Forestry Commission

Birch in Spruce Plantations

Management for Biodiversity

Edited by Jonathan Humphrey, Kate Holl and Alice Broome

Technical Paper 26

FORESTRY COMMISSION TECHNICAL PAPER 26

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Management for Biodiversity

Edited by Jonathan W. Humphrey[1], Kate Holl[2] and Alice C. Broome[1]

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Front cover: Semi-natural woodland dominated by downy birch (*Betula pubescens,* spp. *pubescens*) growing alongside Sitka spruce (*Picea sitchensis*) in Kilmichael Forest, Argyll. (*Forest Life Picture Library: 50098*)

Back cover: *Top* Bilberry (*Vaccinium myrtillus*), a principal ground flora species in native birchwoods and birch/spruce mixtures. (*Forest Life Picture Library: 1018313020*)
Inset A specialist birch feeding moth, *Geometra papilionaria,* found in native birchwoods and birch/spruce mixtures. (*Forest Research, Entomology Branch*)
Below Lichen *Evernia prunastri,* recorded frequently on young and mature birch trees. (*Forest Life Picture Library: 1007603020*)

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Summary

This Technical Paper brings together a series of papers presented at the symposium 'Birch in spruce plantations: management for biodiversity' held at Scottish Natural Heritage's Battleby Conference Centre, Perth, in February 1997. The aim of this symposium was to present the findings from a series of collaborative research projects funded jointly by the Forestry Commission and Scottish Natural Heritage, looking into aspects of biodiversity associated with birch in spruce plantations. Chapter 1 provides an introduction to the subject area and the background to the research projects. Chapters 2-6 summarise information on birch distribution, ground vegetation, lichens and invertebrates. In conclusion, Chapter 7 sets these findings within the wider context of forest design planning, and highlights options for the future management of birch within spruce plantations. It is concluded that remnant native (semi-natural) birchwoods in spruce plantations have a high biodiversity value, particularly for rare and characteristic species, and should be the main focus of conservation and enhancement programmes. Birchwoods can be extremely dynamic in space and time, which necessitates the creation of 'birchwood maintenance zones' within spruce forests, where adequate space is provided to cater for all successional stages. However, pure spruce stands also have some value for biodiversity. They provide a shaded, moist habitat, particularly valued by some insect groups. Where birch occurs in mixture with spruce, management should aim to aggregate the birch into distinct clumps, as these are more valuable for biodiversity than intimate mixtures of birch and spruce. The possibility that these clumps could function as 'habitat stepping-stones' between widely dispersed fragments of native birchwood is also discussed, although more research is needed to substantiate this hypothesis. There is also considerable scope for improving the commercial management of birch/spruce mixtures. Establishment techniques such as direct sowing of birch have been the subject of recent research, and birch/Norway spruce mixtures are managed on a successful commercial basis in Scandinavia. However, there is little information about whether such mixtures or, alternatively, Sitka spruce/birch mixtures can be grown successfully in Britain, and research is needed to identify the optimum densities of birch and spruce on different site types to maximise the yield and biodiversity value of both species.

Foreword

In all of the major land uses there is a growing awareness that biodiversity matters. The concept of conserving biodiversity is important for both wildlife and the environment: it is thought that the fostering of biodiversity promotes stability in the ecosystem. Biodiversity is important in the supply of many raw materials for a huge variety of products. Biodiversity is therefore not just a luxury, but it is something that, whatever form of land use you are associated with, you need to take seriously. This is equally true for agriculture, fish farming, industrial development or forestry.

A few days before writing this foreword, I was involved in judging the four final farms for the 1998 Silver Lapwing Award. This is an award that is given for commercial farming that incorporates the principles of wildlife conservation. The key criterion in reaching a decision is that the farmer is taking a holistic view of his farm, earning an income from the farm but at the same time maintaining or enhancing its biodiversity. In forestry, the same principles apply equally. First, forestry has to be on a commercial scale. Second, forestry ought to incorporate the principles of landscape and biodiversity conservation. If these are to be integrated, then we need to take a holistic view of the forest, bringing together the demands of timber production for an economic return and of care for the natural heritage.

In agriculture, the economically important and unimportant species are not intimately mixed together. There is usually a small spatial separation. For example, a farm plan may aim to maintain or enhance the natural features, such as ponds and copses, that occur on the farm. These are not component parts of the arable fields and pastures, but are beside them, part of the farmland landscape. Similarly in forestry, there have been attempts to manage rides and other open spaces to favour a diversity of flowering plants, birds and insects. Natural features, such as old clumps of birch, can be retained. The margins of a forest can be managed more sympathetically for landscape considerations, as well as for the practical use of reducing the probability of windblow. But perhaps the boldest actions can be taken in restocking and redesigning the forest at the time of the next rotation.

This publication stresses the importance of devising new methods of land use so that forest enterprises are growing crops that are financially viable, but yet which also enhance the local biodiversity and landscape. The chapters focus on the restructuring of Norway and Sitka spruce forests and the value of growing birch within them. Birch enhances the number of species of vascular plants and mosses, it supports a greater number of species of lichens, and it increases the species diversity of moths. But not everything is simple, and in some groups of arthropods birch appears not to increase the species diversity. Biodiversity does not just happen, but it needs propagules, either of plants or animals, if they are to flourish within these mixed species forests. We also need to consider the structure of forests, and ask whether small clumps of a species are better than an intimate mixture of individual trees. The focus on the value of growing birch within plantations of Sitka spruce and Norway spruce is important. It is a step in learning how to increase the biodiversity of our forests, but it is very much a first step. Nevertheless, it is an important step in aiming to improve the all-round importance of Britain's forest estate.

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Chapter 1

Introductory address

David Henderson-Howat

I am delighted to have this opportunity to introduce today's symposium, on behalf of Sir Michael Strang-Steel, Chairman of the Native Woodland Advisory Panel, who is extremely sorry that he cannot be here today.

It is fascinating to look back over recent years and to see how interest in native woodlands has developed. One important strand of this 'native woodlands movement' has concerned the role and management of native species within commercial plantations, particularly in upland areas. Indeed, the use of native species in second rotation forests is to be the main focus of work for one of the Native Woodland Advisory Panel's sub-groups. And the Native Woodlands Policy Forum has identified the important role of native woodlands as a component of new and redesigned non-native plantations (Native Woodlands Policy Forum, 1996).

The aim of today's symposium is to bring together the findings from a series of research projects funded by Scottish Natural Heritage (SNH) and the Forestry Commission (FC) looking into aspects of biodiversity associated with birch in spruce plantations. This is, of course, highly relevant to the subject of native species in productive forests.

Birches (*Betula pubescens* and *Betula pendula*) are by far the most common native trees in upland areas of Britain, and are an important feature of a range of semi-natural woodland types, particularly in the Scottish Highlands. Many large areas of spruce forest have been established in Scotland and upland areas of England and Wales over the last half-century and these are now under an active programme of restructuring to improve their appearance in the landscape and their value for recreation and wildlife. In 1993, the Forestry Commission launched a Biodiversity Initiative and many of you will be familiar with Phil Ratcliffe's agenda-setting booklet on *Biodiversity in Britain's forests* (Ratcliffe, 1993). The Biodiversity Initiative aims to take these aspects of restructuring further, and the inclusion of broadleaved species within spruce forests has been identified as an important step in achieving this objective.

There has already been some important work carried out. The concept of restructuring emerged in Kielder in the early 1980s (Hibberd, 1985) and was soon being reproduced elsewhere. In 1990 a study of Kielder Forest, funded by the Forestry Commission and the then Nature Conservancy Council, was carried out by John Good of the Institute of Terrestrial Ecology. This identified broadleaved woodland, dominated by birch, as being one of the key habitats for wildlife. Work by a number of other authors has also shown the potential benefits of birch for wildlife in upland conifer forests and suggests that it can enhance the variety of most groups including plants, fungi, invertebrates, birds and mammals. This has been reviewed in Gordon Patterson's Bulletin on *The value of birch in upland forests for wildlife conservation* (Patterson, 1993).

Birch can tolerate a wide spectrum of harsh climatic conditions and can readily colonise areas of restocked forest on a range of different soil types provided that seed sources are available. They are thus well suited to the role of improving the biodiversity, and the attractiveness, of upland conifer forests. The area of felling and restocking in Scotland averages about 7000 hectares per year and should increase substantially as timber production doubles over the next decade or two. This, of course, offers enormous potential to improve the value of our production forests for wildlife in the second rotation.

Interest in the commercial utilisation of birch has come to the fore in recent years and increasingly the economic benefits of managing birch in mixture with conifer crops are being recognised. In 1990, the Forest Industry Committee of Great Britain (FICGB) undertook to support an investigation into the potential economic silvicultural and ecological benefits of native birch in Scotland. This initiative was launched by the publication of a collection of commissioned essays edited by Roy Lorrain-Smith and Rick Worrell (Lorrain-Smith and Worrell, 1991). These essays acted as an important background document to a symposium hosted by the FICGB in 1991, at which the commercial potential of upland birch in Scotland was explored in considerable depth. Together with the commissioned essays, the symposium provided a springboard for promoting interest in birch as a timber crop in its own right. Among the major offshoots of the symposium was the launch of a birch genetic improvement programme at the Forestry Commission's Northern Research Station (Rook and Fletcher, 1991) and a major study at Aberdeen University Department of Forestry looking into aspects of yield and timber quality (Cameron, 1996).

This developing impetus also led to the setting-up in October 1992 of Highland Birchwoods, charged with the task of promoting the fortunes of birchwoods by securing good management through the identification and development of market opportunities and best practice. In addition, following the proposal in the Scottish Rural White Paper, the Forestry Commission has recently established a Scottish Hardwood Timber Market Development Group to help stimulate new opportunities for marketing birch and other broadleaved species.

Despite all this activity, the FC and SNH have been finding it difficult to give reliable guidance to forest managers on some detailed aspects of management. For example, should managers seek to regenerate birch in large groups or should they promote an even scattering of smaller groups through the spruce forests? More information is needed on where best to locate areas of birch; whether birch should be managed as an admixture with spruce, or as distinct patches, and how continuity of birch habitat can be maintained throughout the normal rotation of spruce trees. A pilot study was undertaken in 1991/92, funded by the Forestry Commission, to investigate the amount of natural regeneration of birch in restocked areas of Sitka spruce in Scotland. A subsequent study, the first in the joint FC/SNH collaborative research programme, examined the development of plant communities associated with birch in spruce forests. It is these pieces of work that Hilary Wallace describes in the first two presentations of this symposium.

The joint FC/SNH initiative, entitled 'The environmental benefits of birch in spruce forests', was launched by the Forestry Commission's then Director General, Robin Cutler, and the Chairman of the Nature Conservancy Council for Scotland, Magnus Magnusson. As part of this initiative, there have been two further projects looking, respectively, at the lichens associated with birch in upland Sitka spruce and most recently at the invertebrate fauna associated with birch in spruce forests. These findings are described by Alan Orange, Alan Watt and David Barbour.

The results of all this work will be incorporated into the next edition of the Forestry Commission's *Nature conservation guidelines*. The final presentation contains much of the raw material from which this part of the guidelines will be crafted. Jonathan Humphrey sets the research findings within the wider context of forest design planning and highlights options for the future management of birch within plantations. I am sure that we will look forward to the publication of the new guidelines. In the meantime it is intended that the proceedings of today's symposium will be published in the Forestry Commission Technical Paper series.

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Chapter 2

Distribution of birch in Scottish spruce plantations

Hilary L. Wallace

Summary

Colonisation of second rotation spruce plantations by birch was limited by the availability of a mature seed source. Mature birch were scarce in Grampian and the Borders, and at all sites above 200 m. The densities of birch colonising restocked sites were limited principally by the proximity of mature birch trees; at distances of greater than 200 m only low density mixtures of spruce/birch could be expected. Overall, densities were highest in the SW highlands where seed sources were most prevalent. In young crops colonising densities were low where vegetation cover was high, especially on brown earths and gleyed mineral soils where the grasses *Holcus lanatus, Agrostis capillaris* and *Deschampsia cespitosa* were prominent. The highest densities were recorded on podzolic soils where rate of ground vegetation colonisation was slower and comprised mainly mosses, sub-shrubs and the grass *D. flexuosa*. High rates of birch mortality were recorded when spruce cover exceeded 40%, and only low density mixtures were sustainable above a spruce cover of *c.* 65%.

Introduction

The extensive clearfelling and restocking of upland plantation forests in Scotland provides opportunities to meet the objectives for the enhancement of biodiversity and the promotion of wildlife in upland forests through restructuring of forest design in the second rotation (Patterson, 1990; Ratcliffe, 1993). The introduction of a greater range of stocking densities and species mixtures can both enhance the visual diversity of the forests (McIntosh, 1995) and increase individual species performance (Kerr *et al.*, 1992). The inclusion of more broadleaved species during the restocking phase is strongly recommended for improving the forest habitat for a wide range of taxa (Good *et al.*, 1990; Thornber *et al.*, 1993; Patterson, 1993). However, the optimal densities and distribution of these trees is unclear. As little as 5-10% of birch in mixtures within conifers can increase the abundance and diversity of many invertebrate taxa, including Lepidoptera and Hemoptera (Patterson, 1993). In lowland forests small clumps and individual trees can increase bird density and diversity but larger areas may be necessary in the highlands (Peck, 1989; Petty and Avery, 1990); the optimal pattern for ground flora development remains uncertain (Simmons and Buckley, 1992).

Birches, *Betula pubescens* Ehrh. and *B. pendula* Roth. (nomenclature follows Clapham, Tutin and Moore (1985) for vascular plants), are the most abundant native trees in Scotland (Miles and Kinnaird, 1979; Forestry Commission, 1983) and form a major component in many native broadleaved woodland communities (Rodwell, 1991). They are recommended for inclusion in many broadleaved woodland planting schemes aimed at recreating native broadleaved woodland vegetation communities (Rodwell and Patterson, 1994). The encouragement of birch within the second rotation of Scottish plantations of Sitka spruce is considered desirable for wildlife enhancement (Patterson, 1993). Birch requires very open conditions for germination and colonisation, being inhibited even by low growing vegetation if present at high cover (Kinnaird, 1974; Miles and Kinnaird, 1979). Since much of the seed is shed within *c.* 50 m of the parent, close seed sources are recommended for full stocking with birch (Sarvas, 1948). Although birch readily colonises clearfell sites in plantations and can sometimes check the growth of the crop where thickets develop, the conditions required to sustain birch as a minor component within planted conifers after clearfelling of the first rotation stand are not known. Similarly, conditions required to achieve localised thickets which might be retained as non-productive areas are not fully understood. The extent of birch within plantation high forest in 1998 was estimated, for the UK, to be only *c.* 1000 ha, including pure and mixed stands (Kerr *et al.*, 1992); this represents less than 0.1% of the total forest area. There is thus considerable scope for improving the representation of these species within the second rotation of Scottish forests.

This chapter presents work to identify major factors limiting the distribution and abundance of birch within second rotation stands of Sitka spruce in

Scotland and makes recommendations for the management requirements across a wide range of site types.

Methods

The study was conducted in two phases; in 1991 a preliminary survey examined factors affecting the density of birch recruited into compartments of second rotation Sitka spruce restocked since 1966. A second survey, conducted in 1992, studied first and second rotation sites where birch was prevalent to assess tree growth and ground vegetation development associated with different densities of birch within the crop. Chapter 3 deals with the aspects of ground vegetation development.

Preliminary survey of randomly selected second rotation compartments

Three areas were selected for this survey; the northern and eastern Grampian, the southwest highlands (Argyll and the Trossachs area of Central region) and Dumfries and Galloway. The Forestry Commission database was used to provide listings of sub-compartments restocked with Sitka spruce since 1966. The data were grouped according to five soil types: brown earths, podzols, peaty gleys, non-peaty gleys and deep peats, and five age classes. Stands of the following ages were selected: 1 year and 4, 9, 14 and 19 years. These groupings produced 75 region/soil/age strata. Selection for survey was restricted to soil/age strata having more than two sub-compartments within an area; this resulted in the selection of 64 sub-compartments for survey.

Sub-compartments were surveyed using transects of four plots, each of 200 m^2 (Bunce and Shaw, 1973), centred at 15 m, 45 m, 75 m and 105 m from the crop edge. A count was made of all crop species within the plot; diameter at breast height (dbh) was recorded for those with a dbh greater than 5 cm. Canopy cover was measured using the line intercept method (Mueller-Dombois and Ellenberg, 1974). Birch were counted and assigned to two size classes: under or over 2 m height. At five points within the plot, 1 m x 1 m quadrats were used to determine cover and depth of brash and litter, cover of bare soil and ground vegetation. Assessment of the latter followed four broad categories: shrub, sub-shrub, forb and bryophyte. In addition, estimates were made of the ground cover of the principal species within the plot (i.e. those achieving >5% cover over the whole plot). All mature birch within 1 km of each plot were mapped onto stock maps; the shortest distance between a plot and a mapped birch tree has been used in subsequent analyses as the 'distance to the nearest seed source'.

Survey of sites with established birch

The FC database was interrogated to produce listings of sub-compartments containing birch. Searches were made of districts north of the central lowlands including Tayside, Strathclyde, Highland, Central and from the southern uplands and the coastal area of Dumfries and Galloway. Kielder in Northumberland was also included as an additional area typical of the southern upland forests. The paucity of birch-rich samples in the preliminary survey of Grampian resulted in this area being omitted from the second phase of the study.

The primary stratification recognised three age classes: Sitka spruce restocked between 1978 and 1972 and between 1972 and 1963, and first rotation Sitka spruce planted before 1963. A secondary stratification recognised five soil classes (brown earth, podzol, peaty gley, non-peaty gley, deep peat). Four replicates were selected from each of the 15 age/soil strata, two from the northern regions and two from the 'Borders'. The full sampling strategy for the 1992 survey is given in Chapter 3.

Plots were located in stands of trees considered to be uniform with respect to species composition and age class distribution; three canopy stand types were recognised and sampled; spruce with <15% birch ('pure spruce'), intimate admixtures of spruce and birch ('mixtures') and areas of birch dominance ('thickets'). Within each stand type the standard recording unit was a 200 m^2 plot. A count was made for all tree species within the plot; measurements of dbh were made and recorded for those individuals exceeding 5 cm; smaller trees were divided into those greater or less than 2 m in height. Live and dead trees were distinguished during the count. Canopy cover was measured using the line intercept method and estimates made of canopy height.

For some of the analyses the samples have been grouped into biogeographical regions based on the work of Carey *et al.* (1995). The Forestry Commission districts sampled fell within six categories of Carey *et al.*: Central Highlands, Southern Uplands and Highland Margins, Western Mainland, Southern Isles, Southern Lowlands and Southern Coast. The Southern Lowlands and Southern Coast samples have been combined in the current presentation (Figure 2.1).

Results

Regional pattern of birch distribution

The greatest numbers of birch were recorded in the southwest highlands, where *B. pubescens* was the principal species. In the Grampian, densities were

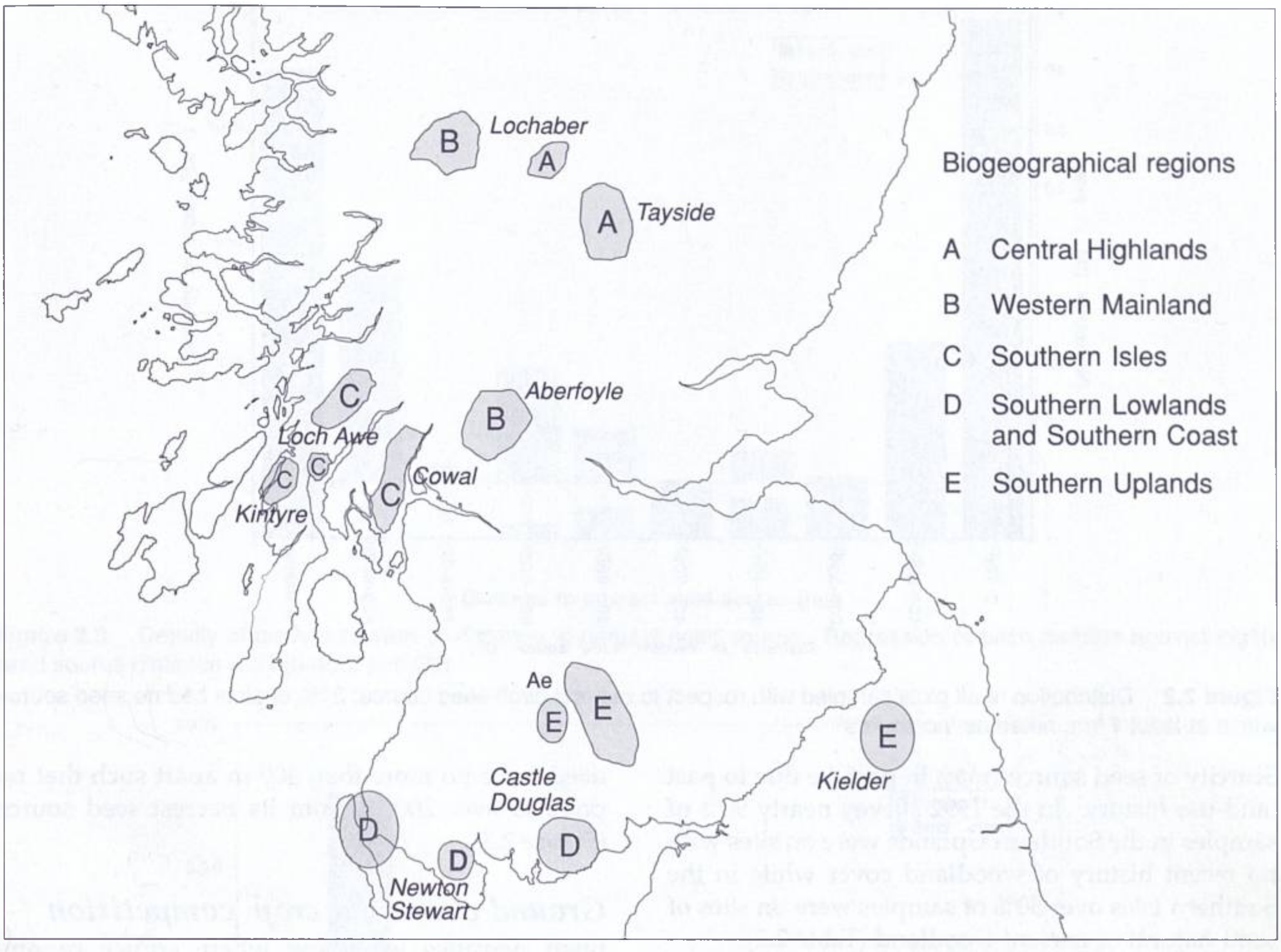

Figure 2.1 Location of survey sites in 1992 and their allocation to the biogeographical regions of Carey *et al.* (1995)

lower and *B. pendula* tended to be more prevalent (Table 2.1). Many sites without regenerating birch (especially in Grampian) were at altitudes of over 200 m; a high proportion of these appeared to lack a potential seed source. Over the three areas, 67% of sites above 200 m lacked a seed source, compared to only 5% lacking a source at lower altitudes (Table 2.1).

The 1992 survey confirmed that birch was most prevalent in the lowland regions of the southwest highlands (the Southern Isles unit of Carey *et al.*, 1995) and the Newton Stewart and Castle Douglas districts (Southern Coast/Lowlands unit of Carey *et al.*, 1995). In the more highland areas of Tayside and Lochaber (Central Highlands of Carey *et al.*) and the Southern Uplands birch samples tended to be concentrated at the lower elevations (Table 2.2).

Table 2.1 The mean density of colonising birches and the distribution of mature birch trees by altitude, across the three regions surveyed in 1991

	Grampian	Southwest Highlands	Dumfries and Galloway	
Mean density of colonising birch (ha^{-1})				
Betula pendula	200	20	10	
Betula pubescens	40	370	95	
Proportion (%) of sub-compartments lacking mature birch trees within 500 m				
Altitude				Mean
Less than 200 m	17	0	0	4.9
Over 200 m	83	71	58	67.0

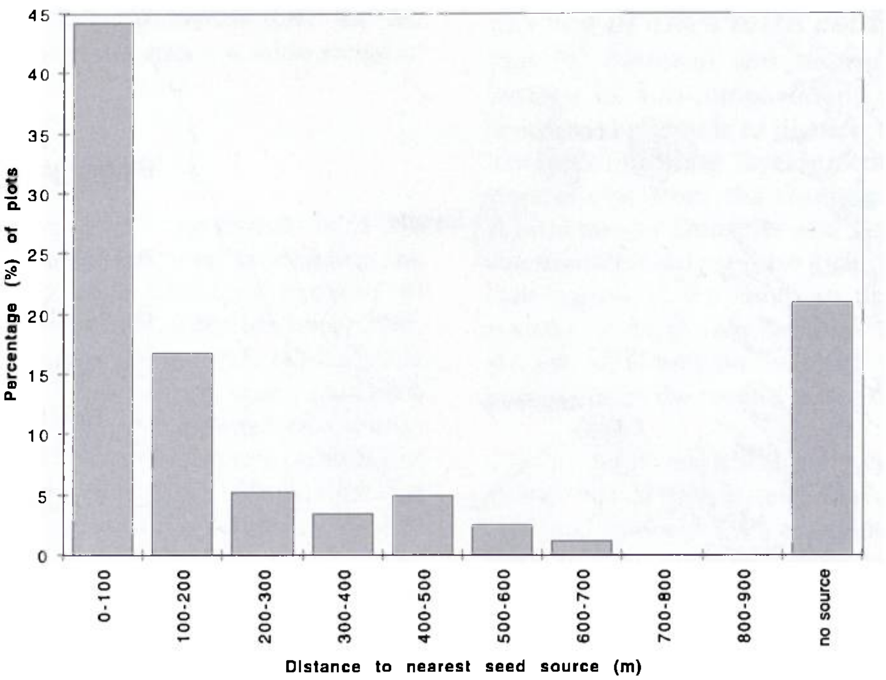

Figure 2.2 Distribution of all plots sampled with respect to nearest birch seed source; 21% of plots had no seed source within at least 1 km: noted as 'no source'

Scarcity of seed sources may, in part, be due to past land-use history. In the 1992 survey nearly 90% of samples in the Southern Uplands were on sites with no recent history of woodland cover while in the Southern Isles over 50% of samples were on sites of semi-natural or ancient woodland (Table 2.2).

Seed source availability

More than 20% of plots surveyed had no mature birch trees within 1 km while over 40% had at least one mature birch within 100 m (Figure 2.2). The number of birch recruited fell with increasing distance to the nearest seed source, the decline being logarithmic rather than linear (Figure 2.3). The data suggest that in order to achieve successful mixtures of birch within the crop, mature birch trees need to be no more than 400 m apart such that no point is over 200 m from its nearest seed source (Figure 2.3).

