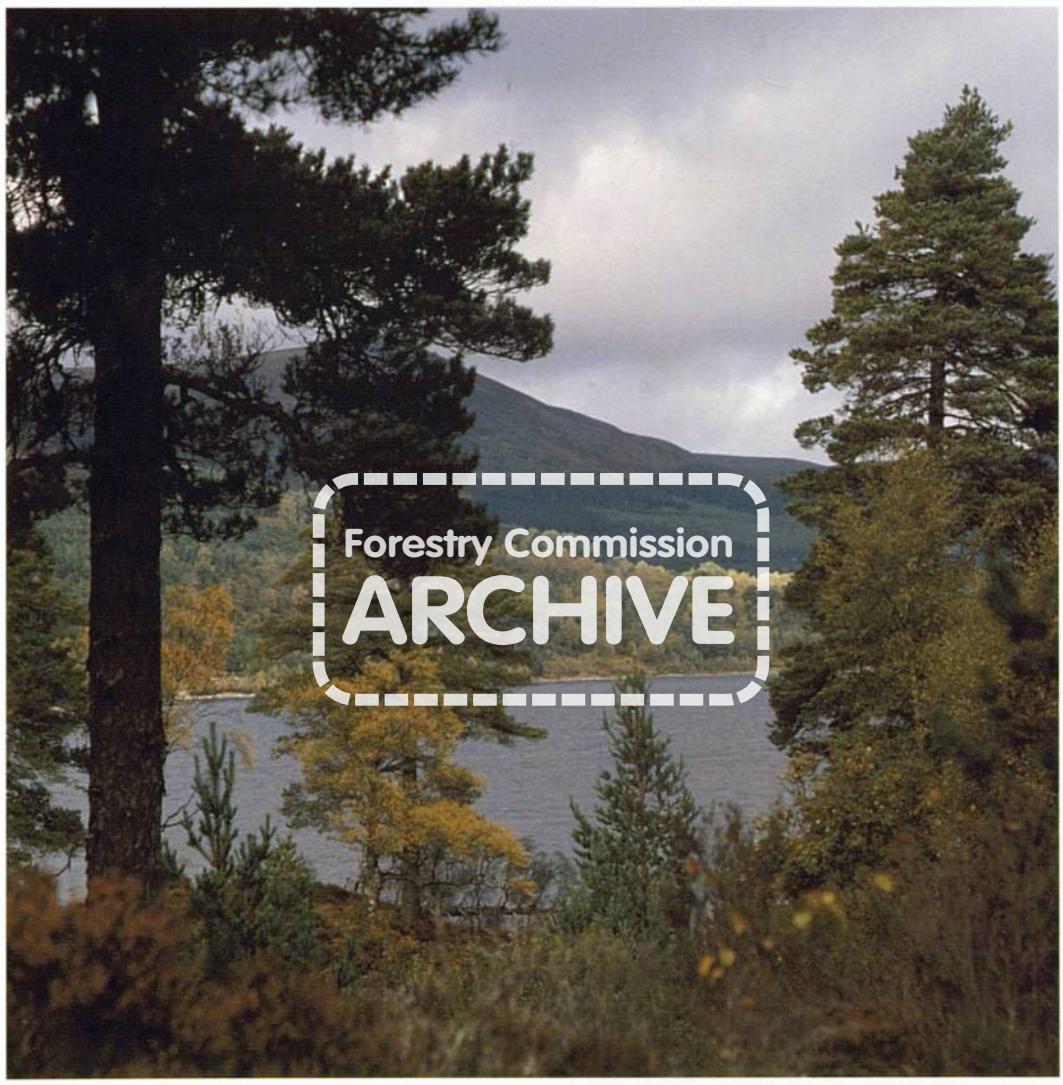
Forestry Commission

The Boreal Forests of Scotland

Richard Worrell



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Enquiries relating to this publication
should be addressed to:

The Research Communications Officer
The Forestry Commission, Research Division
Alice Holt Lodge
Wrecclesham, Farnham
Surrey GU10 4LH

Front cover: Scots pine and birch forest with boreal characteristics, Loch Benevean in Glen Affric (Forest Life Picture Library: 1011862020)

Back cover: World distribution of boreal forest

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Foreword

Recent years have witnessed increasing recognition of the importance of the global perspective in forestry. It is not only timber which is an international commodity: many of the multiple benefits of forests, emphasised in recent years, are of international importance for their contribution to, for example, global biological diversity, global cultural diversity and global climate control. Britain's international commitments made through the United Nations Conference on Environment and Development (UNCED), the Helsinki Conference of European Forestry Ministers and the European Union Habitats Directive, have led to the need to consider our forests in an international, rather than a purely national, context.

In January 1994, the UK Government published *Sustainable forestry: the UK programme* which describes how this country will fulfil its international responsibilities under the UNCED Statement of Forestry Principles and under the guidelines for sustainable management of European forests agreed at Helsinki in 1993. These agreements place a high priority on establishing a satisfactory future for forest ecosystems around the world; of which the boreal forests of Scotland comprise one small unique part. The unique characteristics of the world's boreal forests achieved recognition at an international scientific conference in Jokkmokk, Sweden, in 1992, which helped to place Scotland's boreal forests in the context of an oceanic outlier on the southern fringes of the vast circumpolar forests of North America, Scandinavia and Russia. The Caledonian Forest is identified in the European Union Habitats Directive as a priority habitat of European importance.

This Technical Paper is a result of the Forestry Commission's continuing commitment to both the Caledonian pine and birch forests of the Scottish Highlands, and the more recent conifer plantations, many of which share some characteristics of boreal forests. The study has several aims. Firstly, it contains much of the existing agreed basic knowledge on the current status of boreal forests in Scotland; their ecology, history, social importance, management and policy framework. Secondly, by tracing the affinities between the forests of the Scottish Highlands and the major forest biomes on the continent, it establishes their importance as a highly unique part of the vast belt of boreal forest which encircles the northern hemisphere. Thirdly, it discusses the possible benefits of adopting systems of management in the more recent conifer plantations which reflect the ecological processes and natural dynamics of boreal forests in other parts of the world. Finally, it documents recent policy developments and discusses briefly possible directions in which policy could develop.

Policies for forests in the Highlands have been evolving since the inception of the Native Pinewood Scheme in 1981, and have recently been strengthened by the designation of Caledonian Forest Reserves. This Technical Paper, with its wide geographical context and long time horizon, is intended to inform discussion and provide a useful basis upon which further developments can be built.

Graham Gill
Forest District Manager
Kielder Forest District
Formerly Head of Forestry Practice Division
Forestry Commission

Summary

This Technical Paper draws together information on the forests of the Scottish Highlands, many of which are regarded as being extreme oceanic variants of the boreal forest. The affinities between Scottish boreal forests and their European counterparts are assessed. Many of the Scots pine and birch forests in the Scottish Highlands appear to have sufficient similarities with many Eurasian boreal forests for the term boreal forest to be valid. However they are growing in a climate which is so strongly oceanic that a true boreal climatic zone cannot be identified. An account is given of the composition, structure, dynamics and history of Scottish boreal forests, and an assessment is made of their current status in Scottish forestry. The place of recent conifer plantations in the Highlands of Scotland is described, these having similarities with intensively managed boreal forests in, for example, Scandinavia. Recent forest policy initiatives are described and the future of Scottish boreal forests is assessed.

Chapter 1
Introduction

The global perspective in forestry has gained increased prominence during recent decades. Recognition of the international importance of forests began with tropical forests, but has now been extended to include all types of forest throughout the world. Boreal forests have received special attention, partly on account of their scale and their importance for both timber production and the conservation of biodiversity. This process of increasing awareness has involved dialogue between government, non-governmental organisations (NGOs), and the forestry industry, and is now underpinned by international agreements under the United Nations (UN) and the European Union (EU).

The native pine and birch forests of the Scottish Highlands are regarded by many British ecologists and foresters as part of the boreal forest biome (a biome being defined as the global vegetation zone, the characteristics of which are determined by climate and soil). However these woods are also clearly different in many respects from continental boreal forests. This Technical Paper explores the affinities between native woodland in the Scottish Highlands and boreal forests abroad and, in the light of this, considers the status of our native woodlands as part of the global boreal forest biome.

Planted forests in the Highlands can develop some similarities with boreal forests in Scandinavia or North America, particularly where these have been managed with timber production as a priority. The ways in which planted forests in the Highlands are similar to, or different from, boreal forests abroad are also described.

Considering British forests in an international context can be useful in several ways. It is increasingly recognised that in many situations there are considerable benefits in managing forests more as forest ecosystems and less as tree crops. The information which allows us to refine management prescriptions to achieve this is often available only from abroad; and we need to identify those forest types which are most similar to our own from which to import such information.

Native forests in Scotland have been altered by man to such an extent that natural features, management techniques and their place in the culture of Scotland have become obscure. Information which allows us to emulate natural forest ecosystems, to manage native forests effectively and to reinstate their social and economic value can all usefully be sought abroad.

Information about the status of British forests in the global context can also help in valuing them; if a forest type in Britain can be shown to be unique or valuable on a global scale, this heightens its value as a national asset.

As the international community shows increasing interest in the management of forests, we have a duty to make information on our forests available to interested parties abroad. This Technical Paper is therefore intended to act as a means of providing both domestic and foreign readers with basic information upon which an exchange of information could be developed.

The topics covered are:

- The main characteristics of boreal forests.
- The affinities between forests in the Scottish Highlands and boreal forests abroad.
- The nature and status of those forest types in Scotland which have boreal characteristics, including their composition, dynamics, history and management.
- Current policies towards both native woodland and planted forests, and the directions in which policy and practice could develop.

