

Plant assemblages in British beech woodlands within and beyond native range: Implications of future climate change for their conservation

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Abstract

In Britain, some climate change models predict a shift in the climatic suitability envelope for beech (*Fagus sylvatica*) to the north and west, beyond its past-native range, whereas much of the current conservation effort targets beech woodlands in the south and east. Possible implications for the conservation of typical beech woodland plant assemblages were explored by comparing the occurrence of the component species in southern (inside past-native range) and northern England (outside past-native range, but within future climate-suitability envelope) through comparison of county lists of plants, and direct comparison of stands in each region.

Most plants listed in the National Vegetation Classification beech woodland community tables already occur in the two northern counties' plant lists. There was also much overlap in the species recorded in the field surveys between northern and southern sites. Thus, there appears to be good potential for beech woods beyond their past-native range to develop assemblages similar to those currently valued in southern Britain.

A short questionnaire survey of 47 individuals involved in forestry and conservation management in Britain suggests that while climate change is recognised as a factor that will affect future conservation management, there is less acceptance to date of a need to modify current policies and practice to take account of possible future range changes.

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1. Introduction

The distribution of vegetation communities and plant species changes over time, but much nature conservation policy and practice is based on implicit assumptions that it does not (at least if appropriate management is applied). Thus, protected sites are designated to maintain a particular species or plant assemblage in a particular place: this can be seen in the selection procedures in Britain for Sites of Special Scientific Interest (SSSIs) (NCC, 1989) and for Special Areas of Conservation (SACs) under the

European Union Habitats and Species Directive (European Commission, 1992). In the past changes in species or assemblage distribution were often quite slow, but under some future climate change scenarios distribution changes may be much more rapid (Harrison et al., 2001).

This paper discusses some implications arising from predictions about the future distribution and growth of beech (*Fagus sylvatica*) in Britain. The particular predictions used (Harrison et al., 2001) may or may not prove correct, but we believe that the issues discussed illustrate some of the challenges for future conservation policy and practice under a changing climate, namely:

- What role might stands of a species or associated plant assemblages existing beyond what is currently considered their 'native range' play in future conservation strategies?

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- Is there a need to reflect that future role in *current* policy and practice?

1.1. Beech and beech woodland in protected sites in Britain

Beech is believed to have been present in Britain since the late Boreal period, but it remained relatively scarce until c3000 BC. Thereafter, it became locally abundant in southern England and in the extreme south of Wales on free-draining soils across the spread of soil pH from very acid to base-rich. Outlying populations may have existed, for example, into northeast Yorkshire (Rackham, 1980), but its generally accepted past-native range (for conservation purposes) is seen as limited to southern England and Wales (Fig. 1). Within this area woods have been selected for protection as SSSIs and SACs to represent the range of variation, particularly in the flora and within these woods beech is encouraged. The beech woodland Habitat Action Plan established under the UK Biodiversity Action Plan also emphasises beech woodland creation and restoration within this presumed past-native range (English Nature, 1998).

The natural spread of beech in the post-glacial period may have been limited by the early clearance of much of the British woodland. It has been widely planted in the north and west beyond the past-native range and often regenerates freely (e.g., Watt, 1931). Beech continues to spread in woods beyond its past-native range that have been identified as examples of oak (*Quercus* spp.) or ash (*Fraxinus excelsior*) woodland types, and management is frequently carried out to reduce its abundance or even eliminate it completely (Wesche, 2002). However, should some beech stands within the predicted climate-suitability envelopes for 50–100 years hence be allowed to

develop as future-natural beech communities, and hence be valued as such in conservation terms?

1.2. Potential impact of climate change on beech and beech woodland in Britain

In Britain beech (*Fagus sylvatica*) has been identified as potentially sensitive to the effects of climate change because it is known to be sensitive to summer drought (Peterken and Mountford, 1998). The Modelling the Natural Resource Responses to Climate Change (MONARCH) project (Harrison et al., 2001) indicated that beech may show a significant expansion northward and westward (towards the wetter coast) in the UK, although other models indicate limitations on westward expansion due to inadequate chilling conditions (Sykes et al., 1996). Under the more extreme scenarios parts of Kent and Sussex could become unsuitable for beech (Broadmeadow and Ray, 2005). Broadmeadow et al. (2005) note that beech is not likely to disappear from southern England, but that its yield potential is likely to fall and its competitive ability compared to ash or oak is therefore likely to change.