Ground cover and crop competition

Birch densities were low where spruce canopy cover exceeded 50%; however, in plots where spruce canopy cover was less than 50% considerable variation was observed in the density of birch recruited (Figure 2.4) with no significant correlation between spruce cover and birch density (p<0.001). Thus, factors other than spruce density have to be sought to explain the variations in the density of birch which are apparent both between regions and between soil types. The proportion of sites lacking a seed source in Dumfries and

Table 2.2 Ranges of altitude and slope for all plots surveyed during the 1992 survey together with a summary of their woodland history based on the categories of Walker and Kirby (1988). Regions are based on those of Carey *et al.* (1995)

	Central Highlands	Southern Isles	Western Mainland	Southern Lowlands and Coast	Southern Uplands
Ranges of altitude and slope					
Sample number	55	181	78	112	81
Altitude (mean, m)	260	67	87	69	191
Altitude range	170-395	5-180	10-225	10-150	75-300
Slope (degrees)	11.4	15.3	9.8	5.7	6.8
Slope range	0-37	0-50	0-28	0-28	0-25
Proportion (%) of sites on land with different woodland histories					
Ancient/semi-natural	38	55	23	9	9
Plantation broadleaved	26	7	38	49	17
No woodland history	39	36	39	41	89

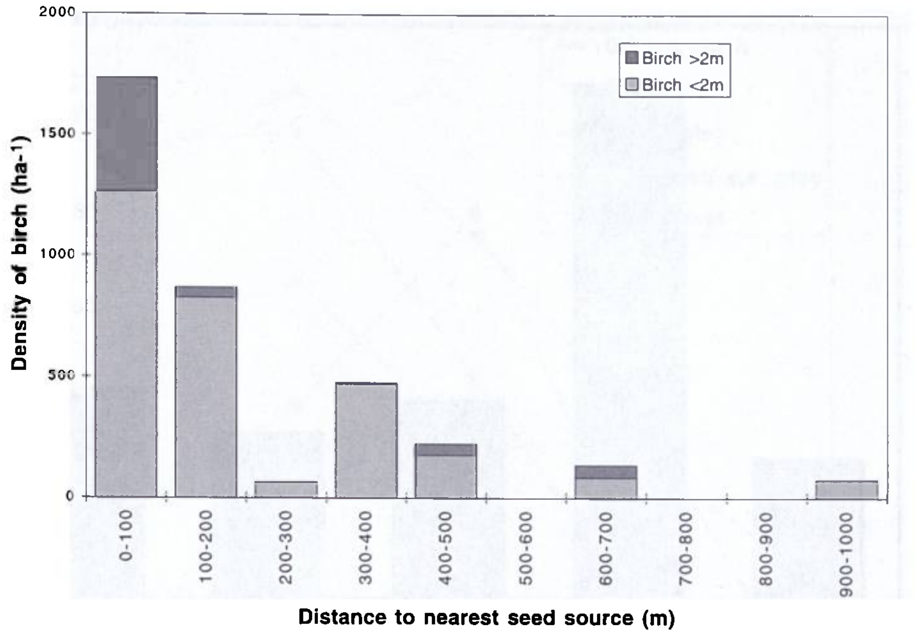

Figure 2.3 Density of birch in relation to distance to nearest seed source. Regression of birch number against log10 seed source distance = 3140-450, $p<0.001$

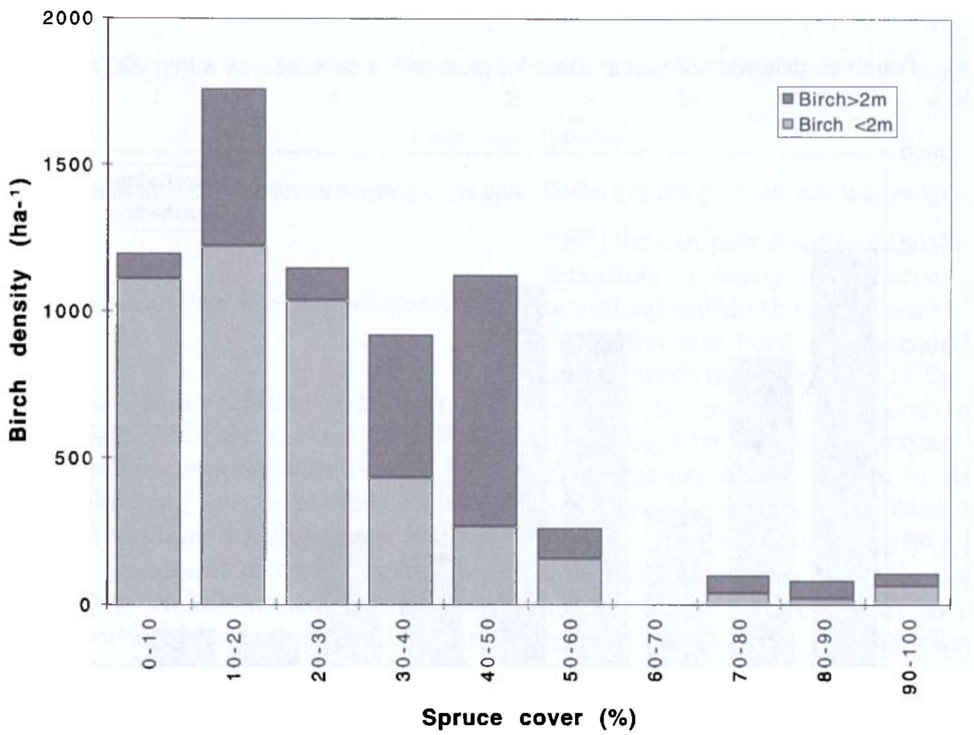

Figure 2.4 Density of birch in relation to spruce cover

Galloway is lower than in the southwest highlands, yet birch densities in the crop here are much depressed.

Correlation analyses between birch density and ground cover parameters suggested a number of additional factors which might be influencing the establishment of birch in the second rotation crops. When effects due to crop cover and distance to the nearest seed source are removed, a number of factors emerge which appear to be restricting birch densities. There were significant differences in birch densities between the five soil types (Figure 2.5), with much higher densities on podzols than on the other soil types. High forb cover is also associated with reduced density of birch; above an apparently critical cover of *c.* 50% total forb cover, birch density falls to less than 1000 ha^{-1} (Figure 2.6). The interaction between soil type and rate of ground vegetation colonisation may be a major determinant of potential birch density as forbs colonise deeper mineral soils more rapidly than podzols and deep peats in the first 4 years after felling and replanting of the tree crop (Figure 2.7).

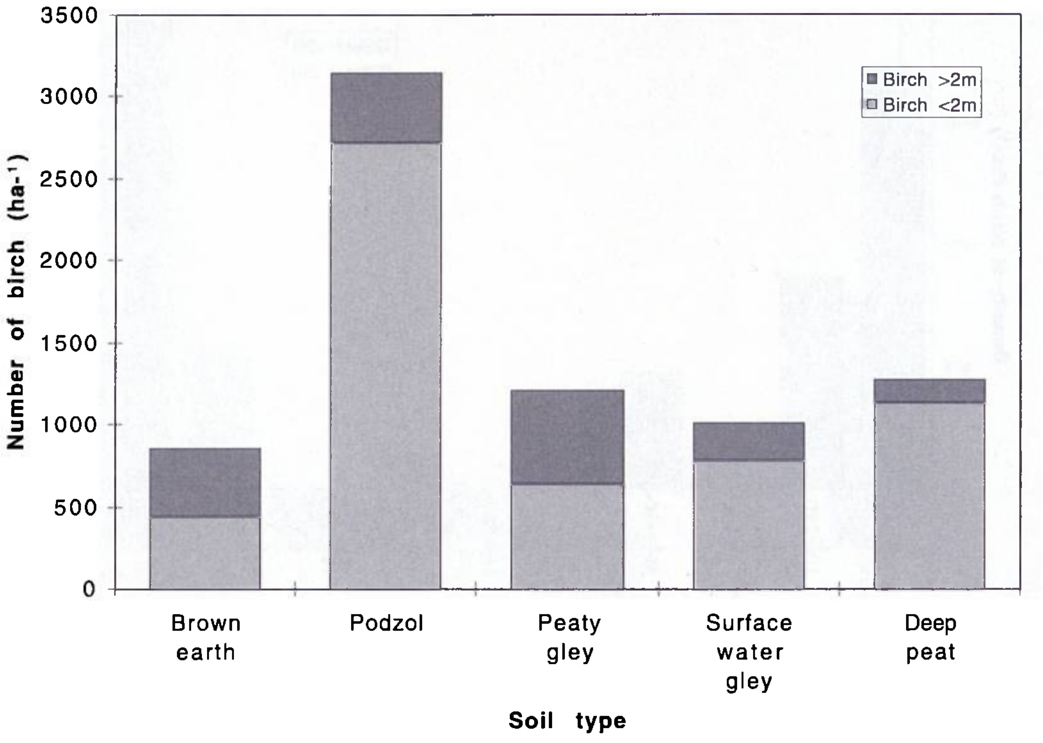

Figure 2.5 Density of birch on different soil types. Data for plots with a seed source within 200 m and spruce cover of <50%

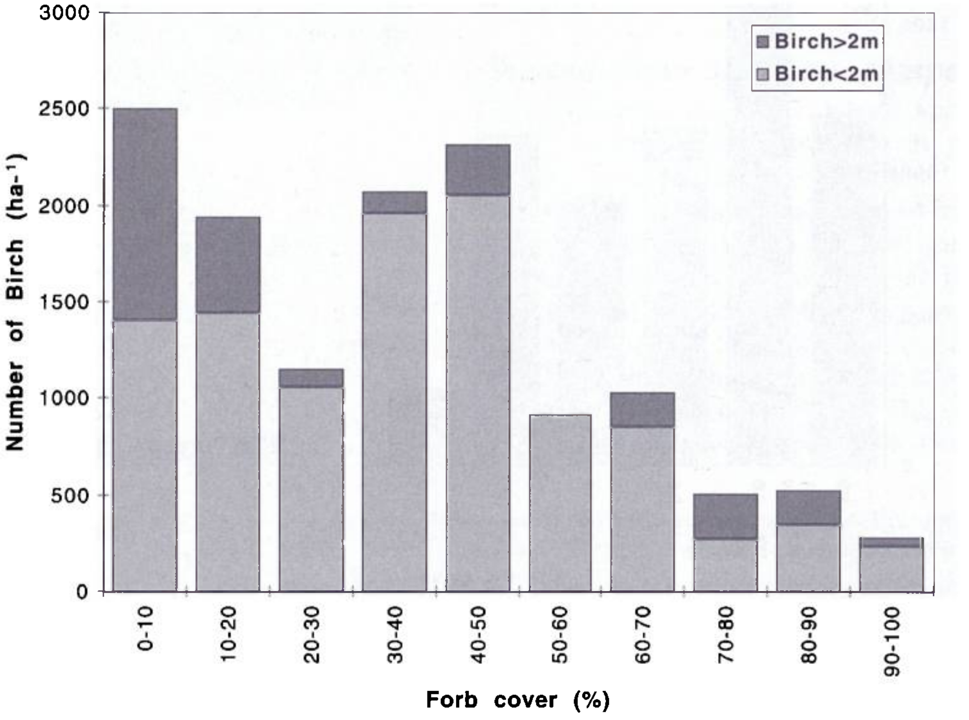

Figure 2.6 Density of birch in relation to forb cover. Data for plots with a seed source within 200 m and spruce canopy cover of <50%. Regression analysis *r*=2650-30, *p*<0.001. Forbs include grasses, rushes, sedges, herbs and ferns

The inclusion of older crops in the 1992 survey provided no evidence of increasing birch mortality in first rotation crops (Table 2.3) due to increased Sitka cover. However, in the younger second rotation crops, mortality increased with increasing spruce cover (Table 2.3) and birch appeared disadvantaged as spruce cover exceeded *c.* 40%.

Competition between birch and spruce was evident in both rotations. The top height and mean diameter of spruce were reduced in birch thickets compared to pure stands of spruce or spruce/birch mixtures. Birch, in contrast, showed a reduced top height only in the 'pure' spruce stands though a progressive decline in diameter from the 'pure' spruce to the 'pure' birch thickets was demonstrated (Table 2.3).

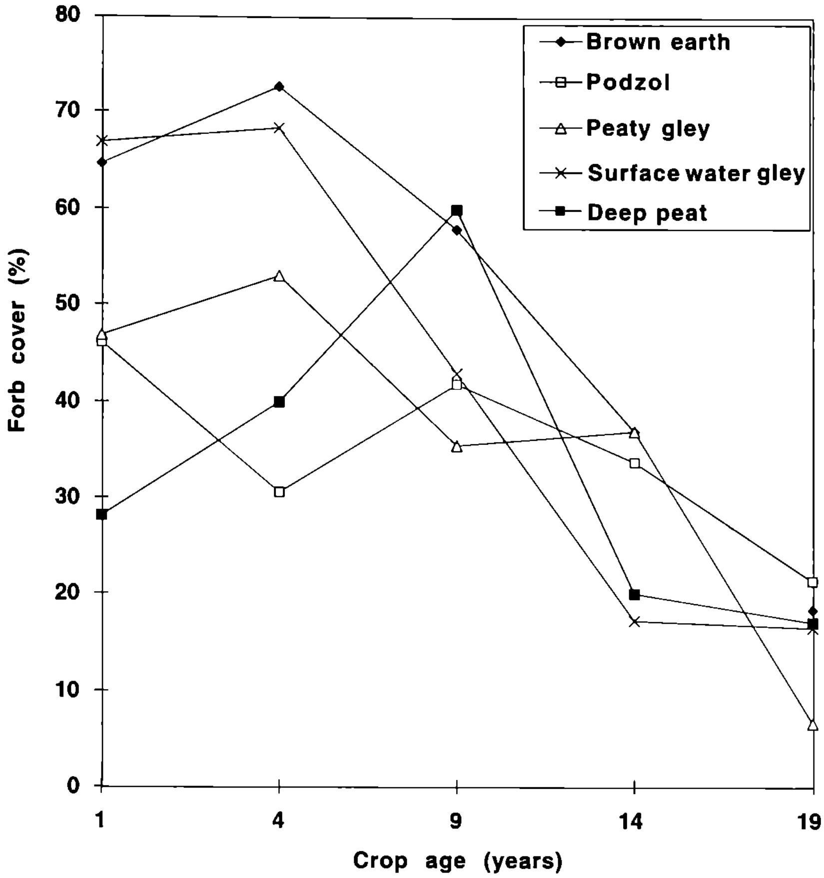

Figure 2.7 Changes in forb cover with increasing crop age. Forbs include grasses, rushes, sedges, herbs and ferns

Discussion

From the study the following four key discussion points emerged.

- *The principal factor limiting birch colonisation of restocked sites is the lack of available seed sources within the forests.* Much of the regional variation in the density of birch colonising spruce plantations can be attributed to past land-use which has resulted in a scarcity of birch woodland in some regions of Scotland (Kirby, 1984). Woodland history indicates that a higher proportion of sites surveyed in the southwest highlands (Southern Isles of Carey *et al.*, 1995) were on areas which had formerly supported ancient or semi-natural woodland compared to sites in the Borders. The hills of the Southern Uplands, with a long history of hill farming and woodland clearance, have a low density of natural woodland and hence few stands of mature birch have been included within forest plantations (Walker and Kirby, 1988). This resulted in a low frequency and density of birch colonising the second rotation crops in the Southern Uplands. A similar pattern of woodland clearance in other hillfarm areas has resulted in an overall depletion of seed sources above 200 m. In contrast, where afforestation has occurred on sites formerly supporting ancient or semi-natural woodland, the frequency and densities of colonising birch were much higher. In the southwest highlands (Southern Isles of Carey *et al.*, 1995) the complex terrain of the area has resulted in retention of many small areas of broadleaved woodland within the forest estate. The situation in Grampian has been compounded by the sale of mature birch for pulp in the 1970s. The lack of sites in some districts having a woodland history, where birch might be expected to be prevalent, reflects the age structure of the forests in these regions; the extensive plantations in the Western Mainland and Central areas were in the early years of restocking and thus had no sites of suitable age for the current study. Forests in areas with no recent woodland history are likely to require planting of birch if natural colonisation of second rotation stands is to be achieved.

- *The density and pattern of parent source provision will be determined by the required stocking rate of birch in the second rotation.* The number of birch recruited fell sharply with increasing distance to the nearest seed source. This logarithmic decline in densities with increasing distance indicates that for mixtures with a density in excess of 1000 birch ha^{-1} parent sources will need to be at a spacing of no more than 400 m. Supplementary planting will be required where naturally occurring birch are scarce. The development of pure thickets of birch appeared to be rare and where they did occur they were usually small. Of the 76 thickets sampled within spruce stands only 20% exceeded 200 m^2 while 64% were under 100 m^2 in area. Since their development

Table 2.3 Characteristics of birch and spruce growth in different crop stands

	First rotation			Second rotation		
	Pure	Mixture	Thicket	Pure	Mixture	Thicket
Number of stands	47	39	34	37	85	64
Mean crop age (yr)	43	38	38	20	19	21
Spruce cover (%)	64.4	43.2	7.9	65.4	41.5	11.0
Spruce density (ha^{-1})	1415[a]	1235[a]	385	1930	1480	555
Spruce basal area (m^2 ha^{-1})	50.3	29.8	5.9	34.3	19.8	5.3
Spruce dbh (cm)	20.8[a]	17.6[ab]	14.6[b]	15.2[a]	13.9[a]	11.6
Spruce top height (m)	19.7[a]	18.0[a]	8.7	13.2[a]	12.2[a]	8.5
Birch cover (%)	2.1	20.7	43.5	6.2	26.0	52.4
Birch density (total ha^{-1})	217	1783	2769	1435	4752	6880
Percentage dead birch	42.5[a]	45.2[a]	29.2[a]	56.9	39.6[a]	26.9[a]
Birch basal area (m^2 ha^{-1})	0.9	7.1	15.8	1.5	4.3	11.1
Birch top height (m)	1.1	13.9[a]	13.2[a]	4.5	9.1[a]	10.3[a]

[a] Within each rotation, analysis of variance results between stand types were significant at the $p<0.001$ for all variables except percentage of dead birch in first rotation crops.

[b] Values within a rotation not significantly different at $p<0.05$ denoted by the same letter.

requires a seed source within *c.* 100 m to provide sufficient seed rain within the first years after felling, provision of extra seeding, or more closely spaced planting, will be needed if such high densities are required over extensive areas. The small size of many thickets makes them vulnerable to suppression as the crop around them matures, and this may account for small areas of high density but moribund birch within older second rotation crops now classed as 'pure' spruce.

• *Given adequate seed supply, soil type and stand density will determine the recruitment and survival of birch within the crop.* The low recruitment of birch when forb cover exceeded 50%, coupled with the different rates of spread and competition from the characteristic species associated with different soil types, suggests there may be an important interaction between soil type and birch densities. Podzolic soils, with their slower rate of ground cover colonisation, provide open niches for establishment for a longer time period after felling than brown earths and surface water gleys and are thus less sensitive to annual fluctuations in birch seed production in the first few years after clearfelling. The species which colonise the brown earths and surface water gleys, *Agrostis capillaris, Holcus lanatus* and *Deschampsia cespitosa,* rapidly produce dense carpets of cover which are likely to inhibit establishment of young birch trees even if seed sources are adequately provided. Even on peaty gley soils *Deschampsia cespitosa* can rapidly colonise sites where there has been admixing of the peat and mineral horizons (Davy, 1980; Wallace *et al.,* 1992). In these situations there is likely to be need for post-felling weed control in areas where birch is to be encouraged. It may be that on some of the damper mineral soils other species of broadleaves might more appropriately be planted, e.g. ash and alder on the dampest surface water gleys and oak on the freely drained base-poor brown earths (Rodwell and Patterson, 1994).

• *Competition from the growing crop results in mortality of birch leading to very low density mixtures.* At spruce covers of *c.* 65%, birch mortality exceeded 50% and densities of live birch were reduced to less than 1000 ha^{-1}; the trees tended to be subordinate in the canopy achieving very low heights and making little or no contribution to the total canopy cover. Growth of spruce at *c.* 40% canopy cover allowed densities of birch of *c.* 3000 ha^{-1} to persist with no reduction in the yield of the individual spruce trees; at higher birch densities (i.e. in birch thickets) where the birch was the dominant component of the canopy there was a reduction in the yield of the individual spruce within the stand. The final decision as to the level of crop thinning will be determined by the required yield of the stand. It seems likely that some early thinning would extend the life expectancy of the birch beyond the thicket phase. Further thinning might only be considered in those areas where ground flora and other taxa show a sustained benefit from the continued presence of the birch within the crop.

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Chapter 3

Ground flora associated with birch in Scottish spruce plantations

Hilary L. Wallace

Summary

The ground flora under pure spruce stands was compared with that of stands of spruce/birch mixtures and pure birch thickets. The vegetation of these managed stands was compared with that of unmanaged birch and semi-natural woodland within the forest estate. The retention of birch within the managed spruce crop enhances cover and diversity of the ground flora in first and subsequent rotation stands. The response of the ground flora was closely related to the density of birch; thickets supported consistently higher cover and diversity of species than mixtures or pure spruce. There were significant differences between the flora of managed birch thickets compared to unmanaged birch within the forest estate. These differences are apparent in the cover of different components of the ground vegetation and in their species composition. Forbs in managed stands have low cover and diversity compared to unmanaged birch while bryophyte cover and diversity are inflated in the managed thickets. Floristic differences between biogeographical regions were retained in managed thickets but lost in pure spruce. Fewer vegetation communities were recognised in the managed birch; the greatest number being in the thickets with the lowest in the pure spruce. The species composition of recognised communities in managed birch deviated from that of their unmanaged counterparts; many species (especially forbs) were missing while others (notably bryophytes) were over-represented. Retention of birch to maximise vegetation biodiversity should concentrate primarily on those areas of unmanaged birch within the forest estate and secondarily on the thickets within the managed crop.

Introduction

Birches, *Betula pubescens* Ehrh. and *B. pendula* Roth., are the most abundant native trees in Scotland (Miles and Kinnaird, 1979; Forestry Commission, 1983) and form a major component in many native broadleaved woodland communities (Rodwell, 1991). They are recommended for inclusion in planting schemes aimed at recreating native broadleaved woodland vegetation communities (Rodwell and Patterson, 1994). The encouragement of birch within the second rotation of Scottish plantations of Sitka spruce is considered desirable for wildlife enhancement (Patterson, 1993).

The extensive restocking of the upland forests provides opportunities to move away from the traditional pattern of pure conifer stands, with their poor associated ground flora, towards a system of mixed species stands. These can both enhance the visual diversity of the forests (McIntosh, 1995) and increase individual species performance (Kerr *et al.*, 1992). The inclusion of broadleaves at restocking is strongly recommended for the enhancement of a wide range of taxa (Patterson, 1993).

Although birch readily colonises cleared sites in forests, densities and ideal patterns of birch for the enhancement of wildlife are unclear. For example, as little as 5 -10 % canopy cover of birch in mixtures within conifers can increase the abundance and diversity of many invertebrate taxa, including Lepidoptera and Hemoptera (Patterson, 1993). In lowland forests small clumps and individual trees can increase bird density and diversity but larger areas may be necessary in the highlands (Peck, 1989; Petty and Avery, 1990); the optimal pattern for ground flora development remains uncertain (Simmons and Buckley, 1992).

In the current study the ground flora under pure spruce stands was compared with that of stands of spruce/birch mixtures and pure birch. The vegetation of these managed stands was compared with that of unmanaged birch and semi-natural woodland within the forest estate. The survey was designed such that each sample contained a pure spruce 'control' and adjacent stands of mixed spruce/birch and of pure birch within a spruce stand and on the same soil type. These stands were then further compared with natural birch and semi-natural woodland in the same area and on the same soil type. The response of the ground flora to the presence of birch was examined using criteria of species cover and diversity; the extent to which these responses influenced the development of vegetation associations within the plantations was also considered.

Methods

Site selection

The low density (or absence) of birch in many stands sampled in the 1991 survey (Wallace, Chapter 2) indicated the need for a sampling strategy for this survey that ensured birch was present at the sites selected. The Forestry Commission sub-compartment database was interrogated to provide listings of sub-compartments containing birch; these were stratified by district (Highlands and Borders), crop age (restock 14–20 years, restock 21–30 years, first rotation >30 years) and soil type (brown earth, podzol, peaty gley, surface water gley, deep peat).

Crop by soil type strata were paired with unmanaged birch and natural woodland within the same 1 km square. Sub-compartments lacking such pairings were omitted from the subsequent selection procedure. Four replicates were selected from each of the 15 crop/soil strata (two replicates from each district).

Field survey

Plots were located in stands of trees considered to be uniform with respect to species composition and age class distribution. Seven canopy types were recognised and sampled, together with stands of open vegetation without tree growth (Table 3.1). At each site selected all stand types which were present were sampled. The basic recording unit was a 200 m^2 plot. All trees were counted and diameter at breast height (dbh) measured. Individuals with dbh less than 5 cm were divided into those over and under 2 m height. Canopy cover was measured using the line intercept method (Mueller-Dombois and Ellenberg, 1974). Soil type was determined using an 80 cm metal augur. Ground vegetation was recorded in five 2 m x 2 m quadrats placed at fixed locations within the plot to give an objective measure of the average cover of all species of vascular plant, bryophyte and lichen.

The 417 plots, comprising all spruce stands together with stands of unmanaged birch, but excluding those where crop failure resulted in no canopy development, and unplanted areas, were subdivided according to stand type and age. Four unmanaged birch stand types were recognised, representing a time sequence from thicket to mature and semi-natural (Table 3.1). The managed stands were also segregated into four age classes: first rotation stands over and under 40 years and second rotation stands of 11–16 years and over 17 years. In addition, data for crops under 10 years have been drawn from the 1991 survey (Wallace, Chapter 2) for inclusion in the ground cover comparisons; less than 500 birch trees ha^{-1} being classed as pure spruce, densities of 500–5000 ha^{-1} being assigned to mixtures and those with a greater density being classed as thickets.

Data analysis

Regional variation and woodland history

The data were grouped into biogeographical regions (Carey *et al.*, 1995) to investigate regional variations in floristic composition. The regions, based on climate and altitude, show a close correlation with natural species distribution patterns and are similar to those proposed by Rackham (1986); their value in conservation planning is that they represent the limitations to the distribution of some species and may be used to predict potential ranges of species occurrence. The sites studied fell within five biogeographical regions: Central Highlands, Western Mainland, Southern Isles, Southern Lowland and Coast, and Southern Uplands (Wallace, Chapter 2, Figure 2.1). The distribution of samples between regions and

Table 3.1 Stand types sampled for each site (i.e. crop x soil strata)

Managed stands of Sitka spruce	Unmanaged birch stands	Others
Spruce with <15% birch cover (PURE SPRUCE)	Young birch having few trees of dbh >3 cm (THICKETS)	Unplanted vegetation without tree cover
Intimate admixture of spruce and birch (MIXTURE)	Most birch >3 cm dbh but few attaining 20 cm (POLE)	
Areas of birch dominance (THICKET)	Most birch with dbh >15 cm, few of <5 cm (MATURE)	
	Areas of birch dominance within semi-natural woodland (NATURAL)	

their woodland history is summarised in Chapter 2. In the Southern Lowlands and Southern Uplands few plantations occurred on land formerly supporting ancient or semi-natural woodland; in the Southern Uplands most sites had no former woodland history. The Southern Isles (in part coincident with the Atlantic bryophyte zone of Ratcliffe (1968)) showed the greatest frequency of plantations on sites of former semi-natural woodland. Against this background species diversity of different components of the ground flora have been compared between regions to assess the extent to which birch in the crop is a factor in the retention of regional distinctiveness within the vegetation. Counts were made of the number of forb (includes here grasses, sedges, rushes and all herbaceous species), moss, liverwort and lichen species for each plot and average values compared between regions and stand types.

Relationships between ground cover, species richness and stand age

The cover of forbs and bryophytes, overall species richness (all species groups combined) and richness of forbs, mosses, liverwort and lichens were compared between managed and unmanaged birch stands of all ages. Differences in ground cover and species richness through the crop rotation were tested using Analyses of Variance and Tukey Pairwise comparisons; comparisons included between age classes of a single stand type and between stand types of the same age.

Species composition

A comparison was made of the frequency of occurrence of the principal species (those occurring in 40% or more of plots within a stand type) of forb, moss and liverwort in managed and unmanaged stands. The managed stands were divided into the same age classes as those used for comparisons of species richness.

Community development and distribution

A phytosociological analysis was conducted to investigate the extent to which regional and management induced variations in species diversity and cover affect the range of vegetation communities within plantations. The full data set, including unplanted stands of natural vegetation, were subject to TWINSPAN (Two-way Indicator Species Analysis; Hill, 1979b). TWINSPAN is designed to perform a divisive cluster analysis on multivariate data; in this case, stand types characterised by their species composition. The analysis groups stand types of similar composition. In this study, these groups were then assigned to National Vegetation Classification community and sub-community types (Rodwell, 1991), with the aid of the FORTRAN program MATCH (Malloch, 1990).

Of the 490 samples analysed, 283 were in the highland regions (Southern Isles, Western Mainland and Central Highlands) with the remaining 207 in the Borders (Southern Upland and Southern Lowlands and Coast).

Results

Regional variation and woodland history

Mosses and liverworts were most diverse in plots from the three regions forming the highland sample (Table 3.2). Species richness in the unmanaged ('natural') woodland samples was similar to that in the managed birch thickets and mixtures. In pure spruce the overall richness of both species groups was much lower and regional differences were largely eliminated. Lichens were most diverse in the unmanaged woodlands and birch thickets of the Central Highlands though regional differences were less distinct than for the mosses and liverworts. Although forb species richness was uniformly higher in the Southern Isles there was no consistent regional variation. In pure spruce stands herb cover was equally low in all stand types. The variation in moss and liverwort diversity between regions parallels differences in woodland history; only 9% of plots in the Borders were on sites of former semi-natural woodland while in the highland sample the overall average was 44%, with the highest proportion (55%) in the Southern Isles.

Relationship between ground cover, species richness, species composition and stand age

Ground cover

The total forb cover varied significantly between different crop stages. The magnitude and direction of the changes in the pure spruce and spruce/birch mixtures were very similar; the highest values were observed in crops of less than 16 years while older second rotation stands and first rotation crops had significantly lower forb cover ($p<0.01$; Figure 3.1). In contrast, birch thickets showed no significant difference in forb cover through the crop cycle. In the older crops of both rotations the thickets have a higher forb cover than either the pure spruce or the mixtures ($p<0.001$) while between 11 and 16 years there were no differences between the three stand types; the lower value for thickets aged <10 years may simply reflect the small number of such stands sampled (Figure 3.1). Forb cover in the managed stands was, in general, much lower than that in the unmanaged birch where the mean cover in mature stands exceeded 50%.

