *Sambucus nigra* (*n* = 56), and *Thuja plicata* (*n* = 14). Where a lichen species was recorded from each of these trees it was coded as '*uses*', and otherwise as '*unknown*'.

This left 13 species for which an semi-quantitative assessment was considered possible (coding as '*obligate*', '*high*', '*partial*', or '*cosmopolitan*'): *Aesculus hippocastanum* (*n* = 743), *Ilex aquilifolium* (*n* = 1945), *Juglans nigra* & *Juglans regia* (*n* = 599), *Larix decidua* (*n* = 1099), *Ligustrum vulgare* (n = 101), *Malus sylvestris* (n = 1751), *Pinus sylvestris* (n = 3388), *Platanus* x hybrid (*n* = 261), *Prunus spinosa* (*n* = 467), *Sorbus aucuparia* (*n* = 6724), *Tilia platyphyllos* (*n* = 2514), and *Ulmus procera/glabra* (*n* = 9610)

In certain cases lichen records for several tree species are grouped within the British Lichen Society database under a genus-level classification; this was the case for *Betula* spp. and *Salix* spp. during Phase 1 reporting. Likewise, one of the Phase 2 species (*Tilia platyphylos*) was a native tree whose records had been included in the assessment made during Phase 1 of this survey for *Tilia cordata*, and the records were considered transferable between these species. Within Phase 2: (i) *Abies alba* used records coded as *Abies* spp., (ii) *Juglens nigra* and *J. regia* shared values for records coded as *Juglens* spp., (iii) *Larix decidua* used records coded as *Larix* spp., (iv) *Plantanus* x hybrid used records for *Platanus* spp., and (v) *Ulmus procera/glabra* used records coded as *Ulmus* spp.

16.6 Mammals - non bats

For many of the mammal/tree species combinations under consideration, it was only possible to assess the level of association as 'Uses' or 'Likely' for level of association (rather than high, partial, cosmopolitan etc). There are a number of important points to consider if this information were to be used to assess the suitability of these trees as alternatives to ash for these mammals:

a) for many of the mammal species, preferences and level of usage are likely to vary considerably between tree species identified as 'Used' or 'Likely'. Further, not only was information on level of association often not available, level of association (in terms of use relative to availability) is often likely to vary tremendously through the year (or years) depending on mast timing etc. In addition to which, relative use of a species will vary greatly between habitats depending on what alternative tree species (or, for example, winter grazing for deer) are available. (e.g. (Wauters, Swinnen & Dhondt 1992) for squirrels).

b) interactions between mammal species (and indeed other species) would need to be taken into account when considering suitable trees for a given mammal species. For example, whilst red squirrels may utilise and benefit from presence of medium/large-seeded deciduous trees in the absence of grey squirrels, the planting of such trees where greys are present would have significant negative impacts for red squirrels.

The two species of horseshoe bat (*Rhinolophus* spp), and the grey long-eared bat (*Plecotus austriacus*) are not generally associated with trees for roosting; their known roosts are in buildings. Their UK populations are small and they have restricted distributions in the south or west of England and wales. These are classed as having no association with the alternative tree species, as would be the case for their association with any tree species (incl Ash). The whiskered bat (*Myotis mystacinus*), Brandt's bat (*Myotis brandtii*) and the Serotine bat (*Eptesicus serotinus*) roost predominantly in built structures but roosts in trees are known; these have been scored as 'rare' in their level of association with the alternative tree species. Leisler's bat uses trees for roosting elsewhere in its range but in the UK the known roosts are in buildings. It is assumed therefore to be capable of roosting in trees with appropriate roosting sites and therefore scored as 'likely'.

16.7 Mammals - bats

There is little hard evidence for a particular species of UK bat roosting in particular tree species, and such evidence is especially unlikely to be found between UK bats and exotic tree species, unless their species ranges overlap elsewhere. In these cases, unless there is evidence to the contrary, the scoring is given as 'likely' associated for the tree-roosting bat species, and the level of confidence in the evidence is given as 'anecdotal' – based upon expert opinion. The alternative tree species are sometimes recorded as being used for roosting by tree-roosting bat species, but even where there is no direct evidence of an association, it is scored as likely/anecdotal, where the size and shape of the tree is likely to yield tree holes or wounds suitable for occupancy by roosting bats, particularly once the tree is old. Some of the alternative tree species are considered to be large shrubs or would only grow into small trees. The use of these alternative tree species, are scored as 'Rare' ie not considered likely to be used by bats for roosting, (Crab Apple - *Malus sylvestris*), or 'No', not considered useful for roosting by bats at all (Privet - *Ligustrum vulgare*, Blackthorn – *Prunus spinosa* and Elder – *Sambuccus nigra*) .

Although the size and shape of tree-roosting holes is known for some of the UK bat species, there is no current systematically collected evidence as to the morphology of holes, crevices, fissures or other wounds that are likely to form in the alternative tree species.

Most of the information obtainable on bats related to whether or not they roost in trees or built structures and rarely mentions particular tree species. The main sources of such information, which was counted as 'anecdotal' were the following information web sites, and the Mammals of the British Isles:

www.bats.org.uk

www.bio.bris.ac.uk/research/bats/britishbats/batpages

http://www.ptes.org

Racey PA (2008) Bats: Order Chiroptera. Chapter 8 in the Mammals of the British isles: Handbook 4th Edition. S.Harris and D.W. Yalden (eds). The Mammal Society, Southampton.

17 Appendix 5: References used in assessment of alternative tree species

The references and web sites listed below are those used by species experts in addition to those used in the Phase 1 report to assess if the ash-associated species will use the alternative tree species. These references are not cited with in the text.

ADAMÍK, P. KORÒAN, M. 2004. Foraging ecology of two bark foraging passerine birds in an old-growth temperate forest. *Ornis Fennica,* 81, 13-22.

ADAMÍK, P., KORÒAN, M., VOJTEK, J. 2003. The effect of habitat structure on guild patterns and the foraging strategies of insectivorous birds in forests. *Biologia*, 58, 275-285.

AGASSIZ, D.J.L., BEAVAN, S.D., HECKFORD, R.J. 2013. *A Checklist of the Lepidoptera of the British Isles*. Royal Entomological Society, St Albans, UK.

ALEXANDER, K N A. 2009. *Prostomis mandibularis* F. (Coleoptera: Prostomidae), *Pandivirilia melaleuca* (Loew) (Diptera: Therevidae) and other saproxylic insects in Cantabria (Insecta: Coleoptera, Diptera and Hemiptera). *Boletin de la S.E.A.* 45, 545-546.

ALEXANDER, K.N.A. 1994. *Pandivirilis (Psilocephala) melaleuca* (Loew) (Diptera: Therevidae) new to Gloucestershire. *British Journal Entomology & Natural History* 7, 180.

ALEXANDER, K.N.A. 2002. *The invertebrates of living & decaying timber in Britain and Ireland - a provisional annotated checklist.* English Nature, Peterborough.

ALFORD. D.V. 2010. *Plant pests: a natural history of pests of farms and gardens.* HarperCollins, UK.

ALLAN, A.A. 1981. *Psilocephala melaleuca* (Loew) (Dip., Therevidae) apparently surviving in S.E. London. *Entomologist's Monthly Magazine* , 117, 256.

ANON 2007. *Guide des Papillons Nocturnes de France*. Delachaux et Niestle.

ANTHONY, M., SATTER, R., COONEYSOVETTS, C. 1983. Morphogenetic potential of *Fraxinus ornus* under the influence of the gall mite *Aceria fraxinivora. Canadian Journal of Botany,* 61, 1580-1594.

AUKEMA, B., SCHWARTZ, M.D., DEN BIEMAN, K. 2009 *Tropidosteptes pacificus* (Van Duzee, 1921), another Nearctic mirid in Europe. *Zootaxa*, 2135, 65-68.