Beech tends to dominate the canopy in woods where it occurs and plays a major role in distinguishing mature stands from other woodland types (Rodwell, 1991). It might become difficult to maintain that sites are still representing ‘beech woodland’ if the beech component in mature stands drops much below 30% of the canopy cover. It is thus necessary for the conservation movement to consider the implications of possible reductions in beech in parts of its current range and a continued expansion in woods where it is not currently deemed native.

1.3. Species and assemblage responses to climate change

Plant species respond individually to climate change: for example, two species commonly associated with beech on calcareous soils (*Sanicula europaea* and *Taxus baccata*) showed little indication of predicted change in distribution under the MONARCH project scenarios, while holly (*Ilex aquifolium*), a common associate on mesotrophic and acid soils, appears to be spreading both in Britain (Kirby et al., 2005) and on the continent (Walther et al., 2005). The beech woodland assemblage will not simply move from the southeast to the northwest en masse even if the climate change scenarios prove correct.

In addition, potential shifts in distribution under climate change scenarios may not occur in practice. Many woodland plants, often referred to as ‘ancient woodland indicators’ or ‘woodland specialists’, are relatively poor colonisers (Peterken, 1974; Hermy et al., 1999; Kirby et al., in press) and woodland cover in Britain is highly fragmented. It is unlikely that such species would be able to migrate from southern England and colonise northern woodland in line with predicted rates of climate change (Hill et al., 1993). However, if the species commonly found in beech woodland in the south already occur in woods in the north and west in association with other

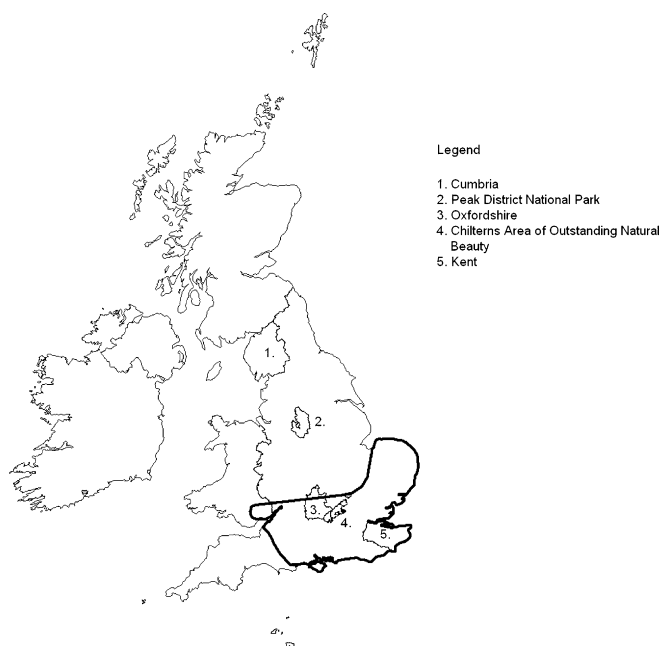


Fig. 1. Native beech zone and location of study sites.

Table 1
Field sample site descriptions indicating woody composition and vegetation cover