Table 3.2 Influence of crop type on species richness (number per 4 m^2) across districts. Differences between biogeographic regions (Carey *et al.*, 1995) tested using analysis of variance (ANOVA); values not significantly different between regions at $p<0.05$ denoted by the same superscript letter ($^{a, b}$)

	Central Highlands	Southern Isles	Western Mainland	Southern Lowlands and Coast	Southern Uplands	ANOVA
Forbs						
Natural woodland	$15.8^{a,b}$	16.6^{a}	10.6^{b}	$14.8^{a,b}$	12.2^{b}	0.003
Thickets	7.2^{b}	14.0^{a}	$10.1^{a,b}$	9.1^{b}	$11.5^{a,b}$	0.005
Mixtures	8.0^{b}	11.7^{b}	7.1^{a}	7.6^{a}	$8.4^{a,b}$	0.002
Pure spruce	5.5	5.6	6.2	3.6	7.5	0.214
Mosses						
Natural woodland	13.3^{a}	12.9^{a}	$11.4^{a,b}$	9.4^{b}	8.4^{b}	<0.001
Thickets	11.2^{b}	14.4^{a}	$12.4^{a,b}$	10.1^{b}	11.1^{b}	<0.001
Mixtures	$11.0^{a,b}$	11.1^{b}	$9.7^{a,b}$	8.4^{a}	8.8^{a}	0.002
Pure spruce	$7.8^{a,b}$	9.0^{a}	$7.4^{a,b}$	5.2^{b}	$7.5^{a,b}$	0.003
Liverworts						
Natural woodland	2.7^{a}	4.3	$1.9^{a,b}$	$1.3^{a,b}$	0.9^{b}	<0.001
Thickets	$2.7^{a,b}$	3.9^{a}	$2.2^{a,b}$	1.2^{b}	1.3^{b}	<0.001
Mixtures	$2.8^{a,b}$	2.7^{b}	3.0^{b}	1.6^{a}	$2.2^{a,b}$	0.013
Pure spruce	2.0	2.8	1.9	1.4	1.7	0.093
Lichens						
Natural woodland	3.1	1.3^{a}	0.7^{a}	0.5^{a}	0.9^{a}	<0.001
Thickets	2.7	0.8	1.1	0.9	1.7	0.192
Mixtures	$1.8^{a,b}$	0.9^{a}	1.3^{a}	0.5^{a}	2.7^{b}	0.013
Pure spruce	0.8	0.3	1.4	0.3	0.4	0.093

Bryophyte cover in the pure spruce and the mixtures peaked in restocked stands between 11 and 16 years, with significantly lower values recorded in younger and older second rotations ($p<0.01$; Figure 3.1). The rise in cover within older mixtures may be a consequence of natural thinning. Bryophyte cover in the thickets showed no significant difference between crop ages. With the exception of the 11–16 age class, managed thickets retained the highest bryophyte cover while the pure spruce supported the lowest cover; values in the mixtures were intermediate between pure spruce and thickets. The cover of bryophytes in managed stands was close to that recorded in the unmanaged birch; only in the older pure spruce were values significantly depressed (Figure 3.1).

Species richness

Differences in species richness were apparent between age classes and stand types (Table 3.3). Young second rotation (less than 16 years) pure spruce and spruce/birch mixtures had a significantly higher species richness than their older counterparts (of either rotation $p<0.05$); in contrast, thickets showed no significant variation in species richness with crop age. In consequence, species richness was similar in all young managed stands while in the older crops of both rotations the thickets maintained a higher richness than the pure stands or mixtures. Forb species richness was highest in all stand types under 16 years of age with no significant difference between stand types; in older stands of both rotations the thickets had a significantly more diverse flora than the pure or mixed stands ($p<0.001$; Table 3.3).

Bryophyte species richness appeared constant with age and was consistently higher in the thickets than the pure spruce ($p<0.05$ – $p<0.001$); only in the youngest crops were the mixtures significantly less rich than the thickets ($p<0.05$). Lichens, like the forbs, displayed a peak of diversity in the 11–16-year-old restocks ($p<0.001$).

Species composition

The distribution of the principal ground cover species between age classes and stand types was similar to the patterns shown for species diversity. In this comparison, only species present in 40% of samples in any one stand/age class are considered

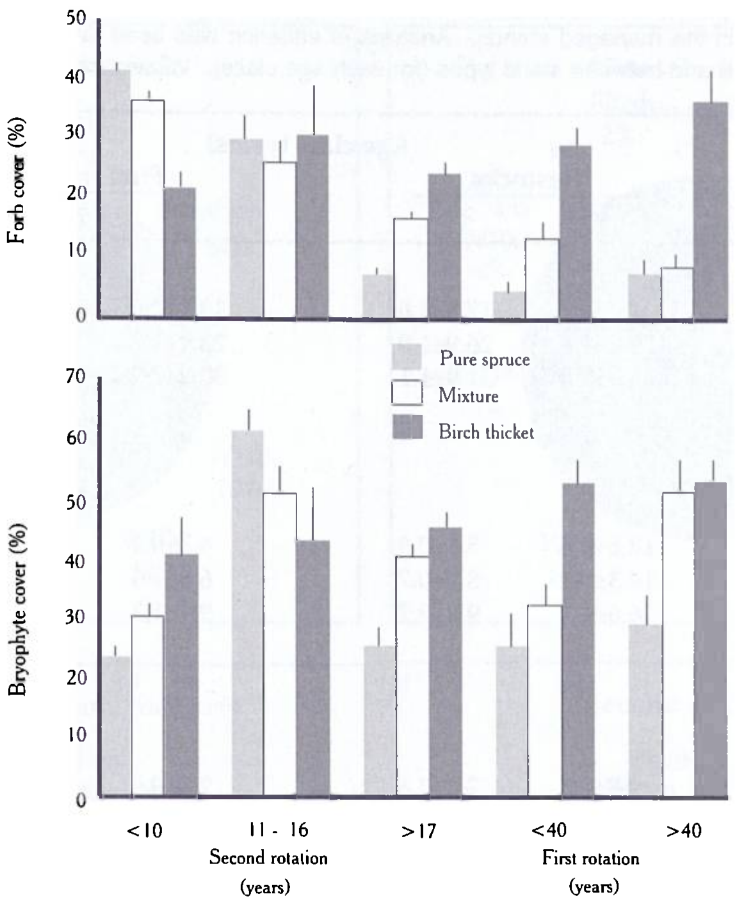

Figure 3.1 Variation in forb and bryophyte cover related to both crop age and stand type. Analysis of variance used to test for significant differences between crop ages (within a stand type) and between stand types (within a crop age). Values are means ± standard error

(Table 3.4). Sixteen of the 23 principal forb species were present in unmanaged birch while, with the exception of the youngest crops (<16 years), fewer than five were recorded in pure spruce and mixed stands. Of the managed stands birch thickets had the highest number of forb species. A number of species commonly found in unmanaged birch were very scarce or absent in the managed stands, notably *Pteridium aquilinum, Anthoxanthum odoratum, Holcus mollis, Agrostis capillaris, Lonicera periclymenum* and *Viola riviniana*. In the younger managed stands grasses typical of unmanaged birch were largely replaced by species of damp, disturbed conditions, notably *Holcus lanatus, Deschampsia cespitosa* and *Juncus effusus*. Mosses tended to be most prevalent in the thickets and mixtures. Some shade tolerant species, notably *Hypnum jutlandicum* and *Plagiothecium undulatum,* were uniformly common in pure spruce, birch thickets and mixtures, while many species characteristic of natural oak–birch woodland were only prevalent in the mixtures and thickets (e.g. *Dicranum majus*).

Only one species of liverwort (*Lophocolea bidentata*) was present in all stand types, while *Calypogeia muelleriana* was favoured by the more shady habitats and *Lepidozia reptans* was most prevalent in the thickets.

Community development and distribution

Based on the outputs from the TWINSPAN and MATCH analyses a number of NVC communities were identified. These relate broadly to the different soil types. On the peaty and podzolic soils three sub-communities of the *Quercus petraea-Betula pubescens-Dicranum majus* woodland (W17) predominate; the *Isothecium myosuroides-Diplophyllum albicans* sub-community (W17a), the most bryophyte-rich unit, the Typical sub-community (a unit with affinities with W17a but lacking the extreme oceanic bryophytes) and the *Rhytidiadelphus loreus* sub-community (W17d), a unit normally confined to the Scottish Highlands. Occasional stands of W18, the *Pinus sylvestris-Hylocomium splendens* woodland, were also recorded.

On mineral soils the two principal vegetation types were W17c, the *Anthoxanthum odoratum-Agrostis capillaris* sub-community of *Quercus petraea-Betula pubescens-Dicranum majus* woodland and W11a, the *Dryopteris dilatata* sub-community of *Quercus petraea-Betula pubescens-Oxalis acetosella* woodland.

Table 3.3 Variations in species richness (number 4 per m^2) between crops of different ages showing, in addition, the effect of birch density within the managed stands. Analysis of variance was used to test for difference between age classes (within a stand type) and between stand types (for each age class). Values are means ± standard errors

	Age class (years)				ANOVA
	Restocks		First rotation		by age class
	11-16	>17	<40	>40	
All species					
Pure spruce	31.2±4.2	17.5±1.6	18.1±2.0	18.5±1.7	a
Mixture	35.3±1.4	26.9±1.0	23.4±1.7	24.9±2.3	c
Birch thicket	34.2±1.8	31.9±1.1	30.2±2.2	31.8±2.6	NS
ANOVA by stand type	NS	c	c	c	
Forbs					
Pure spruce	12.6±2.6	5.6±0.9	4.3±0.9	4.0±0.7	c
Mixture	14.3±0.8	8.8±0.7	6.6±1.0	5.8±1.7	c
Birch thicket	16.6±1.1	9.0±0.7	9.9±1.3	11.2±1.7	c
ANOVA by stand type	NS	b	b	c	
Bryophytes					
Pure spruce	9.6±1.2	7.0±0.6	7.5±0.9	7.3±0.6	NS
Mixture	10.0±0.6	10.4±0.4	9.3±0.8	8.2±0.8	NS
Birch thicket	14.3±0.9	11.8±0.5	11.3±0.7	10.5±0.9	a
ANOVA by stand type	c	c	b	a	
Lichens					
Pure spruce	2.5±0.9	0.2±0.1	0.2±0.1	0.6±0.2	c
Mixtures	2.7±0.6	0.8±0.2	0.9±0.2	1.1±0.4	c
Birch thickets	1.2±0.3	1.1±0.2	0.7±0.2	1.3±0.3	NS
ANOVA by stand type	NS	b	NS	NS	

[a] $p<0.05$; [b] $p<0.01$; [c] $p<0.001$.

On flushed soils two ash woodland associations were distinguished; the lowland *Alnus glutinosus-Fraxinus excelsior-Lysimachia nemorum* woodland (W7) and its northern, upland counterpart, the *Fraxinus-Sorbus aucuparia-Mercurialis perennis* community (W9). Some stands of very base-enriched flushed vegetation were retained as a distinct group. Occasional records were also noted for other woodland communities, notably W4 (*Betula-Molinia*) and W10 (*Quercus robur-Pteridium aquilinum-Rubus fruticosus*) and for scrub units.

The distribution of communities was compared across the different stand types (Figure 3.2). It is apparent that in the natural woodlands the four sub-communities of W17 and W11a were equally distributed across the survey area. A similar distribution pattern was maintained in the unmanaged birch stands (thicket, pole and mature) within the forest estate (Figure 3.2). In managed stands there was evidence of a progressive reduction both in the variety of communities recognised and in the relative prevalence of those that did occur. In first rotation stands the extent of W17a diminished as the proportion of birch in the crop declined from thicket to pure spruce dominance. Stands of W17c and W11a diminished in a similar pattern. W17b was, however, more prevalent in the pure spruce. The proportion of stands which could not be assigned to a recognisable vegetation unit on account of their species poverty increased with increasing spruce dominance. In the second rotation crops, though a similar pattern of reduced diversity of communities was apparent, the extent of 'non-fitting' was less than in the first rotation. This probably reflects the younger age of the second rotation sample. W17b was more prevalent than expected in both thickets and pure spruce while W17a failed to persist into the second rotation. W11a tended to be widespread

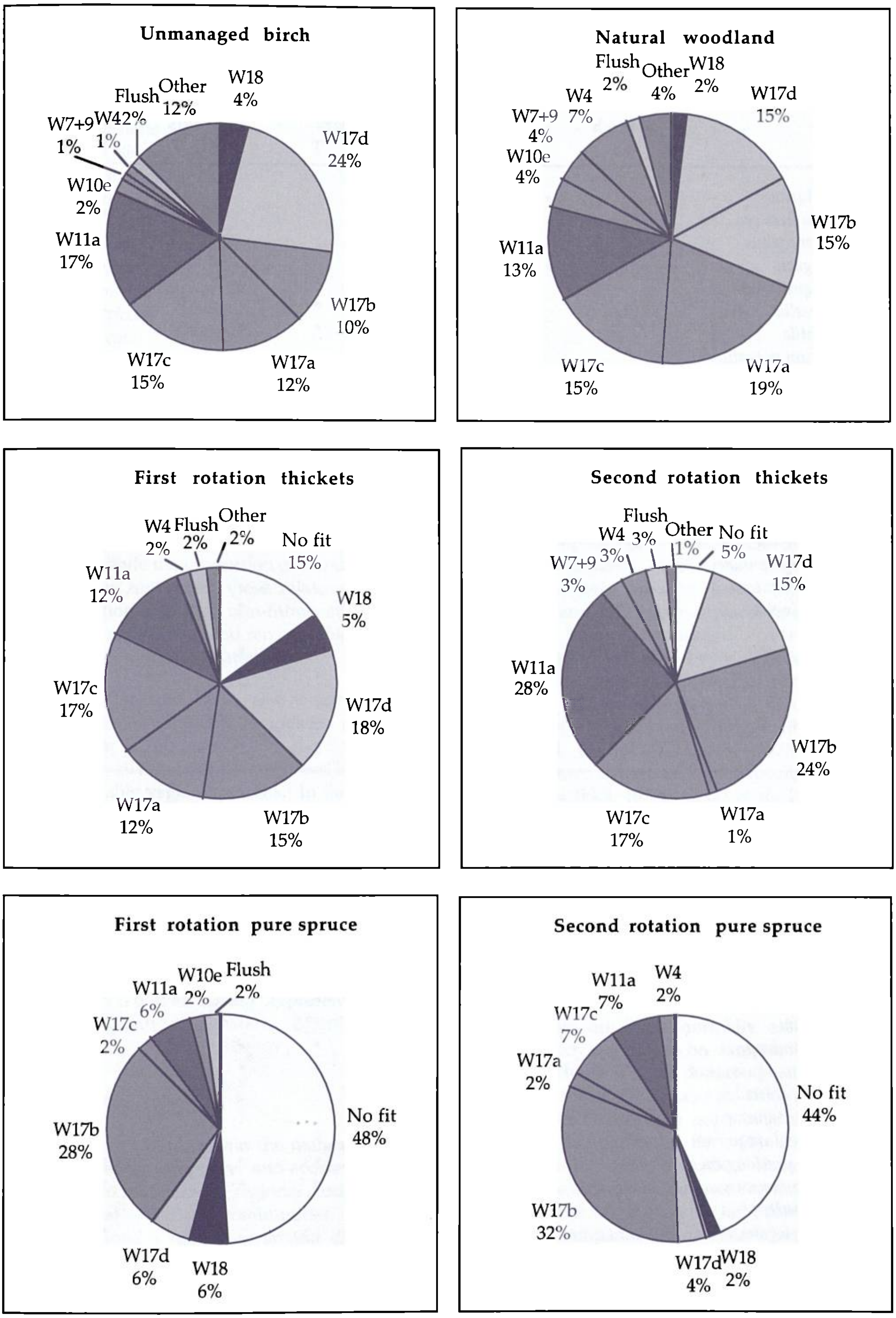

Figure 3.2 Distribution of vegetation communities (see Table 3.1 for key to stand types)

Table 3.4 Occurrence of principal species (species present in 40% or more of samples) in natural woodland stands and in crop stands of first and second rotations. Managed stands are P: pure spruce, M: birch/spruce mixtures and T: birch thickets in spruce

	Natural birch	First rotation						Second rotation					
		<40 years			>40 years			<16 years			>17 years		
		P	M	T	P	M	T	P	M	T	P	M	T
Vascular plants													
Deschampsia flexuosa	*		*	*	*	*	*		*	.	*	*	*
Vaccinium myrtillus	*		*	*	*	*	*		*	*		*	*
Calluna vulgaris	.			.			.		*			.	.
Pteridium aquilinum	*	.		.			.		.	.		.	.
Oxalis acetosella	*	*		*			*	.	*	*		*	*
Galium saxatile	*			*			*	*	*	*			*
Anthoxanthum odoratum	*												
Holcus mollis	*								.				
Agrostis capillaris	*			.		.	.	.	.	.		.	.
Agrostis vinealis	*			*		.	*	*	*	*	.	*	*
Blechnum spicant	*			*		*		*	*	*	*	*	*
Rubus fruticosus	.			.			.		*	*		*	*
Molinia caerulea	*	.		*		.	*	.	*	*			.
Potentilla erecta	*	.	.	.	.	.	.	*	*	.	.	.	.
Dryopteris dilatata	*	*	*	*	*	*	*	*	*	*	*	*	*
Lonicera periclymenum	*								.	.		.	.
Deschampsia cespitosa								.	*	*		.	*
Dryopteris felix-mas								*	*	*		*	*
Viola riviniana	.						.	.		*			.
Holcus lanatus	*						*	*	.	*		.	*
Luzula pilosa	*						*		*	.		*	*
Rubus idaeus							.		.	*			
Juncus effusus	.	.	.	.	.	.	.	.	*	*	.	.	.
Total	**16**	**2**	**3**	**8**	**3**	**4**	**9**	**7**	**15**	**14**	**3**	**8**	**11**
Mosses													
Polytrichum formosum	*		*	*	.	.	.		*	*	*	*	*
Hylocomium splendens	*		*	*	.	*	*		.	*		.	*
Rhytidiadelphus loreus	*		*	*	*	*		.	*	*		*	*
Pleurozium schreberi	*			*		.		*	*	*		.	*
Dicranum majus	*	.	.	*	.	*	.	.	.	*	.	*	*
Plagiothecium undulatum	*	*	*	*	*	*	*	*	*	*	*	*	*
Thuidium tamariscinum	*	*	*	*	*	*	*	*	*	*	*	*	*
Dicranum scoparium	*	*	*	*	*	*	*	*	.	*	*	*	*
Mnium hornum	*	*	*	*	*	*	*	*	.	*	*	*	*
Hypnum jutlandicum	*	*	*	*	*	*	*	*	*	*	*	*	*
Rhytidiadelphus squarrosus	*			.		.	*	*	.	*		.	*
Isothecium myosuroides	*		.	.	.	.			.	.		.	.
Hypnum cupressiforme	*		*	*	*	*	.	.	*	*		*	*
Pseudoscleropodium purum	*		.	*		.	*	.	.	*	.	.	*
Eurhynchium praelongum	*		*	*		*	*	*	*	*	*	*	*
Polytrichum commune					.		*	*	*	.	*	*	*
Sphagnum palustre		.	.	.	.					*	.	.	.
Isopterygium elegans		*	*	*	*					.	*	*	-
Dicranella heteromalla			*		*			.		.			
Brachythecium rutabulum		.			.		.	.	.	*	.		
Sphagnum recurvum	.	.	.	.	.	.	*	.	*	*	.	.	.
Total	**15**	**6**	**12**	**14**	**9**	**10**	**11**	**9**	**10**	**17**	**9**	**12**	**15**

Table 3.4 continued

	Natural birch	First rotation						Second rotation					
		<40 years			>40 years			<16 years			>17 years		
		P	M	T	P	M	T	P	M	T	P	M	T
Liverworts													
Lophocolea bidentata	*	.	*	*	*	*	*	*	*	*	*	*	*
Diplophyllum albicans	*	*	*	*			.						*
Scapania gracilis	*	.		.	.	.	*	.	.	.	.	.	.
Lepidozia reptans	*	.	.	*	*	*	*	*	*	.	*	*	*
Calypogeia muelleriana	*	*	*	*	*	*		.	*	.	*	*	
Marsupella emarginata					.	.		*		.			
Frullania tamarisci					.	*				.			
Nowellia curvifolia					*	.	.	.		.			
Lophozia ventricosa		.				.	.	*		*			
Metzgeria furcata		.	.			.	.			*			
Plagiochilla porelloides	.	.	.	.	.	.	.	.	.	*	.	.	.
Total	5	2	3	4	4	4	3	4	3	4	3	3	3

in the thickets but declined as the spruce component of the crop increased; in pure spruce, with the exception of W17b, all units were under-represented. Within mixtures in the first rotation the proportion of non-fitting stands was intermediate between that of the pure spruce and the thickets while the proportion of stands assigned to W17b was highest in these mixtures. In the second rotation mixtures non-fitting stands were surprisingly uncommon and recognisable stands of W17c and W11a predominated.

Regional differences were also evident in the representation of the units; the greatest proportion of non-fitting stands occurred in the South Coast region where all managed plots showed high values for unassignable vegetation units. In the Southern Isles and Western Mainland a higher proportion of managed stands resembled poor expression of W17b rather than being unassignable; this may reflect the naturally greater diversity and abundance of bryophytes in these more oceanic regions where more areas of natural woodland also occur. W17a was restricted to the Southern Isles while W18 was most frequent in the Western Mainland; W17d was equally represented in the Central Highlands, Western Mainland and Southern Isles.

Discussion

The retention of birch within the managed spruce crop enhanced ground cover and species diversity and helped to maintain the regional distinctiveness of the natural woodland communities. Managed thickets retained a higher cover and diversity of forbs than mixtures or pure spruce, but their values were still low compared with unmanaged birch. The sequence of increasing forb cover and diversity typical of restocked sites (Wallace *et al.*, 1992; Kirby, 1993) was suppressed in the managed thickets. This probably reflects the high densities of birch saplings which achieve canopy closure earlier than the birch/spruce mixtures or pure spruce stands. The peak cover of forbs in the youngest restocks was largely composed of species which readily colonise disturbed ground: *Deschampsia cespitosa, Holcus lanatus, Molinia caerulea, Juncus effusus, Rubus fruticosus* and *Chamerion angustifolium*. The high diversity comprised mainly ruderal species; colonisation by woodland species, in contrast, was poor. Although shifts in the proportions of grassland and heathland species can lead to the development of a flora similar to that of oak–birch woodland (Hill and Jones, 1978) the poor colonisation by woodland species in most plantations (Hill, 1979a; Good *et al.*, 1990) leads to an impoverished flora as the crops age, which is particularly noticeable on sites with no history of former woodland cover (Sykes *et al.*, 1989; Wallace *et al.*, 1992). Many grass species typical of semi-natural oak–birch woodlands were scarce in the managed birch, notably the vernal *Anthoxanthum odoratum* together with *Holcus mollis* and *Agrostis capillaris*; these were largely replaced by *Holcus lanatus, Deschampsia cespitosa* and *Molinia caerulea*, species that are more normally associated with willow–birch woodlands on damp soils. The rapid spread of the *Molinia* on disturbed soils is common in upland forests (Wallace *et al.*, 1992) and the wide tolerance of *Deschampsia cespitosa* to soil moisture and soil pH provides it with a competitive advantage in many disturbed situations (Davy, 1980). The absence of *Anthoxanthum odoratum* may be a response to the different light phase in birch or mixtures compared to oak–birch woodland: the earlier expansion and fall of birch leaves compared to oak encourages autumn growing bryophytes rather than vernal woodland herbs (Barkman, 1992), and this, combined with low colonisation rates, may further suppress the development of a woodland herb flora. The higher acidity of the spruce needles may also inhibit woodland herbs characteristic of richer mineral soils. The increase in forb cover in older first rotation birch may coincide with the natural dieback of birch, a naturally short-lived species (Gimingham, 1984).

The moss flora of the managed stands, in contrast, showed a much closer agreement to that of the unmanaged stands. Disturbance and reduced humidity at clearfelling resulted in a reduction in moss cover in young restocks; managed thickets once more showed the least fluctuation and maintained a higher cover throughout the cycle. The increase in cover in crops over 17 years was not however matched by an increase in species diversity; it seems that those species present expand and contract with changing conditions, but are not lost from the stands. The species composition is more closely related to geographical location and past woodland history. There were, however, significant differences between the composition of managed and unmanaged birch stands. Some species exhibit an ability to keep pace with the increasing needle fall under conifers more efficiently than they are able to cope with high levels of broadleaved litter (Brackenheilm, 1977). In Swedish forests *Brachythecium rutabulum* and *Lophocolea heterophyllum* survive well under *Picea abies* while in Wales *Hypnum jutlandicum* and *Lophocolea cuspidatum* were highly successful under *Picea sitchensis* (Hill and Jones, 1978). In the current study *Hypnum jutlandicum, Plagiothecium undulatum, Dicranum scoparium, Mnium hornum* and *Thuidium tamariscinum* performed well (the first two are noted for their success in plantation forests: Hill *et al.*, 1991), while many species typical of oak–birch woodland were much less prevalent than expected, e.g. *Pleurozium schreberi* (a species also noted for its failure to survive the thicket stage of Sitka spruce in Wales: Hill and Jones, 1978), *Dicranum majus, Isothecium myosuroides, Pseudoscleropodium purum* and *Polytrichum formosum.* This latter group of species, with the exception of *Pleurozium* are not common in unplanted grassland or heathland communities and their absence in many stands may partly indicate poor colonisation.

The combined effects of shade and litter within the managed stands resulted in a flora which was distinct from that of the unmanaged birch: forbs were less diverse while mosses were more prominent. This restricted the range of vegetation communities which developed within the managed birch, even the thickets. Thus, the greatest diversity of vegetation communities recorded was in the semi-natural woodland and unmanaged birch stands within the forest estate. Thickets retained a good diversity of communities, however, some units were more prevalent while others were less frequent than expected. The high cover but low diversity of bryophytes in thickets produced vegetation with affinities to the Typical sub-community of western oak–birch woodland (W17b), the bryophyte-rich W17a was scarce while grass-dominated units survived in the thickets (W17c and W11a). As the proportion of birch decreased the diversity of communities declined, W17b became the principal unit while the grass-dominated units were lost as forb cover declined, and the proportion of stands which are too species-poor to fit any recognised unit increased.

Management implications

Although the retention of birch significantly enhances the diversity and cover of the ground flora within the managed crop most thickets are still impoverished compared to areas of unmanaged birch. The restricted development of the flora and reduced diversity of vegetation communities in managed stands indicates that, for maximum diversity, areas of non-productive birch and semi-natural woodland should be retained wherever possible. Thickets and mixtures provide an extended period of ground vegetation cover compared to pure spruce, and retention of some of these areas through crop thinning at the canopy closure stage would extend the duration of enhanced ground cover through the rotation. Priority areas may be selected for this enhancement programme; sites with a former woodland history tend to support a richer woodland flora and extended rotations including birch in these areas are likely to provide a greater wildlife benefit than on areas of former upland sheep walks.

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Chapter 4

Lichens in upland spruce plantations

Alan Orange

Summary

The results of a lichen survey of spruce plantations in Northumberland, the Southern Uplands and the Southwest Highlands are presented. The lichen flora associated with pure spruce stands (*Picea sitchensis* and *P. abies*) was compared with the flora of young and mature birch stands, and semi-natural oakwoods. A total of 73 species were recorded on birch, with mature stands (42-57 years old) carrying a more diverse flora than young stands (13-23 years old). Most species were part of the acidophilous community *Pseudevernietum* grading into the *Parmelietum laevigatae* community in high rainfall areas. Oak carried a generally less acidophilous flora than birch, and included the *Lobarion* community which is of high conservation importance. The lichen flora of spruce stands was impoverished when compared to birch and oak, with only 39 species recorded and community development was poor. This is attributable to the unsuitability of spruce bark as a substrate (due to its low pH), the lack of old trees and deadwood, excessive shade in densely stocked stands, and the lack of ecological continuity associated with the patch clearfelling system. It is proposed that lichen diversity in commercial spruce forests can be improved by: encouraging birch and other native species at all stages of the rotation, retaining semi-natural stands, and exploring the use of continuous-cover silviculture to promote continuity of woodland conditions and other features of 'old-growth' such as older trees and deadwood.

Introduction

A large proportion of the British lichen flora comprises species which are completely or principally confined to trees, either on bark or on deadwood. For this reason, the composition and management of woodland is of great relevance to lichen conservation. Lichens are epiphytes, and do not exhibit the host-specificity of many non-lichenised fungi, but they are sensitive to factors like bark pH, texture, and water-holding capacity, such that each 'host' species of tree (or phorophyte) typically bears a certain range of lichen communities.

It is well established that the occurrence of many lichen species is dependent upon the age and ecological continuity of a woodland (Rose, 1976, 1992). This is due in part to the need for specialised conditions, such as continuous shelter and humidity, or for microhabitats found only on ancient trunks, and partly due to the poor colonising ability of some lichen species. Commercial exploitation of woodland is often inconsistent with the maintenance of a rich lichen flora containing old-forest or old-growth lichen species, and this is a problem in both temperate and tropical areas (Rose, 1992; Wolseley, 1991, for example).

Because of the sensitivity of many lichens to the nature of the substratum, and to disturbance and management, the maintenance of lichen diversity within commercial spruce plantations presents a particular challenge.

Methods

Lichens were studied within 200 m^2 plots established during earlier surveys of tree cover and ground vegetation. Plots containing stands of birch or semi-natural woodland which had been noted as 'lichen-rich' by surveyors were selected for lichen survey, together with nearby stands of spruce. Within each plot, all species of lichen growing on trees, stumps and other woody debris were recorded, together with a note of the substratum and a rough estimate of abundance using the DAFOR scale. Recording was carried out in March and April 1993. Lichen nomenclature follows Purvis *et al.* (1993).

The sites

Forty-seven plots were recorded in Northumberland, the Southern Uplands, and the Southwest Highlands (Table 4.1).

The plots studied were grouped into a number of broad stand types depending on age and dominant species:

Table 4.1 Location of plots studied

	Number of plots	Grid reference
Highland Region		
District: Loch Awe	14	NR93.90, 93.91, 94.91
District: Kintyre	9	NR77.87, 77.88, 78.88
Southern Uplands and Border Region		
District: Ae	14	NX81.86, 81.87, 90.68, 91.68
District: Kielder	10	NY62.93, 63.93, 64.94

1. Young spruce, second rotation, planted 1970-1980 (age 13-23 years), with rare to occasional birch of similar age: 14 plots.
2. Young birch dominant within or adjacent to spruce of similar age, spruce planted 1970-1973 (age 20-30 years): 6 plots.
3. Mature first rotation spruce, planted 1931-1951 (age 42-62 years): 5 plots.
4. Recently felled spruce: 3 plots.
5. Mature birch, planted or spontaneous, age mostly unknown, some associated with crops planted 1935-1951 (42-57 years old): 14 plots.
6. Semi-natural areas with mature oak, with or without birch: 3 plots.
7. Others (alder, and open area dominated by *Myrica gale*): 2 plots.