Chapter 2

Boreal forest: definitions and characteristics

Definitions

Boreal simply means northern, after *Boreas*, a personification of the north wind in Greek mythology. The term 'boreal' is used to describe:

- The northernmost forests, or forest biome in the northern hemisphere.
- The associated flora and fauna, i.e. species with a boreal distribution.
- The climatic zone in which the forests grow, i.e. the boreal climatic zone.

The boreal forest

Distribution

Boreal forest is taken to mean the zone of northern coniferous forest (also called Taiga) which stretches round the northern hemisphere between 50°N and 65°N, to the south of the arctic tundra and to the north of mixed or deciduous temperate forest (see Figures 3.1, 3.2, 3.3, 3.4). The southern limit of the boreal forest zone is clearly displaced northwards in oceanic areas such as western Europe and Alaska due to the moderating influence of the ocean on winter conditions.

Tree species

Boreal forests are predominantly coniferous. Relatively few species are represented, of which spruces (*Picea* spp.), pines (*Pinus* spp.), larches (*Larix* spp.) and firs (*Abies* spp.) are most important. The broadleaved component is of limited abundance, though broadleaves generally dominate during early successional stages or near treelines. Birches (*Betula* spp.) and aspens (*Populus* spp.) are the most abundant broadleaved species; alders (*Alnus* spp.) and willows (*Salix* spp.) are locally abundant on wet sites.

Dynamics

Fire caused by lightning strike is a major ecological factor determining forest composition and dynamics, particularly in continental boreal forests. Wind assumes greater significance in more oceanic areas.

Sites and soils

The sites, soils and ecosystems are young, having been developed only during the 10-15 000 years since the last ice age; and younger still where land has been emerging from seas or lakes or exposed by retreating glaciers. Permafrost occurs at the most northern latitudes. The soils are typically acidic with mor humus, and podzols are common. Nutrient cycling is slow.

Vegetation

Ground vegetation is dominated by shrubs (particularly Ericaceae), feather mosses, and in some areas lichens. There are a restricted number of commonly associated and highly characteristic herbs such as wintergreens. Areas of mire (bog, peatland muskeg) are widespread, and may be expanding or contracting.

Fauna

Animal populations are relatively species poor. Herbivores include moose and elk (*Alces* spp.), deer, caribou and reindeer (*Rangifer tarandus*), beaver (*Castor fiber*) and squirrel. Predators include wolf (*Canus lupis*), fox (*Vulpes* spp.), lynx (*Lynx* spp.) and scavengers such as bear (*Ursa* spp.) and wolverine (*Gulo gulo*). Typical woodland birds include members of the grouse family, woodpecker, crossbill and a range of small songbirds; raptors are also well represented. Flies, beetles and aphids dominate the insect populations, with Diptera being relatively more abundant than in more southern ecosystems. Relatively little is known about other invertebrates.

Human social

Boreal forest regions are sparsely populated by humans, and human settlement has a relatively short history. Indigenous peoples still occupy significant areas. Opportunities for conversion of forest to agricultural use is limited. Compared with other temperate forests exploitation and management of the timber resource has occurred only recently. Boreal forests, particularly in Russia and north America, represent some of the last relatively unaltered forest landscapes outside of the tropics. Many of these characteristics (except the history of human settlement) are shared with tropical forests and contrast strongly with temperate mixed and Mediterranean forests.

Timber production

Boreal forests are valued for timber production, hunting and, increasingly, nature conservation. Management for timber production is still expanding. Currently, boreal forests produce 38% of the world's sawnwood, 19% of panels, 53% of mechanical pulp and 33% of chemical pulp (Kuusela, 1992a). Per capita annual income from timber exports ranges from $196 in Norway to $403 in Canada and $942 in Finland.

In Scandinavia forests have undergone a relatively long period of management, resulting in a transition towards even-aged crops managed for the production of high quality joinery and construction timber. Scandinavian forests are widely regarded as a model for efficient timber production. In Canada and Russia the majority of timber is derived from logging primary ('old growth') stands, converting these to more intensively managed stands.

Conservation

The small area of primary forest remaining in Scandinavia (*c.* 5%) and the loss of natural features is causing concern among nature conservation organisations (International Working Group on Boreal Forests, 1992). Management for timber production has caused reductions in biodiversity (Naturskydds Föreningen, undated; Heliövaara and Väisänen, 1986; Gustafsson and Hallingbäck, 1988). Considerable areas of primary forest still exist in Canada and Russia (*c.* 40-60%), but certain types of forest have been preferentially logged and are becoming more scarce (International Working Group on Boreal Forests, 1992; Wightman, 1992).

The boreal climate

The boreal climate is ultimately what determines the unique character of boreal forests and their associated flora and fauna. The principal feature of the boreal climate is extreme seasonal variation in insolation and temperature. The majority of the boreal zone coincides with continental landmasses. In these regions the climate is characterised by very low winter temperatures and fairly warm summers. The transition from winter to summer and vice versa is abrupt. The presence of snow during winter is practically ubiquitous, lasting for 5-7 months, and the frost-free season is short. Precipitation, a large part of which falls as snow, is generally low, 400-800 mm yr^{-1} being typical.

Towards the edges of the landmasses the climate is moderated by proximity to the sea and temperature variation is less extreme. The mean temperatures of the warmest months in such regions are often between 10°C and 15°C and the coldest months +2°C and -3°C (Kuusela, 1992a). Precipitation is also higher; Kuusela (1992a) states that annual precipitation in oceanic boreal forest in western Norway and Newfoundland may be up to 1000 mm. Snow cover is more intermittent and the frost-free season is longer.

On the basis of differences in climate, the boreal climatic zone can be split into maritime (or oceanic), continental and high continental subzones, of which the oceanic is the smallest (Kuusela, 1992a).

Chapter 3

Affinities between Scottish and European boreal forests

Climate

If a boreal zone exists in Scotland, it must clearly be a part of the oceanic subzone mentioned by Kuusela (1992a). Mean temperatures in Scotland fall close to the range quoted by Kuusela (see above), particularly on upland sites. For example, in Braemar and Wick the mean temperatures of the warmest months are about 12-13°C and the coldest months +0.4°C (Braemar) to +3.1°C (Wick). Annual rainfall values at low elevations in the central and eastern Scottish Highlands fall close to the maximum value of 1000 mm quoted by Kuusela (Wick 783 mm, Pitlochry 824 mm, Braemar 859 mm, Glenmore Lodge 1024 mm, Fort Augustus 1098 mm). However, at higher elevations and in the western Highlands rainfall significantly exceeds 1000 mm.

A large part of Scotland was classified as oceanic boreal by Birse (1976, 1982), including all of the western seaboard north of Skye. However, in a preliminary bioclimatic classification of Scotland for forestry, Pyatt (personal communication) classified the Highlands as 'temperate rainforest' and 'temperate moist forest', but suggested that it may be possible to identify a boreal subzone in part of the area.

Thus the climate of the Scottish Highlands can be conceived as having affinities with oceanic boreal, but with a strong element of transition to a temperate moist type. The climate is also characterised by rapid clines in temperature, moistures and windiness, particularly east-west and with altitude. Together these features represent a relatively unique combination of climatic characteristics in global terms.

Forest

The Scots pine and birch forests of the Scottish Highlands share (or shared) many, but not all, of the characteristics of boreal forests listed above; a restricted number of tree species is represented; ecosystems and soils are young and podzols are the most common soil type; the ground vegetation is dominated by ericaceous shrubs, mosses and lichens; the fauna is relatively species poor but several characteristic species of animal and bird are represented; and human settlement has a relatively short history.

The main differences between native forests of the Scottish Highlands and a 'typical' Eurasian boreal forest are:

- Tree species: only one conifer is represented (Scots pine: *Pinus sylvestris*) and *Picea* spp. and *Larix* spp. are notably lacking, and some broadleaved species are missing (e.g. *Alnus incana*).
- Flora: this has a greater frequency of oceanic species and communities compared with continental counterparts and several of the characteristic continental boreal plant species are missing.
- Fauna: this is relatively impoverished due to some species not having colonised and others having become extinct.

The forests of the Scottish Highlands are regarded by several British forest ecologists as being boreal. For example, Tansley (1949) states that:

> 'the most northern regions of Britain belong climatically to the coniferous forest formation of northern Europe, or more correctly to the transitional zone between this and the deciduous summer forest'.

and that [Scottish]

> 'birchwood and pinewood are properly considered as belonging to one climatic formation, the Eurasian formation of Northern coniferous forest ...'