Site name	Location (approx. grid reference)	Max. dbh (cm) class	Main canopy spp. after beech	Main understorey species (where present)	Vegetation cover (mean % based on five plots)			
					Bare soil	Litter	Bryophytes	Field layer
Chilterns, calcareous								
1. Hammond's Wood 1	SU648833	51–60	<i>Fraxinus excelsior</i>	<i>Fraxinus excelsior</i>	14	70	15	4
2. Aston Wood	SU740974	51–60	<i>Fraxinus excelsior</i>	<i>Fraxinus excelsior</i>	15	85	2	4
3. Shirburn Wood	SU716946	>61	<i>Corylus avellana</i> , <i>Fraxinus excelsior</i> , <i>Taxus baccata</i>	<i>Corylus avellana</i> , <i>Sambucus nigra</i>	29	61	11	4
4. Greenfield Copse 2	SU709921	>61	<i>Fraxinus excelsior</i>	<i>Fraxinus excelsior</i> , <i>Acer pseudo-platanus</i> , <i>Sambucus nigra</i>	18	76	3	2
5. Howe Wood	SU703916	>61	<i>Fraxinus excelsior</i>	<i>Fraxinus excelsior</i> , <i>Ilex aquifolium</i>	23	77	<1	4
6. Shambridge Wood 2	SU712906	>61	<i>Fraxinus excelsior</i>	<i>Ilex aquifolium</i>	11	88	<1	3
Chilterns, acidic								
7. Hammond's Wood 2	SU648833	51–60		<i>Ilex aquifolium</i>	2	96	2	3
8. Harpsden Wood	SU760803	>61			1	98	1	4
9. Withy Copse	SU681804	51–60		<i>Ilex aquifolium</i>	3	94	3	1
10. Rumerhedge Wood	SU671821	51–60			1	99	<1	3
11. Greenfield Copse 1	SU709921	>61		<i>Ilex aquifolium</i> , <i>Taxus baccata</i>	2	98	<1	2
12. Shambridge Wood 1	SU712906	>61			2	98	<1	2
Cumbria, calcareous								
13. Serpentine Wood	SD509927	>60	<i>Fraxinus excelsior</i> , <i>Acer pseudo-platanus</i> , <i>Ulmus procera</i>	<i>Ilex aquifolium</i> , <i>Fraxinus excelsior</i> , <i>Ulmus procera</i> , <i>Acer pseudo-platanus</i>	6	84	7	3
14. Whitbarrow 1	SD460867	21–30	<i>Acer pseudo-platanus</i>		2	82	14	1
15. Whitbarrow 2	SD458865	31–40	<i>Fraxinus excelsior</i> , <i>Acer pseudo-platanus</i> , <i>Taxus baccata</i>		5	74	17	1
Cumbria, acidic								
16. Beech Hill Wood	SD391892	>60			10	80	10	1
17. Linsty Green	SD347855	31–40	<i>Betula</i> spp.		9	83	7	1
18. Yewbarrow	SD349870	51–60			4	85	8	1
19. Castlehead Wood	NY270226	>60	<i>Quercus</i> spp.		53	18	29	1
20. Dalton Park 1	SD546746	31–40	<i>Fraxinus excelsior</i>		1	93	6	3
21. Dalton Park 2	SD546746	41–50			2	92	4	3

Beech was predominant in the canopy in all sites. All sites, except 6 and 13, are ancient woodland.

woodland types, then assemblages similar to those of southern beech woodland communities might be more likely to develop.

This potential was explored by looking at the composition of beech woodland communities (as illustrated in Rodwell's (1991) National Vegetation Classification tables) in relation to regional species pools (as represented by county floras) and through a small field survey of sites within and outside the presumed native range of beech. Forty-seven conservation managers, foresters and woodland ecologists were also canvassed to explore attitudes towards the conservation of beech in north and west England.

2. Methods

2.1. Regional species pool study

British beech woodland is divided in the National Vegetation Classification into three types based on soils and species composition (Rodwell, 1991). Representing about 40% of beech habitat, *F. sylvatica*–*Mercurialis perennis* woodland (NVC W12) is characterised by base-rich soils. *F. sylvatica*–*Rubus fruticosus* woodland (NVC W14) is found on brown earths of low base status, often with slightly impeded drainage. It represents about 45% of beech habitat. *F. sylvatica*–*Deschampsia flexuosa* woodland (NVC W15) occurs on infertile soils usually with a pH below four, making up about 15% of beech habitat.

The 217 samples used to compile these tables came from across the country (including about 17% from beyond the past-native range of beech). The list of woodland plants derived from the three tables combined represents those commonly associated with beech woodland, but excludes the species occurring in less than 5% of samples that were not listed in the tables.