Lichen microhabitats in plantations and woodland

Many lichen species show a high substratum specificity, and the large- and small-scale distribution of most species is influenced by parameters such as pH, shade, degree of exposure to sun and drying winds, and degree of shelter from direct rain. Different communities can be found occupying different microhabitats on a single tree, including twigs, the damp upper surface of an inclined trunk, the dry lower surface of an inclined trunk, and the trunk base and root buttresses. Mature and over-mature trees have a greater variety of microhabitats than young trees. The number of lichen species recorded on each age and species of tree is shown in Tables 4.2 and 4.3.

Lichens on birch

At least 235 species of lichen have been recorded on birch (*Betula* spp.) in the British Isles, but birch species are considered to be relatively poor phorophytes when compared to certain other native trees (Coppins, 1984). The main reason for the poor lichen flora is the low pH of birch bark, which is approximately 3.2-5 in unpolluted areas (Coppins, 1984). In addition, the bark is hard, with a low water-holding capacity, and birches are relatively short-lived trees.

In the present study, all birch encountered was downy birch (*Betula pubescens*), although the lichen flora of the two native tree birches is believed to be similar. Young birch growing within spruce plantations 13-23 years old carried a relatively species-poor lichen flora, with most of the species confined to twigs. Frequently recorded species included *Evernia prunastri, Fuscidea lightfootii, Hypogymnia physodes, H. tubulosa, Parmelia sulcata, Platismatia glauca* and *Usnea subfloridana*; these are all widespread and common on acidic bark in Britain. At Kielder, birch twigs carried the lichen *Cetraria sepincola*; this is a local species which is almost confined to birch in Great Britain. Young birch trunks carried at most a very limited flora comprising *Parmelia* and *Lepraria* species, and many young trunks were devoid of lichens. In total, 35 species were recorded on young birch.

Mature birch (most stands undated, some associated with spruce 42-57 years old) carried a more diverse lichen flora than young birch. The flora of twigs was similar to that of young birch, although the twig flora of mature trees was difficult to record adequately. Frequent species on trunks included *Evernia prunastri, Hypogymnia physodes, Mycoblastus sterilis, Ochrolechia androgyna, Parmelia saxatilis, Platismatia glauca* and *Usnea subfloridana*. These are all components of the association *Pseudevernietum furfuraceae*, which is a common and widespread community of acidic bark in Britain (James *et al.*, 1977). In Kintyre, the most westerly district studied, some plots carried species such as *Parmelia laevigata, P. taylorensis* and *Sphaerophorus globosus*, which are characteristic of the association *Parmelion laevigatae*. This association tends to replace the *Pseudevernion* in oceanic westerly areas of Britain where a high rainfall is distributed over at least 180 wet days per year (Coppins, 1976). Species

Table 4.2 Comparison of number of lichen species recorded per plot on different species and ages of tree

	Young spruce	Young birch	Mature spruce	Mature birch	Oak
Number of plots studied	12	18	5	14	3
Number of lichen species per plot					
range	3-13	7-16	6-14	9-31	24-34
mean	6.7	10.5	9.8	17.9	29

Table 4.3 Total number of lichen species recorded from various tree species

	Spruce	Birch	Oak	Alder
Number of plots containing this species	22	33	3	1
Number of lichen species	39	73	49	16

of *Cladonia* (including *C. coniocraea, C. chlorophaea, C. macilenta, C. ochrochlora* and *C. squamosa*) were also frequent, particularly on the bases of the trunks. Dry-bark communities were generally poorly developed, and mostly dominated by one or more species of *Lepraria* (including *L. incana, L. jackii, L. lobificans, L. rigidula* and *L. umbricola*). *Lecanactis abietina* was locally frequent in stands at Kielder. In total, 73 species were recorded on birch, of which only 2 were confined to young stands.

Birch wood tends to rot quickly, and become dominated by bryophytes and species of *Cladonia;* in consequence the flora is poor when compared to wood of trees such as pine and oak. In the present study, birch wood was very scarce, so that the lichen flora of this substratum could not be studied.

Lichens on spruce (Picea *spp.*)

There have been no studies which have specifically evaluated the lichen flora of introduced species of conifers in the British Isles. As is the case with birch, the low pH of the bark limits the diversity of the lichen flora.

In the present study, spruce in all but one of the plots was Sitka spruce (*Picea sitchensis*); in the other plot it was Norway spruce (*P. abies*). Young spruce in plantations 13-23 years old (mostly mixed with birch) had a poor lichen flora and, as with birch, most species were confined to twigs; the most frequent species were often those which were also frequent on birch twigs. Young spruce trunks were very species poor, in part due to the deep shade and shelter from rain provided by the branches.

Mature spruce was no more species-rich than young spruce. The trunks usually had a very species-poor flora, often of poorly developed or inconspicuous species. The diversity of the lichen flora is limited in part by the deep shade in the interior of mature stands. One of the few species preferential for spruce in the present study was *Porina leptalea,* which has been found to be frequent, but overlooked, on shaded root buttresses in spruce plantations in Wales. A total of 39 species were recorded on spruce. Only 8 species were recorded on spruce that were not also found on birch. In contrast, 42 species found on birch were not found on spruce.

Deadwood was in short supply in most stands. In second rotation stands 13-23 years after planting, deadwood carried a flora rich in conspicuous lichens of the genus *Cladonia,* including *C. chlorophaea, C. glauca, C. macilenta, C. ochrochlora, C. polydactyla* and *C. squamosa. Omphalina ericetorum* and *Trapeliopsis flexuosa* were also frequent. Unshaded or lightly shaded stumps carried a much richer lichen flora than shaded stumps, which were often dominated by a species-poor moss community. The wood of spruce stumps was soft and easily broken. No large logs or snags remained, and microhabitats sheltered from rain were virtually absent. *Xylographia vitiligo* was confined to a single dead standing trunk. Deadwood in mature first rotation stands, 42-62 years old, carried an extremely poor lichen flora comprising very small quantities of few species. Although the supply of deadwood was limited in these stands, the poverty of the flora is attributed mainly to heavy shade.

Lichens on oak (Quercus *spp.*)

The two native species of oak are regarded as the most important species of phorophyte in the British Isles, with a total of 326 species recorded on them (Rose, 1974; Harding and Rose, 1986). The rich lichen flora is due to a number of factors including the relatively high bark pH in unpolluted areas and the longevity of the tree.

Three plots in Kintyre containing fragments of semi-natural sessile oak (*Quercus petraea*) woodland were studied to provide a comparison with surrounding spruce plantations. It was clear that oak carried a rich lichen flora, with many species that were not found on birch or spruce, including *Arthopyrenia ranunculospora, Degelia atlantica, Lobaria pulmonaria, L. scrobiculata, L. virens, Nephroma laevigatum, Pachyphiale carneola, Parmelia crinita* and *Zamenhofia coralloidea*. These are all typical members of the association *Lobarion pulmonariae*, which tends to occur on bark of higher pH than that found in birch. This association, and the above species, are now uncommon throughout much of the British Isles, and frequently of relict status. The association is largely confined to old-woodland sites with a long history of ecological continuity. In the west of Scotland the species of this association are less ecologically restricted, but are scarcely represented on conifers or birch. Species of the *Parmelion laevigatae*, namely *Parmelia laevigata, P. taylorensis* and *Sphaerophorus globosus*, were sparsely represented on oak.

Lichens on other tree species

Alder (*Alnus glutinosa*) was dominant in a single plot in Ae District; the lichen flora was similar to that found on birch, referable to the association *Pseudevernietum furfuraceae*. A small number of rowan (*Sorbus aucuparia*) in two plots dominated by mature birch at Kielder had four species not found on birch.

Effects of site history

Given the relatively small number of plots surveyed, and in the absence of complete information about the history of each site, it was not possible to determine the influence of the history of the site on the present lichen flora in more than a general way. Young plantations on previously wooded sites appeared to be as poor as those on previously unwooded sites. This is perhaps to be expected, since plantations are in any case unsuitable for most species of semi-natural woodland. Some of the plots of mature birch which carried a species-poor flora probably represent relatively young stands of birches in areas with little previous woodland cover. One plot, for instance, appeared to comprise birch that had recently colonised boggy ground: old or dead trees were absent.

Lichen diversity throughout a single rotation

Young spruce and birch have a relatively limited flora, confined mainly to twigs. In first rotation stands, deadwood is absent. In second rotation stands, a limited lichen flora develops on stumps and debris of the previous rotation, but snags and large logs are absent. In mature spruce stands, the lichen flora on trunks and on deadwood is severely limited by shade. In addition, the straight trunks provide a low diversity of damp and dry microhabitats.

Clearfelling removes most of the lichens that were present within the mature stand. Only a few species seem able to persist into the next rotation. Some species in felled plots, including *Cladonia macilenta* and *C. ochrochlora*, had evidently persisted on bark at the base of trunks, and growth on the now dead bark was probably more vigorous than on the living trunk. It is likely that these species are able to colonise the stumps as they lose their bark. In the few plots examined, felled a few years previously, only a few lichens had colonised wood exposed by loss of dead bark, including *Bacidia saxenii, Mycoblastus sterilis, Omphalina ericetorum, Trapeliopsis flexuosa* and *Xylographa trunciseda*.

Discussion

The following conclusions are suggested by the present survey:

1. Mature birch is much more species-rich than young birch.

2. Birch usually carries an acidophilous flora (trunks with *Pseudevernietum*, grading into the *Parmelietum laevigatae* in high rainfall areas).

3. Oak carries a generally less acidophilous flora than birch, including the important *Lobarion* community at suitable sites.

4. Deciduous species other than oak or birch often carry additional species to either.

5. Spruce carries a species-poor lichen flora with only fragmentary communities.

The results of the present survey clearly show the extreme impoverishment of the lichen flora of spruce plantations, compared with areas of semi-natural woodland. Mature plantations were poor both in terms of species number and in the quantity of each species present. In addition, communities were fragmentary and difficult to assign to those present in semi-natural woodland.

This study shows that lichen diversity in young spruce plantations can be increased by allowing an admixture of birch. In mature plantations, stands of mature birch can have a relatively rich lichen flora, and greatly increase lichen diversity within the plantation as a whole. Even in semi-natural oak woodland, birch may be the primary host of communities such as the *Parmelietum laevigatae* which require acidic bark. It is likely that lichen diversity will be greater if stands of birch are allowed to remain as more or less permanent features from one rotation to another. Stands of birch will experience greater fluctuations in humidity following felling of a surrounding crop, to the detriment of many lichen species. The size of birch stand needed to minimise these effects is unknown, and will depend on the degree of exposure of the site.

However, birch alone can carry only a fraction of the potential lichen flora of woodland. Fragments of semi-natural woodland within plantations are extremely important for lichens. Species such as oak carry important communities that do not occur on birch or spruce; and the age and structure of the stands, and the ecological continuity provided by lack of clearfelling, means that these stands may support whole communities, and many species, that may never be represented in commercial plantations. In addition, semi-natural stands act as sources of inocula for colonisation of young plantations nearby.

Preservation of mature birch and oak stands within the forest is the best way of maintaining lichen diversity, but it depends upon the maintenance of permanent semi-natural areas. Thus it is important to also consider strategies to increase lichen diversity in commercial stands. The physical and chemical characteristics of spruce bark mean that it is unsuitable for certain important lichen communities (such as the *Lobarion*), but the other principal reasons for the poor lichen flora of spruce are a consequence of:

1. The age and form of the trees: old trees are absent, and trees are typically straight and well-formed, providing a low diversity of microhabitats. Deadwood is rare.

2. Density of stocking: shade appears to be one of the main limiting factors in mature plantations.

3. Lack of ecological continuity caused by clearfelling.

In productive stands of spruce an alternative silvicultural system to clearfelling is likely to give the greatest benefits in terms of lichen diversity. A group selection system to produce an old growth plantation (Peterken, 1996) would benefit lichens by the provision of older trees, increased light levels, and a greater degree of ecological continuity. It is likely that lichen diversity in such stands will continue to increase for many years, whereas the flora of clearfelled stands is inevitably limited to those species that can colonise during the course of one rotation. If a certain amount of deadwood and native deciduous tree species can be tolerated then there will be further benefits. The precise extent of these benefits is not yet known; there are few examples of group selection, and the lichen flora of these has not been studied in relation to examples of other systems.

The results of this survey suggest the following general recommendations for preserving and improving lichen diversity in commercial forests:

- Encourage birch and other native species at all stages of the rotation.

- Retain or create permanent stands of birch and other native species. These stands should be large enough to withstand exposure caused by felling nearby. Deadwood should not be removed.

- Scrupulously conserve semi-natural stands.

- Explore silvicultural systems other than clearfelling.

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Chapter 5

The abundance, diversity and management of arthropods in spruce forests

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Summary

The abundance and diversity of arthropods was sampled within three Scottish spruce forests: Dalbeattie, Moray and Knapdale. At each study site, sampling was carried out in 7-8 plots of spruce with varying amounts of birch (approximately 0%, 5%, 30% and 100% birch in old and young spruce), a semi-natural birchwood, a clearfell plot, and a plot in nearby grassland or moorland. Approximately 800 000 insects and other arthropods were collected in Malaise traps. The abundance of Diptera, Hymenoptera and most other groups of arthropods were as great or greater in spruce plantations as in nearby birchwoods. Only Hemiptera and Coleoptera (beetles) were more abundant in the birchwood plots than in the spruce plantation plots. Coleoptera and Hemiptera increased significantly in abundance as the amount of birch in a plot increased. No other arthropod group was affected by the amount of birch in a plot except Syrphidae (hoverflies) which declined in terms of percentage abundance as the amount of birch in a plot increased. Over 3500 hoverflies were collected from Malaise traps and identified to species. A total of 70 species were recorded. Many of the hoverfly species found were either locally uncommon or nationally notable. The species diversity of hoverflies was particularly low in the natural birchwood plots. Almost 3900 beetles were collected in pitfall traps and identified to species. A total of 185 carabid, staphylinid and other beetle species were recorded, 7 of which are classified as nationally notable. The largest numbers of Carabidae were caught in the natural birchwood and the clearfell plots. Carabid species diversity was generally low and did not vary greatly between plots either with or without birch. The highest individual numbers, but lowest diversity, of Staphylinidae were trapped in the birchwood plots. The birchwood Staphylinidae were heavily dominated by a small number of characteristic species largely absent from the other plots. In conclusion, even low percentages of birch mixed within compartments of spruce are beneficial to many arthropod groups. However, since the best habitat for insects associated with birch is semi-natural birchwood, the few areas of mature birch that exist within spruce plantations should be given full protection, and areas of younger birch within spruce plantations should be protected and enlarged so that they become birchwoods rich in arthropods in the future.

Introduction

The encouragement of birch in upland conifer plantations has benefits for a wide range of wildlife including lower and higher plants, birds and mammals (Good *et al.*, 1990; Buse and Good, 1993; Patterson, 1993; Chapters 2, 3, 4, 6 and 7, and Posters 1-6). In this chapter, we consider the effect of birch on arthropod abundance and diversity in spruce plantations.

Plantations of exotic conifers, particularly of spruce species, are considered to be poor in arthropod diversity. In contrast, native broadleaved species are thought to encourage arthropod diversity. The available data for plant-feeding insects demonstrate the difference in insect species richness between conifers and broadleaved trees (Claridge and Evans, 1990): spruce (*Picea* spp.) has 90 recorded plant-feeding insect species whereas birch (*Betula* spp.) has 334. There is good reason, therefore, to expect that the presence of birch in spruce plantations would lead to an increase in the diversity of insect herbivores and other arthropod species associated with them, i.e. predators and parasitoids. The extent to which the presence of birch affects the diversity of arthropod species not directly associated with trees is more difficult to predict, as is the impact of birch on the relative abundance of different groups of arthropods and other species groups which feed on them. For example, the presence of birch might lead to an increase in species diversity, but no overall increase in the overall abundance of arthropods and, consequently, no improvement in the abundance of the prey of insectivorous birds.

In 1993 we started a project to quantify the effects of introducing birch into second rotation spruce plantations on the abundance and diversity of insects and other arthropods. The specific objectives of the project were:

1. to compare the abundance and diversity of arthropods in natural birchwoods with that found in spruce plantations;

2. to compare the abundance and diversity of arthropods in areas of spruce plantations with different amounts of birch.

Field sites, materials and methods

The study was replicated across three forest sites (Dalbeattie in southwest Scotland, Knapdale in Argyll and Moray in northeast Scotland). Within each site, plots containing different amounts of naturally regenerating birch were established in young (5-10 years) and older (15-20 years) spruce. Plots were also established in nearby semi-natural birchwoods, clearfell areas and in either moorland or grassland. The spruce plantation plots were selected as follows:

1. no birch present

2. low-percentage, approximately 5%, of birch present

3. high-percentage, approximately 30 %, of birch present

4. discrete clump of birch present, approximately 100%, and at least 30 m across.

In 1994 a vegetation survey of all the above plots was carried out by Glimmerveen (1994). There was no precise match between the 'nominal' amounts of birch in each plot and the amounts estimated by the vegetational survey, largely because of the fact that plots were chosen on the basis of estimating the percentage relative composition of birch and spruce. Nevertheless, the vegetation survey data show that the plots represented gradients in the amount of birch in, and nearby, spruce plantations and all measures of birch were correlated with the nominal amounts of birch ($R^2>0.66$, $p<0.001$).

The abundance and diversity of insects and other arthropods were assessed by Malaise traps, light traps and pitfall traps. Malaise traps are 'passive' traps designed to catch flying insects; light traps are 'active' traps for sampling moths (the moths are attracted to the light during night sampling); pitfall traps are designed to catch insects which are active on the soil surface. At each plot a 50 x 50 m sampling area was selected. A line of 10 pitfall traps was laid down along one diagonal of the plot, and one (Professional Model) Heath light trap operated by a 70 amp/h battery was placed near the centre of the plot. A Malaise trap was also placed near the plot centre. In 1993, sampling started in Dalbeattie in July, and continued until late September. In 1994, sampling started in Moray and Knapdale in May and continued until late September.

Arthropod abundance: results

Approximately 800 000 insects and other invertebrates were collected in Malaise traps, 180 000 from Dalbeattie, 330 000 from Knapdale and 290 000 from Moray. Approximately 10% were removed and sorted to order and sub-order.

Malaise trap samples were dominated by Diptera and Hymenoptera, the former accounting for over 70% of the total number of arthropods sampled at each plot. Hymenoptera made up 12-15% of arthropods sampled. Collembola, which were more abundant in the Dalbeattie samples than elsewhere, Hemiptera and Coleoptera also contributed significantly towards the total number of arthropods. Together these five groups made up 98% of the samples overall (Figure 5.1).

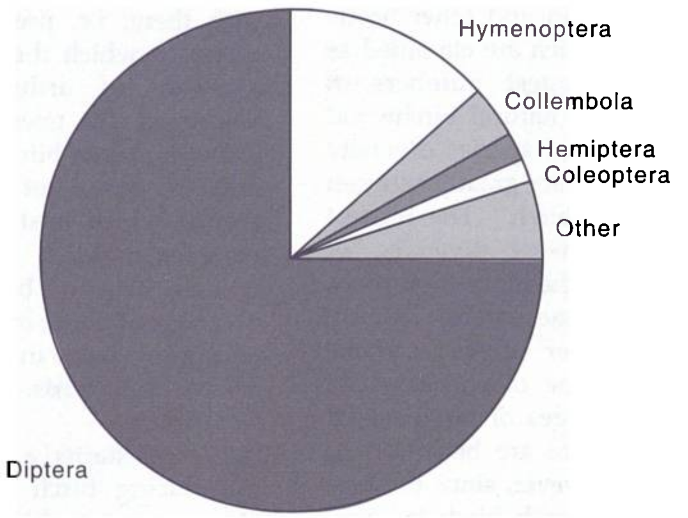

Figure 5.1 Composition of Malaise trap catches in all birch and spruce plots combined

For the purpose of this chapter, the abundance of arthropods is presented as an average of the data collected from the three forests (Figure 5.2). The total number of arthropods was greatest overall in the 100% birch clumps within spruce plantation plots, the ~5% birch in old spruce plots and the clearfell plots. Arthropod abundance was lowest in the ~5% birch in young spruce plots and the moorland/grassland plots. Arthropod abundance in the birchwood plots was intermediate, and similar to the abundance of arthropods in the birch-free spruce plots. Thus the amount of birch in a plot had no consistent effect on the total abundance of arthropods.

Diptera

Diptera (true flies) were dominated by Nematocera and Brachycera (Tipulidae (craneflies), Chironomidae (non-biting midges), Cecidomyidae (gall-midges), Tabanidae (horse-flies), Asilidae (robber-flies)); but about a third of the flies were in families of the Cyclorrhapha (Muscidae (house-flies), dung-flies etc., Syrphidae (hoverflies) etc.). Overall, the relative abundance of the separate suborders was similar.

Variation in the total number of Diptera caught in the Malaise traps closely paralleled the variation in the total number of all arthropods, not surprisingly, given the numerical dominance of Diptera in the

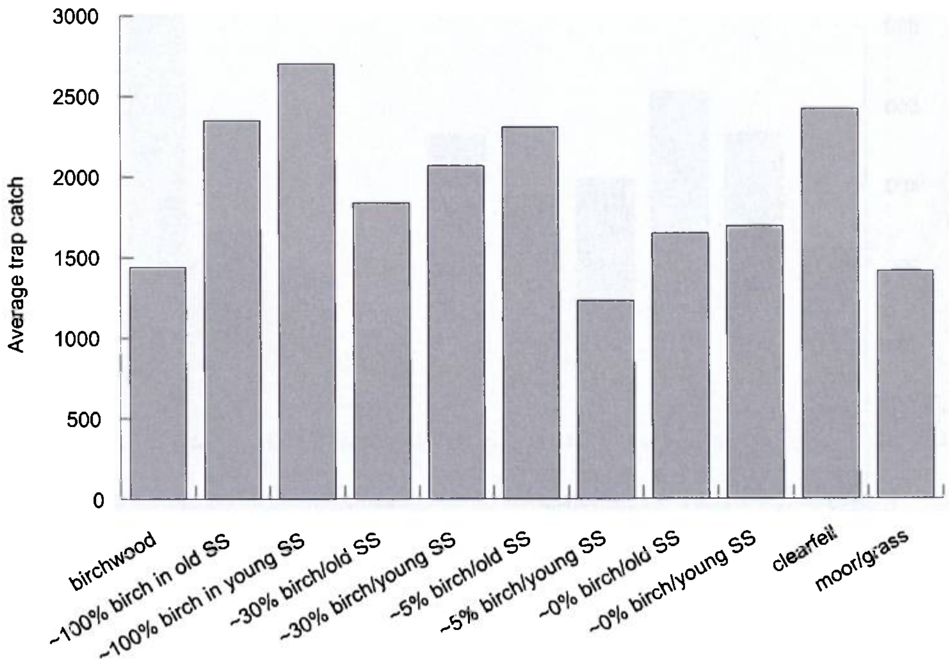

Figure 5.2 Abundance of arthropods in Malaise traps in Dalbeattie, Knapdale and Moray. SS: Sitka spruce

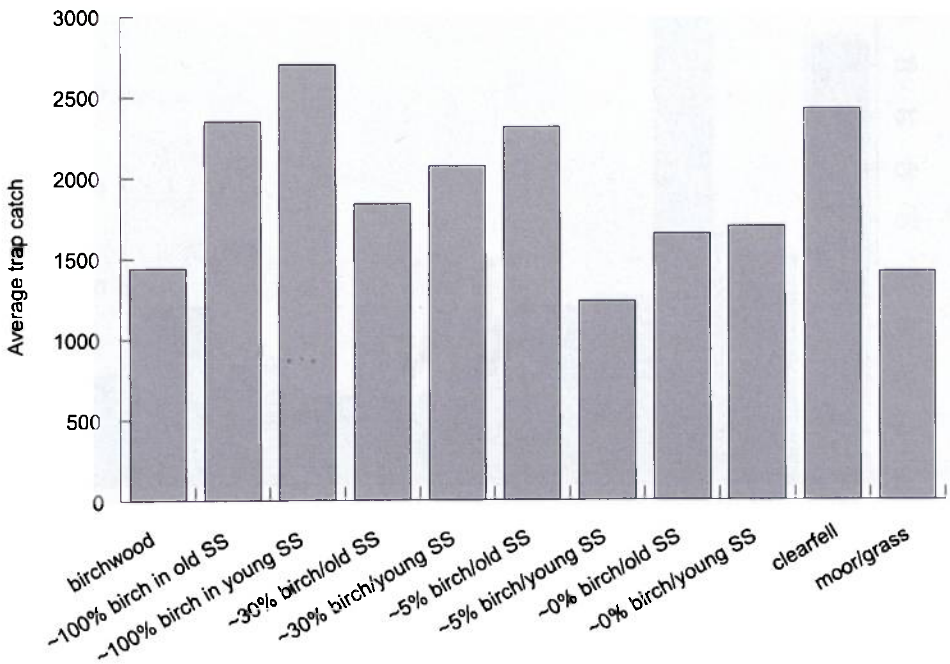

Figure 5.3 Abundance of Diptera in Malaise traps in Dalbeattie, Knapdale and Moray

Malaise samples (Figure 5.3). Thus, the amount of birch in a plot had no impact on Diptera abundance. It is notable, however, that the proportion of arthropods which are Diptera is lower in the birchwood plots than the other plots: 63% in birchwood plots, 71-84% elsewhere.

Hymenoptera

Most of the Hymenoptera sampled were Parasitica (parasitic wasps) and the abundance of Parasitica in different plots reflected the overall abundance of Hymenoptera. The abundance of Aculeata (bees, wasps and ants) showed no consistent trend among the plots of each area, other than being notably low in abundance in the birchwood and clearfell plots. The abundance of Symphyta (sawflies) was too low in all plots to permit adequate comparisons. The abundance of Hymenoptera was not related to the amount of birch in a plot (Figure 5.4). Overall, the poorest plots for Hymenoptera were the grassland / moorland plots.

Coleoptera

Coleoptera (beetles) were more abundant in the birchwood than in other plots, and decreased in abundance as the amount of birch in the plots declined (R^2=0.29, p=0.01; Figure 5.5).

Hemiptera

Hemiptera, comprising mirids and other 'true bugs', aphids, froghoppers and other plant-sucking

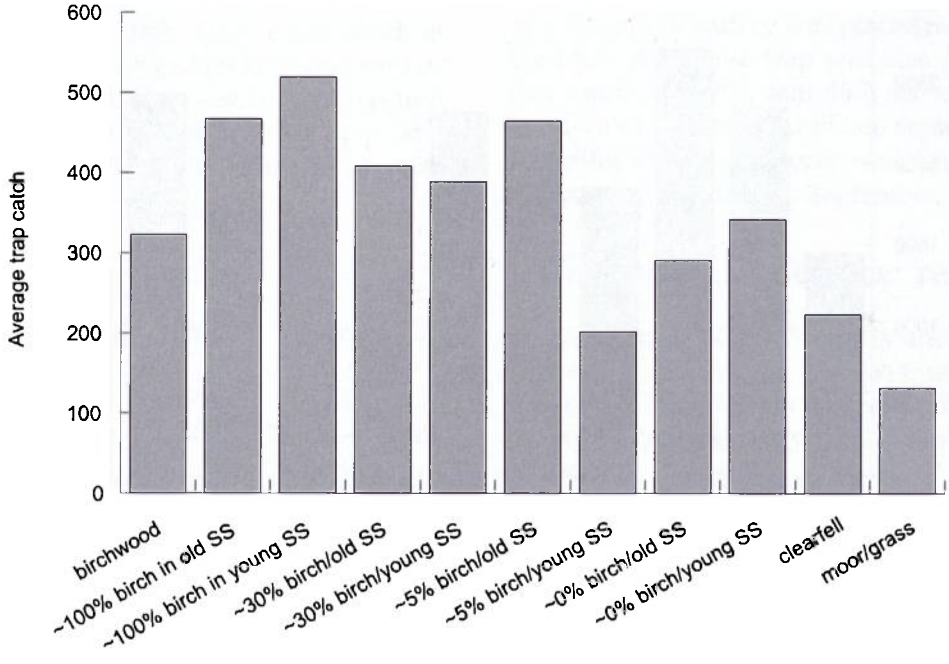

Figure 5.4 Abundance of Hymenoptera in Malaise traps in Dalbeattie, Knapdale and Moray

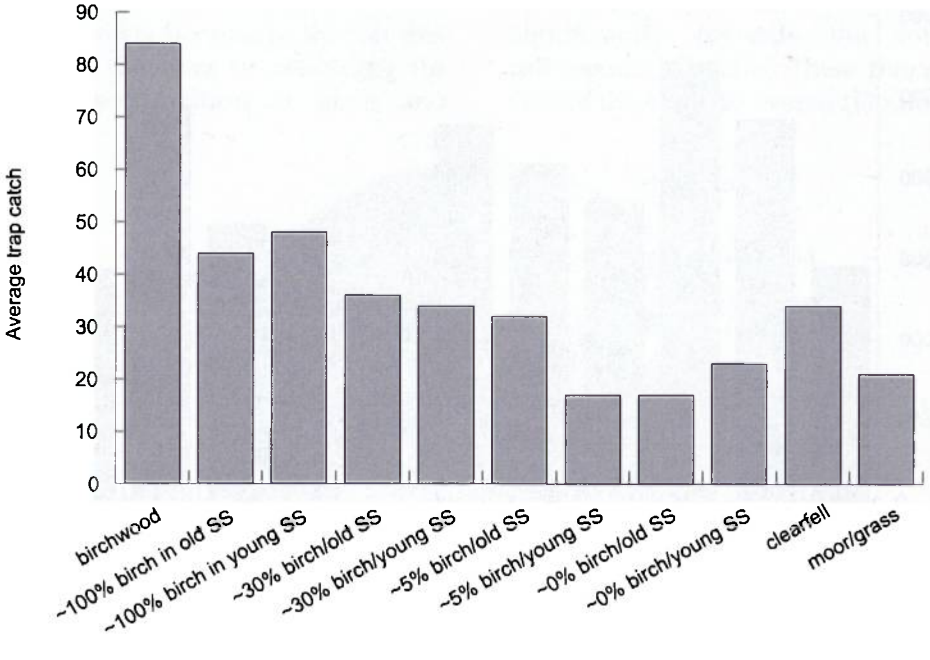

Figure 5.5 Abundance of Coleoptera in Malaise traps in Dalbeattie, Knapdale and Moray

insects, were more abundant in the birchwood control than elsewhere, and overall their abundance declined as the amount of birch in the plot declined (R^2=0.42, p=0.002; Figure 5.6).