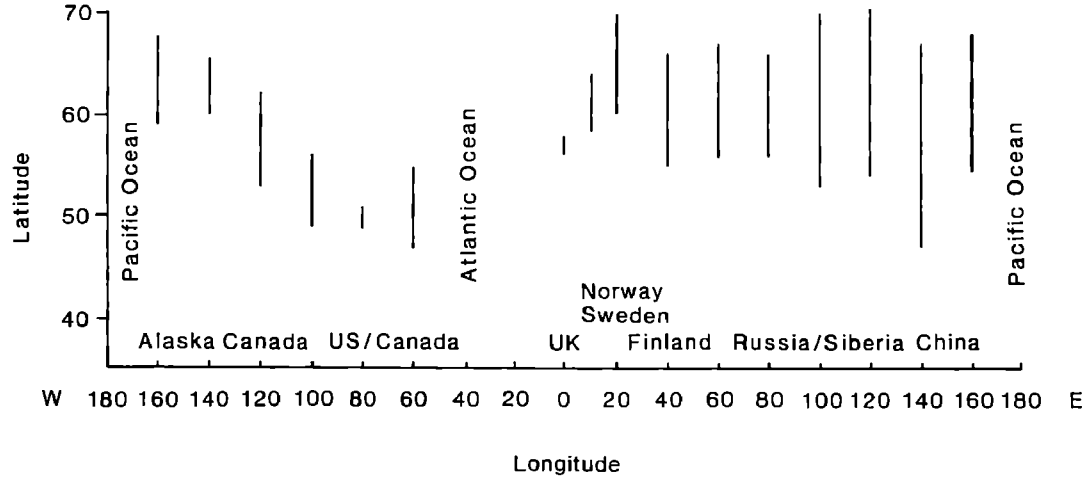

Figure 3.1 Latitudinal range of boreal forests at different longitudes

McVean considers the Scottish forests as:

> 'forming an extreme western phase of the west European transition from temperate deciduous forest, through boreal conifer forest to boreal deciduous forest',

the latter referring to the birch belt in north and west Scotland (McVean and Ratcliffe, 1962; Chapter 5 by McVean in Burnett, 1964). He continues:

> 'the distribution of native pine and birch in the northern Highlands .... is extremely like the situation in Norwegian and Finnish Lapland in spite of the difference in latitude' (Burnett, 1964).

Ratcliffe (1977) states that:

> 'The pinewoods of Scotland represent a southern and western outlier of the boreal coniferous forest of northern Europe.'

and adds rather paradoxically that birchwoods in northern Scotland:

> 'represent the closest approximation in Britain to the "Taiga" of the Arctic'.

Bunce (1981), Birse (1982) and Peterken (1986) all refer to the vegetation of northern Scotland as boreal.

Pine and birch forests in Scotland occur in a narrow latitudinal band between 56°N, and about 59°N (Stevens and Carlisle, 1959). This falls within that of the boreal forests of Eurasia and North America, though the southern limit is clearly displaced northwards due to the moderating influence of the Atlantic ocean (Figure 3.1). However, global maps of boreal forests sometimes include parts of northern Scotland and at other times do not (Figures 3.2 and 3.3). Equally they sometimes include western Norway, which has a forest flora similar to the Scottish Highlands, and sometimes do not (Figure 3.4). Thus there is no universally agreed definition of, or distribution for, boreal forest at the western end of their range.

Scottish boreal forests are remarkably similar to the forests of south-western Norway where Norway spruce is naturally absent (Table 3.1).

Table 3.1 Locations in Norway where forests bear the greatest affinities to Scottish boreal forests

Scotland	Norway
Western pinewoods	Parts of south-west Norway (Sogn, Hordaland, Rogaland)
Eastern pinewoods	Pine dominated sites in inland southern Norway (inner parts of Hordaland, Rogaland, Adger, Southern Telemark)
Northern birchwood	Coastal south-western Norway, especially islands in Hordaland and Rogaland

Figure 3.2 World distribution of boreal forest after Tamm (1976)

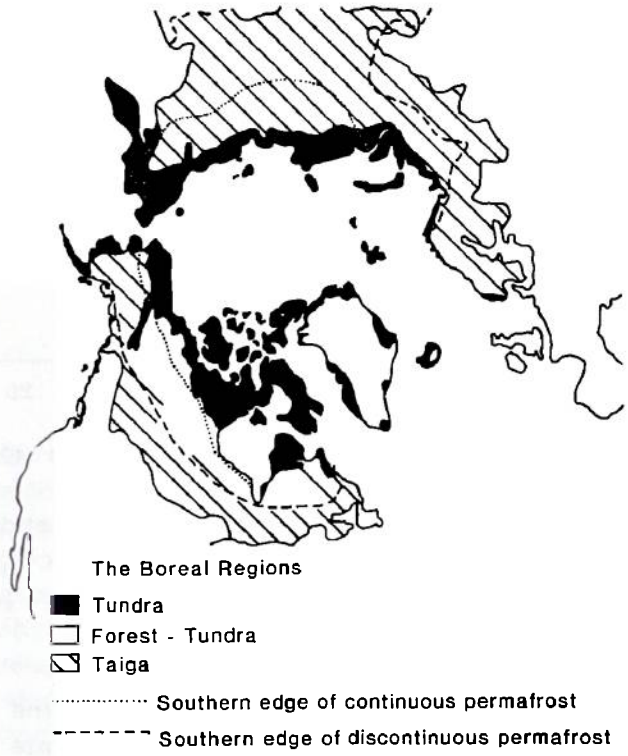

Figure 3.3 World distribution of boreal forest after Pruitt (1978)

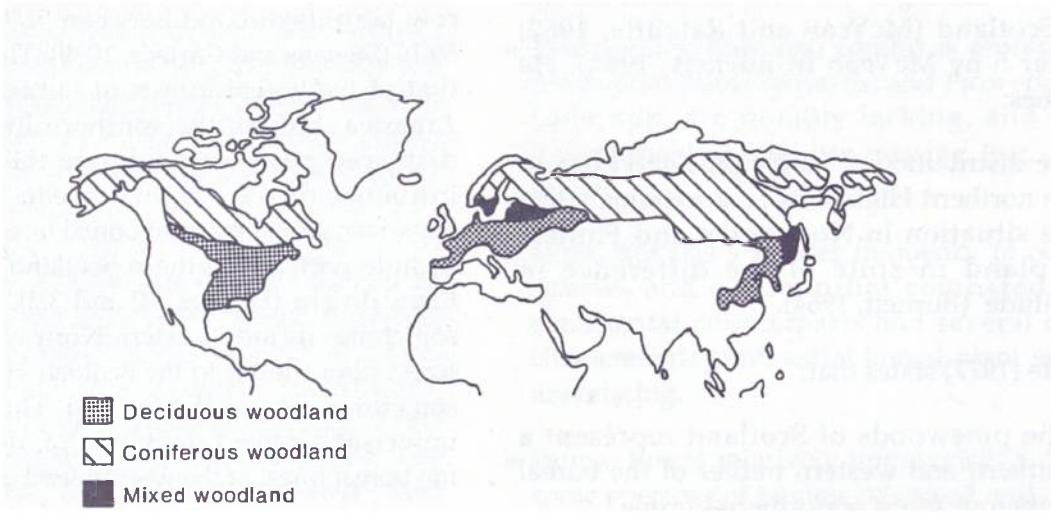

Figure 3.4 World distribution of boreal forest after Vasari (1977)

These are referred to in Norway as 'south boreal' at elevations of up to about 400 m, and mid boreal at elevations of 400 to 700 m (Haugen, 1992; Wielgolaski, 1993). The vegetation of the extreme western coastal strip (about 25 km wide) is referred to as boreo-nemoral, and has characteristics of both boreal and temperate mixed forest. Thus Norwegian ecologists regard most of their western forests as being essentially boreal, albeit with special characteristics resulting from their southern location and relatively oceanic climate.

Aune (1977) describes the 'west Norwegian heather pine forests' as being most similar to Scottish pinewoods. Such forests are probably restricted to 4 or 5 counties in south-western Norway and are relatively poorly documented. Aune (1977) states 'It is regrettable that the forest vegetation of western Norway has not yet been satisfactorily examined', and recent contacts confirm that this is still the case (Wielgolaski, personal communication).

It is not clear how much undisturbed forest remains in south-western Norway. Peterken (1992)

did not record any in his study of European virgin forests (see Figure 3.5). However, recent efforts by the Norwegian Government to identify and protect 280 km^2 of primary forest in Norway, 25 km^2 (2500 ha) of which were to be in western Norway has resulted in the mapping of 68 km^2 (6800 ha) of relatively undisturbed forest in western Norway (Haugen, 1992).

Transitions with other forest types

Scottish boreal forests intergrade with the other major forests' biomes in Scotland, namely:

1. *Temperate rainforest* (Alaback, 1990; Weigand *et al.*, 1992).

2. *Temperate mixed forest*, which is broadleaved in Scotland (Tansley, 1949; McVean and Ratcliffe, 1962; McVean, 1964a; Ratcliffe, 1977; Peterken, 1981; Peterken, 1989).

Thus most forests in the Scottish Highlands have affinities not only with boreal forests but with temperate rainforest and temperate broadleaved forest. Transitional types between the major biomes are common, even to the extent of being regarded as being dominant in the Highlands by some ecologists (P. Wormell, personal communication).

Temperate rainforest

In western parts of Scotland many of the typically boreal elements of the ground vegetation are lacking (Rodwell, 1991), and several phytosociological differences (differences in plant communities and their organisation) have been recorded between pine–birch woodlands in eastern and western areas which cast doubt on the boreal status of the western woods (McVean and Ratcliffe, 1962; McVean, 1964a; Rodwell, 1991).

Some ecologists have classified the most western parts of Scotland as 'coastal temperate rainforest', with affinities to those in coastal southern Norway, Canada, Alaska, Chile, Japan, New Zealand and Tasmania (see Figure 3.6; Weigand *et al.*, 1992). These forests are characterised by:

- An abundance of water throughout the year; rainfall >2000 mm yr^{-1}, spread over at least 100 days, and 10% or more occurring during summer months; the absence of fire as an ecological or evolutionary factor, but frequent disturbance by wind.
- Cool summers (July isotherm <16°C).
- Absence of persistent snow.
- Occurrence within 150 km of the coast (Weigand *et al.*, 1992).
- Abundance of bryophytes on the forest floor and in the canopy.
- Frequent epiphytes (Alaback, 1990).