The list of 99 species from the three communities combined was compared with the published floras for four English counties where beech currently thrives: Kent (Philp, 1982), Oxfordshire (Killick et al., 1998), Cumbria (Halliday, 1997) and Derbyshire (Moyes and Willmot, 2002). Oxfordshire and Kent lie within the native range of beech, while Cumbria and Derbyshire lie outside its current range but within its future projected climate space under MONARCH scenarios (Harrison et al., 2001). This comparison indicates the degree to which the regional pool of species found in the northwest might permit development of characteristic beech wood types under current conditions.

For each species its frequency in the NVC tables was compared with its frequency, in terms of the number of tetrads (2 km × 2 km squares) occupied, in each of the four county floras. The number of woodland specialists (Kirby et al., in press), which may be more sensitive to variations in environmental conditions, was also compared within each county.

2.2. Field survey

Field surveys of ground vegetation were conducted in beech woodlands within and beyond its native range. Southern sample

sites were located in the Chiltern Hills in Oxfordshire County (except for one site, Aston Wood, which is located 2 km north of the Oxfordshire border) and northern sites were located in Cumbria.

Locations in the Chilterns and in Cumbria were sampled, including both calcareous sites (Chilterns 6 sites, Cumbria 3) and more acidic soils (Chilterns 6 sites, Cumbria 6). Sample sites were chosen based on: accessibility, size, location and percentage of beech cover. Beech was the dominant canopy species in all sites, but the accompanying trees and shrubs varied. The Chiltern sites were all mature (>100 years) or near mature, while the Cumbrian sites were more varied in age. Although little information was available on their past management, the beech stands in most cases included some trees at least 30 cm in diameter, indicating that they were a minimum of 60–80 years old. Table 1 summarises the general vegetation cover and woody species composition of the sample sites.

Sampling of the tree and shrub layer was done along a 25 m × 5 m transect centered on a 5 m × 5 m ground flora quadrat. Five samples were taken at each site, separated by at least 50 m. The information collected included: (a) species occurrence and abundance (Domin scale) in the plot, (b) percentage cover by species for canopy, shrub layer, field layer and ground layer, (c) numbers and sizes of beech trees adjacent to the transect and (d) general site descriptions.

Community structure was investigated using DECORANA (Hill, 1979). Ground flora species were characterised using three widely accepted methods: woodland specialist designations (Kirby et al., in press), Grime Strategy Types (Grime et al., 1988) and Ellenberg indicator values (Hill et al., 1999). The sets of plots from each area were allocated to NVC types using the MATCH programme (Malloch, 1998).

2.3. Attitudes to beech conservation policy and practice outside its native range

A short questionnaire (Wesche, 2002) was sent to 20 selected forestry/conservation academics, policy staff and researchers. Subsequently, this questionnaire was also used with 27 local English Nature staff concerned with regulating and managing SSSIs (Kirby, unpublished data). The results from four of the questions are presented here. Respondents were asked to indicate on a 1–5 scale the level of agreement/disagreement with the following statements:

- Climate change will have an impact on the natural environment in the UK.
- Climate change should be a consideration in the development of conservation policy and strategies in the UK.
- We should strive to maintain beech woodlands in areas of current conservation focus in southeast England (e.g., Kent, Chilterns).
- Beech woodland should be actively encouraged as a future-natural woodland type in the north and west of Britain beyond its current native range.

3. Results

3.1. Regional pool study

The regional species pools across the four counties were similar with respect to species found in the NVC beech tables. Of the 99 species all but three (*Cephalanthera damasonium*, *Ruscus aculeatus* and *Vaccinium myrtillus*) had been recorded in each of the counties surveyed during the past 25 years. There were some species with a southern distribution that are more likely to occur in beech woodland in the south than in the north (e.g., *Campanula trachelium*, *Clematis vitalba*, *Cynoglossum officinale*, *Daphne laureola*, *Iris foetidissima*, *Neottia nidus-*

avis and *Tamus communis*), but there were other species more common in the north and west that might correspondingly appear more frequently in beech stands in those regions (e.g., *Blechnum spicant*, *Hypericum pulchrum* and *Luzula pilosa*).