Collembola

Collembola (springtails) were particularly abundant in the clearfell plots and the plantation plots with older spruce and no birch, but there was no significant relationship overall between the abundance of Collembola and the amount of birch in a plot (p=0.48; Figure 5.7).

Arthropod abundance: discussion

Of all the arthropod groups sampled by Malaise traps, only the abundance of Hemiptera and Coleoptera increased with the amount of birch in a plot. The abundance of other groups, notably Diptera and Hymenoptera, was not related to the amount of birch in a plot. Thus of the insect groups sampled in large numbers by Malaise traps, the Hemiptera and Coleoptera, containing species most intimately associated with host plants (e.g. phytophagous species and wood-boring species), were the only groups to show an increase in abundance as the amount of birch in a plot

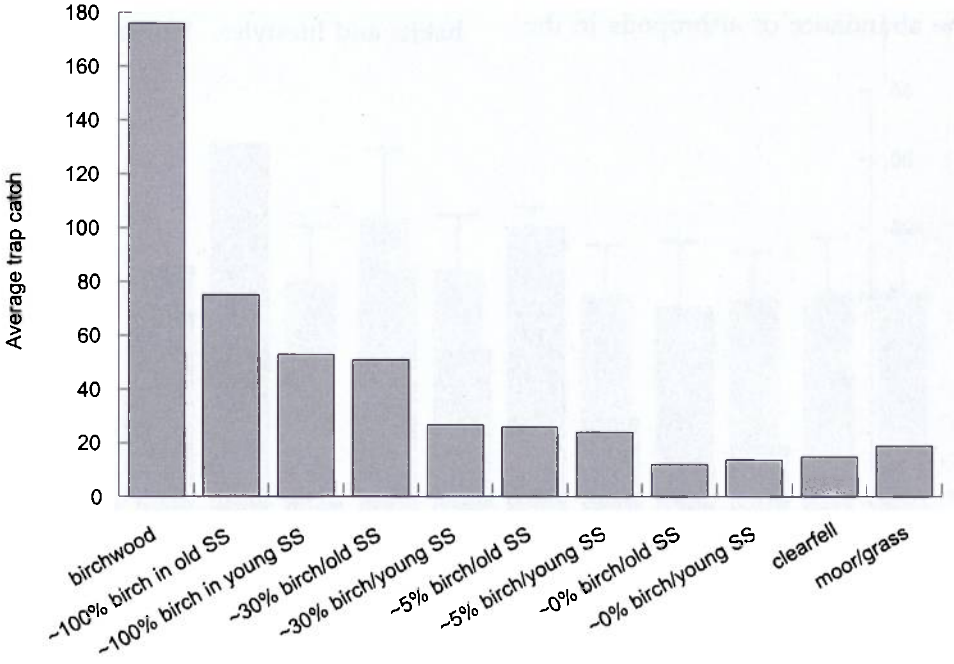

Figure 5.6 Abundance of Hemiptera in Malaise traps in Dalbeattie, Knapdale and Moray

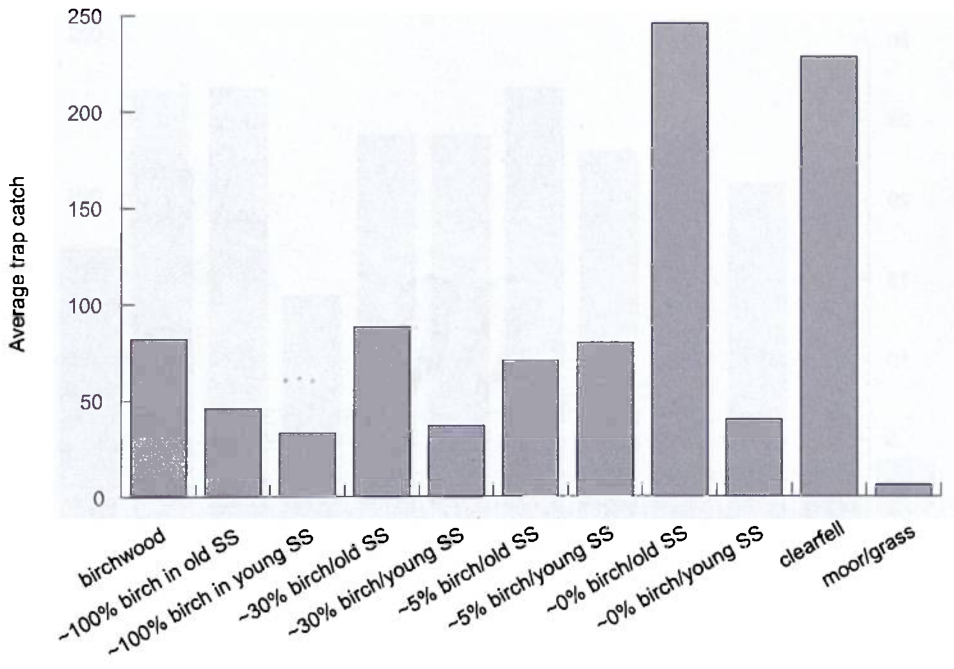

Figure 5.7 Abundance of Collembola in Malaise traps in Dalbeattie, Knapdale and Moray

increased. Other groups, particularly Diptera, which include relatively few phytophagous, predatory or parasitic species and are classified as 'tourists' in studies of arthropod communities on trees, were not significantly affected by the amount of birch in a plot.

Thus spruce plantations are no worse than birchwoods in terms of the abundance of flying insects (i.e. those caught by Malaise traps). This implies that spruce plantations are as suitable as birchwoods for insectivorous birds. However, this is only true if arthropod abundance was closely correlated with arthropod biomass (a better measure of the food resource for insectivorous birds), and if the abundance of arthropods in the Malaise traps also reflected the abundance of arthropods on the trees (and other vegetation) in each plot.

Arthropod diversity

The data discussed above tell us nothing about arthropod diversity: the diversity of an arthropod group may or may not be correlated with the overall abundance of the group. To examine the effect of birch in spruce plantations on arthropod diversity, three groups were chosen: hoverflies, macrolepidoptera and ground-dwelling beetles (Carabidae and Staphylinidae). These insect groups were chosen to represent taxa with different feeding habits and lifestyles. Hoverflies are in themselves

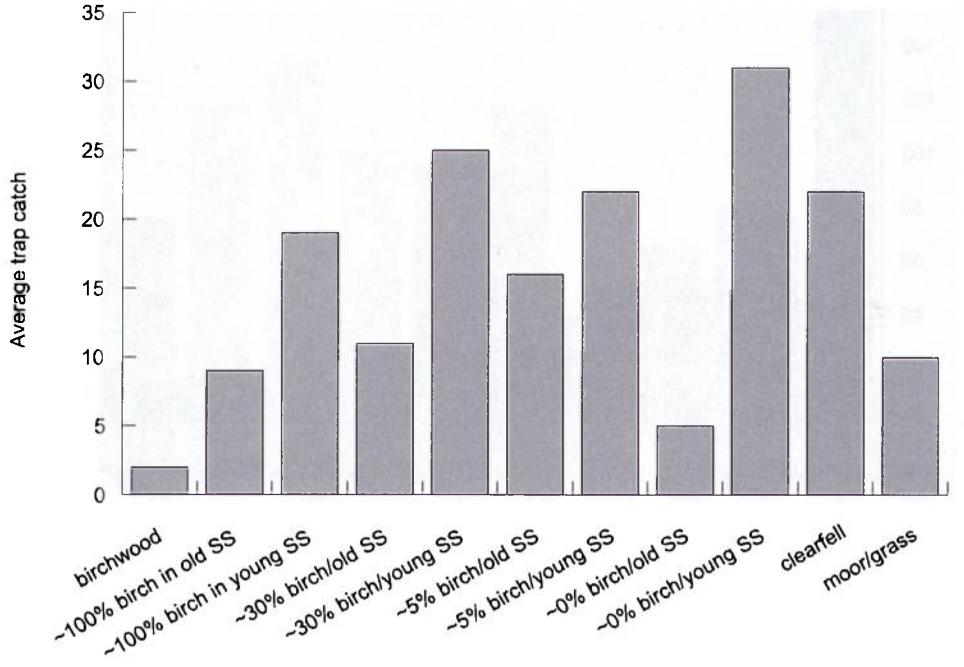

Figure 5.8 Abundance of hoverflies in Malaise traps in Dalbeattie, Knapdale and Moray

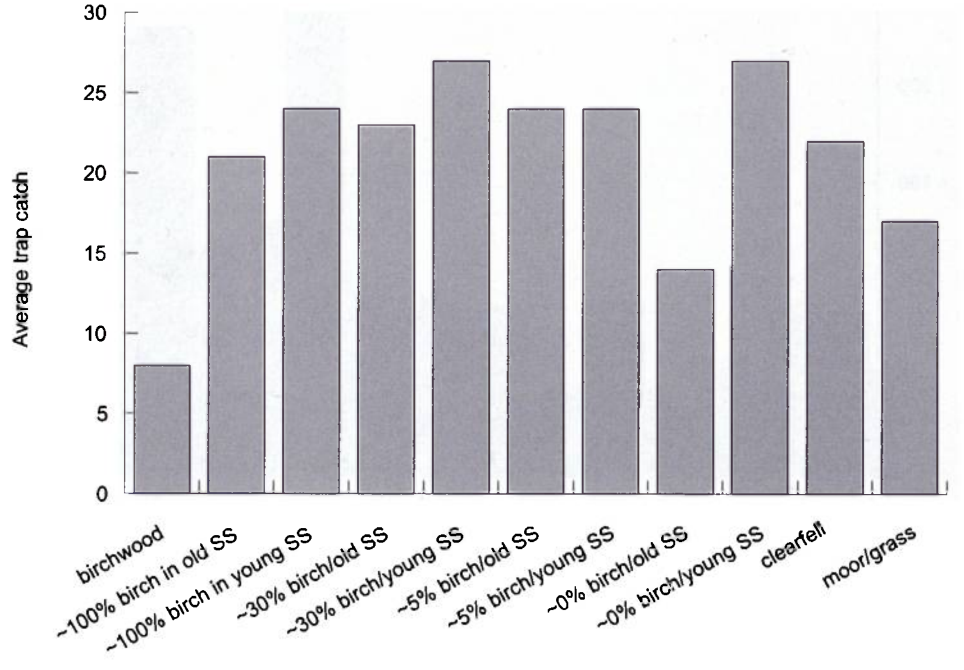

Figure 5.9 Number of Syrphidae species in Malaise traps in Dalbeattie, Knapdale and Moray

very varied in their habits: many hoverfly larvae are predatory, some feed on decaying wood, some are phytophagous, some are scavengers and others live in water. In contrast the Lepidoptera are mainly phytophagous (as larvae), and ground-dwelling beetles are predators or scavengers. Lepidoptera are discussed in Chapter 6; the present chapter focuses on hoverflies and ground-dwelling beetles.

We use two measures of diversity: the total number of species, commonly referred to as species richness, and the log series index of diversity alpha (α) (Williams, 1947; Taylor *et al.*, 1976), one of a number of indices of diversity which provide measures of species richness and evenness (Magurran, 1988).

Hoverflies

Hoverflies were notably uncommon in the birchwood plots and, overall, the proportion of hoverflies (of the total abundance of arthropods) was negatively related to the amount of birch (R^2=0.18, p<0.05; Figure 5.8). Hoverflies were more abundant in the young spruce plots than the older spruce plots. In all, 2125 individuals of 60 species were present in the samples from Moray; 1399 individuals of 48 species were present in the samples from Knapdale.

The number of hoverfly species (Figure 5.9) and hoverfly α diversity (Figure 5.10) was lowest in the birchwood plots. In addition, hoverfly α diversity

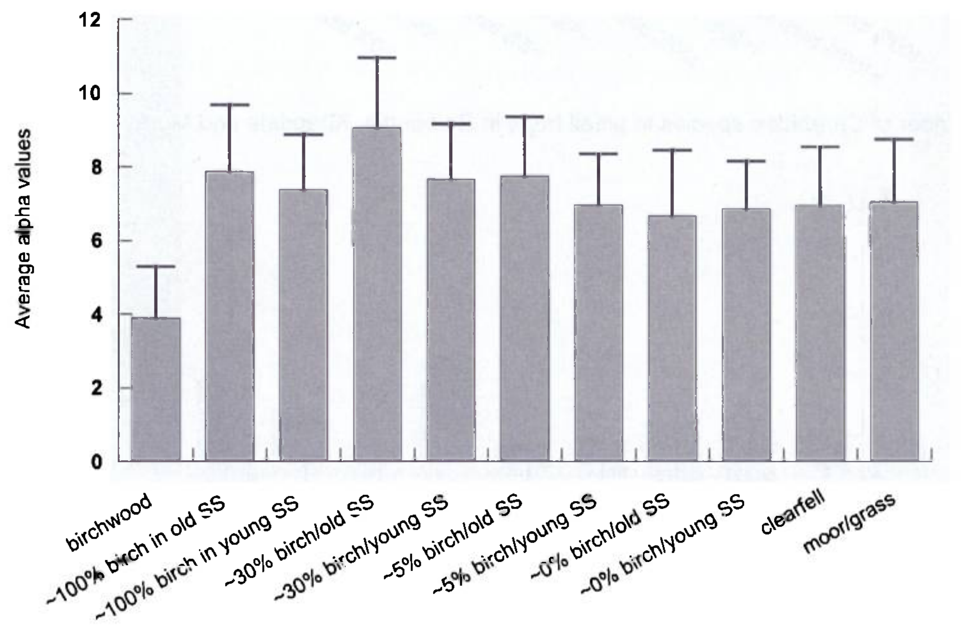

Figure 5.10 Syrphidae alpha diversity in Malaise traps in Dalbeattie, Knapdale and Moray

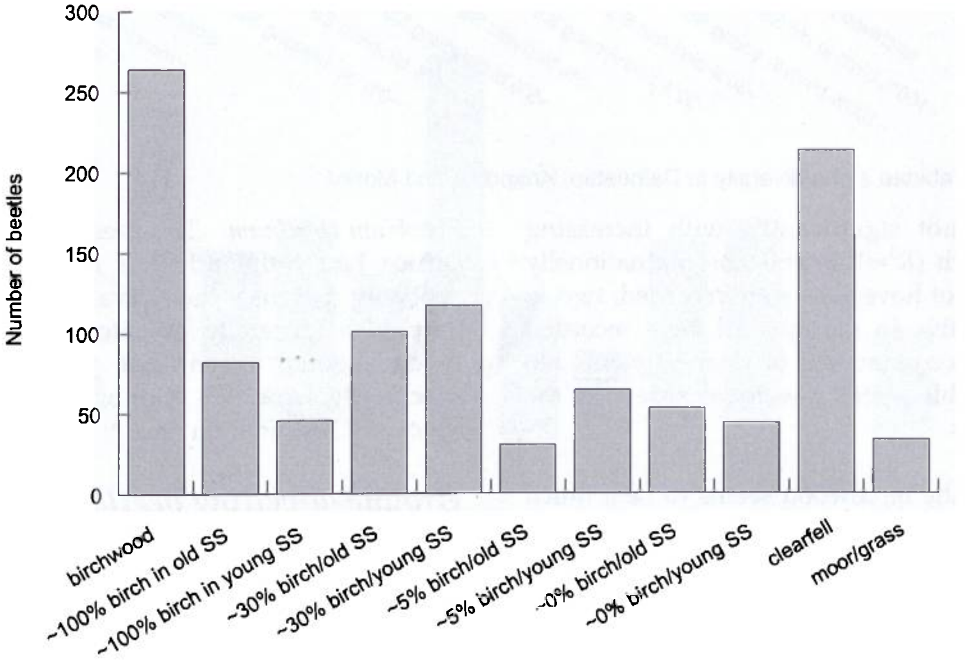

Figure 5.11 Abundance of Carabidae in pitfall traps in Dalbeattie, Knapdale and Moray

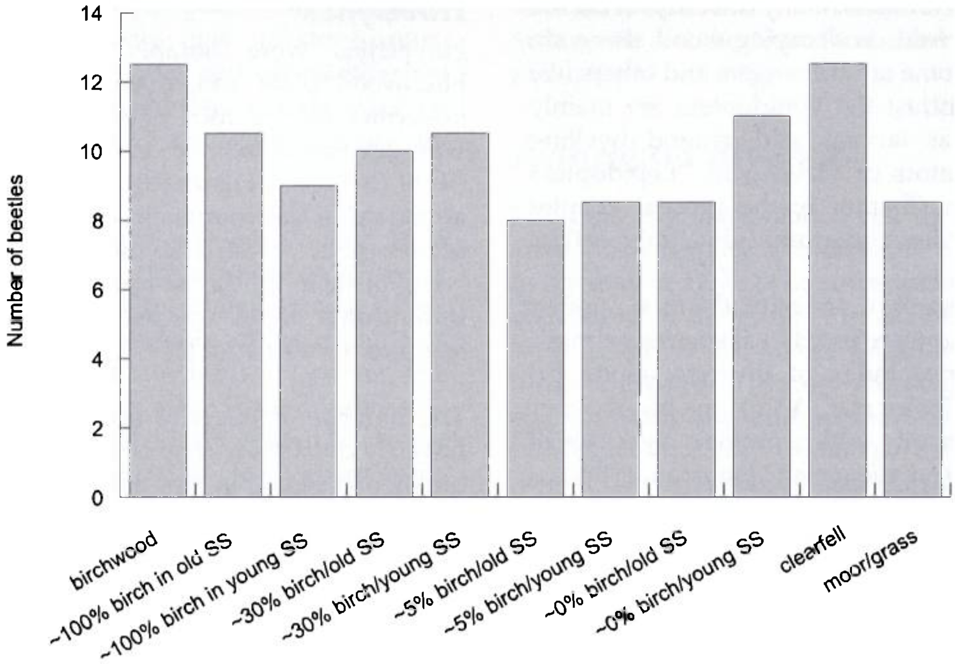

Figure 5.12 Number of Carabidae species in pitfall traps in Dalbeattie, Knapdale and Moray

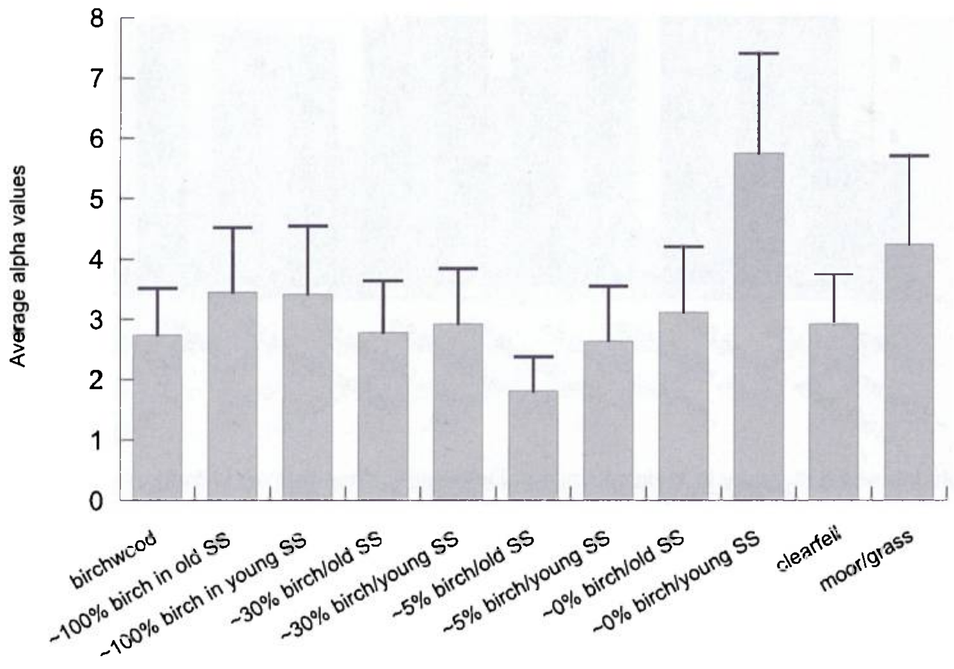

Figure 5.13 Carabidae alpha diversity in Dalbeattie, Knapdale and Moray

declined, but not significantly, with increasing amounts of birch (R^2=0.20, p=0.09). Six nationally notable species of hoverflies were recorded, two in Knapdale and five in Moray. All were recorded within the spruce plantation or clearfell plots. No nationally notable species were recorded in the birchwood plots.

For hoverflies, the birchwood seems to be a much less favourable habitat than the spruce plantation. Because the majority of the most abundant hoverfly species recorded in the spruce plots were aphid predators, it is likely that the trees and other vegetation hosted large numbers of aphids, such as *Elatobium abietinum*. The presence of birch within spruce had little influence on species diversity probably because the larval feeding habits of Syrphidae (generally predatory, saprophagous or mycophagous) mean that no species can be specifically associated with birch in the way many species of Lepidoptera are.

Ground-dwelling beetles

Carabidae

The abundance of ground beetles, Carabidae, was greatest in the birchwood and the clearfell plots (Figure 5.11). This was undoubtedly due to differences in ground vegetation and structure rather than differences in tree composition *per se*. Although the greatest numbers of species were recorded in these plots (Figure 5.12), the difference was not as marked as the difference in abundance. The α diversity values calculated for catches in the birchwood plots were no higher than the average of those in the corresponding spruce/birch plots and there was no significant relationship between carabid diversity and amount of birch in a plot (R^2=0.04, p=0.48; Figure 5.13).

Staphylinidae

Like the Carabidae, rove beetles (Staphylinidae) were more abundant in the birchwood plots than elsewhere (Figure 5.14). Staphylinid species richness was greater in the birchwood plots than any of the other plot types except the 30% birch in young spruce plantation plots (Figure 5.15). There was no significant relationship between staphylinid α diversity and the amount of birch in a plot (R^2=0.20, p=0.14). The birchwood Staphylinidae were heavily dominated by a number of characteristic species, largely absent from the other plots. For example, the Staphylinids *Tachyporus signatus* and *Philonthus decorus* were almost confined to birchwood plots and were extremely abundant in them.

Seven nationally notable beetle species were recorded. Similar numbers of nationally notable species were recorded in most plot types.

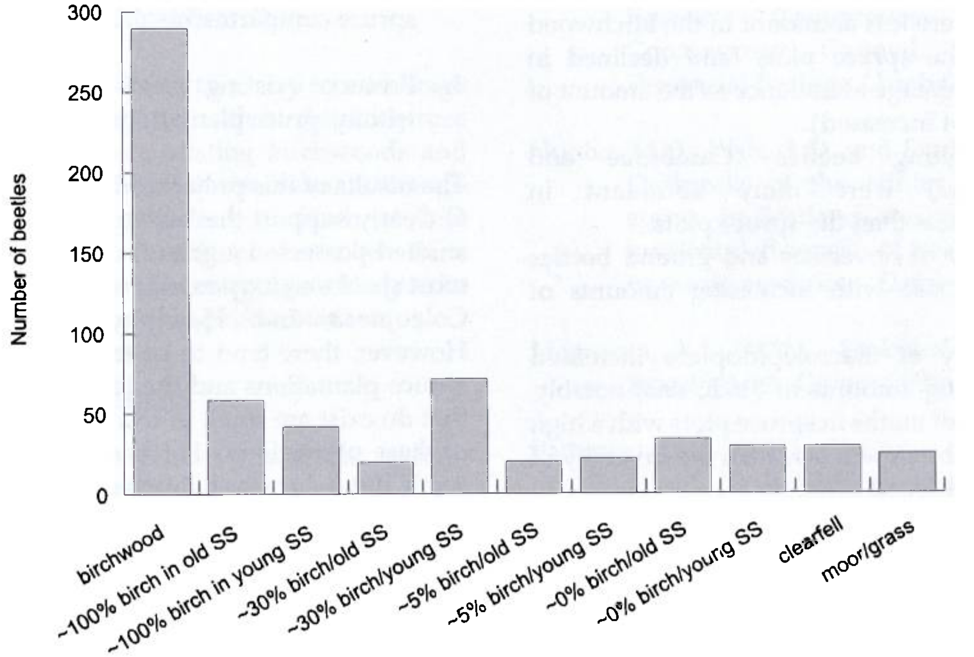

Figure 5.14 Abundance of Staphylinidae in pitfall traps in Dalbeattie, Knapdale and Moray

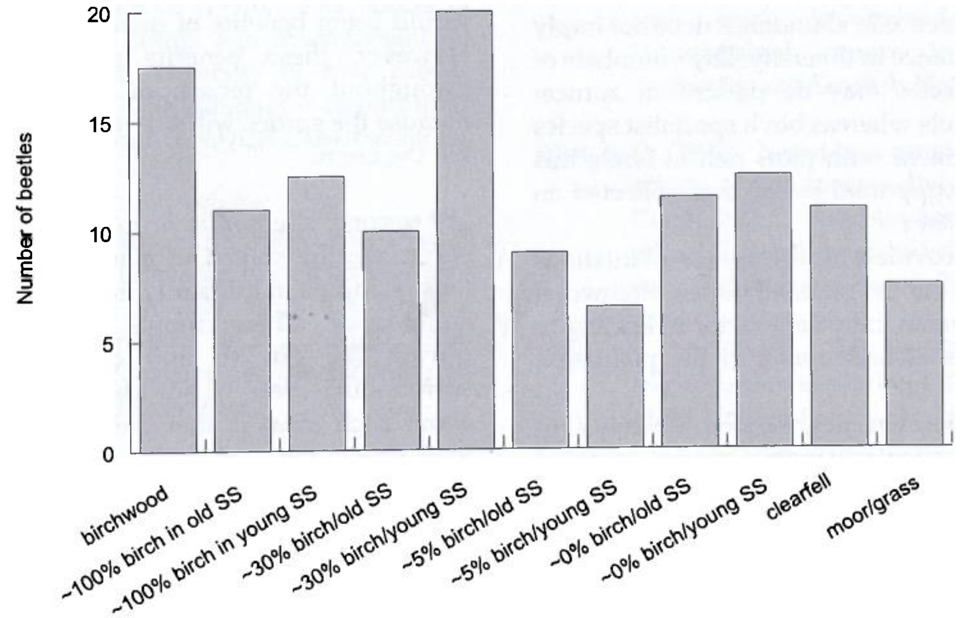

Figure 5.15 Number of Staphylinidae species in pitfall traps in Dalbeattie, Knapdale and Moray

Conclusions

The results of this two-year study on the abundance and diversity of arthropods in spruce plantations in Scotland (including those aspects of the study covered in Chapter 6) can be summarised as follows:

- The abundance of Diptera, Hymenoptera and most other groups of arthropods were as great or greater in spruce plantations than in nearby birchwoods.
- Hemiptera and Coleoptera tended to be more abundant in the birchwood plots than in the spruce plantation plots and increased significantly in abundance as the amount of birch in a plot increased.
- Hoverflies were less abundant in the birchwood plots than the spruce plots (and declined in terms of percentage abundance as the amount of birch in a plot increased).
- Ground-dwelling beetles (Carabidae and Staphylinidae) were more abundant in birchwood plots than the spruce plots.
- The diversity of hoverflies and ground beetles did not increase with increasing amounts of birch.
- The diversity of macrolepidoptera increased with increasing amounts of birch, and, notably, the diversity of moths in spruce plots with a high frequency of birch was less than the diversity of moths in birchwood plots.
- A number of insect species, including several with an acknowledged status as rare or endangered species, were primarily associated with the birchwoods plots.

The following limitations of this study should, however, be noted:

- A lack of difference in abundance does not imply a lack of difference in diversity; large numbers of generalist species may be present in spruce-dominated plots whereas birch specialist species may be associated with plots rich in birch: this possibility is supported by the data collected on macrolepidoptera.
- The shelter provided by the spruce plantations in comparison to the relatively open birchwood may have been an important factor in leading to high numbers of arthropods in the plantation plots.
- To some unknown degree, the diversity of arthropods, particularly mobile species, sampled in each of the plots will have been affected by the presence of other treatments; for example, the birch-feeding species found in pure spruce plots must have originated elsewhere.
- Plantation plots with young and 'older' spruce were sampled, but no plots with spruce over 20 years of age were sampled.

Further research is needed to address these concerns. Until this is done, much of the data presented here showing a surprising diversity of arthropods within areas of pure spruce should be treated with caution.