Some authors refer to the most northern parts of the temperate rainforest biome as boreal or subboreal rainforest (Alaback, 1990; Haugen, 1992). Clarification is required of the bioclimatic zone and forest biome boundaries where boreal and temperate rainforest zones interface.

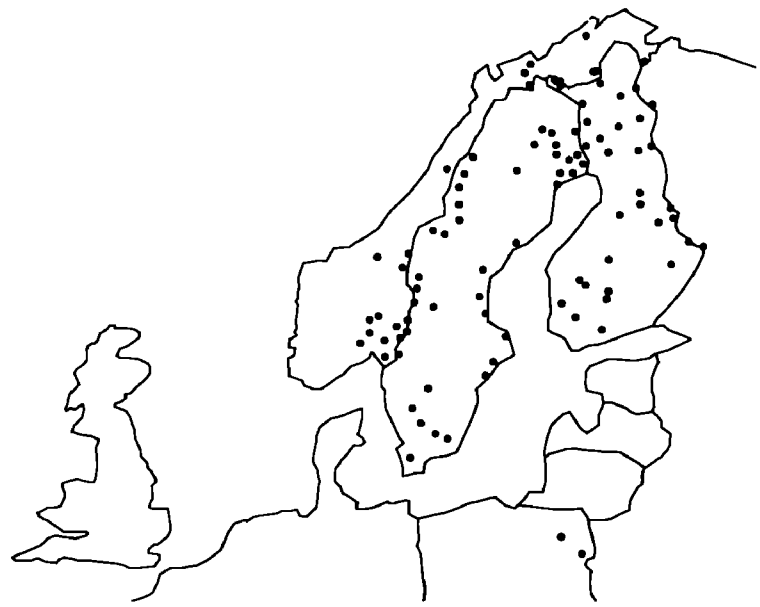

Figure 3.5 Distribution of near-virgin forest in Scandinavia (Peterken, 1992)

Figure 3.6 Coastal temperate rainforests of the world (Weigand *et al.*, 1992)

Temperate broadleaved forest

Temperate broadleaved forest exists to the south of the Highlands and extends up the major valley systems in the Highlands and up the west and east coasts (McVean and Ratcliffe, 1962). Such forests are characterised by the predominance of broadleaved trees and shrubs, relatively high summer temperatures and the presence of brown forest soils. The plant com-munities and fauna are similar to those of continental Europe.

Environmental clines

Thus, within Scotland there is an east-west transition within the Highlands from boreal forest in central Highlands to temperate rainforest in extreme western areas; and a north-south transition between temperate broadleaved forest mainly south of the Highland boundary fault and boreal forest to the north. In addition, transition between temperate broadleaved forest, boreal forest and even subalpine scrub occurs as a result of increase in elevation (McVean, 1964a). Thus many of the major valley systems in the Highlands have a clear component of temperate broadleaved forest, and pine and birch only begin to dominate on the valley sides (particularly on northern aspects).

The wide diversity of forest types within a relatively small area, the rapid transition between them, and the steepness of the climatic clines which give rise to them, are distinguishing features of Scottish forests. This complexity is compounded by the highly variable topography which complicates the process of delineating specific forest biomes. Some authors consider the problems to be so great as to render the task potentially fruitless (McVean, personal communication). The extreme variability of Scottish forests is a source of great interest and value; however, it complicates management, planning and the formulation of policy.

Relatively little work has been carried out clarifying the distribution of different forest biomes in Scotland since the efforts of McVean and Ratcliffe 30 years ago. A better understanding is needed of the distribution of forest types in Scotland, together with the climatic and site factors associated with them.

Conclusion on affinities

It can be concluded that the Scots pine and pine-birch forests in the Scottish Highlands have sufficient affinities with many Eurasian boreal forests for the term boreal forest to be valid. They are particularly similar to the oceanic boreal forests of western Norway, most of which are termed south boreal in Norway. However, they are growing in a climate which is more strongly oceanic than other regions where boreal forests occur and it is questionable whether the term boreal should be used to describe the climate in which they grow. This situation has arisen partly as a result of the high degree of disruption to the migration of tree species caused by glaciation and the isolation of Britain from western Europe.

Chapter 4

Boreal forest types in Scotland

Two Scottish forest types have been described as boreal:

1. **The Caledonian Scots pine forests** (Tansley, 1949; Stevens and Carlisle, 1959; McVean and Ratcliffe, 1962; Burnett, 1964; Rodwell, 1991). These include associated juniper (*Juniperus communis*) woodland (Rodwell, 1991) and a large component of birch woodland (*Betula pubescens* and *B. pendula*).

2. **The zone of birch dominated (*Betula pubescens*) forest to the north and west of the distribution of pinewood** (McVean and Ratcliffe, 1962; Burnett, 1964; Ratcliffe, 1977). This is considered by McVean to be equivalent to the zone of birch woodland found to the north of the coniferous boreal forests in Scandinavia.

Within these two broad woodland types smaller areas of other woodland communities exist dominated by species such as alder (*Alnus glutinosa*), willows (*Salix* spp.) and aspen (*Populus tremula*).

Thus, the broadleaved forest dominated by oak (*Quercus petraea*), which occurs in southern Scotland and penetrates the Scottish Highlands along valley floors and up the western seaboard, is not considered as boreal (McVean and Ratcliffe, 1962), though the ground flora of such woods may have a boreal component (Rodwell, 1991). Even some of the pinewood remnants in western Scotland are probably better considered, along with the western oakwoods and other broadleaved woods, as temperate rainforest.

At higher elevations remnants of treeline shrub communities occur, dominated by birch, juniper and willows (Tansley, 1949; Burnett, 1964; Rodwell, 1991). Such communities have affinities to sub-alpine shrub communities in boreal and continental regions, particularly those in Scandinavia.

In addition it could be argued that many of the planted forests of Scotland growing on sites which once supported natural boreal forest, represent a form of quasi-boreal forest, in which:

- species and mixtures of species are present which could not have arisen naturally;
- forest structure is greatly simplified;
- life cycle of trees is almost invariably curtailed and deadwood is practically absent;
- soils, ground flora and fauna develop in ways seldom replicated elsewhere.

Similar modifications have been introduced into boreal forests elsewhere, particularly Scandinavia (Naturskydds Föreningen, undated).

Whether it is useful to think of planted forests in this way is an open question. Such forests may be regarded as sufficiently non-natural that it is more appropriate to consider them exclusively as crops rather than components of ecosystems or biomes. The contrary view is that planted forests established on old woodland sites will acquire some characteristics of forest ecosystems. They can be managed to maintain and increase such affinities; and considering them as part of such ecosystems helps in this process.

In this study the native forest types with boreal affinities are divided, somewhat simplistically, into pine dominated woods, birch dominated woods and woods of other species. In addition, conifer plantations of exotic species are included where this is relevant and helpful. The area of Scotland regarded as having boreal affinities includes the eastern and central Highlands and those parts of northern Scotland to the east of the main watershed (eastern Inverness-shire, Easter Ross, most of Caithness

and eastern Sutherland). In this region, the natural forests have clear boreal affinities and the climate has some boreal, or at least, continental characteristics.

Areas near and to the west of the West Highland watershed are regarded as belonging to the temperate mixed forest and temperate rainforest biomes and the moist temperate climatic zone; though even here the pine and birchwoods show some affinities with boreal forests. One region of particular doubt in this respect concerns the extreme north-west of Scotland (Wester Ross and Sutherland).

Chapter 5

Characteristics of Scottish native boreal forest remnants

Scots pine dominated forests

Distribution

Native pinewoods occur within the Scottish Highlands in a narrow latitudinal band between 56° 22′ N and 57° 57′ N which excludes the extreme north of Scotland (Stevens and Carlisle, 1959). Those with the greatest boreal affinities occur in eastern Scotland, most notably in Deeside, Speyside and to the east of the watershed in Inverness-shire. Scots pine also occurs in oceanic areas of western Scotland. The eastern pinewoods can be distinguished from those in the west in terms of their genetic composition, structure, associated ground flora and their greater capacity to regenerate. The current extent of native pinewoods in Scotland is severely reduced from its former distribution (see Chapter 8).

Planted pine plantations cover *c.* 100 000 ha (1000 km^2) in the Scottish Highlands. Some of these show certain affinities to natural forests, particularly when older and on sites formerly occupied by pine (Rodwell, 1991; Callander and MacKenzie, 1991a).

Composition and structure

Scots pine (*P. sylvestris* var. *scotica* (Willd.) Schott) is the most abundant tree, with birch (mainly *B. pubescens* but some *B. pendula* in the east) and rowan (*Sorbus aucuparia*) as the most common associated tree species (Rodwell, 1991). Associated trees are typically infrequent, though this is thought to be partly a result of preferential interference by man (O'Sullivan, 1977; Rodwell, 1991). Birch, and in some places oak, are most common where pinewoods intergrade with other woodland communities. Other tree species which occur within pinewoods include alder (*Alnus glutinosa*) and willows (*Salix* spp.) in wet areas and aspen (*Populus tremula*). The most characteristic shrubs are holly (*Ilex aquifolium*) and juniper (*Juniperus communis*).

Stocking is variable, spanning the range from dense forest through to heath with trees. Canopy cover is usually less than 70%, with the denser woods being found in east Scotland, more open ones in the west (Stevens and Carlisle, 1959; McVean and Ratcliffe, 1962).

A mosaic of well-segregated age classes exists in most of the large woods. McVean and Ratcliffe (1962) noted three arrangements: even-aged 80-150 years old, two generation mixtures 150-200/80-100 years old; and pine heaths with trees 150-200 years old. In most woods old trees predominate (maximum age 300). Dead trees, fallen dead wood and regeneration, although present, are all rare.