AUSTARÅ, O. 1991. Severe outbreaks of the ash sawfly Tomostethus nigritus F. (Hymenoptera, Tenthredinidae) on ornamental trees in Oslo. *Anzeiger für Schadlingskunde, Pflanzenschutz und Umweltschutz,* 64, 70-72.

AVERIS, A.B.G. 1991. *A survey of the bryophytes of 448 woods in the Scottish Highalnds.* Edinburgh, Nature Conservancy Council Scottish Field Unit.

AVERIS, A.B.G. 2007. Habitats of *Colura calyptrifolia* in north-western Britain. *Field Bryology,* 91, 17-21.

BAGNALL, J., HARRISON, R.S. 1921. New British Cecidomyiidae. *Entomologist's Record & Journal of Variation,* 33, 166-169.

BAKER, M., MARTIN, J.H. 2011. *Prociphilus fraxinifolii* (Hemiptera: Aphididae), a new species to Britain. *British Journal of Entomology and Natural History*, 24, 221-223.

BALL, S.G., MORRIS, R.K.A. 2000. *Provisional atlas of the hoverflies (Diptera, Syrphidae)*. Institute of Terrestrial Ecology, Huntingdon.

BALLARD, D.W. 2004. *Leicestershire Bryophyte Flora 2004. The mosses and liverworts in the county.* Loughborough, Loughborough Naturalists Club.

BARNES, C.A., EVANS, H.J. 1981. *Results of Forest Insect and Disease Surveys in the Southwestern Region of Ontario, 1981*. Report from Great Lakes Forest Research Centre and The Ontario Ministry of Natural Resources.

BARNES, H. F. 1951. *Gall midges of economic importance*. Vol. V. Crosby Lockwood, London.
BATES, J.W.1995. A bryophyte Flora of Berkshire. *Journal of Bryology,* 18, 503-620.
BATT, L. 1993. Hawfinches feeding like crossbills on Scots pine. British Birds, 86: 133.
BELLOWS, T.S., PAINE, T.D., ARAKAWA, K.Y., MEISENBACHER, C., LEDDY, P., KABASHIMO, J. 1990. Biological control sought for ash whitefly. *California Agriculture*, 44, 4-6.
BENGTSSON, B.A., JOHANSSON, R. 2011. *Nationalnyckeln till Sveriges Flora och Fauna. Lepidoptera:Roeslerstammiidae - Lyonetiidae*. ArtDatabanken, Sveriges, Sweden.
BENGTSSON, B.A., PALMQUIST, G. 2008. *Nationalnyckeln till Sveriges Flora och Fauna. Lepidoptera:Micropterigidae - Psychidae*. ArtDatabanken, Sveriges. Sweden.
BENSON, R.B. 1952. *Symphyta. Handbooks for the identification of British Insects Vol. VI, Part 2(b).* Royal Entomological Society of London.
BIJLSMA, R. G. 1998. Breeding biology and population trend of hawfinches Coccothraustes coccothraustes in Flevoland. Limosa, 71, 137-148.
BLOCKEEL, T.L. (ed.) in prep. Draft species accounts for new edition of Atlas.
BLOCKEEL, T.L. 2013. Tales of the unexpected, no 2: *Ulota calvescens* in the southern Pennines. *Field Bryology,* 110, 35-38.
BODDY, M. 1991. Some aspects of frugivory by bird populations using coastal dune scrub in Lincolnshire. *Bird Study*, 38, 188-199.
BOSANQUET, S., GRAHAM, J., MOTLEY, G. 2005. *The mosses and liverworts of Carmarthenshire.* Pontypool, self-published.
BOSANQUET, S.D.S., LARA, F. 2012. *Orthotrichum cambrense* sp. nov. (Orthotrichaceae), a distinctive moss from Wales, United Kingdom. *Cryptogamie, Bryologie,* 33, 329-339.
BOULANGER,V., BALTZINGER,C., SAID,S., BALLON,P., PICARD,J.F., DUPOUEY,J.L. 2009. Ranking temperate woody species along a gradient of browsing by deer. *Forest Ecology And Management*, 258**,** 1397-1406.
BRADLEY, J.D., TREMEWAN, W.G., SMITH, A. 1973. *British Tortricoid Moths, Cochylidae and Tortricidae: Tortricinae*. The Ray Society, London.
BREWIS, A., BOWMAN, P., ROSE, F. 1996. *The Flora of Hampshire.* Colchester, Harley Books.
BROUGHTON, R. K., HILL, R. A., BELLAMY, P. E., HINSLEY, S. A. 2011. Nest-sites, breeding failure, and causes of non-breeding in a population of British Marsh Tits Poecile palustris. *Bird Study*, 58, 229-237.
BRYCE,J., CARTMEL,S., QUINE,C.P. 2005. *Habitat Use by Red and Grey Squirrels: Results of Two Recent Studies and Implications for Management*. 1-12. Edinburgh, Forestry Commission.
BUCK, E. undated. *Oystershell Scale (Lepidosaphes ulmi) on Green Ash (Fraxinus pennsylvanica).* University of Idaho: http://extension.ag.uidaho.edu/nursery/Landscape%20problems/oystershell%20scale.pdf (accessed 06/01/2014).
BUHR, H. 1964. Bestimmungstabellen der gallen (zoo-und phytocecidien) an pflanzen Mittel-und NordEuropas. VEB Gustav Fischer Verlag.
BURNAZ, S. 2005. Macrolepidoptera species of the Crăciuneşti gorges and the neighbourhood of the localities Lunca and Băiţa (Metaliferi Mountains, Western Carpathians, Romania). *Buletinul de Informare Entomologică*, 16, 7-34.
BURNAZ, S. 2007. Contribuţii la cunoşterea faunei de macrolepidoptere din rezervaţia naturală Dealul Bolii – Băniţa (judeţul Hunedoara). *Buletinul de Informare Entomologică*, 18, 53-78.
BURNS, R.M., HONKALA, B.H. 1990. *Silvics of North America*, Volume 2, Hardwoods. United States Department of Agriculture, Washington D.C., USA.
BUTET,A., DELETTRE,Y.R. 2011. Diet differentiation between European arvicoline and murine rodents. *Acta Theriologica*, 56**,** 297-304.