3.2. Field survey

The field samples showed differences between the Oxfordshire and Cumbria samples, but there was considerable overlap. The DECORANA ordination analysis of quadrats produced four distinct groupings (Fig. 2a). The first axis of the DECORANA ordination, as expected, correlated most closely with pH and nitrogen Ellenberg indicator values (Fig. 2b and c).

3.3. Woodland stand MATCH classification

The MATCH programme is designed to analyze information from suites of quadrats rather than from individual sites. The sampled communities were generally assigned the highest ranking by the MATCH programme to an NVC beechwood type (W12, 14, 15), with similar levels of matching coefficients (Table 2). The W10 (*Quercus robur*–*Pteridium aquilinum*–*Rubus fruticosus*) often appeared as one of the three closest matches for all suites; W10 exhibits close similarities to beech woodland communities in their main ground flora species, and in Cumbria beech stands are often derived from oak woodland.

3.4. Ground flora

Some species were more abundant in certain field sample locations (Table 3). *Mercurialis perennis* was found in all calcareous sites but at a much higher density in the Chilterns. *Circaea lutetiana*, *Urtica dioica*, *Galium odoratum*, *Lamium galeobdolon* and *Galium aparine* were widespread in Chiltern calcareous sites, but appeared infrequently or not at all in Cumbrian calcareous samples. *Rubus fruticosus* agg. and *Rubus idaeus* were more abundant in the acidic sites in the Chilterns than in Cumbria, whereas the opposite was true for *Agrostis capillaris*, *Deschampsia flexuosa* and *Quercus* spp. seedlings. However, the species concerned are all frequent within both the northern