There are three strategies for promoting the arthropod fauna associated with birch in spruce plantations:

1. Encourage the growth of birch within areas planted with spruce: birch/spruce mixtures.

2. Protect the development of areas of birch within spruce compartments: 'clumps' of birch.

3. Protect existing semi-natural birchwoods within spruce plantations.

The results of this project (this chapter and Chapter 6) clearly support the last strategy: the birchwoods studied possessed a greater diversity of moths, the most speciose group examined, and contained more Coleoptera and Hemiptera than elsewhere. However, there tend to be few birchwoods within spruce plantations and the few areas of birchwood that do exist are small in relation to the overall size of these plantations. Furthermore, these relatively small, but rich, areas of birch are vulnerable because of their size and age.

It is therefore important that the arthropod fauna associated with birch should be encouraged throughout spruce plantations. The question is how? The first alternative, listed above, to encourage the widespread development of low densities of birch within compartments of spruce, would bring benefits of increased insect diversity. However, these benefits are unlikely to last throughout the length of the spruce rotation because the spruce will eventually outcompete and kill the birch.

The second alternative is to protect and perhaps encourage the spread of clumps of birch such as those sampled in this study in Dalbeattie, Knapdale and Moray. These clumps are likely to survive during the growth and development of the surrounding areas of spruce. The main concern about such areas is that the data presented here have shown that, although containing nearly 100% birch, they are not as diverse as birchwoods. It is unclear whether this difference relates to the difference in age between the clumps of birch within areas of spruce and nearby birchwoods, or these differences in size. If left to mature and expand slightly these areas of relatively young birch are likely to develop into arthropod species-rich birchwoods.

It is beyond the remit of this study to consider the economic implications of the strategies discussed above. However, a major economic benefit of encouraging a richer arthropod fauna within spruce plantations is that this is likely to reduce the chance of insect pest outbreaks because a richer arthropod fauna will include a greater variety of predatory and parasitic species (Watt, 1992). At present, there are few damaging insect pests associated with spruce in Scotland (Hunter *et al.*, 1991) but their status may change in response to climate change (Dewar and Watt, 1992) or adaptation by native insects to introduced host plants (Fraser and Lawton, 1994; Fraser, unpublished).

In conclusion, the most effective way to encourage the diverse fauna associated with birch into spruce plantations is to protect existing birchwoods and encourage the development of new ones. Although the widespread development of birch at low densities in spruce/birch mixtures has a benefit in terms of increased insect diversity, this is likely to be effective for only part of the spruce rotation.

Acknowledgements

This project would have been impossible without the species identification skills of Kenneth Watt, Mick Eyre, David Horsefield, Bob Palmer and Keith Bland, the field support of Jonathan Mason, and the co-operation of Forest Enterprise staff in Moray, Castle Douglas and Kintyre Forest Districts.

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Chapter 6

The diversity and larval feeding status of moths in spruce forests

David A. Barbour, Allan B. Watt and Colin McBeath

Summary

Lepidoptera, being wholly phytophagous and a relatively well-known group, were chosen for detailed investigation into species diversity and larval feeding status within spruce forests. Species diversity of light-trapped Lepidoptera (measured by log-series alpha) increased with proportion of birch in both the young-spruce and the older-spruce plot series, and was highest of all in semi-natural birchwood plots. However, in older-spruce plots the diversity only increased rather weakly with proportion of birch; in young-spruce plots the proportional increase was stronger. Moth catches were scored for 'birch-feeding status' according to known feeding preferences of the larvae. Specialist birch-feeding species increased with proportion of birch in both young-spruce and older-spruce plots. Generalist birch-feeding species (those with other foodplants in addition to birch) showed no increasing trend with proportion of birch. Specialist birch-feeding species were further found to fall into two categories: those that increased in simple proportion to the amount of birch in plots, and those that occurred almost exclusively in natural birchwood, rarely or never in the birch/spruce mixtures. Several nationally notable species were caught in small numbers, most in the natural birchwood plots and fewest in the spruce plots with no birch. The conservation implications of these findings are twofold: even a small admixture of birch will increase the Lepidoptera diversity of a spruce plantation; a significant proportion of species, particularly rarer and more specialist ones, will only be conserved by maintaining discrete areas of natural birchwood untouched.

Introduction

The background to this study, and an outline of the methods used, are given in Chapter 5 by Watt *et al.* Lepidoptera is the only major order sampled in the study that comprises entirely phytophagous species. Their (larval) feeding habits are generally well known. Those that feed on birch in the UK have been listed by Atkinson (1992) who further specified their generalist or specialist birch-feeding status by reference to the 'Phytophagous Insects Database' maintained by the Institute of Terrestrial Ecology (Ward and Spalding, 1981).

Lepidoptera have also been the subject of much research on local species diversity. Light-trap samples of moths can be characterised for species diversity by a variety of 'diversity indices' as reviewed by Magurran (1988). One of the most used and best understood is the statistic alpha (α) of the log-series - as developed by Ronald Fisher and C. B. Williams at Rothamsted (Williams, 1947) and subsequently used extensively in the Rothamsted Insect Survey (e.g. Taylor, 1986). Lepidoptera therefore were particularly well suited to study the question of species diversity, its relationship if any to the proportions of birch in spruce plots, and the way this might be explainable by feeding preferences of the individual species.

Species diversity

Species diversity, as measured by log-series alpha (α), was calculated separately for each 2-week collection in each of the 32 plots. Seasonal trends were strongly apparent, e.g. in the natural birchwood plots (Figure 6.1), such that the highest alpha values were obtained from collections made in mid- to late July (collection 3 at Moray and Knapdale in 1994, and the earliest of the complete collections at Dalbeattie in 1993). To achieve comparability between the three study areas, we therefore selected for analysis the collections from all plots from this period of peak diversity (which was also the time of peak abundance).

Comparisons were then made, separately for the young-spruce and the older-spruce plots, of alpha as it related to the amount of birch in the plots (~0%, ~5%, ~30% or ~100%). The young-spruce and older-spruce series were also separately compared with results in the 'natural birchwood' controls (Figures 6.2 and 6.3).

The plotted alpha values, though with a substantial scatter in some cases, did show a positive correlation with amount of birch in both series (r^2=0.729,

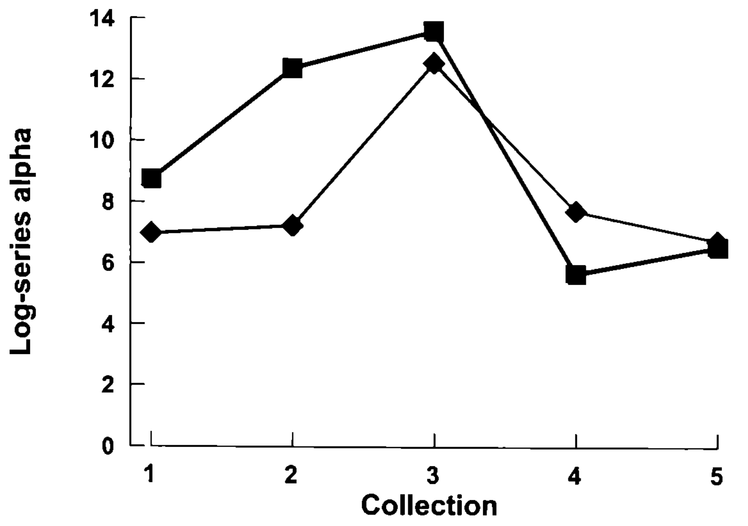

Figure 6.1 Log-series alpha calculated for moth catches in natural birchwood plots in five successive collections. 1. May-June, 2. June-July, 3. July, 4. August, 5. September-(October). ■ Moray, ◆ Knapdale

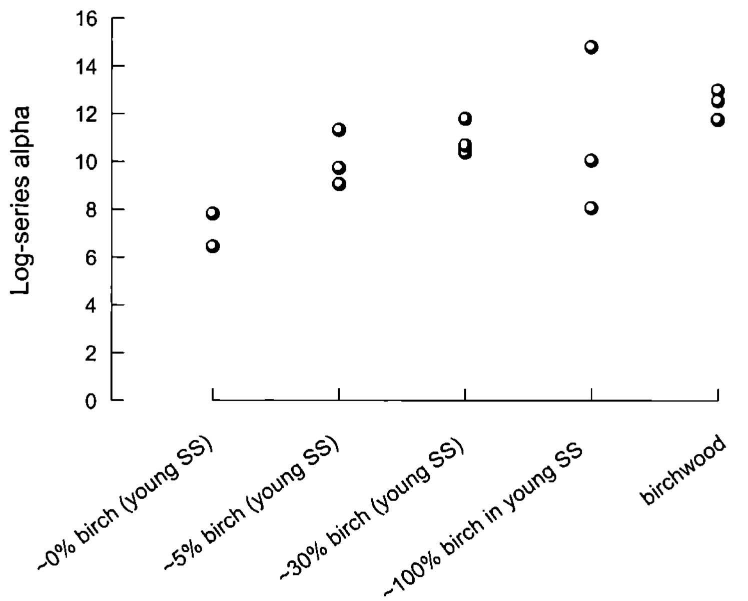

Figure 6.2 Log-series alpha calculated for moth catches in plots of younger spruce with four different frequencies of birch compared with alpha values for natural birchwood plots. SS: Sitka spruce

0.587, $p<0.05$). However, the form of the relationship was different between series. In young spruce the alpha values increased markedly with even the ~5% and ~30% birch admixture, and in the ~100% birch they were not significantly less than values in the 'natural birchwood' (mean 11.0 versus 12.5). In older spruce there was little increase in alpha with the ~5% and ~30% birch admixture, and even the ~100% birch treatment had alpha significantly less than the natural birchwood (8.8 versus 12.5). The difference may lie in the much more open structure of the young-birch plots, which retain an element of open-moorland vegetation (Glimmerveen, 1994) and probably much of the quite diverse invertebrate fauna associated with it.

Birch-feeding status of larvae

This was assessed from the known feeding-preferences of larvae, as listed by Atkinson (1992) and updated by reference to the full ITE Phytophagous Insects Database. Five categories of species were distinguished:

- N not recorded feeding on birch
- P polyphagous, recorded on birch
- T deciduous-tree feeder, recorded on birch
- TB deciduous-tree feeder with strong preference for birch
- B monophagous on birch

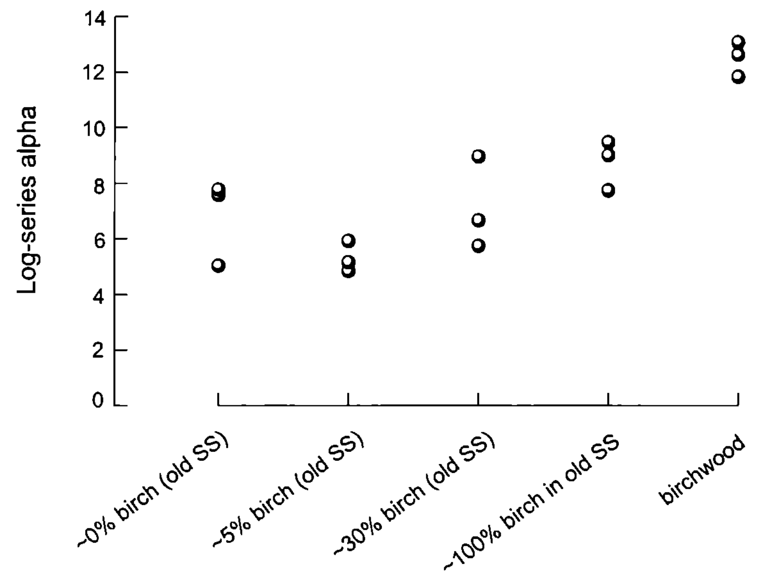

Figure 6.3 Log-series alpha calculated for moth catches in plots of older spruce with four different frequencies of birch compared with alpha values for natural birchwood plots. SS: Sitka spruce

Because there were no (or very few) deciduous trees besides birch in the plots, it is likely that species characterised as T were in fact essentially birch-feeding in these areas.

Each fortnightly collection was then 'scored' according to the birch-feeding status of the component species, weighted by numbers of individuals caught of each. Scores were assigned in a geometrically increasing scale as follows:

P = 1	classed as 'Generalist' birch-feeders
T = 2 TB = 4 B = 8	together classed as 'Specialist' birch-feeders

(The B and TB species were relatively less frequent than T species, so despite their high score-weighting they tended to contribute less to variation in birch-feeding score than T species.)

As in the case of the diversity measures, birch-feeding status score showed a trend through time (being significantly lower in the late moth catches than in early ones). We therefore again selected catches from the mid-season period, to make valid comparisons between the different study areas. The feeding-status scores were then compared within and between series, to evaluate the influence of proportion of birch and to relate the results in plantation plots with those from natural birchwood controls. The results are presented separately for Specialist and for Generalist birch-feeder scores (Figures 6.4 - 6.7).

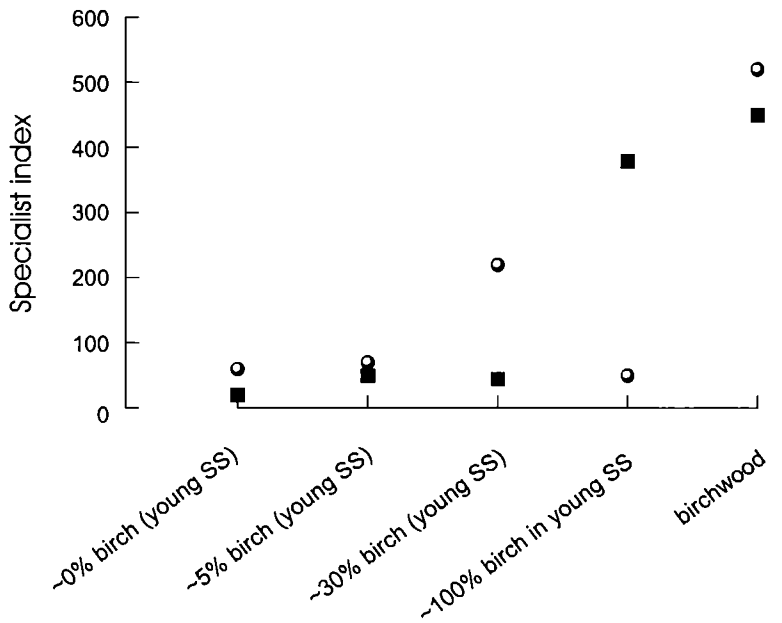

Figure 6.4 Specialist birch-feeding scores for moth catches in plots of younger spruce with four different frequencies of birch compared with scores for natural birchwood plots; squares = Knapdale, circles = Moray

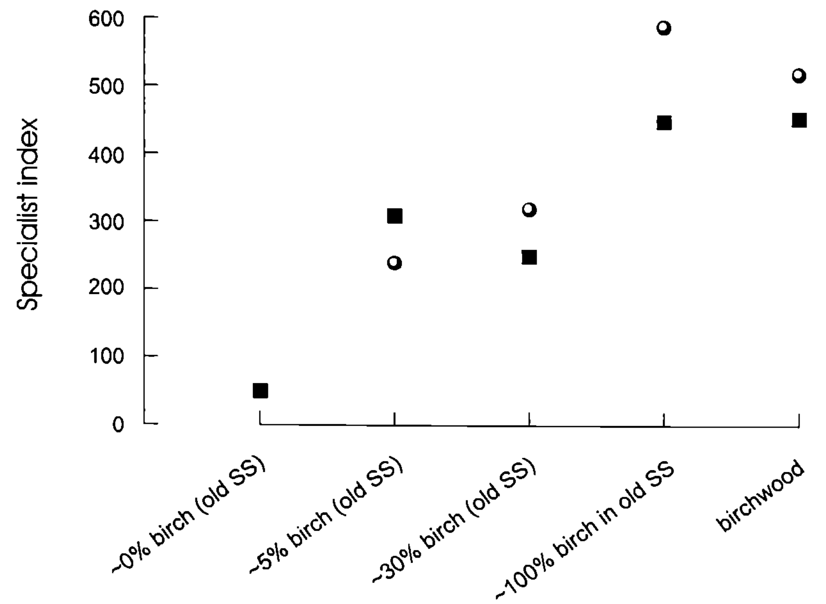

Figure 6.5 Specialist birch-feeding scores for moth catches in plots of older spruce with four different frequencies of birch compared with scores for natural birchwood plots; squares = Knapdale, circles = Moray

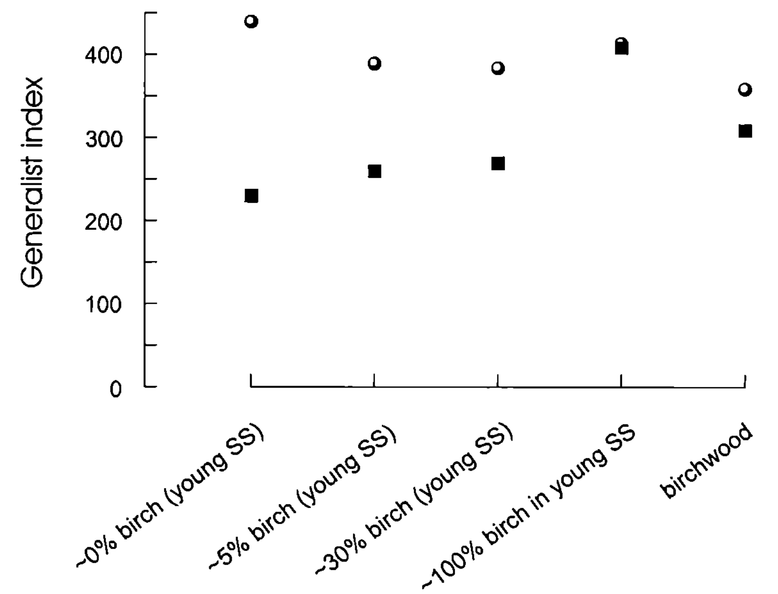

Figure 6.6 Generalist birch-feeding scores for moth catches in plots of younger spruce with four different frequencies of birch compared with scores for natural birchwood plots; squares = Knapdale, circles = Moray

It was immediately obvious that the Specialist birch-feeder scores and the Generalist birch-feeder scores behaved differently. The Specialist birch-feeder scores showed, as expected, a marked increase with proportion of birch present, in both the young-spruce and the older-spruce plots. However, the Generalist birch-feeder scores showed *no* increase with proportion of birch present, in either of the plot series.

Looking more closely at the Specialist scores, we see that there was again a difference in pattern between the young-spruce and the older-spruce plot series. In young-spruce plots the birch-feeder score increased little with small percentages of birch (~5%, ~30%) and in one case even with ~100% birch. In older-spruce plots the birch-feeder score increased strongly with even ~5% or ~30% birch, and in the case of ~100% birch the birch-feeder score even equalled that of the natural birchwood controls.

The difference again probably lies in the structure of the stands of spruce at the different ages. The rapid increase in birch-feeder score with proportion of birch in the older-spruce plots is probably because few moths besides birch-feeders actually penetrate these pole-stage stands (and there are very low numbers of moths in pure spruce stands without birch). The more limited increase in birch-feeder score seen in young-spruce plots is likely to be because the birch-feeders, though increasing, are 'swamped' by large numbers of other moth species characteristic of open-ground habitats.

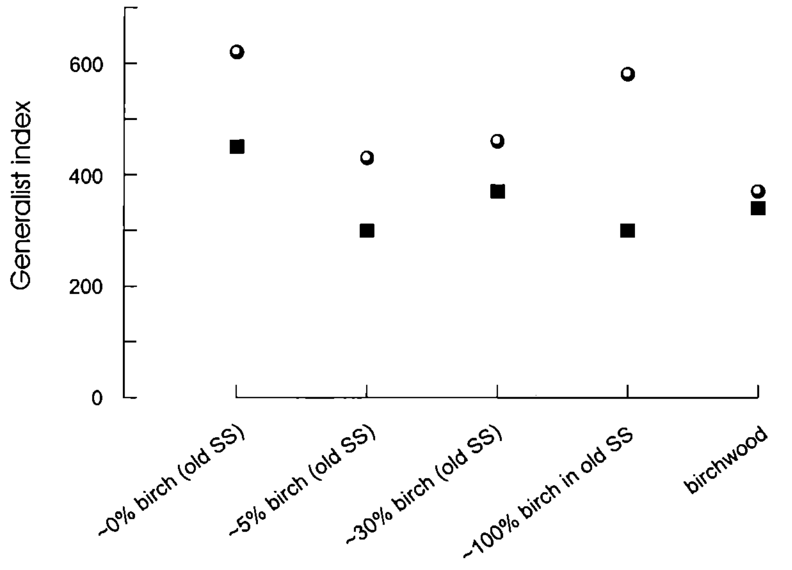

Figure 6.7 Generalist birch-feeding scores for moth catches in plots of older spruce with four different frequencies of birch compared with scores for natural birchwood plots; squares = Knapdale, circles = Moray

The absence of any increases in Generalist birch-feeder scores with proportion of birch is surprising, but again may be explainable by a 'swamping' effect by largely polyphagous species (particularly of Noctuids).

Birch fidelity

The question of feeding-status was further investigated by looking at the Specialist birch-feeders in terms of the particular species, and the numbers of individuals of these species caught in the different plots. Nine Specialist species were caught in sufficient numbers to make a worthwhile analysis possible.

All but one of these species showed the expected trend of strongly increasing numbers with increasing proportion of birch (Table 6.1). However while five species showed a reasonably smooth, progressive increase with amount of birch, three other species seemed to show a 'cut-off' response, with very few individuals being trapped in any plots outside of the natural birchwood controls.

Progressive response	**'Cut-off' response**
Diarsia dahlii	*Pheosia gnoma*
Campaea margaritata	*Ochropacha duplaris*
Cabera pusaria	*Graphiphora augur*
Ptilodon capucina	
Geometra papilionaria	

Table 6.1 Mean numbers of moths of Specialist birch-feeding species caught in each of four classes of plot with progressively decreasing frequency of birch

Area	Species	Number caught per plot category			
		Birchwood	~100% birch	~5% and 30% birch	~0% birch
Moray	*Pheosia gnoma*	27	1.5	1.0	0.25
	Diarsia dahlii	137	75.5	16.0	2.0
	Campaea margaritata	95	92.5	9.5	0.75
	Eulithis testata	0	0.5	2.75	1.75
	Geometra papilionaria	22	4.0	0.75	0.0
Knapdale	*Pheosia gnoma*	10	1.0	1.0	0.25
	Diarsia dahlii	24	15.5	1.0	0.25
	Ochropacha duplaris	10	1.5	0.5	0.0
	Campaea margaritata	140	81.5	19.25	2.0
	Geometra papilionaria	10	7.5	2.75	0.25
	Cabera pusaria	14	4.5	2.0	0.0
	Graphiphora augur	56	0.5	1.0	0.5
	Ptilodon capucina	5	2.0	0.5	0.25

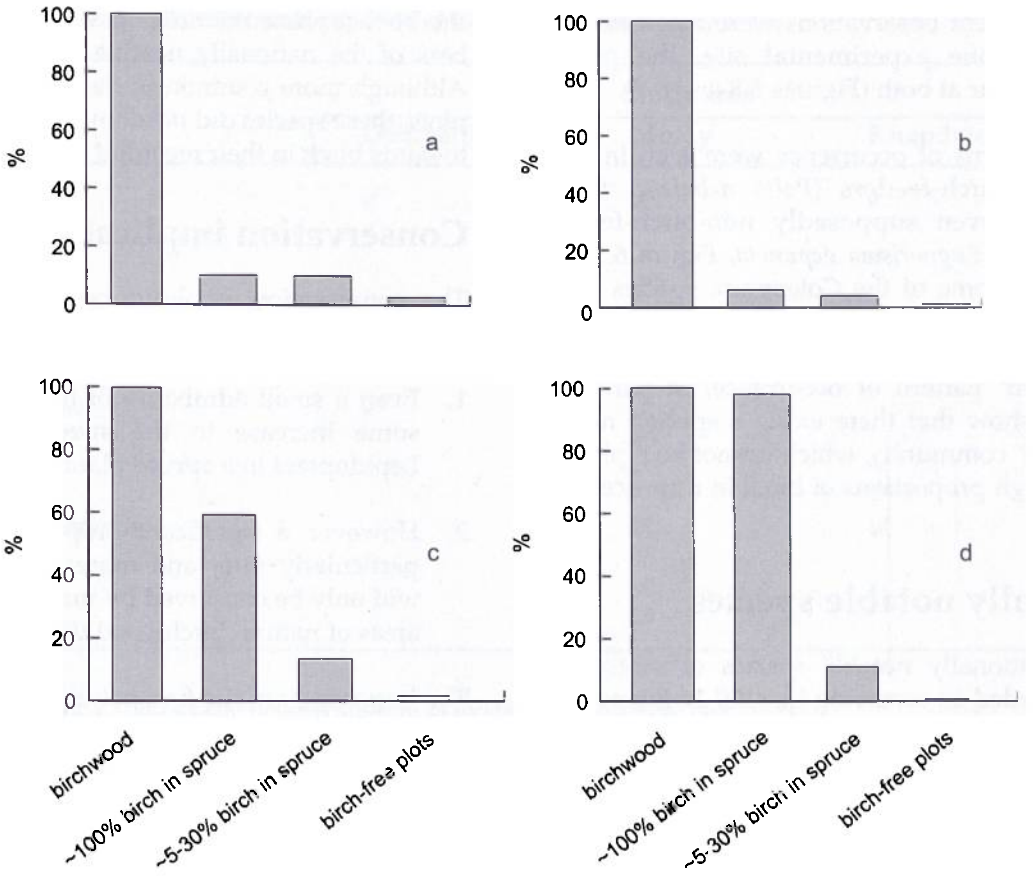

Figure 6.8 Birch fidelity of species in two study areas: (a) *P. gnoma*, Knapdale, (b) *P. gnoma*, Moray, (c) *C. margaritata*, Knapdale, (d) *C. margaritata*, Moray. Numbers of moths caught as percentage of the number caught in birchwood plot

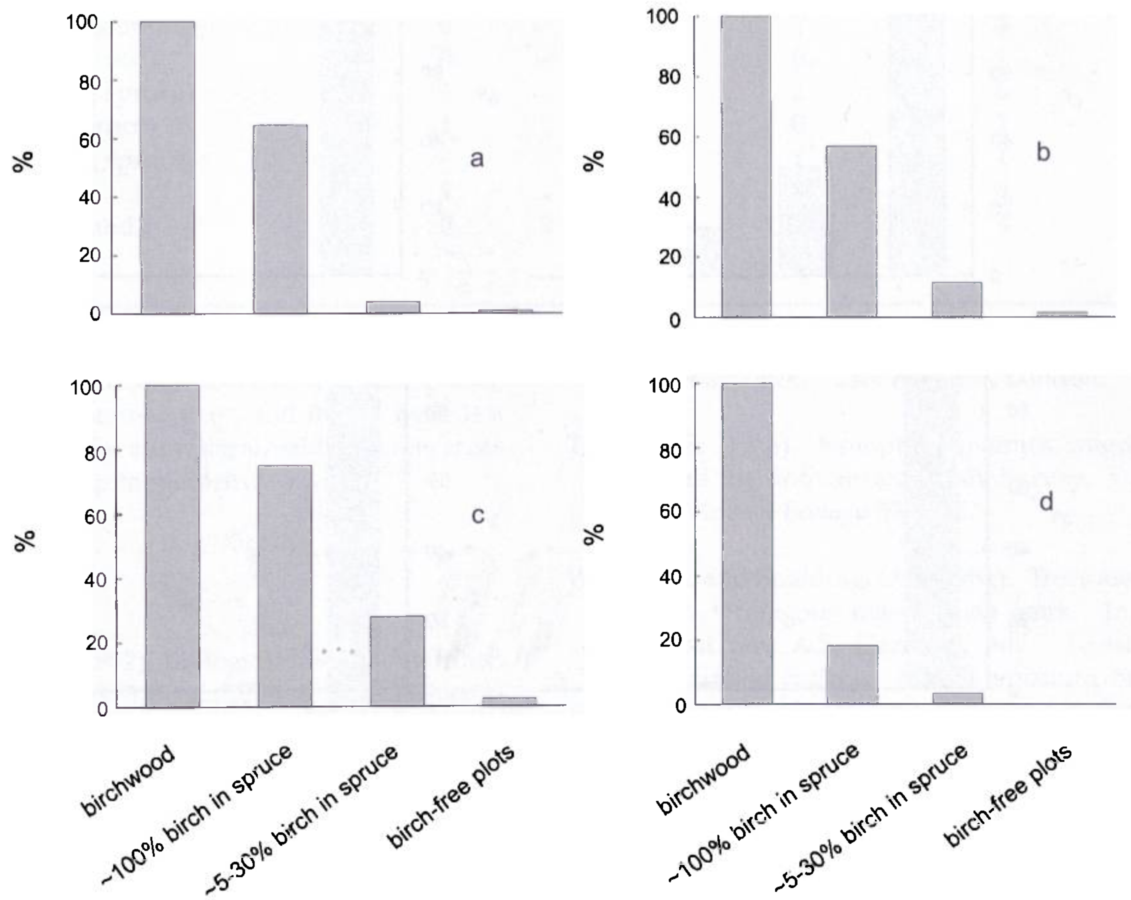

Figure 6.9 Birch fidelity of species in two study areas: (a) *D. dahlii*, Knapdale, (b) *D. dahlii*, Moray, (c) *G. papilionaria*, Knapdale, (d) *G. papilionaria*, Moray. Numbers of moths caught as percentage of the number caught in birchwood plot

Where sufficient observations were available from more than one experimental site, the pattern seemed similar at both (Figures 6.8 and 6.9).

Similar patterns of occurrence were seen in some Generalist birch-feeders (*Polia nebulosa*, Figure 6.10(b)) or even supposedly non-birch-feeding Lepidoptera (*Eugnorisma depuncta*, Figure 6.10(d)), and also in some of the Coleoptera species in the pitfall-traps.