CALLADINE, J., MORRISON, N. 2010. The ranging behaviour and habitat selection by three Hawfinches Coccothraustes coccothraustes in late winter in Scotland. *Ornis Fennica*, 87, 119-123.
CARLSON, A., SANDSTROM, U., OLSSON, K. 1998. Availability and use of natural tree holes by cavity nesting birds in a Swedish deciduous forest. *Ardea*, 86, 109-119.
CARTER, D.J. 1943. *Pest Lepidoptera of Europe with Special Reference to the British Isles*. Dr. W. Junk Publishers, Dordrecht, Netherlands.
CASTRO,J., GOMEZ,J.M., GARCIA,D., ZAMORA,R., HODAR,J.A. 1999. Seed predation and dispersal in relict Scots pine forests in southern Spain. *Plant Ecology*, 145, 115-123.
CEBECI, H.H., ACER, S. 2007. The Occurrence of some Lepidopterous species on the horse chestnut (*Aesculus hippocastanum* L.) at Istanbul-Belgrad Forest in Turkey. *Acta agriculturae Slovenica*, 89, 95-102.
CHANDLER, P.J. 1988. *Checklists of Insects of the British Isles, Part 1: Diptera. Handbooks for the Identification of British Insects Vol. XII, Part I.* Royal Entomological Society of London.
CHARMAN, E.C., SMITH, K.W., DODD, S., GRUAR, D.J., DILLON, I.A. 2012. Pre-breeding foraging and nest site habitat selection by Lesser Spotted Woodpeckers Dendrocopos minor in mature woodland blocks in England. *Ornis Fennica*, 89, 182-196.
CHISWELL, J.R. 1964. Observations on the life histories of some leafhoppers (Homoptera: Cicadellidae) occurring on apple trees, and their control with insecticides. *Journal of Horticultural Science*, 39, 9-23.
CLARIDGE, M.F., WILSON, M.R. (1981) Host plant associations, diversity and species – area relationships of mesophyll-feeding leafhoppers of trees and shrubs in Britain. *Ecological Entomology*, 6, 217-238.
COE, R. 1953. *Diptera, Syrphidae. Handbooks for the identification of British insects. Vol. X., Part 1.* Royal Entomological Society of London.
CORNELIS,J., CASAER,J. HERMY,M. 1999. Impact of season, habitat and research techniques on diet composition of roe deer (Capreolus capreolus): a review. *Journal of Zoology*, 248, 195-207.
COULIANOS, C-C. 1998. Annotated catalogue of the Hemiptera-Heteroptera of Norway. *Fauna Norwegia* Ser.B, 45, 11-40.
CSÓKA, G., SZABÓKY, C. 2005. Checklist of herbivorous insects of native and exotic oaks in Hungary, I. (Lepidoptera). *Acta Silvatica et Lignaria Hungarica*, 1, 59-72.
CZESZCZEWIK, D. WALANKIEWICZ, W. 2003. Natural nest sites of the pied flycatcher Ficedula hypoleuca in a Primeval Forest. *Ardea*, 91, 221-229.
DAVIS, H., FLECHTMANN, R., BOCZEK, J. BARKE, H.E. 1982. *Catalogue of Eriophyid Mites (Acari: Eriophyoidea)*. Warsaw Agricultural University Press, Poland, 254pp.
ĐORDEVIC,N., POPOVIC,Z., BEUKOVIC,M., BEUKOVIC,D. ĐORDEVIC M. 2011. Characteristic of natural nutrition brown hare (Lepus Europaeus) in modern agro-biocenose . *International Symposium Food safety production, Trebinje.*, 140-143.
DRAKE, C.M. 1991. *Provisional atlas of the larger Brachycera (Diptera) of Britain and Ireland.* Institute of Terrestrial Ecology, Huntingdon.
DRAPER, I., LARA, F., ALBERTOS, B., GARILLETI, R., MAZIMPAKA, V. 2006. Epiphytic bryoflora of the Atlas and Antiatlas Mountains, including a synthesis of the distribution of epiphytic bryophytes in Morocco. *Journal of Bryology,* 28, 312-330.
DUSSAIX, C. 2005. Liste provisoire des syrphes (Diptera, Syrphidae) du département de la Sarthe (72-France). Période 1990-2004. (1re actualisation). *L'Entomologiste* ,61**,** 159-178.
DVORAK,J. 2013. Diet preference of Eurasian Beaver (Castor fiber L., 1758) in the environment of Oderske vrchy and its influence on the tree species composition of river bank stands. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 61**,** 1637-1643.
EBER, S., SMITH, H. P., DIDHAM, R. K., CORNELL, H. V. 2001. Holly leaf-miners on two continents: what makes an outbreak species? *Ecological Entomology*, 26, 124-132.

EDWARDS, S.R. 2003. *English names for British bryophytes.* 3rd ed. Loughton, Essex: British Bryological Society Special vol. no. 5.

EGGERS, S. 2000. Compensatory frugivory in migratory Sylvia warblers: geographical responses to season length. *Journal of Avian Biology*, 31, 63-74.

ELSNER, G., HUEMER, P., TOKAR, Z. 1999 *Die Palpenmotten Mitteleuropas*. František Slamka, Bratislava, Slovakia.

EMMET, A.M. 1992. Chart showing the life history and habits of the British Lepidoptera. *The Moths and Butterflies of Great Britain and Ireland* (ed. by A.M. Emmet and J. Heath), pp. 61–303. Harley Books, Colchester, UK.

EMMET, A.M. 1996. *The Moths and Butterflies of Great Britain and Ireland*. Volume 3: Yponomeutidae - Elachistidae. Harley Books, Colchester, UK.

EZER, T., KARA, R., DUZENLI, A. 2009. The succession, habitat affinity and life-forms of epiphytic bryophytes in the Turkish oak (*Quercus cerris*) forests on Mount Musa. *Ekoloji* 18, 72, 8-15.

FALK, S.J., CROSSLEY, R. 2005. A review of the scarce and threatened flies of Great Britain. Part 3: Empidoidea. *Species Status* 3: 1-134. Joint Nature Conservation Committee, Peterborough.

FASHING, N.J., OKABE, K. 2006. *Hericia sanukiensis*, a new species of Algophagidae (Astigmata) inhabiting sap flux in Japan. *Systematic & Applied Acarology Special Publications*, 22, 1–14.

FAUSKE, G., KNOTT, J., NELSON, D., KANGAS, M. 2005. Cottony ash psyllid in North Dakota. *North Dakota State University Crop & Pest Report*, No. 8, 1. food Newton1967,1964

GEBERT,C., VERHEYDEN-TIXIER,H. 2001. Variations of diet composition of Red Deer (Cervus elaphus L.) in Europe. *Mammal Review*, 31**,** 189-201.

GILL,R. 2000. *The impact of deer on woodland biodiversity. Information Note*. Forestry Commission.

GILL,R.M.A. 1992. A Review of Damage by Mammals in North Temperate Forests: 1. Deer. *Forestry*, 65**,** 145-169.

GJERDE, I., SAETERSDAL, M. 1997. Effects on avian diversity of introducing spruce Picea spp. plantations in the native pine Pinus sylvestris forests of western Norway. *Biological Conservation*, 79, 241-250.

GODFREY, A., WHITEHEAD, P.F. 2001. The Diptera, Coleoptera and other invertebrates recorded from oak sap-flows at Brayton Barff, North Yorkshire. *British Journal of Entomology and Natural History,* 14, 65-81.

GOLISZEK, K., ŁAGOWSKA, BN., GOLAN, K. 2011. Scale insects (Hemiptera, Sternorrhyncha, Coccoidea) on ornamental plants in the field in Poland. *Acta Scientiarum Polonorum Hortorum Cultus*, 10, 75-84.

GRABENWEGER, G., KEHRLI, P., SCHLICK-STEINER, B., STEINER, F., STOLZ, M., BACHER, S. 2005. Predator complex of the horse chestnut leafminer Cameraria ohridella: identification and impact assessment. *Journal of Applied Entomology*, 129, 353-362.

GRAORA, D., SPASIĆ, R. 2008. Prirodni neprijatelji *Pseudaulacaspis pentagona* Targioni-Tozzetti u Srbiji. *Pesticidi i fitomedicina*, 23, 11-16.

GRAORA, D. 2006. Prisustvo i štetnost dudove štitaste vaši, Pseudaulocaspis pentagona Targioni-Tozzetti u Srbiji. *Pesticidi i fitomedicina*, 21, 21-30.

HAGGETT, G.M. 1980. Unusual food of Ennomos fuscantaria Haworth. *Entomologist's Record and Journal of Variation*, 92, 97.

HALPERIN, J., ZUR STRASSEN, R. 1981. Thysanoptera of forest and ornamental woody plants in Israel with a list of species recorded from Israel. *Israel Journal of Entomology* 15, 21-33.

HALPERIN, J. 2006. Comparative flowering ecology of *Fraxinus excelsior, Acer platanoides, Acer pseudoplatanus* and *Tilia cordata* in the canopy of Leipzig's floodplain forest. Unpublished PhD Thesis.