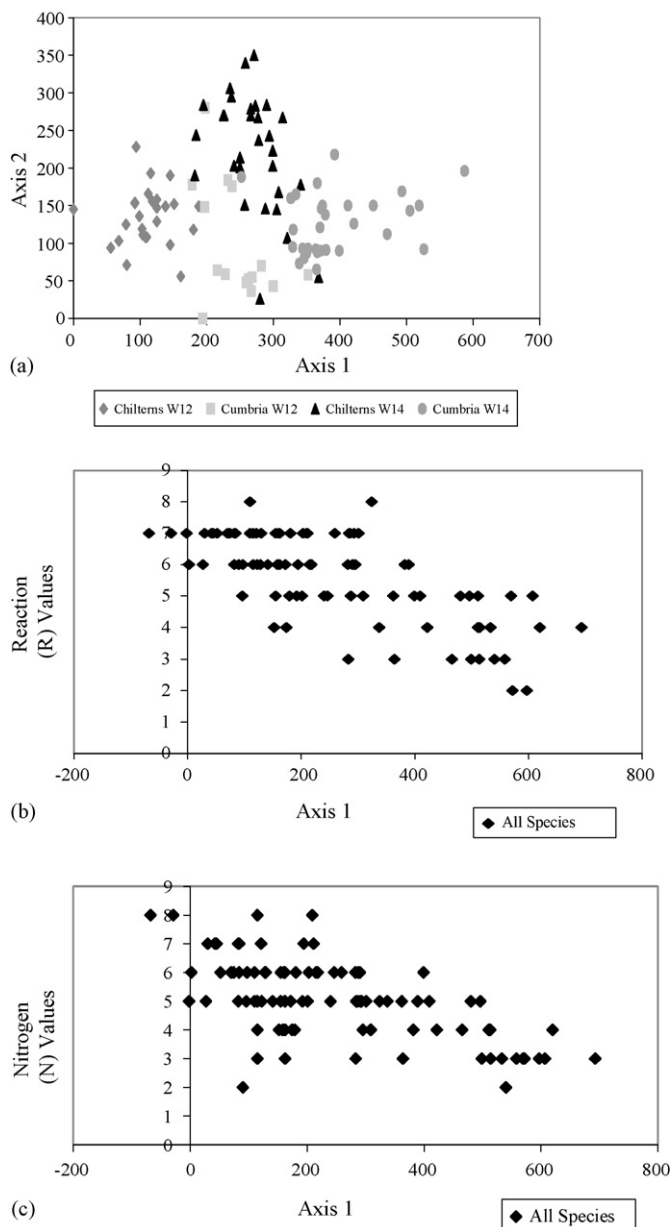


Fig. 2. (a) Sample (quadrat) scores for axes 1 and 2 of the DECORANA ordination. (b) Species scores for Ellenberg reaction (pH) plotted against first axis ordination score. (c) Species scores for Ellenberg nitrogen (N) plotted against first axis ordination score.

Table 2

The closest NVC community matches for the sample data using the MATCH programme, based on suites of plots by region

Woodland type	Closest matches	Matching coefficient (%)
<i>Chiltern calcareous</i>	W12	55.8
	W8	53.9
	W10	40.5
<i>Cumbria calcareous</i>	W12	50.9
	W10	47.9
	W8	44.2
<i>Chiltern acid</i>	W14	44.8
	W10	43.5
	W12	40.6
<i>Cumbria acid</i>	W10	49.5
	W15	49.2
	W14	46.0

Table 3

Frequency of sampled species showing notable differences in occurrence between regions, by habitat type

Calcareous stands			Acidic stands		
Species	Chilterns 6 sites (30 plots)	Cumbria 3 sites (15 plots)	Species	Chilterns 6 sites (30 plots)	Cumbria 6 sites (30 plots)
<i>Mercurialis perennis</i>	6 (29)	3 (5)	<i>Rubus fruticosus</i> agg.	6 (28)	2 (4)
<i>Circaea lutetiana</i>	6 (19)	2 (3)			
<i>Urtica dioica</i>	6 (11)	0	<i>Rubus idaeus</i>	4 (4)	0
<i>Galium odoratum</i>	5 (15)	1(2)	<i>Agrostis capillaris</i>	0	5 (9)
<i>Lamium galeobdolon</i>	5 (13)	0	<i>Deschampsia flexuosa</i>	0	3 (9)
<i>Galium aparine</i>	4 (9)	0			
<i>Dryopteris dilatata</i>	0	3 (9)	<i>Quercus</i> spp. seedling	0	3 (7)

Table 4

The number and proportion of woodland specialists sampled in W12 and W14 stands in the Chilterns and Cumbria

	Calcareous stands		Acidic stands	
	Chilterns	Cumbria	Chilterns	Cumbria
Number of woodland specialists	19	19	8	13
Total number of species	56	48	32	37

and southern counties, so such differences are more likely to reflect local site variations rather than regional differences.

3.5. Species classification

Species were characterised by their strategy types – ruderal, competitor and stress-tolerator (Grime et al., 1988) – to give an idea of the character of the woodland flora and its components. Overall the most common strategy type (by number of species occurrences) was competitive-stress-tolerator; however, there were only minor differences in strategy type classification between calcareous and acidic samples and between the Chilterns and Cumbria. The number of woodland specialists present in the sampled northern and southern beech woodlands was also broadly similar (Table 4).

Table 5

Views of: (a) 20 national experts (foresters, conservationists) and (b) 27 local conservation managers to the likely implications of climate change for beech woodland in the UK

Statement	Number of respondents agreeing with a particular statement				
	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
Climate change will have an impact on the natural environment in the UK					
(a)	11	9			
(b)	19	8			
Climate change should be a consideration in the development of conservation policy and strategies in the UK					
(a)	14	6			
(b)	17	7	2		
We should strive to maintain beech woodlands in areas of current conservation focus in southeast England (e.g., Kent, Chilterns)					
(a)	6	4	4	4	2
(b)	1	7	7	11	2
Beech woodland should be actively encouraged as a future-natural woodland type in the north and west of Britain beyond its current native range					
(a)	1	8	8	2	
(b)	5	4	9	6	3

3.6. Questionnaire results

Among the surveyed forestry and conservation experts, there was clear recognition that vegetation patterns may well shift as consequence of climate change, and that it may not be possible to maintain beech woodland in some of its current strongholds. However, there was less support, particularly amongst the conservation staff, that this should be reflected in changes in current conservation practices (Table 5).