The 'cut-off' pattern of occurrence, in particular, seems to show that there exists a special 'natural birchwood' community, which cannot be replicated even by high proportions of birch in a spruce plantation.

Nationally notable species

Several nationally notable species of moths (i.e. those recorded as occurring in <100 10-km squares nationally) were recorded in small numbers. The 15 species are listed in Table 6.2. The highest number of these species was in the natural birchwood plots, and the lowest in the pure spruce plots and the older of the birch/spruce mixtures. The younger of the birch/spruce mixtures had intermediate numbers of the nationally notable species (Table 6.3). Although more common in the natural birchwood plots, these species did not show any particular bias towards birch in their recorded feeding preferences.

Conservation implications

The conservation implications of these findings appear to be twofold:

1. Even a small admixture of birch will produce some increase in the species diversity of Lepidoptera in a spruce plantation.

2. However, a significant proportion of species, particularly rarer and more specialist species, will only be conserved by maintaining discrete areas of natural birchwood untouched.

The importance of the first point may be limited by the degree to which birch will become shaded out and progressively lost in later stages of a spruce rotation (later stages than were investigated in the present study). In a mixed-age forest the presence of at least some areas of younger crop will allow

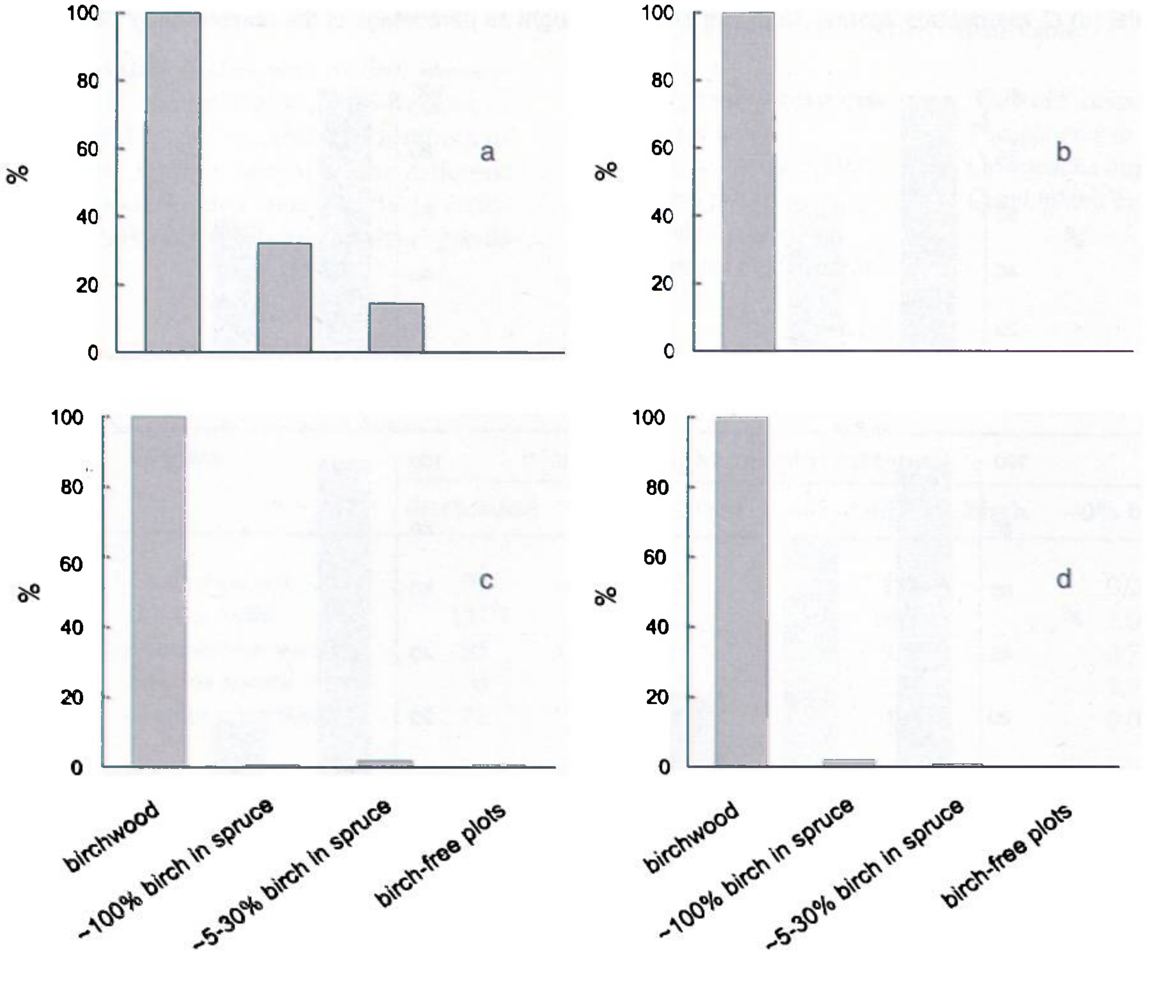

Figure 6.10 Birch fidelity of species in two study areas: (a) *C. pusaria*, Knapdale, (b) *P. nebulosa*, Moray, (c) *G. augur*, Knapdale, (d) *E. depuncta*, Moray. Numbers of moths caught as percentage of the number caught in birchwood plot

Table 6.2 Incidence of nationally notable species of moths in the three study areas

Species	Study area		
	Dalbeattie	Moray	Knapdale
Alcis jubata	✓	✓	✓
Chesias rufata	✓		
Colostygia olivata		✓	✓
Dasypolia templi		✓	
Enargia paleacea		✓	
Epirrita filigrammaria		✓	✓
Hyppa rectilinea			✓
Lithomoia solidaginis	✓	✓	
Paradiarsia sobrina		✓	
Perizoma blandiata		✓	
Polia hepatica			✓
Syngrapha interrogationis		✓	✓
Thera cognata		✓	
Xestia alpicola		✓	
Xylena exsoleta		✓	

Table 6.3 Incidence of nationally notable species of moths in the different plot types

Plot type	Number of species			
	Dalbeattie	Knapdale	Moray	Total
Birchwood	1	5	3	9
~100% birch in old spruce	1	0	1	2
~100% birch in young spruce	1	1	3	5
~30% birch (old spruce)	0	1	0	1
~30% birch (young spruce)	0	2	2	4
~5% birch (old spruce)	0	1	0	1
~5% birch (young spruce)	1	3	2	6
~0% birch (old spruce)	1	0	0	1
~0% birch (young spruce)	-	0	1	1
Clearfell	1	0	3	4
Moorland/grassland	0	2	2	4

birch admixtures to have their effect: however even the existence of these is dependent on the persistence of nearby seed-sources, and this in itself is a strong argument for allowing sizeable discrete areas of birch to develop to maturity.

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Chapter 7

Birch and biodiversity: approaches to management in upland spruce forests

Jonathan W. Humphrey, Bill Mason, Kate Holl and Gordon S. Patterson

Summary

The role and value of birch (*Betula pendula* and *B. pubescens*) for improving the biodiversity of upland spruce forests in Great Britain is reviewed together with current information on the establishment and silviculture of birch in mixed stands. The review focuses on drawing together the research findings presented in Chapters 2-6, and management implications are therefore considered in relation to plant, lichen and invertebrate diversity. The importance of maintaining and expanding semi-natural birchwoods in upland spruce forests is highlighted. Mature birchwood habitat with old trees and deadwood is particularly valuable for lichens, specialist moths (Lepidoptera) and some beetles (Staphylinidae). However, pure spruce and clear-felled stands have considerable value for species groups such as hoverflies (Syrphidae) and ground beetles (Carabidae). Semi-natural birchwoods are dynamic in space and time, and birchwood 'maintenance zones' of 15-20 ha should be created to provide adequate space for the development of a full range of successional stages from thickets to 'old-growth'. These maintenance zones would be centred on existing birchwoods. Within the context of developing regional-scale 'Forest Habitat Networks', birchwood maintenance zones could be located near or contiguous with other semi-natural woodlands, riparian zones and tree-line or montane scrub. Where birch occurs in mixture with spruce, management should aim to aggregate the birch into distinct clumps (birch/spruce mosaics) as these are more valuable for biodiversity than intimate mixtures of birch and spruce. The possibility that birch clumps could function as 'habitat stepping stones' between widely dispersed fragments of long-established semi-natural birchwoods should be considered. Some of these clumps should be allowed to progress to biological maturity to provide continuity of valuable older habitat, but more research is needed to substantiate this hypothesis in relation to key birchwood species of high conservation value. A stand dynamics hypothesis illustrating the possible long-term development of birch/spruce mosaics is proposed. There is also considerable scope for improving the commercial management of birch/spruce mixtures. Establishment techniques such as direct sowing of birch have been the subject of recent research, but little is known about whether Sitka spruce (*Picea sitchensis*) can be grown successfully in mixture with birch, as most information to date relates to the performance of Norway spruce (*P. abies*)/silver birch (*B. pendula*) mixtures in Scandinavian forests. Research is needed to identify the optimum densities of birch and Sitka spruce on different site types to maximise the yield of both species, and when to carry out thinning and respacing.

Introduction

The conservation and enhancement of biodiversity is now firmly enshrined as a major objective of UK Government forestry policy (Anon., 1994a; Anon., 1995). A principal objective is to diversify upland coniferous forests planted since 1920 which are relatively uniform in structure and composition. As well as conserving any remnant semi-natural woodland areas, an important way of improving the value of conifer forests for biodiversity is to increase the proportion of native broadleaved trees and shrubs in both new planting and restocking. The UK Forestry Standard requires a minimum of 5% of broadleaved trees and shrubs in conifer forests (Forestry Commission, 1998). Guidance on species choice, location and design has been given by Low (1986), Anon. (1990, 1993), Ratcliffe (1993) and Rodwell and Patterson (1994). The two main native birch species (downy birch *Betula pubescens* Ehrh. and silver birch *Betula pendula* Roth.) are particularly valuable for this purpose in upland forests as they tolerate a wide range of harsh climate regimes and poor soil conditions, they can rapidly colonise new areas, and they provide a habitat for a wide range of flora and fauna (Patterson, 1993).

Interest in the commercial utilisation of birch in the uplands has also come to the fore in recent years (Lorrain-Smith and Worrell, 1991; Seaman, 1994). This has been reflected in the establishment of organisations such as Highland Birchwoods which aims to encourage the better management and restoration of native birchwoods. Increasingly, the economic benefits of managing birch in mixture with conifer crops is being recognised (McRobbie, 1991), but guidance is needed on how best to manage for both ecological and economic objectives while retaining landscape and amenity value.

In this chapter we review the role and value of birch for improving the biodiversity of upland conifer forests in the light of the new research findings reported in the symposium papers. The main focus, therefore, is on plants, lichens and invertebrates. We also review current information on the silviculture and establishment of birch and suggest possible management options which balance economic and ecological objectives.

Biodiversity in the context of forest management

When considering how to improve the value of conifer plantations for biodiversity, it is necessary to assess their current biodiversity value, and to have some idea of their future ecological capacity (Newton and Humphrey, 1997). Within forest ecosystems, biodiversity is frequently considered to encompass a range of spatial scales (e.g. landscape, stand, species and genetic scales; Heywood and Baste, 1995), but forest management and design planning is almost always carried out at the landscape and stand scales (Ratcliffe and Peterken, 1995; Ferris-Kaan, 1995; Burton *et al.*, 1992). Species, stand scale, and hence landscape diversity is influenced by manipulating forest structure and tree species composition (Ratcliffe, 1993): in effect creating ecological niches for various species groups (Ratcliffe and Peterken, 1995). On any given site there is a range of options available to the forest manager which will yield different benefits for different species groups. For example, broadleaved trees tend to support different assemblages of insects and fungi than conifers (Claridge and Evans, 1990; Newton and Haigh, 1998; Ozanne, 1996).

A major consideration therefore is how to define the number and range of ecological niches we wish to create in conifer plantations. It is necessary to ascribe some relative value to different types of biodiversity. Newton and Humphrey (1997) propose four ways of evaluating biodiversity in plantations. Management can aim to: increase the number of rare (or specialised) habitats or species; increase overall species or habitat diversity; improve naturalness; encourage keystone species (i.e. those species which have wider functional role in ecosystems and play an important part in food webs). All four of these approaches are relevant to the management of birch in spruce plantations.

Site requirements of birch and spruce

Because both species of birch have such wide edaphic and climatic tolerances, they can occur as a significant component within a whole range of semi-natural woodland types (Kirby, 1984; Patterson, 1993). They occur in association with oak in W17 *Quercus petraea-Betula pubescens-Dicranum majus* woodland and W11 *Quercus petraea-Betula pubescens-Hyacinthoides non-scripta* woodland, and with Scots pine in W18 *Pinus sylvestris-Hylocomium splendens* woodland (Rodwell, 1991). Riparian woodlands (W9, W7) and wet woodlands (W4, W3) also invariably contain birch as a major component. Birch also occurs commonly as pure stands in the eastern Highlands and these stands are considered to be 'birchwoods' if the canopy comprises more that 50% birch (Anon., 1994b). Guidance on the most suitable site types for establishing birch is available as part of the Forestry Commission's Ecological Site Classification (ESC) system (Pyatt and Suárez, 1997). In general, downy birch is more suited to wetter or poorer soil types, e.g. podzols, podzolic gleys and peaty gleys (Pyatt and Suárez, 1997). Silver birch has a wider ecological amplitude than downy birch and can grow (GYC 2-6) on virtually all but the very wettest and driest sites (Pyatt and Suárez, 1997), although it is most suited to loamy brown earths, brown gleys and surface water gleys of high base status. Of the two species, downy birch appears to be by far the most prolific coloniser of spruce stands (Wallace, Chapter 2). Birch stands on the poorer sites tend to have less diverse field layer vegetation development than stands on better sites, but this trend is reversed for bryophytes (Wallace, Chapter 3). It is interesting to note the overlap between the site requirements of the birch species and spruce species (*Picea abies* and *P. sitchensis*; Figure 7.1), and it is therefore reasonable to assume that birch and spruce can occur together.

Value of semi-natural birchwoods for biodiversity

The value of semi-natural birch stands for wildlife has been summarised by Patterson (1993). The research findings reported in this symposium confirm that semi-natural birchwoods have distinctive plant communities when compared to plantation stands of birch or spruce (Wallace, Chapter 3). A number of species such as chickweed wintergreen (*Trientalis europea*) are preferentially associated with semi-natural birchwoods. However, invertebrates contribute most to the special value of semi-natural birchwoods. Atkinson (1992) records over 120

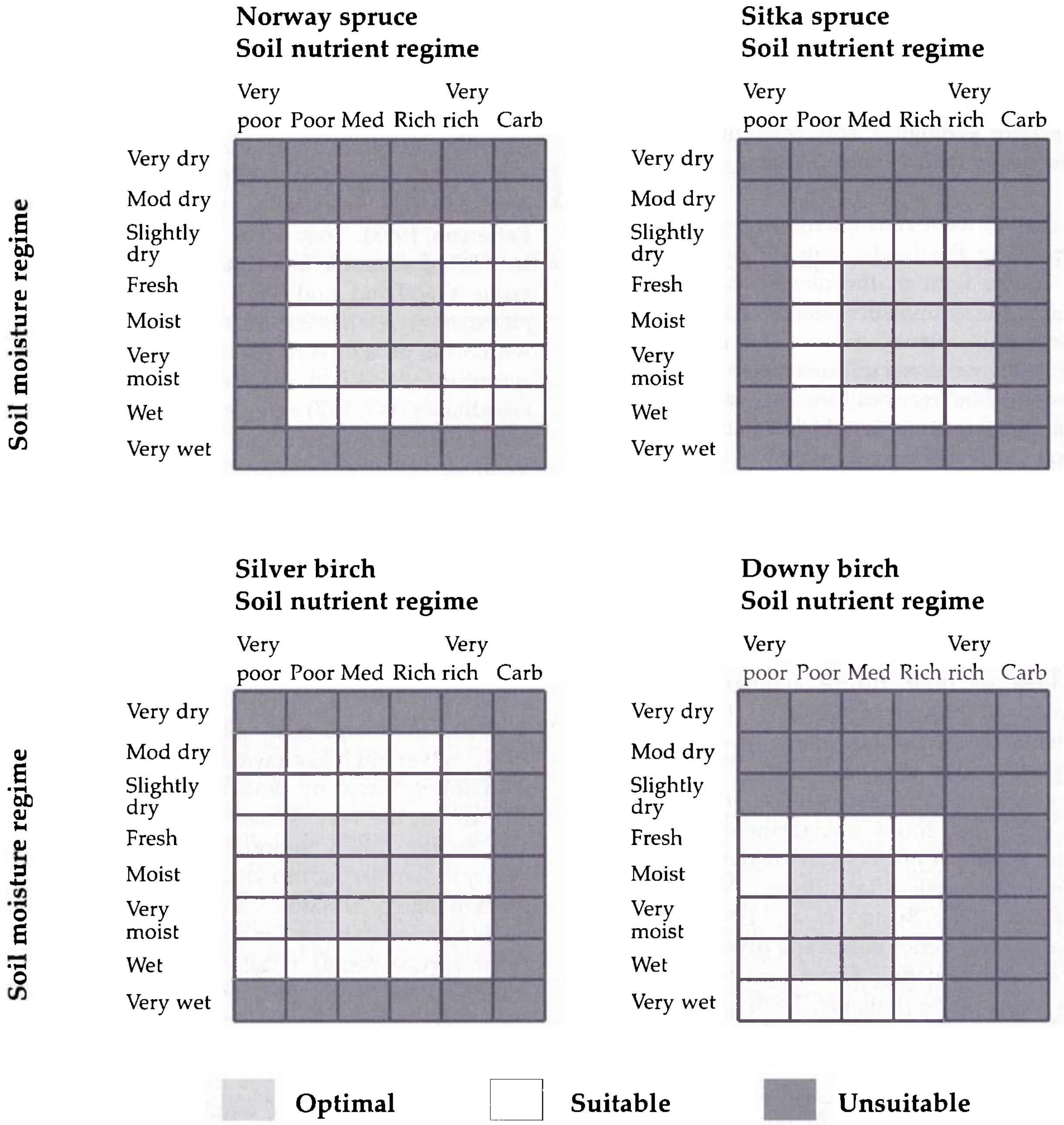

Figure 7.1 Site preferences of Norway spruce (*Picea abies*), Sitka spruce (*P. sitchensis*), downy birch (*Betula pubescens*) and silver birch (*B. pendula*) in relation to the Forestry Commission's Ecological Site Classification (ESC) soil quality grid (Pyatt and Suárez, 1997). Carb: carbonate soils

species of insect which are found on birch only, and use no other tree as a host. Many specialist and often rare or uncommon species (e.g. lepidopteran species) are found associated with birch, particularly in older stands (Barbour *et al.*, Chapter 6). Similar results for saproxylic beetles were obtained by Økland *et al.* (1996) for birch growing in mature *Picea abies* forests in Norway, where a number of specialist species were found associated with decaying birchwood. The diversity and abundance of the epiphytic lichen flora on birch was relatively poor in comparison to other native woodland types such as the oceanic oakwoods, but Orange (Chapter 4) indicates that older and dying trees can be important hosts.

Value of spruce stands for biodiversity

On the basis of the information presented at this symposium and from other studies (e.g. Ozanne, 1996) it is clear that spruce stands do have wildlife value in their own right. They provide a different kind of habitat to birch stands and are host to a different suite of generalist communities. A wide range of habitats of varied structural type are generated by the patch-clearfell system in spruce plantations, and some of these cater for species that are not found within semi-natural birchwoods. For example, some carabid beetles favour open habitats, clear cuts and young regrowths (Niemalä *et al.*, 1993; Watt *et al.*, Chapter 5). Closed canopy spruce communities are known to be dominated by species that are particularly suited to the moist shaded habitats within spruce canopies, notably invertebrates from the orders Collembola, Psocoptera and Acarina (Ozanne, 1996). The results presented by Watt *et al.* in Chapter 5 substantiate these findings, but also illustrate the value of clearfell and older spruce stands for hoverflies (syrphids); a number of nationally notable species were found in these stand types. However, some of these species may be vagrants, and normally associated more closely with non-crop habitats (Watt *et al.*, 1997). Recent data collected for the Forestry Commission's research programme *Biodiversity assessments in managed forests* indicate that spruce stands also provide a habitat for a diverse range and abundance of saprophytic and mycorrhizal fungi (A.C. Newton, personal communication). Spruce trees can contribute to forest biodiversity by providing habitat structure; the needles and branches of *Picea abies*, for example, provide important niches for spiders in both Scandinavian (Gunnarson, 1990) and British forests (Hambler and Speight, 1995).

In contrast, spruce stands provide a poor habitat for woodland plant communities, epiphytic lichens and bryophytes (Orange, Chapter 4; Wallace, Chapter 3), and phytophagus insect groups such as the Lepidoptera (Barbour *et al.*, Chapter 6). However, in some instances this may well be related more to stand structure (i.e. the deep shade cast by the closed canopy) than the unsuitability of the trees themselves as substrates. Large diameter conifer deadwood (fallen or standing) can provide habitat for saproxylic lichens and bryophytes (Forestry Commission, unpublished data). In *Picea abies* stands in southwest Sweden large logs support rare hepatics which require moist microclimate with even humidity (Gustafsson and Hallingbäck, 1988). Similarly large diameter fallen deadwood provides an important habitat for saproxylic beetles and fungus gnats (mycetophilids) (Økland *et al.*, 1996; Økland, 1996).

Relative value of birch/spruce mosaics and mixtures for biodiversity

One of the key biological characteristics of natural boreal forests is that they contain mixed stands of conifers and broadleaves (Esseen *et al.*, 1992). Mixed stands perpetuate until the conifers grow and outlive the broadleaves. Broadleaves such as birch are essentially pioneers, and re-colonise stands after disturbance, which is usually fire (Peterken, 1987). At any one time up to 40% of all stands may contain broadleaves (Heinselman, 1973 in Peterken, 1987). However, even old-growth *Picea abies* forests occurring on moister site types, where fire does not occur, can have a density of 15% broadleaves (Syrjänen *et al.*, 1994).

The spatial arrangement of tree species in mixed stands in natural forest can be extremely variable with species occurring in intimate mixtures of one or more individuals or mosaics of pure species stands. In natural mixtures, 'clumping' of species tends to be a common feature and relates to niche separation where mosaics of different site types occur and support groups of different tree species (Rackham, 1992). (For the purposes of the research reported here, mosaics are defined as arrangements of pure species stands or clumps of 30 m or more in diameter; Watt *et al.*, 1997.) A consideration of the relative merits of mixed birch/spruce stands can be seen in terms of these two alternative spatial arrangements.

At the landscape scale, intimate mixtures do not appear to confer any wildlife benefits as long as semi-natural birchwoods are maintained within the forest block. They do not provide an additional habitat to that provided by the spruce or birch alone, and in any case the conifers will tend to shade out the birch over time (Wallace, Chapter 2). Furthermore, if every spruce stand contained an equal peppering of birch this would lead to loss of habitat diversity at the landscape scale.

Birch clumps appear to be more valuable than intimate mixtures for two reasons. Firstly, they provide a distinctive habitat in their own right (Wallace, Chapter 3; Watt *et al.*, Chapter 5; Barbour *et al.*, Chapter 6). Clumps provide vegetation community types which are distinctive both from pure spruce communities and semi-natural birchwoods (Wallace, Chapter 2) and support a higher number of vascular plant and bryophyte species, and a higher density of individual invertebrates than either intimate mixtures of spruce and birch or pure spruce stands (Figure 7.2). Although these data are a very crude measure of the relative wildlife value of the different stand types, they are useful in indicating the general trends.

In addition, birch clumps could also provide habitat links (or 'stepping stones': Kirby, 1995) between existing semi-natural birchwoods (Figure 7.3). It will be important to allow some of these clumps to progress to maturity to provide over-mature birchwood habitat. This will necessitate retaining some clumps after felling the surrounding spruce and maintaining a continuous age range of clumps so that there is temporal continuity in the supply of the over-mature habitat type. These birch clumps appear to function as suitable habitat for some

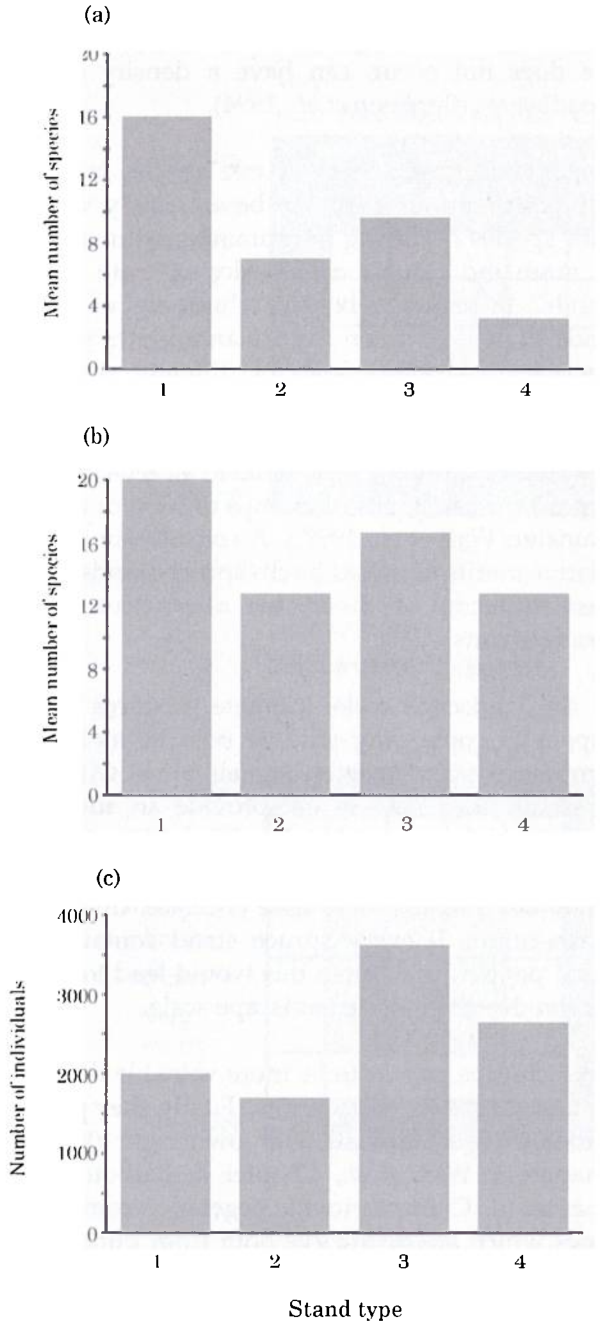

Figure 7.2 Number of (a) vascular plant species, (b) bryophyte and lichen species and (c) individual invertebrates recorded in 1: semi-natural birchwoods, 2: birch/spruce mixtures, 3: birch clumps in spruce, 4: pure spruce. (Data from Wallace, Chapter 3; Orange, Chapter 4; Watt *et al.*, 1997)

birchwood species (Wallace, Chapter 3; Watt *et al.*, Chapter 5), but due to their small size this habitat may only be transient in nature.

It is worth considering the prospects for maintaining specialist birchwood species groups using this system. In essence the system assumes that the target species are mobile in space and time and provision of habitat continuity at the landscape (rather than just the stand) scale is sufficient for their needs. In northern upland climates this may well be the case, as it is known that some species are capable of dispersing between patches of suitable habitat (Good *et al.*, 1995; Ahnlund, 1995; Gustaffson and Wilson, 1996). For example, some saproxylic beetle communities can move extensively across forests landscapes of up to 4 km^2 (Økland *et al.*, 1996). Rare species are not necessarily poor colonisers, and their distribution may be limited by habitat availability and the exacting nature of their habitat requirements rather than by inability to disperse between habitats. This factor could be important for birch stands which are relatively shortlived, and, logically, species associated with the older growth stages may have had to move between patches of suitable habitat in the past.

Management of semi-natural birchwoods

Maintaining birchwood habitat within spruce forests

One of the clear priorities for enhancing habitat diversity in spruce forests is to ensure that existing semi-natural birchwoods are conserved, and if possible expanded. This applies especially to pockets of mature birchwood habitat which have particular value for lichens and invertebrates. Birch stands can be relatively short lived in comparison to stands where longer-lived tree species such as oak predominate (Atkinson, 1992; Miles, 1986). The natural life-span of birch is in the range of 60-100 years although in harsher climates with slower growth rates the age limit may be 150-200 years (Brown, 1983).

Birch rarely regenerates under its own shade and succession to other woodland types or open vegetation can occur over relatively short time scales (Patterson, 1993) leading to considerable temporal and spatial fluctuations in the size and boundaries of birch stands over time. On better soils, Patterson (1993) maintains that birchwoods can form a cyclical succession with other tree species, where older birch stands are colonised and replaced by longer lived trees such as oak. However, many birch stands can enter a second generation if seed sources for other trees are not present (Kirby, 1984). The challenge for the forest manager is to manipulate the dynamic nature of birch stands to retain continuity of habitat as well as ensuring a sustainable yield of timber from the surrounding spruce. In large plantations covering many hundreds of hectares, this demands careful planning at the landscape scale.