HALSTEAD, A.J. 2010. Some sawfly host plants not listed by Benson. *British Journal Entomology & Natural History,* 7, 191-192.
HARRIS, H., YALDEN, D.W. 2008. *Mammals of the British Isles: Handbook*. The Mammal Society, Southampton.
HARTLEY, P.H.T. 1953. An Ecological Study of the Feeding Habits of the English Titmice. Journal of Animal Ecology, 22: 261-288.
HEELER, A.G.W., JR., HENRY, T.J., HOEBEKE, E.R. 2006. Palearctic plant bugs (Hemiptera, Miridae) in Newfoundland, Canada: First North American records for *Phytocoris longipennis* FLOR and *Pilophorus cinnamopterus* (K IRSCHBAUM), new records of eight other species, and review of previously reported species. *Denisia*, 19, 997-1014.
HERNANDEZ, A. 2009. Summer-autumn feeding ecology of Pied Flycatchers Ficedula hypolueca and Spotted Flycatchers Muscicapa striata: the importance of frugivory in a stopover area in north-west Iberia. Bird Conservation International, 19, 224-238.
HEWSON, C.M., AUSTIN, G.E., GOUGH, S.J., FULLER, R.J. 2011. Species-specific responses of woodland birds to stand-level habitat characteristics: The dual importance of forest structure and floristics. *Forest Ecology and Management*, 261, 1224-1240.
HILL, M.O., PRESTON, C.D., SMITH, A.J.E. (eds.) 1991. *Atlas of the bryophytes of Britain and Ireland. Volume 1 Liverworts (Hepaticae and Anthocerotae).* Colchester, Harley Books.
HILL, M.O., PRESTON, C.D., SMITH, A.J.E. (eds.) 1992. *Atlas of the bryophytes of Britain and Ireland. Volume 2 Mosses (except Diplolepideae).* Colchester, Harley Books.
HILL, M.O., PRESTON, C.D., SMITH, A.J.E. (eds.) 1994. *Atlas of the bryophytes of Britain and Ireland. Volume 3 Mosses (Diplolepideae).* Colchester, Harley Books.
HILL, M.O., PRESTON, C.D., BOSANQUET, S.D.S., ROY, D.B. 2007. *BRYOATT. Attributes of British and Irish mosses, liverworts and hornworts.* NERC Centre for Ecology and Hydrology & Countryside Council for Wales.
HINO, T. 1985. Relationships between bird community and habitat structure in shelterbelts of Hokkaido, Japan. *Oecologia*, 65, 442-448.
HODGETTS, N.G. 2003. *The status of pale bristle-moss* Orthotrichum pallens *in Britain.* Report Number 221. English Nature, Peterborough/Plantlife, Salisbury.
HOEBEKE, E.R., JOHNSON, W.T. 1985. A European privet sawfly, Macrophya punctumalbum (L.): North American distribution host plants, seasonal history and descriptions of the immature stages (Hymenoptera: Tenthredinidae). *Proceedings of the Entomological Society of Washington,* 85, 25-33.
HOEBEKE, E.R., WHEELER JR, A.G., BROWN, J.W. 2008. *Archips xylosteana* (L.) (Lepidoptera: Tortricidae), a Palearctic leafroller new to North America. *Proceedings of the Entomological Society of Washington*, 110, 789-795.
HOGSTAD, O. 2010. Sexual differences in foraging behaviour in the Lesser Spotted Woodpecker *Dendrocopos minor*. *Ornis Norvegica*, 33, 135-146.
HOLYOAK, D.T. 2012. Bryophytes of Cornwall and the Isles of Scilly. www.cisfbr.org.uk/Bryo/Cornish_Bryophytes_Introduction.html
HOSEY, G.R. 1981. Annual Foods of the Roe Deer (Capreolus-Capreolus) in the South of England. *Journal of Zoology*, 194**,** 276-278.
HULME, P.E., BORELLI, T. 1999. Variability in post-dispersal seed predation in deciduous woodland: relative importance of location, seed species, burial and density. *Plant Ecology*, 145, 149-156.
IASON, G.R., O'REILLY-WAPSTRA, J.M., BREWER, M.J., SUMMERS, R.W., MOORE, B.D. 2011. Do multiple herbivores maintain chemical diversity of Scots pine monoterpenes? *Philosophical Transactions of the Royal Society B-Biological Sciences*, 366, 1337-1345.
IORDANOU, N.C., IOANNOU, Y.M. 1979. *Effect of thrips and wind on the development of epidermal injuries on citrus fruits in Cyprus.* Technical Bulletin, Agricultural Research Institute, Ministry of Agriculture and Natural Resources 26, 12pp.

JACKSON, J. 1977. Annual Diet of Fallow Deer (Dama-Dama) in New Forest, Hampshire, As Determined by Rumen Content-Analysis. *Journal of Zoology*, 181, 465-473.
JACKSON, J. 1980. The Annual Diet of the Roe Deer (Capreolus-Capreolus) in the New Forest, Hampshire, As Determined by Rumen Content-Analysis. *Journal of Zoology*, 192, 71-83.
JAMES, R., PRITCHARD, I. 1988. Influence of the holly leaf miner, Phytomyza ilicis (Diptera Agromyzidae), on leaf abscission. Journal of natural history, 22, 395-402.
JERINIĆ-PRODANOVIĆ, D., PROTIĆ, L. 2013. True bugs (Hemiptera, Heteroptera) as psyllid predators (Hemiptera, Psylloidea). *ZooKeys*, 319, 169–189.
JESSOP, L. 1983. The British species of *Anthocoris* (Hem., Anthocoridae). *Entomologist's Monthly Magazine*, 119, 221-223.
KAVURKA, V.V. 2010. New records of Tortricid moths (Lepidoptera, Tortricidae) from Ukraine. *Vestnik zoologii*, 44, e-10-e-17.
KIRBY, P. 1992. *A Review of the Scarce and Threatened Hemiptera of Great Britain*. Joint Nature Conservation Committee, Peterborough, UK.
KIZIROGLU, I. 1976. Zur Kenntnis der Fliedermotte, Gracilaria syringella (F.) (Lepid., Gracilariidae) : 2. Biologie. Zeitschrift für Angewandte Entomologie, 81, 43–61.
KOLLÁR, J. 2007. The harmful entomofauna of woody plants in Slovakia. *Acta entomologica serbica*, 12, 67-79.
KOSINSKI, Z., KEMPA, M. 2007. Density, distribution and nest-sites of woodpeckers picidae, in a managed forest of Western Poland. *Polish Journal of Ecology*, 55, 519-533.
KOSIŃSKI, Z., WINIECKI, A. 2004. Nest-site selection and niche partitioning among the Great Spotted Woodpecker Dendrocopos major and Middle Spotted Woodpecker Dendrocopos medius in riverine forest of Central Europe. *Ornis Fennica*, 81, 145-156.
KOZLOWSKI, J. 1974. Eriophyoidea (Acarina) of some broadleaved trees in the Laski forest district (Poland). *Prace Komisji Nauk Rolniczych i Komisji Nauk Lesnych,* 38, 167-171.
KROJEROVA-PROKESOVA, J., BARANCEKOVA, M., HAMSIKOVA, L., VOREL, A. 2010. Feeding habits of reintroduced Eurasian beaver: spatial and seasonal variation in the use of food resources. *Journal of Zoology*, 281, 183-193.
KRÜGER, S. 1979. Der Kernbeißer, Wittenberg Lutherstadt: A. Ziemsen Verlag.
KULA, E. 2007. Caterpillars of the crown fauna in stands of substitute tree species. *Folio Oecologica*, 34, 30-40.
KULA, E., PATOČKA, J., ŠIMON, V. (2009) Caterpillars of Lepidoptera in crowns of mountain ash (*Sorbus aucuparia* L.) in the Ore Mountains. *Folio Oecologica*, 36, 94-107.
KULFAN, M. 1997. Motýle (lepidoptera) žijúce na duboch nížinných oblastí juhozápadného Slovenska. *Folia faunistica Slovaca*, 2, 85-92.
KULFAN, M., HOLECOVÁ, M., FAJČÍK, J. 2006. Caterpillar (Lepidoptera) communities on European Turkey oak (*Quercus cerris*) in Malé Karpaty Mts (SW Slovakia). *Biologia*, 61, 573—578.
KURINA, O. 1994. *Thereva nobilitata* (Diptera, Therevidae) reared from Boletales and Agaricales (Basidiomycota). *Entomologica Fennica,* 5**,** 186.
LE QUESNE, W.J., PAYNE, K.R. 1981. *Cicadellidae (Typhlocybinae) with a check list of the British Auchenorhyncha (Hemiptera, Homoptera). Handbooks for the Identification of British Insects, II, 2c.* Royal Entomological Society, London, UK.
LEACH, I.H. 1981. Wintering blackcaps in Britain and Ireland. *Bird Study*, 28, 5-14.
LEATHER, S.T. 1991. Feeding specialisation and host distribution of British and Finnish *Prunus* feeding macrolepidoptera. *Oikos*, 60, 40-48.
LEE,T.H. 2002. Feeding and hoarding behaviour of the Eurasian red squirrel Sciurus vulgaris during autumn in Hokkaido, Japan. *Acta Theriologica*, 47, 459-470.
LI,Y.. ZHANG,M. 2005. Food - habits of red deer in winter in Wanda Mountain Forest Region. *Journal of Northeast Forestry University*, 33, 104-105.
LISTON, A.D. 1984. Sawfly fauna of a wooded park within the city of Edinburgh (Hymenoptera Symphyta). *Entomologist's Record & Journal of Variation* **96**: 17-21.