The canopy is usually 13-15 m high though occasionally reaching 20 m on more fertile sites (Stevens and Carlisle, 1959; Rodwell, 1991). It is often stated that bigger, better formed trees have been preferentially extracted.

Classification

The National Vegetation Classification (NVC) recognises five subcommunities of *Pinus–Hylocomium* woodland according to the phytosociology of the ground cover (Figure 5.1). The NVC also identifies a separate *Juniperus communis–Oxalis acetosella* community (W19) where Scots pine may occur as isolated trees. This community often occurs as an ill-defined mosaic with, and as a successional stage towards, *Pinus–Hylocomium* woodland. McVean and Ratcliffe (1962) divided the pinewoods into two associations; a pinewood *Vaccinum*–moss association common in the central and northern Highlands and a pinewood *Vaccinium–Calluna* association which is characteristic of more open pine and pine-birch forest and includes the forests of western Scotland. The relationships between the current NVC classification and those produced by other ecologists are given in Rodwell (1991) and some are shown in Appendix 1.

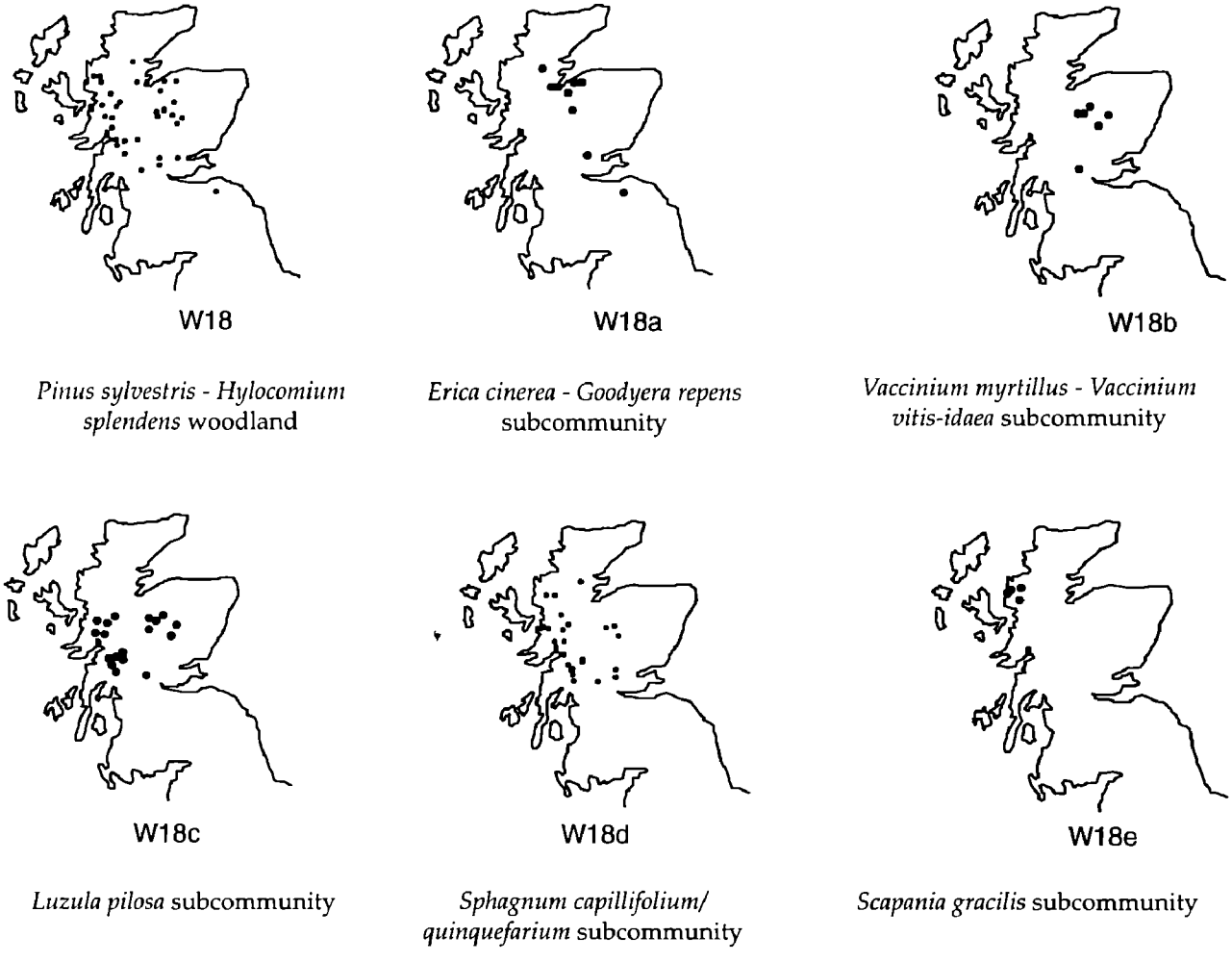

Figure 5.1 Subcommunities of pine woodlands according to the National Vegetation Classification (Rodwell, 1991)

Affinities with continental forest types

Genetic affinities

Whether Scots pine in Scotland colonised via land bridges from the continent and subsequently through England, or from glacial refuges to the west of Scotland or Ireland, has not been satisfactorily resolved. Colonisation from the continent was assumed by early workers on the basis that the severity of climate precluded the possibility of glacial refugia, and because fossil evidence for pine in late glacial refuges was absent (McVean and Ratcliffe, 1962; Goodwin, 1975). In addition, study of morphological traits and monoterpene composition revealed a large degree of similarity between some native and continental populations (Carlisle, 1958; Stevens and Carlisle, 1959; Forrest, 1982).

The hypothesis of colonisation from glacial refugia has recently gained support from studies of pattern of migration of the species into Britain during the Holocene. A discontinuity exists in the pattern of spread from England to Scotland in the region of the borders and central valley, while pine appeared spontaneously in north-west Scotland (Figure 5.2; Huntley and Birks, 1983; Kinloch *et al.*, 1986; Birks, 1989). Further evidence is provided by studies of the genetic structure using monoterpene and isozyme analysis (Kinloch *et al.*, 1986) which have revealed that populations in the north-west of Scotland are genetically distinct from those elsewhere in Scotland.

Phytosociological affinities

The pinewoods of Scotland belong to the Vaccinio-Picetea of Braun-blanquet *et al.* (1939); i.e. the spruce, pine–birch communities of

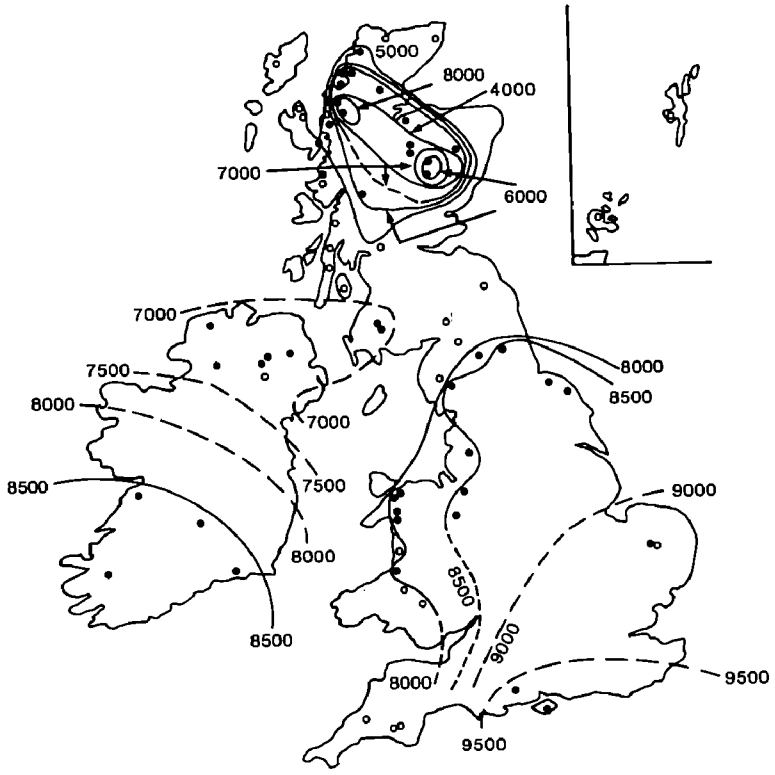

Figure 5.2 The spreading of Scots pine during the Holocene based on pollen analysis (Birks, 1989). Isochrones (lines of equal date) are based on data from the sites indicated by dots and are shown as radiocarbon years BP. Sites where the pollen record shows no evidence for local presence are shown as open circles. Broken lines indicate estimated isochrones where data points are sparse.

northern, eastern and montaine Europe on acidic podzolic soils (Peterken, 1981; Rodwell, 1991). The nearest equivalent in Europe is to be found in the pine forests of western Norway, where the climate is relatively oceanic (Aune, 1977; Rodwell, 1991).

McVean and Ratcliffe (1962) and McVean (1964) equate the pinewood *Vaccinum*-moss association with the Pineto-Vaccinetum myrtilli of Braun-Blanquet *et al.* (1939) and record close affinities between the ground flora of Scottish and Norwegian woods of these types. (They also reported that the closest continental equivalent to McVean's pinewood *Vaccinium-Calluna* association appears to be among the spruce forest associations of central Europe (e.g. the Mastigobryeto-Piceatum of Braun-Blanquet *et al.*, 1939) which do not have a typically boreal distribution). Both the dry Cladonia dominated pinewoods and more calcicole pinewood associations which occur in Norway are practically absent in Scotland.