In the uplands a typical semi-natural birchwood rotation (biological) is likely to be 100+ years and must be integrated with normal spruce rotations

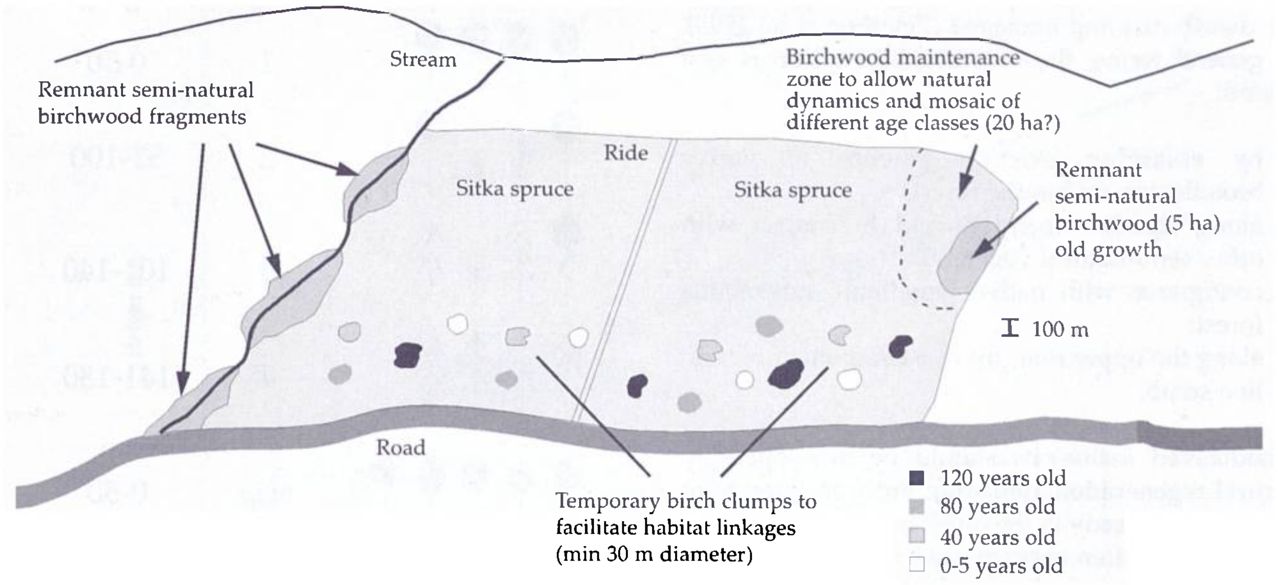

Figure 7.3 Location of semi-natural birchwood 'maintenance zone' within a hypothetical forest landscape

which are likely to be approximately 50 years. To ensure that birchwoods are maintained within the landscape, the Forestry Commission's management guide for birchwoods (Anon., 1994b), suggests aiming for a continuous supply of three or more age class groups. It is important to encourage expansion of birchwoods on to new ground to perpetuate birchwoods in the landscape over time and allow migration of species to stands as they mature. One way of achieving this might be to have a 'birchwood maintenance zone' within spruce forests based around existing semi-natural woodland fragments which would allow these fragments to regenerate onto open ground and create the appropriate age class mix (Figure 7.2). The older age classes would gradually decay and degenerate providing the valuable late successional habitat, while at the same time allowing the development of new birch regeneration on open clearfelled sites. However, on richer soil types, competing vegetation may restrict the potential for birch colonisation more than on poorer sites, where the establishment of ground vegetation is slower (Wallace, Chapter 2).

In lowland woods 5 ha blocks are considered to be a minimum size for providing a core woodland habitat as opposed to edge habitat (Usher, 1995). Peterken (1995) also considers 5 ha to be the minimum size for retention of woodland habitat and processes. Therefore to retain three or more different age-classes as recommended (Anon., 1994b), it seems reasonable to aim for a minimum size of 15-20 ha for these maintenance zones with mature or over-mature birchwood habitat comprising 5 ha at any given time (Figure 7.2).

In smaller spruce forests (<50 ha), the opportunity to manage birch at the landscape scale is limited. Semi-natural birchwoods may be restricted to small fragments and management to create a range of age-classes may not be possible. In these situations, the best choice from a biodiversity perspective (assuming that spruce should be retained for commercial reasons) would be to convert the stand to a birch/spruce mixture or mosaic. Options for the management of these mixtures and mosaics are discussed in the Management recommendations section towards the end of this chapter.

Management of birchwoods at the regional scale

At a much wider regional scale, 'biodiversity friendly plantations' with a significant proportion of broadleaves have a role in linking woodland habitats. In the past, site scale measures have been used to conserve relict woodland habitats (e.g. SSSI designations). This approach is generally regarded as insufficient for several reasons: it has failed to arrest loss and fragmentation of semi-natural habitats outside identified sites; it does not afford protection to species with large ranges and territories; it takes no account of the seasonal migration and dispersal of many species; and it provides no linkages between areas of suitable habitat (Peterken *et al.*, 1995). Forest habitat networks need to be developed to enlarge and reconnect existing woods, thereby creating a more complete and ecologically coherent forest resource. For Scottish woods, for example, such networks could embrace the whole forest resource. The limited forest cover of Scotland necessitates that the emphasis be placed on creating new forest habitats. Modified plantation forests could make a major contribution to the network provided they are restructured to provide woodland habitat as described above. Clearly, the effectiveness of Scotland's forest habitat network for wildlife depends on how the native broadleaved and conifer element within the plantation forests are distributed and managed (Peterken *et al.*, 1995). In general terms, the broadleaved portion is best placed:

- by enlarging existing patches of native broadleaves within the forest;
- along riparian corridors and in contact with other semi-natural vegetation;
- contiguous with native woodland outside the forest;
- along the upper margins as a component of tree-line scrub.

Broadleaved inclusions should be developed by natural regeneration spreading out from groups of native trees already in the forest in the form of irregular patches, often concentrated near outcrops and streams, and groups established after clearfelling. Planting and protecting clumps of birch on rides, roadsides and streamsides, at intervals of about 150-300 m, and at least 10-15 years before felling starts in adjacent conifer plantations, will create seed sources and should be an efficient way of expanding birch in first rotation spruce monocultures (Patterson, 1993).

Silviculture and dynamics of birch/spruce mosaics and mixtures

Birch/spruce mosaics

In this section we consider what might be the long-term prospects for birch/spruce mosaics in terms of their stand dynamics. We also consider some ideas for managing and maintaining such mosiacs, based on current theories of stand dynamics in even-aged stands (Oliver and Larson, 1990).

For this purpose, the assumed starting point is a uniform first rotation Sitka spruce forest of the type widely planted in upland Britain since the 1950s. The first possibility of introducing birch will occur during restructuring, with the consequent availability of clearfell sites (Figure 7.4). Assuming satisfactory establishment of planted or regenerated birch, after 40-50 years the birch may have reached 20 m in height and a stocking density of perhaps 300-400 stems ha^{-1} (stage 1) if thinned to give best stem quality when 6-10 m in height (cf. Cameron, 1996). At this stage, natural regeneration of Sitka spruce and other intermediate and shade-tolerant conifers could begin to colonise the understorey and initiate the process that will result in the replacement of the first birch stands by conifers as the old birch start to die (stages 2 and 3) (Figure 7.4). Eventually a pure spruce stand develops (stage 4) which is then felled, restarting the process (stage 5).

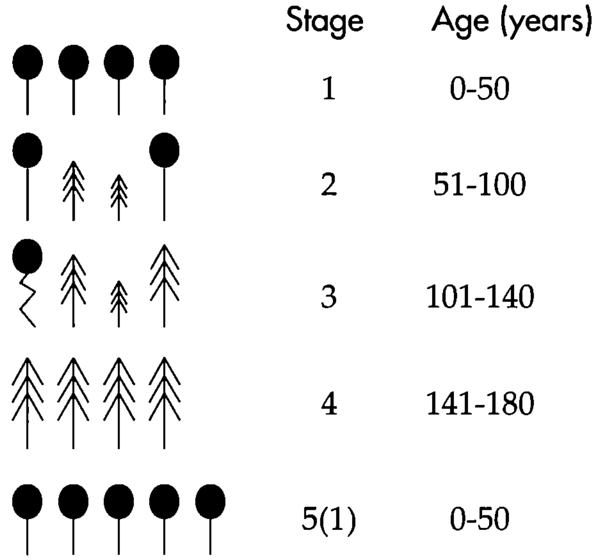

Figure 7.4 Theoretical development of birch stands in spruce forests over time; birch, spruce.

Since birch begins to seed at a young age (*c.*10 years) and parent trees produce large numbers of seeds (>150 000 m^{-2}; Cameron, 1996), natural regeneration of birch should have occurred throughout the surrounding clearfelled coupes, and allowed development of successor seed stands and re-colonisation of the original stand. Thus over time, there will be a shifting mosaic of pure birch, pure spruce and spruce/birch mixtures occurring at different stages of successional development. Spruce should be prevented from colonising some of these birch clumps to allow 'old-growth' (i.e. deadwood) birch communities to prosper and spread to new sites.

The realisation of this hypothetical succession between birch and spruce will depend upon a number of critical factors including the comparative competitiveness of the two species on different site types (e.g. peaty gleys as against brown earths) and the differential browsing pressure from deer. Other studies (e.g. Ratcliffe and Mayle, 1992) have shown that roe deer browse broadleaved regeneration in preference to conifers. Therefore, this succession may not be viable where deer densities exceed 5 beasts 100 ha^{-1}.

Birch/spruce mixtures

From a biodiversity perspective birch/spruce mosaics yield more benefits than intimate mixtures of the two species. However, these mixtures are likely to arise naturally and could be usefully managed for commercial benefits and landscape enhancement.

Little formal research on the dynamics of Sitka spruce/birch mixtures has been carried out in Britain, so conclusions on the likely development of mixed stands of these species must be derived

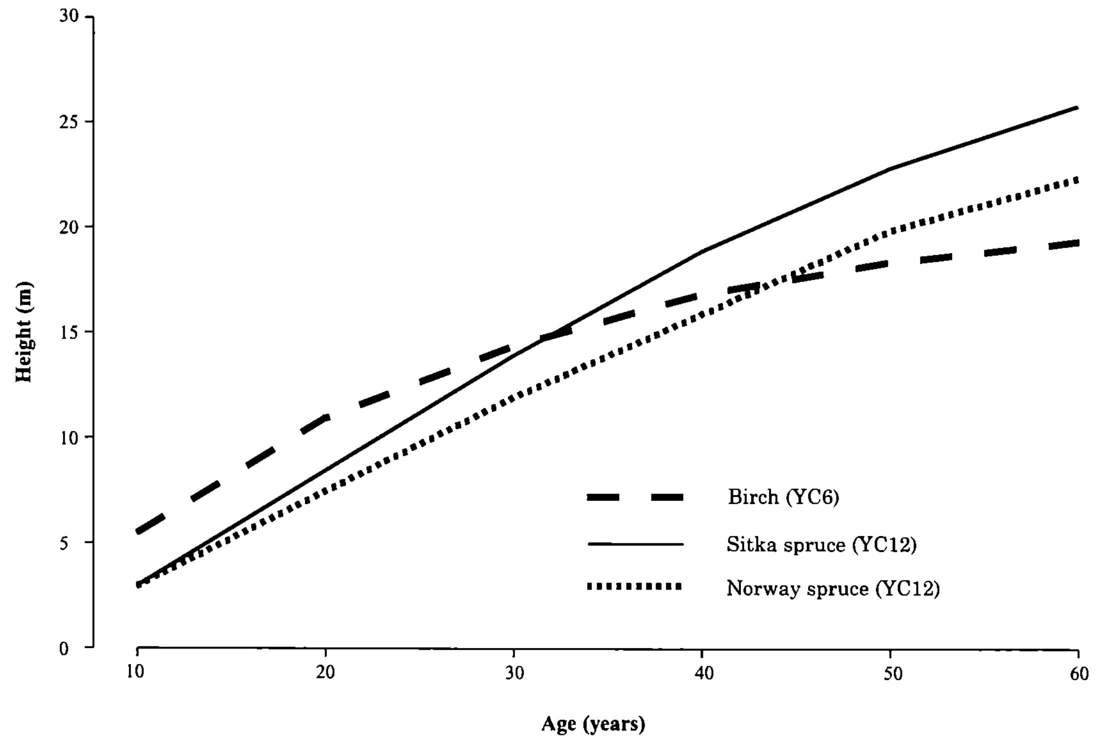

Figure 7.5 Height growth of Norway spruce (*Picea abies*), Sitka spruce (*Picea sitchensis*) and silver birch (*Betula pendula*) over time. (Adapted from standard yield tables: Edwards and Christie, 1981)

either from the Scandinavian literature or from first principles. Studies of planted Norway spruce/birch even-aged mixtures show that birch height growth is much faster than Norway spruce in the early stages and creates a two-storied structure with an overstorey of birch and an understorey of Norway spruce. Birch height growth slows in the latter stages of stand development and spruce gradually assumes dominance (Figure 7.5). Except on nutrient poor and/or dry sites, these stands will eventually develop into pure spruce stands due to the break up of the birch overstorey through snow damage or other causes of mortality of the short-lived birch (Frivold and Groven, 1996; Johansson, 1996).

A number of studies have been undertaken into the yield of these mixed stands (e.g. Mård, 1996; Tham, 1988). The findings generally show a reduction in spruce volume in treatments with an overstorey of birch compared with pure plots of spruce. However, this is often outweighed by the gains in birch production. Thus, in a study of eight Swedish sites, Mård (1996) reported that total stem biomass of two-storied birch/Norway spruce stands was *c.*50% greater than the pure spruce stands. In addition, it has been found that, following removal of the birch at around 30-40 years (e.g. in a fuelwood thinning), the Norway spruce understorey recovered vigour and grew similarly to trees in pure plots (Tham, 1988). While these results are based upon studies with silver birch, they can be extrapolated to mixtures with downy birch, but the yield of the downy birch component is likely to be less than with silver birch, based on evidence from pure stands (Frivold and Mielikäinen, 1991).

The extent to which these results can be extrapolated to British conditions depends upon the relative growth rate and shade tolerance of Sitka spruce when compared with Norway spruce. While definitive data are not available, there are indications that Sitka spruce may be less easy to manage in mixture with birch than Norway spruce. The growth data plotted in Figure 7.5 show that although Sitka spruce has a similar pattern of slow initial height growth to Norway spruce the subsequent growth of the former is faster so that it would be competing in the crown with birch by about 30 years whereas this may take another 10-15 years in Norway spruce. Limited studies on shade tolerance of non-native conifers (e.g. Brown and Neustein, 1970) also indicate that Sitka spruce is less shade tolerant than Norway spruce. This suggests that the competitive pressures exerted by birch upon Sitka spruce in Britain may be greater than upon Norway spruce in Scandinavia, and more intensive remedial cleaning or respacing of the birch may be necessary to avoid substantial penalties in terms of reduced spruce yields. This could be particularly important on high windthrow hazard classes where Sitka is unthinned and grown for pulp/roundwood on short rotation, and good early growth rates are required.

The biggest operational difficulty encountered by managers is deciding when and how much competing birch to remove. Such 'cleaning' operations should generally take place when the spruce are 4-5 m tall and are entering the 'stem exclusion' stage. There should be no need to remove the birch if the spruce are of similar height or taller since the latter will out-compete the former within a few years. If the broadleaves are appreciably taller than the spruce, then it is recommended that the birch be reduced to a density of perhaps the best 100 stems ha^{-1} and allow these to grow to produce quality stems at *c*.40 years of age.

It should be clear from the above that there are substantial uncertainties attached to the management of birch/spruce mixtures in Scotland. In particular, we need to know how far the development of these mixtures conform to results reported from Norway spruce/birch mixtures in Scandinavia and how the British experience may be affected by soil type and/or exposure. We also need to be clear on the extent to which downy birch and silver birch differ in terms of their development in mixture with Sitka spruce. There are reports of nutritional nursing benefits from spruce growing in mixture with birch (McRobbie, 1991) and limited field experimentation has confirmed these results to date. In a nursing experiment established on a deep peat site in Shin forest near Lairg, the growth of Sitka spruce was significantly enhanced when grown with a birch (*B. pubescens)* nurse (Table 7.1).

Establishment of birch from seed

Wallace (Chapter 2) has shown that birch readily colonises clearfell sites by natural seeding from existing trees, which usually occurs along rides or roadsides. Natural colonisation is usually restricted to areas 100-200 m from parent trees. In parts of the forest where parent seed trees are absent, birch clumps can be established by direct seeding. Two pilot experiments established in the late 1980s by the Forestry Commission examined the effects of different ground preparation techniques on the success of birch establishment from seed on different site types (Patterson and Humphrey, unpublished data). Seedling densities of up to 127 600 stems ha^{-1} were achieved for downy birch after 1.5 growing seasons and 65 600 stems ha^{-1} for silver birch after 2.5 growing seasons (without ground preparation or fencing). Direct sowing of birch therefore appears to be a cheap and effective establishment method for both clumps and mixtures.

Management recommendations

We consider that the presence of birch in Sitka spruce stands is part of the inevitable 'naturalisation' of first rotation conifer forests, and that the dynamics of these mixed stands can be managed to provide both timber and biodiversity benefits. In terms of the management of these mixtures and semi-natural birchwoods, the following general principles and management recommendations have been highlighted:

1. Existing semi-natural birchwoods have high biodiversity value, particularly mature habitats with larger trees and deadwood; these should be maintained and expanded.

2. Spruce stands have a value in their own right for biodiversity, especially for invertebrate groups such as hoverflies (Syrphidae).

3. There are some benefits to biodiversity from transient intimate mixtures of birch and spruce, but birch/spruce mosaics with birch clumps of 30 m or more in diameter provide additional habitats for a range of species and could also function as habitat linkages between existing semi-natural birchwoods. A range of birch 'clump' ages will be needed to ensure continuity in supply of older growth stages.

4. Semi-natural birchwoods are very dynamic in space and time and birchwood 'maintenance zones' should be identified with a suggested minimum area of 15-20 ha, to allow full and continual development of successional stages. Core 'old growth' birch stands (5 ha minimum) should be perpetuated within these 'maintenance zones'.

Table 7.1 The effects of nitrogen fertilisation and nursing by birch (*B. pubescens*) and Scots pine (*Pinus sylvestris*) on the height growth of Sitka spruce after 11 years (J.C. Dutch, unpublished data)

Treatment	Height of Sitka spruce (m)
Control	2.17
Nitrogen only	3.23[a]
Birch nurse	2.47[a]
Scots pine nurse	2.72[a]

[a] Significant difference (p<0.05) between treatment and control.

5. Natural stand dynamics of birch/spruce mosaics suggest that spruce will eventually colonise old birch clumps. To avoid detrimental effects on biodiversity, some of these old clumps should be kept free of spruce to provide continuity of over-mature birch habitat, and new areas for birch establishment should be provided to replace birch clumps which revert to spruce.

6. Although there are uncertainties about whether birch and Sitka spruce can be grown successfully in mixture, there is evidence that the initial growth of spruce on poor soils may be improved where birch is present. However, considerable 'cleaning' of the birch may be needed in the longer term to avoid substantial penalties in spruce yield.

7. Birch can be readily established by natural colonisation if seed trees are within 150 m or successfully established by direct seeding.

Suggestions for further research

Birch and other native broadleaves will become an increasing component of spruce forests in the future. Increasingly the management of conifer-broadleaved mixtures will become a focus for both ecological and commercially based research, mirroring to some extent the current situation in countries such as Sweden and Finland where broadleaves are a significant component of semi-natural boreal forests. Specific research needs include:

- Improve knowledge of the stand structure and dynamics of semi-natural birchwoods, especially within conifer plantations.
- Test the hypothesis that older birch clumps may act as habitat stepping stones for key (rare) birchwood species (e.g. old-birchwood Lepidoptera such as *Pheosia gnoma, Polia nebulosa* and *Eugnorisma depuncta*).
- Obtain better information on the habitat requirements and life history traits of these key birchwood species.
- Determine the potential of old conifer stands as a habitat for saproxylic species.
- Investigate the long-term stand dynamics of birch/spruce mosaics perhaps by modelling.
- Explore silvicultural solutions to maximising the yield and timber quality of spruce/birch mixtures.

Acknowledgements

This chapter is based on a presentation made at the symposium 'Birch in spruce plantations: management for biodiversity'. The authors have relied heavily on the research of Hilary Wallace, Allan Watt, David Barbour, Alan Orange and others, which has been reported in Chapters 2-6. Helpful comments on early drafts were received from Elspeth Macdonald and from deliberation during symposium discussion sessions. Data presented in Table 7.1 were kindly supplied by Janet Dutch. The symposium and research project were funded jointly by the Forestry Commission and Scottish Natural Heritage.

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Poster abstracts

1

Argyll hazel woods: management for biodiversity

PETER R. QUELCH

The options for sustainable management of Argyll hazel woods are demonstrated, with emphasis on maintaining biodiversity, particularly the richness of Atlantic bryophytes and epiphytic lichens. The Atlantic coast of Scotland is home to extensive areas of hazel scrub of high nature conservation value. There is evidence of historic use of much of this resource for at least casual coppice management for a range of uses including barrel hoops, thatching spars, lobster creels and hurdles. Their history this century is one of long neglect, but this lack of disturbance in some hazel woods has allowed luxuriant growth of bryophytes and lichens.

A revival of interest in coppice management has promoted a close look at other options for management of this woodland type. The main options are listed and a new silviculture of 'coppicing with retentions' is suggested.

Also described is a demonstration woodland in the Barnluasgan Reserve in Knapdale Forest (FE), managed by Argyll Green Woodworkers Association. Some outstanding lichens are illustrated in new photos by Lorne Gill of SNH.

2

Is birch a soil improver? Effects of birch growth on acid soils on the Isle of Rum

ANNA J.P. CAMPBELL and BRIAN R. WILSON

The ecological importance of native woodland in the Scottish Highlands and Islands is widely acknowledged and many calls for its expansion have been made. There has been a considerable amount of research into the effects of such an expansion on the above ground ecosystem, but little is known about the impact it would have on the underlying soils. Experimental tree plots, containing species native to western Scotland, were established on the Isle of Rum National Nature Reserve during the 1960s. Studying the soils in these tree plots allows an assessment to be made of the effects of 35 years of native tree growth on soil properties.

Soil samples were collected from pure stands of birch (*Betula* spp.) growing on both acid, organic soils and on less acid, mineral soils. In each case samples were also collected from unwooded sites to provide a comparison. Comparison sites were selected which had the same topography and parent material as the wooded sites, so that any differences in the soil characteristics between them could be attributed to the effects of tree growth. Differences in the soil moisture content, bulk density, loss on ignition, pH and extractable cation content were identified.

Preliminary results indicate that the growth of birch has contributed to a reduction in soil organic matter and acidity, although no significant increases in the availability of soil nutrients have as yet been identified. On this basis it appears that the growth of birch on acid soil has led to a partial soil improvement. The results of this research will be applicable to much of western Scotland, enabling predictions to be made regarding the effects of birch woodland expansion on soil characteristics.

3

Why manage riparian woodlands?

JOHN PARROTT

Scottish Native Woods (SNW) recently produced a suite of publications on the management of riparian woodlands:

- *Why Manage Riparian Woodlands? Information and Guidance for Managers*: a 20 page colour booklet describing the importance of riparian woodlands and providing advice on their management.

- *Grants*: a 6 page leaflet summarising the range of grants available for riparian management and suggesting some sources of advice.

- *The Riparian Woodland Ecotone*: a 55 page literature review researched by Neil MacKenzie, presenting a comprehensive review of published research on the ecological relationship between woodland and fresh water. This technical document is likely to be of value principally to those with a professional interest in the management of freshwater fisheries and riparian woodlands.

The SNW display comprises three free-standing wooden panels, made entirely from birch. Using photographs and a minimum of text, the panels:

- describe the importance of native riparian woodland for conservation, landscape and recreation;

- emphasis the crucial role they play in helping to maintain the health and productivity of rivers and burns, and especially salmonid production;

- summarise the benefits of improved riparian management;

- suggest some management options;

- describe some possible avenues for funding work.

A 3-year pilot project to promote the management of riparian woodlands in North and West Highland (launched in April 1997) is being part-funded by the Highlands and Islands Partnership Programme. The project organises talks and seminars, as well as establishing demonstration sites to disseminate information to riparian owners.

4

Ecological site classification for British woodlands: diagnosing soil nutrient regime

SCOTT WILSON

Ecological Site Classification (ESC) is a new system under development at the Forestry Commission's Northern Research Station. The aim is to provide a framework for classifying forest sites on an ecological basis, in order to underpin appropriate species selection and silvicultural practice for multiple-objective forest management. Sites will be characterised principally by variables of climate, soil moisture regime and soil nutrient regime. It is intended that the classes of soil nutrient regime should be recognisable in the field, without recourse to laboratory analysis. The poster provides an interim progress report on a PhD project being conducted at the University of Edinburgh to develop the use of ground vegetation indicator species and humus form as diagnostic tools for this purpose.

Some 70 forest sites throughout the UK have been studied over two field seasons, with both ground vegetation and soil being sampled at each. The ground flora species composition by cover fraction is being compared with the results of laboratory soil nutrient analyses to identify and quantify important inter-relationships. Interim results suggest that the ground vegetation can be used effectively to assess the status of the two key soil variables, base status and mineralisable nitrogen availability. Humus form can act as a useful secondary indicator of soil nutrient regime.

This new system provides the opportunity to understand the occurrence (and suitability for re-establishment) of the National Vegetation Classification (NVC) woodland communities in terms of fundamental site characteristics.

5

'Having your cake and harvesting it': the potential for birch timber from mixed plantations

ANDREW THOMPSON

An illustration is given of the potential for management of naturally regenerated or planted silver birch (*Betula pendula*) on high yielding sites to deliver quality timber in addition to biodiversity benefits.

Photo illustrations with captions show:

- Existing birchwood remnants of very high biodiversity value: scope for further enhancement through management of mixed plantations providing habitat linkage between isolated remnants.
- Effect of early thinning on diameter growth of silver birch.
- Potential for spruce plantations to yield significant component of high quality birch timber at clearfell.
- Example of highland grown silver birch, suitable for veneer peeling or furniture production.
- Sample of high quality birch plywood produced from highland grown silver birch log.
- Examples of other high added-value product potential for birch timber, produced from well-managed birch stands or stand components.

6

Vegetation responses to fire disturbance in a primeval pine-spruce forest in Finland

PETER R. HOBSON
and JED BULTITUDE

A comparative study of the vascular plant and lichen communities was carried out in three distinctive post-fire forest stands in Oulanka National Park, Kuusamo, Finland.

Old growth stands, over 200 years old, consisted of predominantly well-spaced mature *Picea abies* punctuated by *Betula pubescens* and *Pinus sylvestris*. Deadwood of variable diameters was a prominent feature. Mid-successional stands established since 1839 supported a higher density of stems including deadwood, and with greater presence of *Pinus sylvestris*. In both stands the field layer was robust, dominated by ericoidal shrubs, in particular *Vaccinium myrtillis*. Late successional woodland species were also apparent including *Paris quadrifolia* and *Melampyrum pratense*. Recent burn sites (1925) were almost all *Pinus sylvestris* and little deadwood. The field layer was patchy with scant cover of *Calluna vulgaris* and lichen-dominated ground cover.

Greatest lichen diversity occurred in old-growth sites with significantly fewer species present in intermediate successional stands and in recent burn sites. Similarly, overall abundance of lichens was highest in the mature stand and lowest in the early pioneer stands. Greatest cover of lichens occurred on small diameter wood (< 7 cm dbh). Stand-specific species in old growth wood included species of *Ramalina* and *Busnea*. Conversely, species exclusively associated with recent burn sites included *Foraminella ambigua*, *F. hyperopta* and *Parmeliopsis aleurites*.

List of delegates

Dr Jean Balfour
Dr David A. Barbour
Mr William Beattie
Mr Bob Black
Mr Iain Brodie
Ms Alice Broome
Mr Ken Brown
Dr Jed Bultitude
Mr Peter Cairns
Ms Anna J.P. Campbell
Mr Hugh Chalmers
Mr Douglas Clark
Mr Hugh Clayden
Mr James Connolly
Mr Baxter Cooper
Dr Brian J. Coppins
Ms Sandy Coppins
Mr Ian Cornforth
Mr John Darbyshire
Mr Ivor Davies
Mr Philip Davies
Mr Jim Dewar
Mr J. Dobson
Ms Angela Douglas
Mr Bob Dunsmore
Mr Colin Edwards
Mr Craig Forrest
Mr J. Fowler
Mr Ian Fraser
Ms Diana Gilbert
Mr Graham Gill
Ms Iris Glimmerveen
Mr John Good
Mr Tim Goucher
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Mr David Henderson-Howat
Mr Paul Hill-Tout
Dr Peter R. Hobson
Ms Kate Holl
Ms Jane Horwood
Mr Sid House
Mr Richard Howe
Dr Jonathan Humphrey
Professor Thomas Huxley
Mr Alister Jones
Mr Paul Kirkland
Ms Erica Knott
Dr John Kupiec
Mr David Laird
Dr Jim Latham
Professor Douglas Malcolm
Mr Bill Mason
Mr Colin McBeath
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Dr Allan B. Watt
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Dr Brian Wilson
Dr Scott Wilson
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Dr Stephen Worth
Mr Chris Wright
Mr John Youngs

The role and management of native trees within commercial plantations has been a focus of interest in recent years, particularly in upland areas. This Technical Paper brings together the findings from a series of research projects funded by Scottish Natural Heritage and the Forestry Commission, looking into aspects of biodiversity associated with birch in spruce plantations, and originally presented at a symposium in Perth in 1997.

Detailed information is provided on birch distribution in spruce forests, ground vegetation, lichens and invertebrates. A concluding discussion sets the research findings within the wider context of forest design planning, and highlights options for the future management of birch within spruce plantations.

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