LISTON, A.D. 2010. New hostplant records for European sawflies (Hymenoptera, Tenthredinidae). *Entomologist's Monthly Magazine,* 146, 189-193.
LOCKHART, N., HODGETTS, N., HOLYOAK, D. 2012. *Rare and Threatened bryophytes of Ireland.* Holywood, National Museums Northern Ireland.
LOHMUS, A., KINKS, M., SOON, M. 2010. The Importance of Dead-Wood Supply for Woodpeckers in Estonia. *Baltic Forestry*, 16, 76-86.
LOPPI, S., BONINI, I., DE DOMINICIS, V. 1999. Epiphytic lichens and bryophytes of forest ecosystems in Tuscany (central Italy). *Cryptogamie, Mycologie,* 20, 127-135.
MAAS-HEBNER,K.G., EMMINGHAM,W.H., LARSON,D.J., CHAN,S.S. 2005. Establishment and growth of native hardwood and conifer seedlings underplanted in thinned Douglas-fir stands. *Forest Ecology And Management*, 208**,** 331-345.
MACGOWAN, I. ROTHERAY, G. 2008. British Lonchaeidae. Diptera, Cyclorrhapha, Acalytratae. *Handbooks for the Identification of British Insects* 15. Royal Entomological Society, London.
MACGOWAN, I., ROTHERAY, G.E. 2000. New species, additions and possible deletions to British *Lonchaea* Fallén (Diptera, Lonchaeidae). *Dipterists Digest*, 7, 37-49.
MALUMPHY, C., HALSTEAD, A.J., SALISBURY, A. 2012. First incursion of Chinese Mussel Scale Lepidosaphes chinensis (Hemiptera: Diaspididae) in Europe, with a review of Lepidosaphes species found in Britain. *British Journal of Entomology and Natural History*, 25, 65-74.
MANN, J.C.E., PUTMAN, R.J. 1989 Diet of British Sika Deer in Contrasting Environments. *Acta Theriologica*, 34, 97-109.
MARQUISS, M. 2007. Seasonal pattern in hawk predation on common Bullfinches Pyrrhula pyrrhula: evidence of an interaction with habitat affecting food availability. *Bird Study*, 54, 1-11.
MARTINS,H., MILNE,J.A., REGO,F. 2002. Seasonal and spatial variation in the diet of the wild rabbit (Oryctolagus cuniculus L.) in Portugal. *Journal of Zoology*, 258**,** 395-404.
MATOŠEVIĆ, D., HRAŠOVEC, B., PERNEK, M. 2003. Spread and character of Tomostethus nigritus F. outbreaks in Croatia during the last decade. *In* Proceedings: Ecology, Survey and Management of Forest Insects (eds. McManus, Michael L.; Liebhold, Andrew M.), Krakow, Poland. Gen. Tech. Rep. NE-311. Newtown Square, PA: U.S. Dept. of Agriculture, Forest Service, Northeastern Research Station, pp.39-43.
MATRAI, K., ALTBACKER, V., HAHN, I. 1998. Seasonal diet of rabbits and their browsing effect on juniper in Bugac Juniper Forest (Hungary). *Acta Theriologica*, 43, 107-112.
MATRAI, K., SZEMETHY, L., TOTH, P., KATONA, K., SZEKELY, J. 2004. Resource use by red deer in lowland nonnative forests, Hungary. *Journal of Wildlife Management*, 68**,** 879-888.
MILLARD, P. 2013. *Prays fraxinella* (Bjerkander) (Lep.: Praydidae) is not monophagous on Ash. *Entomologists' Record and Journal of Variation*, 125, 171.
MINDER, I. 2012. Local and seasonal variations of roe deer diet in relation to food resource availability in a Mediterranean environment. *European Journal of Wildlife Research*, 58, 215-225.
MIRONOV, V. 2003. *The Geometridae Moths of Europe*. Larentiinae II Vol. 4. Apollo Books.
MORISON, G. 1947. Thysanoptera of the London area Part II. Key to British genera and species of Thysanoptera. *Supplement to the London Naturalist ,* 27, 37-75.
MORISON, G. 1948. Thysanoptera of the London area Part II. *Supplement to the London Naturalist,* 28, 77-131.
MOUND, L.A. 1968. A review of R.S. Bagnall's Thysanoptera collections. *Bulletin of the British Museum (Natural History)*. Entomology Supplement, 11, 1-181.
MOUND, L.A., MORISON, G.D., PITKIN, B.R., PALMER, J.M. 1976. Thysanoptera. Handbooks for the identification of British insects. Vol. I, Part 11. Royal Entomological Society of London.
MOUNTFORD, G. 1957. The Hawfinch, London: Collins.