Sites and soils

Pinewoods occur on cool sites, usually at elevations between 100 and 460 m, though occasionally lower in the west and up to about 600 m in the Cairngorm mountains. These extend from glacio-fluvial deposits on valley floors, to morainic drift on valley slopes and skeletal soils on clearly submontaine sites at high elevation. Pinewoods are particularly common on northern aspects. Pine often dominates on raised topography where soils are freely draining (e.g. moraines and drumlins) with broadleaves in the wetter hollows (Malcolm, 1957). Soils under pinewoods are generally podzols and are strongly leached and acidic (Malcolm, 1957; Fitzpatrick, 1977; Rodwell, 1991). Pinewoods also occasionally occur on gley and peats (Fitzpatrick, 1977).

Ground vegetation

Most of the ground flora species associated with pinewoods are calcifuge (acid loving) sub-shrubs, herbs and bryophytes, together with a few grasses. The ericaceous sub-shrubs

Vaccinium myrtillus, Vaccinium vitis-idaea and *Calluna vulgaris* are more consistently frequent in pinewoods than in any other British woodland community (Rodwell, 1991). The abundance of these shrubs varies with canopy cover and grazing pressure, *Calluna* being most frequent in open woodlands. *Erica tetralix* is locally frequent on wetter sites in the west. The species *Erica nigrum* ssp. *hermaphroditum* and *V. uliginosum*, both of which are important species in some Scandinavian pinewoods, are rare in Scotland.

Mosses constitute an important component of the ground flora, particularly *Hylocomium splendens, Dicranum scoparium* and *Pleurozium shreberi*, along with uncommon species such as *Ptilium christicastrensis*. *Cladonia* lichens which characterise many Scandinavian pinewoods are relatively rare. Characteristic herbs include *Trientalis europaea, Linnaea borealis, Goodyera repens, Listera cordata*, various wintergreens (*Pyrola* spp., *Monese uniflora* and *Orthilia secunda*), all of which have a strong northern continental (boreal) distribution through Europe (Rodwell, 1991).

Fauna

Several mammals characteristic of boreal forests abroad occur in pinewoods in Scotland, most notably deer (*Cervus elaphus, Capreolus capreolus*), pine marten (*Martes martes*) and red squirrel (*Scuirus vulgaris*). At least 70 species of bird breed regularly in Scottish pinewoods, though 24 depend on openings for feeding or breeding, and 13 others require access to water (Newton and Moss, 1977). The bird fauna is characteristic and contains the crested tit, Scottish crossbill and capercaillie, which are scarce elsewhere in Britain. At least 150 species of beetle are associated with pine in Scotland, of which 44 have a geographic range lying mainly within the pinewood remnants (Hunter, 1977).

Birch dominated woodlands

Distribution

The zone of birchwoods which are specifically described as boreal by McVean and Ratcliffe (McVean and Ratcliffe, 1962; McVean, 1964a; Ratcliffe, 1977) lies in the extreme north of Scotland beyond the natural range of Scots pine, i.e. north of about 58° N. In this region birch has been the dominant tree species during the whole of the period since the ice age (though pine occurred sporadically). Birch also occurs in high elevation woodlands and it is probable that birchwoods (*B. pubescens* spp. *tortuosa*) might have formed the treeline community in many parts of the Highlands as they do in Scandinavia.

Birchwoods are also common throughout the Highlands within the natural range of Scots pine (Rodwell, 1991) and here they form an apparent quasi-climax forest type over a large proportion of the area. The extent to which these woodlands should be regarded as quasi-climax or, alternatively, successional to either pine dominated woodland or mixed broad-leaved woodland is the subject of considerable discussion. The distribution of birchwoods is strongly influenced by man. Birch is a short-lived tree and can therefore easily be eradicated by grazing pressure; but it can equally re-invade disturbed areas in the absence of grazing pressure, leading to a shifting distribution pattern (Fenton, 1984).

Composition and structure

Downy birch generally dominates the canopy. In the extreme north and at high elevations the bushier sub-species *tortuosa* (or *carpatica* according to Rodwell) is most common, while at mid and lower elevations sub-species *pubescens* may be locally abundant. In central and eastern Highlands below about 350 m silver birch (*B. pendula*) occurs widely. Other tree species are generally scarce. Rowan occurs as scattered individual trees; but in the north-west can become co-dominant with birch in low scrubby canopies (Rodwell, 1991). Aspen, willow (notably goat willow, *Salix caprea*), Scots pine and alder may occur as scattered trees.

Canopy structure varies between dense thickets and open frequently moribund trees. Canopy height varies between 15 m where the canopy consists of *B. pubescens* ssp. *pubescens* and about 10 m or lower where ssp. *tortuosa* predominates. Canopies are generally even-aged, though in some woods discrete age classes may occur patchily or old pioneer trees may be surrounded by a second generation of trees (McVean and Ratcliffe, 1962). Regeneration is frequently restricted to a very few saplings and seedlings, but in the absence of grazing, regeneration beyond existing canopy cover can be profuse (Fenton, 1984).

Classification

Rodwell (1991) classifies birch dominated woodlands on freely draining soils in Scotland as part of two major oak-birch woodland communities: *Quercus petraea-Betula pubescens-Dicranum majus* woodland (W17) and *Quercus petraea-Betula pubescens-Oxalis acetosella* (W11) woodland. He records that the absence of oak in the birchwoods of northern Scotland has 'a climatic basis'. However, it has no bearing on the associated ground flora; therefore, it is not possible to distinguish the Highland birch-woods from oak dominated oak-birch woodland elsewhere in Scotland on the basis of their phytosocial characteristics.

Affinities with continental forest types

The W17 woodland *Rhytidiadelphus* sub-community is allied to the Scandinavian calcifuge birchwoods of the *Betuletum myrtillo-hylocomiosum* (Rodwell, 1991). However, Rodwell believes that Scottish stands of W11 woodland have the closest affinities not with Vaccinio-Picetea but with *Quercetea robori-petraeae*, and therefore with mixed deciduous woodland rather than boreal. However, he does record that such woodland 'both in east and west closely approach in their floristics the composition of heathy woodland dominated by *B. pubescens, Juniperus* and *Pinus*'.

Ground flora

Grasses typically make up most of the field layer in a varied and open textured sward (*Deschampsia flexuosa, Anthoxanthum odoratum, Agrostis* spp., *Holcus mollis*), though in W17 woodland *Vaccinium myrtillus* may be prominent. Grazing often keeps the cover fairly short and smaller herbs like *Oxalis, Galium saxatile* and *Potentilla erecta* occur frequently with patchy abundance. *Pteridium* is common and may become abundant on deeper soils and *Blechnum spicant* is frequent. Mosses (*Pleurozium schreberi, Rhytidiadelphus loreus, Dicranum majus* and *Polytrichum formosum*) are common, particularly where soils are thin (Rodwell, 1991). Rodwell also lists the members of a striking bryophyte community characteristic of these woods, though the extent to which these occur in boreal forests rather than temperate rainforest is not clear.

Soils

Soils vary from humic rankers on sites where active weathering is still taking place, through podzols on acidic geology, to more typical podzolic brown earths where there is a moderate degree of base enrichment.

Alder woodland

Alder (*Alnus glutinosa*) woodland occurs throughout the Highlands at low and moderate elevations (up to about 450 m in the central Highlands). It is however restricted to a narrow range of site types and as a result constitutes only about 2% of the current area of semi-natural woodland in the Highlands (MacKenzie and Callander, 1995). Alderwoods occur mainly as narrow strips bordering watercourses and loch shores, on alluvial fans or on damp valley slopes. Alder usually grows on damp mineral soils, though it can be found on peaty mineral soils where these are flushed by moving ground water. It occurs both in pure thickets and in mixtures with downy birch, rowan and willows (e.g. *Salix cinerea*) and at lower eleva-tions with bird cherry (*Prunus padus*). As with birch, it displays many characteristics of a successionary species (effective coloniser, rapid early growth, relatively short lived), but in the Highlands appears to form relatively stable woodland communities.

Willow woodland

Woodlands dominated by willows (*S. caprea, S. cinerea* and *S. aurita*) occur throughout the Highlands at a wide range of elevations. Willow-woods are, however, rarely extensive and their total area is small; according to MacKenzie and Callander (1995) they account for less than 1% of the area of semi-natural woodland in the Highlands. Willows are most abundant on wet sites such as mires, close to the shores of watercourses and lochs, but are also found quite widely on valley slopes even where the drainage is relatively good. They are frequently a component of high elevation woodlands, together with downy birch and rowan.

Aspen woodland

Aspen (*Populus tremula*) occurs throughout the Highlands on a wide variety of site types and at all elevations including areas close to the treeline. It is generally restricted to small clumps of trees (1-30 individuals as monoclonal groups) but may become locally dominant over areas up to about 20 ha in extent (McGowan, 1991; Worrell, 1995). Aspen woodlands are restricted to mineral soils, screes and rock faces. They grow most vigorously and attain their largest dimensions on fertile alluvial soils (up to 23 m height). The distribution of aspen is clearly limited by grazing pressure; perhaps more so than most other species. Aspen grows in mixture with a wide variety of other tree species, but is most commonly associated with birch and alder in boreal forests. It is relatively infrequent on *Calluna* dominated sites in association with pine.

Subalpine communities

Isolated areas of subalpine communities dominated by juniper (*Juniperus communis*) and willows (mainly *Salix lanata*) occur at high elevations where grazing pressures are low. They are usually found near and above the level of the natural birch or birch–pine treeline (now almost entirely destroyed). Rodwell (1991) records *Juniperus communis–Oxalis acetosella* scrub on acidic soils at elevations between 350 and 630 m, and *Salix lapponum–Luzula sylvatica* scrub on ungrazed ledges on more basic rock between 630 and 900 m.