4. Discussion

The survey of county floras indicates that the four counties have comparable regional species pools and similar proportions of woodland specialists. Thus, the re-assembly of plant species associated with beech woodlands appears possible in northern counties provided that there are no significant barriers to local movement and dispersal. It is not necessary to invoke major inter-regional species movement and rare long-distance dispersal events for this to occur.

Relatively little research has been published on the composition and structure of beech stands beyond the presumed native range. Watt (1931) describes some Scottish beech stands and there are unpublished studies from Coed Dolgarrog in North Wales. These, like the records included in the NVC from

northern England, tend to be from acid stands. Near Port Appin (West Scotland), however, there is a mature beech stand on base-rich soil with a rich flora including *Neottia nidus-avis*, *Daphne laureola* and *Cephalanthera longifolia* (Peter Wormell, personal communication). Thus, we believe that further research will confirm that such stands are not necessarily impoverished compared to those within the native range.

Some of the variations observed between regions are likely due to differences in the canopy cover or age structure of the stands. The lower field layer density in northern sites might be explained by a combination of factors, e.g., lower grazing pressure on lowland versus upland woods and higher trunk and canopy density in the Cumbrian stands, characteristics common to early woodland life stages (Kirby, 1988). Further changes might therefore be expected as the Cumbrian woodlands age. Also, the potential exists for managers to modify canopy presence through thinning to encourage the growth of certain ground species.

At one level, therefore, these results suggest that there could be scope for conserving beech woodland communities in the future beyond their current presumed native range to make up in part for possible losses in the southeast as a result of climate change. However, there are important caveats, namely:

- The communities that form will not be exactly the same as those in the southeast; species will respond individually to the particular environmental conditions found in the northwest.
- Climate change will affect the distribution of woodland ground flora independently of its effects on beech; some species currently in Cumbria may not be there in future.
- This study only considered vascular plants, thus the conclusions may not hold for other groups such as fungi, invertebrates or lichens.

4.1. Implications for nature conservation policy and practice

Plant communities do not move en masse; instead species respond individually to change. Comparisons of regional species pools between current and possible future locations can however suggest the potential for re-assembly of something similar to the current communities in a new location. This research contributes to the case for a more dynamic approach to nature conservation, one that considers where species and assemblages currently exist and also where they may be located in future.

At present much conservation effort is focused on resisting change; for example, removing beech from northern and western oakwoods. This strategy is justified and will be continued where the objective is to retain the particular composition of such stands for specific reasons, for example, because of their rich bryophyte communities.

However, the wisdom of pursuing such management as an overall strategy must be questioned considering the evidence that: (a) climate change is likely to affect vegetation patterns and that (b) beech thrives beyond its past-native range.

Identifying select ancient woodland stands where beech is allowed to develop could be an important contribution to future-natural woodland conservation. Prospective candidates for such stands exist in areas where beech is already abundant and regenerating naturally, and preferably where some mature trees are present. Designating stands on both acid and base-rich soils would be desirable since they will develop different floras.

If the existence of future beech stands is considered a valid conservation aim, this will enable a shift from active to passive management on some sites (Dockerty et al., 2003), with the possibility of transferring conservation resources to other projects. It would imply that some aspects of the beech woodland Habitat Action Plan, which emphasise work only in the current native range, would need to be re-written. Conservation objectives (Kirby et al., 2002) for some protected sites would need to reflect potential changes in the composition of the sites compared to their current designated descriptions.

We believe that policy makers and conservation practitioners do need to adopt a more dynamic approach to conservation. Although the questionnaire results from this study are based on a small non-random set of respondents, the findings are consistent with the views expressed in other discussions and meetings within the broader forester/conservationist community. While there exists an appreciation for the potential implications of climate change for woodland communities, such understandings are not necessarily yet being translated down to changes in attitudes regarding shifts in species ranges.

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