MUNILLA, I., GUITIAN, J. 2012. Numerical response of Bullfinches Pyrrhula pyrrhula to winter seed abundance. Ornis Fennica, 89, 197-205.
MYKING, T., SOLBERG, E.J., AUSTRHEIM, G., SPEED, J.D.M., BOHLER, F., ASTRUP, R., ERIKSEN, R. 2013. Browsing of sallow (Salix caprea L.) and rowan (Sorbus aucuparia L.) in the context of life history strategies: a literature review. *European Journal of Forest Research*, 132, 399-409.
NAU, B.S., BROOKE, S.E. 2007. *Brachynotocoris puncticornis* Reuter, 1880 (Hem., Miridae) new to Britain. *Entomologist's Monthly Magazine*, 143, 137-138.
NBN GATEWAY. 2014. www.nbn.org.uk
NÉMETH. R., MOLNÁR, S. 2005. Utilisation of walnut (*Juglans*), robinia (*Robinia pseudoacacia*) and ash (*Fraxinus*) on the basis of Hungarian experiences. COST Action E42, *Growing Valuable Broadleaved Tree Species*, Thessaloniki, Greece, 17–21 May 2005.
NEWTON, I. 1960. The diet and feeding habits of the bullfinch. *Bird Study*, 7, 1-9.
NEWTON, I. 1964. Bud-Eating by Bullfinches in Relation to the Natural Food-Supply. *Journal of Applied Ecology*, 1, 265-279.
NEWTON, I. 1967. The Feeding Ecology of the Bullfinch (Pyrrhula pyrrhula L.) in Southern England. *Journal of Animal Ecology*, 36, 721-744.
NICKEL, H. 2003. *The Leafhoppers and Planthoppers of Germany (Hemiptera, Auchenorrhyncha): Patterns and strategies in a highly diverse group of phytophagous insects*. Pensoft Publishers, Sofia, Bulgaria.
NIXON, C., MCCLAIN, M., DONOHOE, R. 1975. Effects of hunting and mast crops on a squirrel population. *Journal of Wildlife Management*, 39, 1-25.
NOYES, J.S. 2012. Universal Chalcidoidea Database. World Wide Web electronic publication. http://www.nhm.ac.uk/chalcidoids.
OBIDZINSKI, A., KIELTYK, P., BORKOWSKI, J., BOLIBOK, L., REMUSZKO, K. 2013. Autumn-winter diet overlap of fallow, red, and roe deer in forest ecosystems, Southern Poland. *Central European Journal of Biology*, 8, 8-17.
OBRTEL, R., HOLISOVA, V., KOZENA, I. 1985. The Winter Diet of Sika Deer (Cervus-Nippon) in the Bouzovsko Area. *Folia Zoologica*, 34, 1-22.
OLSSON, O., WIKTANDER, U., MALMQVIST, A., NILSSON, S.G. 2001. Variability of patch type preferences in relation to resource availability and breeding success in a bird. *Oecologia*, 127, 435-443.
OWEN, J.A. 1993. Rearing *Pandivirilis melaleuca* (Loew) (Diptera: Therevidae) from larvae. *Entomologist's Record & Journal of Variation,* 105, 257-259.
PAGOLA-CARTE, S. 2010. A revision of the genus Brachynotocoris Reuter, 1880 and other miridological contributions (Hemiptera: Heteroptera: Miridae) from the Basque Country (northern Iberian Peninsula). *Heteropterus Revista de Entomología*, 10, 107-129.
PALMER, M.W. 1986. Pattern in corticolous bryophyte communities of the North Carolina Piedmont: do mosses see the forest or the trees? *Bryologist* ,89, 59-65.
PALMER, R.M. 1997. Some notes on Lepidoptera in Surrey, 1994-6. *The Entomologist's Record and Journal of Variation*, 109, 210-211.
PALMER, S.C.F., TRUSCOTT, A.M. 2003. Browsing by deer on naturally regenerating Scots pine (Pines sylvestris L.) and its effects on sapling growth. *Forest Ecology and Management*, 182, 31-47.
PECK, K.M. 1989. Tree species preferences shown by foraging birds in forest plantations in Northern England. *Biological Conservation*, 48, 41-57.
PEEV, D. (ed.) 2011. *Red Data Book of the Republic of Bulgaria. Vol. 1. Plants and Fungi.* Sofia, Bulgarian Acadamy of Sciences & Ministry of Environment and Water (see also digital edition, http://www.e-ecodb.bas.bg/rdb/en/vol1/)
PELIKAN, J. 1991. Faunistic records from Czechoslovakia. Thysanoptera. *Acta Entomologica Bohemoslovaca,* 87, 232-234.
PLÁŠEK, V. 2011. Recent findings of mosses from Orthotrichaceae family (Bryophyta) in the Czech part of the Western Carpathians. Part 1. The Moravskoslezské Beskydy Mts and its foothills. *Čas. Slez. Muz. Opava (A)* 60: 268-283.

POKORNY, L., LARA, F., MAZIMPAKA, V. 2006. The bryophyte flora of the city of Trentino (North Italy). *Cryptogamie, Bryologie* 27, 1-20.
RACEY, P.A. 2008. *Bats: Order Chiroptera. Chapter 8 in the Mammals of the British Isles:* Handbook 4th Edition. S.Harris and D.W. Yalden (eds). The Mammal Society, Southampton.
RAUDONIS, L. 2001. Harmful insect fauna in apple orchards and systems of control means to reduce its harm. *Sodininkyste ir Darzininkyste,* 20**,** 55-68.
RAZOWSKI, J. 2002. *Tortricidae of Europe*. Volume 1 - Tortricinae and Chlidanotinae. František Slamka, Bratislava, Slovakia.
RAZOWSKI, J. 2003. *Tortricidae of Europe*. Volume 2 – Olethreutinae. František Slamka,
RIMA,P.C., CAGNIN,M., ALOISE,G., PREATONI,D., WAUTERS,L.A. 2010. Scale-dependent environmental variables affecting red squirrel (*Sciurus vulgaris meridionalis*) distribution. *Italian Journal of Zoology*, 77, 92-101.
ROBINSON, G.S., ACKERY, P.R. KITCHING, I.J. BECCALONI G. W., HERNÁNDEZ, L.M. 2010. HOSTS - A Database of the World's Lepidopteran Hostplants. Natural History Museum, London. http://www.nhm.ac.uk/hosts. (Accessed: 21/01/2014).
ROMERA, L., CIFUENTES, J., VIEJO, J.L., FERNÁNDEZ, J. 2002. Los geométridos del piso supramediterráneo de la Sierra de Guadarrama:estacionalidad y relación con las formaciones vegetales (Insecta: Lepidoptera, Geometridae). *Boletin de la Asociacion Espanola de Entomologia*, 26, 145-162.
ROSE, F., STERM, R.C., MATCHAM, H.W., COPPINS, B.J. 1991. *Atlas of Sussex mosses, liverworts and lichens.* Brighton, Booth Museum of Natural History.
ROTHERAY, G.E., HANCOCK, G., HEWITT, S., HORSFIELD, D., MACGOWAN, I. 2001. The biodiversity and conservation of saproxylic Diptera in Scotland. *Insect Conservation,* 5, 77-85.
RUBINO, F.M., MARTINOLI, A., PITTON, M., DI FABIO, D., CARUSO, E., BANFI, S., TOSI, G., WAUTERS, L.A., MARTINOLI, A. 2012. Food choice of Eurasian red squirrels and concentrations of anti-predatory secondary compounds. *Mammalian Biology*, 77, 332-338.
RYAN, R. 2012. An addendum to Southwood & Leston's Land and Water Bugs of the British Isles. *British Journal of Entomology and Natural History*, 25, 205-215.
SANTAMOUR, J.R., GREENE, A. 1986. European hornet damage to ash and birch trees. *Journal of Arboculture,* 12, 273-279.
SCHEPER, J., SMIT, C. 2011. The role of rodents in the seed fate of a thorny shrub in an ancient wood pasture. *Acta Oecologica-International Journal of Ecology*, 37, 133-139.
SCHMID, U., GROSSMANN, A. 1996. *Brachyopa insensilis* Collin, 1939 (Diptera, Syrphidae) bred from sap run of silver fir *Abies alba* Mill. *Volucella* 2, 98-100.
SCHONROGGE, K., BEGG, T., STONE, G. N. 2013. Native Birds and Alien Insects: Spatial Density Dependence in Songbird Predation of Invading Oak Gallwasps. *Plos One*, 8, issue 1, e53959.
SCHWARTZ, M.D., SCUDDER, G.G.E. 2000. Miridae (Heteroptera) new to Canada, with some taxonomic changes. *Journal of the New York Entomological Society*, 108, 248–267.
SELJAK, G. 2010. A checklist of scale insects of Slovenia. *Entomologia Hellenica*, 19, 99-113.
SENKEVICH, N.G., LINDEMAN, G.V., KOPYL, M.V. 1991. Growth and condition of male and female trees of green ash and downy ash. *Lesovedenie*, issue 5, 42-47.
SHAW, M.R. 1981. Possible foodplant differences of *Amphipyra pyramidea* (L.) and *A. berbera svenssoni* Fletcher (Lepidoptera: Noctuidae), and a note on their parasites (Hymenoptera). *Entomologist's Gazette*, 32, 165-167.
SKOU, P. 1984. *Nordens Malere*. Danmarks Dyreliv, Bind 2. Fauna Boger & Apollo Boger.
SKOU, P. 1991 *Nordens Ugler: Håndbog over de i Danmark, Norge, Sverige, Finland og Island Forekommende Arter af Herminiidae of Noctuidae (Lepidoptera)*. Danmarks Dyreliv Bind 5. Apollo Books.