Conclusions on Scottish boreal forest remnants

- The native Scottish boreal forests are unique species-poor variants of the Scandinavian oceanic boreal forests. They can be conveniently, though simplistically, subdivided into pine dominated and birch dominated woodlands, with small but important areas of other woodland communities.

- The ecology and genetics of the pinewood remnants are relatively well studied, though the question of the origins of the Scots pine population in Scotland has not been finally resolved.

- Less information is available on the ecology and genetics of birchwoods. The zone of birch forest in the extreme north of Scotland is not well studied and its relationships to the boreal forests further to the south and east, and the oak dominated temperate rainforest to the south and west are unclear. In the National Vegetation Classification boreal birch forests are assigned to two oak–birch communities.

- Native Scottish boreal forests have been severely reduced in extent and their composition and structure modified by man.

Chapter 6

Dynamics and regeneration

Dynamics

The frequency, type and pattern of disturbance are fundamental determinants of forest composition, structure and development (dynamics). The nature of disturbance in Scottish boreal forests can only be surmised, or inferred from studies of similar forest ecosystems. The existing structure of stands of pine and birch in Scotland reflect mainly past man-made disturbance in the form of felling, fire and changing grazing pressures, rather than natural disturbance. Regeneration tends to occur on the periphery of stands in conditions modified by surrounding land uses. This leads to woods expanding and contracting around cores which themselves shift through successive generations (Fenton, 1984).

It is generally accepted that disturbance in boreal forests is caused by wind, fire from lightning strikes, and insect attack; but that wind is most frequent and probably most important in Scotland (Peterken, 1989). Goodier and Bunce (1977) hypothesise that strong winds leading to widespread destruction may recur at 300 year intervals, resulting in upturn of mineral soil and therefore suitable conditions for regeneration.

Studies in Sweden have illustrated that storms may cause a mosaic of small-scale disturbances in pine and spruce forest (Serander, 1936; Hytteborn *et al.*, 1991). Hytteborn showed that in an old growth Swedish spruce forest 31% of the forest was made up of small gaps which were mostly initiated by the fall of single trees (often subsequently enlarged by several additional falls). The majority of fallen trees were infected by fungi; 57% were snapped, 29% uprooted and 13% standing dead. The estimated disturbance cycle was 175 years.

Studies in temperate broadleaved forests indicate disturbance cycles of 50-200+ years, with canopy gaps being created at 0.5-2% per year by uprooting, breakage above ground level, death standing and loss of major branches (Peterken, 1989). Peterken states that natural boreal forests sustain a higher incidence of catastrophic disturbance than temperate broadleaved stands. Specific information on the disturbance regimes of oceanic boreal forests seems difficult to obtain, but the greater dominance of wind as opposed to fire suggests that both large and small scale disturbances may be important.

Little that is authoritative can be said about the role of fire, except that it undoubtedly occurred naturally in Scotland, though perhaps less frequently than in continental boreal regions. It appears now to be largely caused by man, though some fires are caused by lightning strikes, particularly in eastern Scotland (I. Ross, personal communication). O'Sullivan (1977) observes that pine regenerates best after fire, and concludes that Scots pine is a 'partially fire-dependent species' in the natural condition. Callander (1986) quoting Diack (undated) reported six major fires (extent and causes unspecified) in Glentanar forest between 1688 and 1920 (once every 40 years). One study in northern Sweden suggested that the average cycle between successive fires before the 20th century ranged from 46 years on dry sandy sites to 122 years on fertile moraine soils and northern slopes (Zackrisson, 1977). However, stands have been identified in the same area which have remained undisturbed by fire for as long as 500 years, and where succession has been driven by small-gap replacement of trees (Steijlan and Zackrisson, 1987).

The pattern of disturbance largely determines stand structure. Catastrophic disturbance causes regeneration over a large area and generates an even-aged stand. Such stands however may eventually start to break up into smaller units under the influence of smaller scale disturb-

ances. Severe (but not catastrophic) disturbance generates patchily even-aged stand structures. Smaller disturbances allow regrowth of suppressed understorey trees and new saplings, leading to uneven-aged group structures (Peterken, 1989). The conventional wisdom states that disturbance in oceanic pine and birch forests generally leads to even-aged and patchily even-aged structures. However, it is possible that the role of major windstorm and fires has been exaggerated in the past and the role of small gap replacement may have been underestimated (G. Patterson, personal communication).

In Scandinavia the classical disturbance sequence is rapid colonisation of the site by broadleaves, followed by varying amounts of pine and spruce according to site type. The conifers slowly attain dominance, and on the majority of sites Norway spruce is thought eventually to attain dominance except on the most infertile sites (though not always; see Steijlan and Zackrisson, 1987). Where spruce is naturally absent, such as in south-west Norway, Scots pine maintains dominance and attains a quasi-climax status (Kuusela, 1992b).

Dominance by spruce tends to lead to increasing accumulation of mor humus in which nutrients, particularly nitrogen, are stored in a form largely inaccessible to trees. Disturbance, particularly by fire, releases nutrients in a form accessible to trees and decreases soil acidity (Kuusela, 1992b). Subsequent colonisation of the site by broadleaves also helps to restore soil fertility. Where fire control has prevented this sequence occurring, uncut stands of spruce eventually begin to degrade due to a lack of nutrient cycling; paludification (bog-formation) is promoted and problems with regeneration may be encountered (Kuusela, 1992b).

Some of the natural processes which occur as a result of disturbance by fire and wind are mimicked during the re-establishment of plantations. Harvesting, site preparation and fertilising cause disturbance which appears to promote satisfactory conditions for the subsequent establishment and growth of conifers.

Regeneration

Significant seed production in Scots pine in Scotland occurs every 2-4 years, and in birch in most (but not all) years. Seed viability is generally good, but it can be poorer in northern and western Scotland and at high elevations (McVean, 1963). Scots pine trees continue to produce significant quantities of viable seed at ages up to and beyond 300 years (Nixon and Cameron, 1994). Dispersal distances are generally 60-100 m but are greater where transport over snow surfaces takes place.

The soil conditions associated with good Scots pine regeneration in Caledonian pine remnants are:

- Well-drained soils (sands, gravels, raised knolls, roadside banks).
- Mineral soils with some surface cover (peat or short vegetation, the latter having been subject to fire or trampling by animals until just prior to seedfall).
- If peat covered soils, peat no deeper than 10 cm (Henman, 1961).

Regeneration frequently occurs in open areas (more than 25% incident light), where the ground layer vegetation is *Calluna* or sparse fine grasses. It rarely occurs in areas dominated by *Vaccinium, Molinia* or *Eriophorum*, or where a moss or deep litter layer occurs. Areas of *Calluna, Nardus, Scirpus* and *Erica tetralix* over deep peat are also unattractive for regeneration (Henman, 1961; Dunlop, 1983). Germination and early growth sometimes occurs on *Sphagnum* and *Sphagnum/Scirpus* bogs. Regeneration is also promoted by fire or screefing (MacDonald, 1952; Henman, 1961; Edwards, 1981).

The growth of seedlings of pine in the pinewood remnants is reported to be very slow due to competition from dense heather, impoverished soils and damage from deer and black game (Henman, 1961). For example, the heights attained by Scots pine on screefed areas in Queens Forest, Inverness-shire were 30-40 cm after 7 years, 90 cm after 12 years and 2.5 m (up to 5 m) after 25 years (Forestry Commission, undated).

Birch regeneration occurs freely on damp disturbed mineral soil and humus. Birch can also successfully colonise areas of *Calluna* when it is in the pioneer or degenerative stages and areas of grassland where the sward is reasonably open. Germination may occur on damp *Sphagnum* but seedlings rarely establish themselves. Regeneration is almost entirely confined to large canopy gaps or beyond the

edges of woods. Colonisation in the absence of grazing can be rapid, particularly where regeneration has been 'stored' in *Calluna* swards. Where grazing prevails regeneration is frequently eliminated.

Conclusions on dynamics and regeneration

- Scottish native woods have been altered by man to such an extent that it has become difficult to establish their dynamics.
- Information from Scandinavia indicates that a mixture of large scale and small scale disturbance affects boreal forests.
- More information is required on
  - the type, frequency and pattern of disturbance,
  - natural regeneration and succession after a variety of disturbance patterns,
  - the structure and composition of oceanic boreal forests.

This information will be gained mainly from studies in Scandinavia.

The implications of such information for the management of boreal forests need further study. The similarities and differences between different silvicultural systems (including clearfelling) and natural disturbance/ regeneration need to be explored.

- The regeneration of Scottish native woodlands is reasonably well documented, though the information concerns mainly expansion of woods onto open ground.

Chapter 7

History

Vegetation history of boreal forests during the Holocene

The main events in the development of pine and birch forests in the Scottish Highlands during the Holocene are shown in Table 7.1. Land exposed by retreating ice sheets was colonised first by tundra-like communities in which heathland plants (notably Empetrum) and shrubs (notably juniper and willow) were common. Shrub communities were rapidly followed by birch and hazel so that after only 1000 years (by 8900 before present (BP)) birch – hazel woodland was widespread.