SKRZYPCZYŃSKA, M. 2002. Studies on insects and mites causing galls on the leaves of common ash *Fraxinus excelsior* L. in the Ojców National Park in Poland. *Anzeiger für Schädlingskunde,* 75**,** 11-12.
SLAMKA, F. 2010. *Pyraloidea (Lepidoptera) of Central Europe*. František Slamka, Bratislava, Slovakia.
SMART, J., TAYLOR, E., AMAR, A., SMITH, K., BIERMAN, S., CARPENTER, J., GRICE, P., CURRIE, F., HEWSON, C. 2007. *Habitat associations of woodland birds: implications for woodland management for declining species.* In RSPB Research Report No. 26. Vol. 26. Sandy: RSPB.
SMITH, D. 2004. Breeding and roosting hawfinches (Coccothraustes coccothraustes) in Merioneth. *Welsh Birds*, 4, 11-19.
SMITH, K. W. 2007. The utilization of dead wood resources by woodpeckers in Britain. *Ibis*, 149, 183-192.
SOLOVYOV, A.N. 2012. Feeding preferences of Common Bullfinch (Pyrrhula pyrrhula) in winter. *Bulletin of Udmurt University*, 3, 78-84.
SOUTHWOOD, T.R.E., KENNEDY, C.E.J. 1983. Trees as Islands. *Oikos*, 41, 359-371.
SOUTHWOOD, T.R.E., LESTON, D. 1959. *Land and Water Bugs of the British Isles*. Frederick Warne & Co. Ltd., London.
SPENCER, K.A. 1972. *Agromyzidae. Handbooks for the Identification of British Insects. Vol. X, Part 5(g).* Royal Entomological Society of London.
STERLING. P., PARSONS, M., LEWINGTON, I. 2012. *Field Guide to the Micro Moths of Great Britain and Ireland*. British Wildlife Publishing Ltd., Hook, Hampshire, UK.
STOKLAND, J.N., SIITONEN, J., JONSSON, B.G. 2012. *Biodiversity in dead wood*. Cambridge University Press.
STONEDAHL, G.M. 1983. New record for Palearctic *Phytocoris* in Western North Amercia (Hemiptera, Miridae). *Proceedings of the Entomological Society of Washington*, 85, 463-471.
STRASSEN, R. 2007. *Fauna Europaea checklist of Thysanoptera (thrips) of Britain, version 1. [Subset of Fauna Europaea version 1.3].* http://www.nhm.ac.uk/research-curation/scientific-resources/biodiversity/uk-biodiversity/uk-species/checklists/NHMSYS0020304427/version1.html
STUBBS, A. 1992. *Provisional atlas of the long-palped craneflies (Diptera: Tipulinae) of Britain and Ireland.* Institute of Terrestrial Ecology, Huntingdon.
STUDLAR, S.M. 1982. Host specificity of epiphytic bryophytes near Mountain Lake, Virginia. *Bryologist,* 85, 37-50.
TAKAHASHI, K., SATO, K., WASHITANI, I. 2007. Acorn dispersal and predation patterns of four tree species by wood mice in abandoned cut-over land. *Forest Ecology and Management*, 250**,** 187-195.
TAYLOR, S., SUMMERS, R. W. 2010. Numbers of breeding birds in old Scots Pine wood at Abernethy Forest, Badenoch & Strathspey, from 1977 to 1987. *Scottish Birds*, 30, 302-311.
TIXIER, H., DUNCAN, P. 1996. Are European roe deer browsers? A review of variations in the composition of their diets. *Revue D Ecologie-la Terre et la Vie*, 51**,** 3-17.
TOMIALOJC, L. 2005. Distribution, breeding density and nest sites of Hawfinches Coccothraustes coccothraustes in the primeval forest of Bialowieza National Park. *Acta Ornithologica*, 40, 127-138.
TÖRÖK, J. 1990. Resource partitioning amoung three woodpecker species Dendrocopos spp. during the breeding season. *Holarctic Ecology*, 13, 257-264.
TRIDAN, S., VIDRIH, M., VIERBERGEN, G. 2012. First record of Aeolothrips gloriosus Bagnall (Thysanoptera: Aeolothripidae) in Slovenia. *Archives of Biological Sciences* 64, 767-770.
ÜLGENTÜRK, S., ÇANAKÇIOĞLU, H. 2004. Scale insect pests on ornamental plants in urban habitats in Turkey. *Journal of Pest Science*, 77, 79-84.
VAN STEENIS, J. VAN STEENIS, W., WAKKIE, B. 2001. Hoverflies in southern Skåne, Sweden (Diptera: Syrphidae). *Ent. Tidskr.* 122, 15-27.

VANDER WALL,S.B. 2001. The evolutionary ecology of nut dispersal. *Botanical Review*, 67**,** 74-117.
VELCHEVA, N. 2009. Lepidopterian fauna in new planted apple orchard in West Bulgaria. *Biotechnology and Biotechnological Equipment*, special issue, 23, 127-131.
VIDELOV, K., LAMBREV, E. 1987. Insect pests of Quercus rubra in park stands in Sofia. *Gorsko Stopanstvo Gorska Promishlenost*, 43, 25-27.
VON HAARTMAN, L. 1978. An account of a small population of hawfinches. *Ornis Fennica*, 55, 132-133.
WARING, P., TOWNSEND, M 2003. *Field Guide to the Moths of Great Britain and Ireland*. British Wildlife Publishing Ltd., Hook, Hampshire, UK.
WATTS, C.H.S. 1968. Foods Eaten by Wood Mice (Apodemus Sylvaticus) and Bank Voles (Clethrionomys Glareolus) in Wytham Woods Berkshire. *Journal of Animal Ecology*, 37**,** 25-41.
WAUTERS, L., SWINNEN, C., DHONDT, A.A. 1992. Activity Budget and Foraging Behavior of Red Squirrels (Sciurus-Vulgaris) in Coniferous and Deciduous Habitats. *Journal of Zoology*, 227, 71-86.
WESOLOWSKI, T., ROWINSKI, P. 2004. Breeding behaviour of Nuthatch Sitta europaea in relation to natural hole attributes in a primeval forest. *Bird Study*, 51, 143-155.
WESOLOWSKI, T., ROWINSKI, P. 2012. The breeding performance of Blue Tits Cyanistes caeruleus in relation to the attributes of natural holes in a primeval forest. *Bird Study*, 59, 437-448.
WESOLOWSKI, T. 1996. Natural nest sites of Marsh tits Parus palustris in a primaeval forest (Bialowieza National Park, Poland). Die Vogelwarte, 38, 235-249.
WHEELER, A. G., HOEBEKE, E.R. 1990. *Psallus lepidus* Fieber, *Deraeocoris piceicola* Knight, and *Dichrooscytus latifrons* Knight: new records of plant bugs In Eastern North America (Heteroptera: Miridae). *Journal of the New York Entomological Society*, 98, 357-361.
WHEELER, A.G. HENRY, T.J. 1980. *Brachynotocoris heidemanni* (Knight), a junior synonym of the Palearctic *B. Puncticornis* Reuter and pest of European Ash. *Proceedings of the Entomological Society of Washington*, 82, 568-575.
WOODS, R.G. 1993. *Flora of Radnorshire.* Cardiff, National Museum of Wales/Bentham-Moxon Trust.
YOKOYAMA, M., KAJI, K., SUZUKI, M. 2000. Food habits of sika deer and nutritional value of sika deer diets in eastern Hokkaido, Japan. *Ecological Research*, 15**,** 345-355.
ZAMUDIO, P., CLAPS, L.E. 2005. Diaspididae (Hemiptera: Coccoidea) Asociadas a Frutales en la Argentina. *Neotropical Entomology*, 34, 255-272.
ZANGARI, L., FERRAGUTI, M., LUISELLI, L., BATTISTI, C., BOLOGNA, M. A. 2013. Comparing patterns in abundance and diversity of hole-nesting birds in mediterranean habitats. *Rev. Écol.(Terre Vie)*, 67, 1-8.
http://www.ptes.org
www.bats.org.uk
www.bio.bris.ac.uk/research/bats/britishbats/batpages

18 Appendix 6: Trait data

Table 18.1 Number of traits for which information was available for each tree species (No)

Latin	English	Code[1]	No.	Confidence[2]
Abies alba	Silver fir	Aal	9	0.75
Acer campestre	Field maple	Aca	12	1.00
Acer platanoides	Norway maple	Apl	12	1.00
Acer pseudoplatanus	Sycamore	Aps	12	1.00
Aesculus hippocastanum	Horse chestnut	Ahi	11	0.92
Alnus cordata	Italian alder	Aco	7	0.58
Alnus glutinosa	Alder	Agl	12	1.00
Betula pendula	Silver birch	Bpe	12	1.00
Betula pubescens	Downy birch	Bpu	12	1.00
Carpinus betulus	Hornbeam	Cbe	12	1.00
Carya ovata	Shagbark hickory	Cov	6	0.50
Castanea sativa	Sweet chestnut	Csa	12	1.00
Corylus avellana	Hazel	Cav	12	1.00
Crataegus monogyna	Hawthorn	Cmo	12	1.00
Fagus sylvatica	Beech	Fsy	12	1.00
Fraxinus americana	American ash	Fam	9	0.75
Fraxinus excelsior	Common ash	Fex	12	1.00
Fraxinus mandschurica	Manchurian ash	Fma	7	0.58
Fraxinus ornus	Manna ash	For	8	0.67
Fraxinus pennsylvanica	Green ash or red ash	Fpe	8	0.67
Ilex aquifolium	Holly	Iaq	11	0.92
Juglans nigra	Black walnut	Jni	8	0.67
Juglans regia	Common walnut	Jre	11	0.92
Larix decidua	European larch	Lde	9	0.75
Ligustrum vulgare	Privet	Lvu	11	0.92
Malus sylvestris	Crab apple	Msy	11	0.92
Ostrya carpinifolia	Hop-hornbeam	Oca	6	0.50
Pinus sylvestris	Scots pine	Psy	9	0.75
Platanus x hybrid	Plane sp	Phy	9	0.75
Populus nigra	Black poplar	Pni	10	0.83
Populus tremula	Aspen	Ptr	12	1.00
Prunus avium	Wild cherry	Pav	12	1.00
Prunus padus	Bird cherry	Ppa	12	1.00
Prunus spinosa	Blackthorn	Psp	11	0.92
Pseudotsuga menziesii	Douglas fir	Pme	9	0.75
Pterocarya fraxinifolia	Caucasian wingnut	Pfr	6	0.50
Quercus cerris	Turkey oak	Qce	11	0.92
Quercus petraea	Sessile oak	Qpe	12	1.00
Quercus robur	Pedunculate oak	Qro	12	1.00
Quercus rubra	Red oak	Qru	10	0.83

Latin	English	Code[1]	No.	Confidence[2]
Salix caprea	Goat willow	Sca	12	1.00
Salix cinerea	Grey willow	Sci	12	1.00
Sambucus nigra	Elder	Sni	12	1.00
Sorbus aria	Whitebeam	Sar	12	1.00
Sorbus aucuparia	Rowan	Sau	12	1.00
Sorbus torminalis	Wild service tree	Sto	11	0.92
Taxus baccata	Yew	Tba	12	1.00
Thuja plicata	Western red cedar	Tpi	7	0.58
Tilia cordata	Small leaved lime	Tco	12	1.00
Tilia platyphyllos	Large leaved lime	Tpl	12	1.00
Ulmus procera/glabra	Wych & English Elm	Upg	12	1.00

[1] Code used in Tables 4.5 & 4.6
[2] The number of traits for which data was available as a proportion which may be used as measure of confidence in the data (1 = information on all traits available and hence comparisons between species are have greater confidence)

Table 18.2 Number of alternative tree species which had trait or Ellenberg information available (maximum = 50)

Trait	No.
Bark Ph	29
Deciduous	50
Floral reward	47
Fruit type	50
Height	50
LDMC	40
Leaf shape	50
Leaf size	35
Length of flowering time	36
Mycorrhizal association	50
Pollen vector	50
SLA	38
Ellenberg moisture (F)	39
Ellenberg light (L)	40
Ellenberg acidity (R)	38
Ellenberg nitrogen (N)	39

Table 18.3 Ranking of alternative tree species by 4 traits in terms of their similarity to ash. Species codes are shown in Table 18.1. Data are standardized with zero = most similar to ash. Blanks are missing data

Height		LDMC		Length of flowering time		SLA	
Code	Data	Code	Data	Code	Data	Code	Data
Bpe	0.00	Sca	0.000	Aca	0	Aca	0.000
Pav	0.00	Cbe	0.000	Apl	0	Psp	0.000
Tco	0.00	Ahi	0.000	Ahi	0	Upg	0.002
Fam	0.00	Iaq	0.000	Agl	0	Pni	0.004
Fpe	0.00	Sto	0.001	Bpe	0	Pav	0.004
Jre	0.00	Aps	0.001	Bpu	0	Qpe	0.005
Aco	0.01	Msy	0.001	Cbe	0	Ahi	0.007
For	0.01	Agl	0.001	Cmo	0	Bpe	0.009
Apl	0.04	Csa	0.001	Fsy	0	Aps	0.010
Aps	0.04	Tba	0.002	Iaq	0	Sau	0.010
Agl	0.04	Sau	0.002	Lvu	0	Cmo	0.015
Bpu	0.04	Upg	0.002	Psy	0	Agl	0.016
Cbe	0.04	Bpe	0.004	Ptr	0	Fsy	0.016
Cov	0.04	Bpu	0.004	Pav	0	Bpu	0.019
Csa	0.04	Jni	0.004	Ppa	0	Jre	0.024
Fsy	0.04	Jre	0.004	Psp	0	Csa	0.026
Fma	0.04	Lvu	0.004	Pme	0	Sca	0.034
Psy	0.04	Apl	0.005	Sca	0	Sci	0.039
Pni	0.04	Qro	0.008	Sci	0	Qro	0.046
Ptr	0.04	Qpe	0.009	Sni	0	Qce	0.047
Qpe	0.04	Cav	0.011	Sar	0	Lvu	0.056
Qro	0.04	Qru	0.012	Sau	0	Ptr	0.060
Tba	0.04	Tpl	0.034	Sto	0	Qru	0.141
Tpl	0.04	Pni	0.036	Tco	0	Tba	0.143
Upg	0.04	Tco	0.037	Upg	0	Cav	0.155
Oca	0.06	Qce	0.037	Aps	0.25	Sar	0.180
Sto	0.06	Fsy	0.042	Csa	0.25	Iaq	0.210
Ahi	0.08	Sni	0.047	Cav	0.25	Msy	0.220
Jni	0.08	Psp	0.049	Jre	0.25	Ppa	0.244
Qru	0.13	Sar	0.067	Msy	0.25	For	0.245
Aca	0.16	Aal	0.086	Qce	0.25	Sni	0.272
Iaq	0.16	Cmo	0.096	Qpe	0.25	Apl	0.278
Ppa	0.16	Aca	0.164	Qro	0.25	Fpe	0.631
Pfr	0.16	Pav	0.187	Tba	0.25	Phy	0.706
Qce	0.16	Ppa	0.187	Tpl	0.25	Tco	0.911
Sar	0.16	Ptr	0.209	Aal		Sto	3.333

Height		LDMC		Length of flowering time		SLA	
Code	Data	Code	Data	Code	Data	Code	Data
Sau	0.16	Sci	0.481	Aco		Cbe	3.752
Cmo	0.36	Lde	1.91	Cov		Tpl	4.464
Msy	0.36	Psy	2.25	Fam		Aal	
Sca	0.36	Fam	2.33	Fma		Aco	
Sni	0.36	Aco		For		Cov	
Sci	0.46	Cov		Fpe		Fam	
Tpi	0.46	Fma		Jni		Fma	
Cav	0.58	For		Lde		Jni	
Phy	0.58	Fpe		Oca		Lde	
Lde	0.71	Oca		Phy		Oca	
Psp	0.71	Phy		Pni		Psy	
Lvu	0.77	Pme		Pfr		Pme	
Aal	0.85	Pfr		Qru		Pfr	
Pme	1.74	Tpi		Tpi		Tpi	