Table 7.1 Main events in the development of forests in the Scottish Highlands during the Holocene (after O'Sullivan, 1977, and Birks, 1989)

Years before present	Forest development
10 000 – 8900	Development of open birch and hazel woodland
8500 – 8000	Rapid expansion of Scots pine begins in north-west Scotland
8000 – 7500	Expansion of pine in Deeside and Speyside
7500	Land bridge to continental Europe lost
6500	Scots pine reaches maximum abundance
6500 – 5000	Pine–birch forest dominant over wide parts of the Highlands
6500 – 5600	Arrival of alder
6000	Limits of pine distribution stable in north-east and west, but southern limits still expanding in Rannoch area
5000	Increased bog formation begins in north-west Scotland First arrival of man in Scotland: temporary very local clearance of forest begins
5000 – 4500	Temporary expansion of pine into Sutherland and eastern Skye and possibly locally in Caithness and the outer Hebrides
4000	Massive contraction of Scots pine begins in north-west Scotland; pine forest replaced by bogs and sometimes heathland
3700 – 3500	First undoubted traces of significant forest clearance by fire
1500 – 1000	Considerable heathland formation due to grazing and forest clearance

Pine forest developed first in north-west Scotland (8500-8000 BP) and later in Deeside and Speyside. Pine reached maximum abundance in about 6500 BP but continued to spread southwards towards Rannoch (around 6000 BP) and northwards into northern Scotland (5000-4500 BP). Much of the spreading of pine happened during the period when Scotland was being colonised by mankind.

The composition of forests prior to significant disturbance by man can be divided into three zones: pine dominated woodland stretching from Deeside and Speyside into the southern parts of the northwest Highlands; birch–hazel woodland with rowan and some aspen in northern and coastal areas; and between the two a zone of mixed pine–birch woodland (Figure 7.1; Birks, 1988). There is some evidence to suggest that undisturbed forests before the arrival of man were more diverse than modern woods (O'Sullivan, 1977).

After about 4000 BP pine underwent a rapid contraction in range; in western Scotland this coincides with increasing bog formation (McVean, 1964b; O'Sullivan, 1977; Birks, 1989). The extent to which this, and subsequent, contractions were caused by man or resulted from climatic change has not been resolved. Birks (1988) considers the main periods of extensive deforestation to have occurred at 3700-3900 BP, 2100-2600 BP, 1400-1700 BP and 300-400 BP.

The impact of man

Man practising hunter-gatherer lifestyles first arrived in coastal areas of Scotland during the Mesolithic period, at around 8500 BP. The first evidence of localised temporary clearance of forest in inland and upland (i.e. boreal) areas dates from around 6000-7000 BP. Such clearance probably involved the use of fire. However, Edwards and Ralston (1984) state that during the Mesolithic,

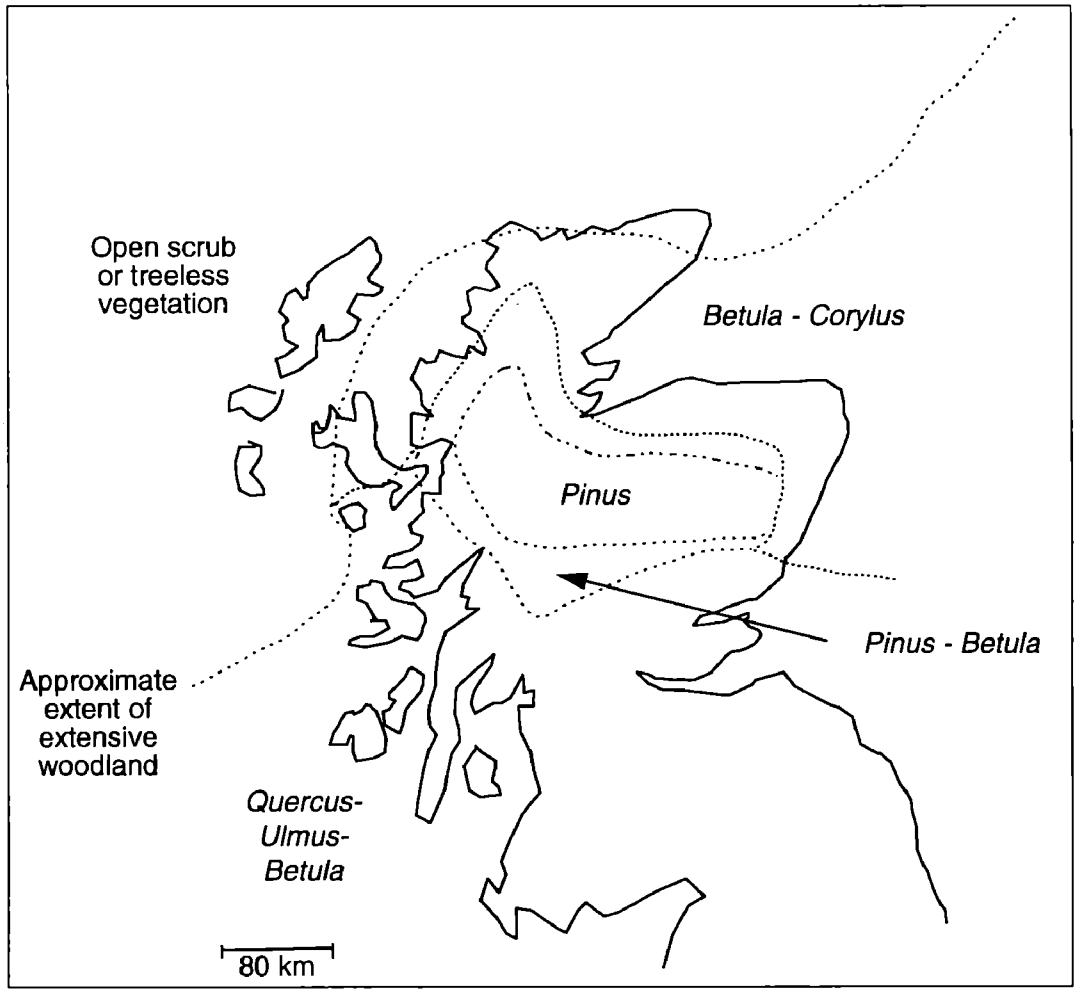

Figure 7.1 Reconstruction of major woodland patterns for the mid-Holocene (7000-5000 BP) (after Birks, 1988).

impacts beyond the major river valleys were likely to have been insufficient to have caused detectable changes to vegetation cover.

The first clear evidence of farming dates from about 5700-6000 BP during the transition from mesolithic to neolithic age. For example, at Balbridie in mid-Deeside cultivation of cereals was clearly taking place, and a large oak timber hall was in use (Edwards and Ralston, 1984). From this time until 4000 BP considerable clearance of forests took place, so that by the end of this period many of the alluvial valley floors and some valley slopes had been cleared for grazing and the cultivation of crops. Thus, the open upland landscape characteristic of Scotland dates back in some areas to as long ago as 4000 years. This process of clearance continued during the bronze and iron ages; iron working led to the need for charcoal from as early as 2600 BP (Shepard, personal communication). However, periods of reduced human activity also occurred which probably allowed partial regeneration of forests. Smout (1992) suggests that as much as 50% of the natural forest of Scotland may have been destroyed by the time of the Roman invasion.

The forests of the Highlands are thought to have been little affected by the Roman occupation, except possibly by displacing lowland peoples into the Highlands and thus locally increasing population pressure. Cultivation of crops and pasturage of animals by a growing population continued into feudal times and reports of the extinction of several of the major forest animals dates from about this time, suggesting continuing impact of man on the forests. There may have been some respite from this after the Black Death and subsequent plagues during the 14th century (Smout, 1992). At this time wood was becoming seriously scarce in the Lowlands, requiring the enactment of several laws to protect and regenerate forest; the importing of Baltic timber including pine was also recorded during the 13th century (Carlisle, 1977). There is some evidence of trade in timber between the Highlands and Lowlands, particularly from Lochaber.

During the 16th century the population of the Highlands was estimated to have been about a quarter of a million people; enough to exert a considerable influence on the remaining forests (Smout, 1969). There is evidence of a local trade in forest produce in areas such as Inverness and Perth (Anderson, 1967). Husbandry of cattle, goats and sheep was common in the Highlands (Smout, 1969). Anderson (1967) gives several reports of pasteurage within the Highlands, and suggests that this must have caused damage to any remaining high elevation woodlands.

By 1600 it is clear from the earliest maps of Christopher Pont that even the Highland forests had undergone very extensive reduction in area. Smout (1991, 1992) believes that by this time the percentage of the Scottish land surface still covered by trees was probably of the order of 5%, most of the deforestation being attributable to domestic animals owned by rural occupiers. Cheape (1992) gives a rather different picture for the Clanranald estates in Western Scotland where woodland was managed relatively carefully until the introduction of sheep by landlords.

Serious felling of the Highland forests for timber is thought to have begun in the 17th century due to increasing population pressure, more building, reduced availability of lowland timber and the development of an iron industry which required large quantities of charcoal. Several iron bloomeries were established in Scotland as far north as Strathnaver and Loch Maree. Oak and birch were favoured, but pine was also used for fuel and there are many references to felling of forests for this purpose during the 17th and 18th centuries. Pine timber was also widely felled for masts of ships and for sawnwood, and floating of timber down the larger rivers became widespread. By the 18th century about 60 sawmills were operating in the woodlands of eastern and central Scotland (Callander, 1986). The forfeiture of the estates following the failed Jacobite rebellion and the subsequent activities of the asset-stripping York Building Company led to uncontrolled fellings in some areas. Felling continued into the early 19th century particularly in Speyside and Deeside during the Napoleonic wars. The felling of forests between 1600 and 1800 caused considerable reduction of forest cover over large areas, though in some areas efforts were made to limit cutting and promote regeneration or coppice regrowth. The first widespread efforts to replant forests began on a number of estates during the 18th century, first using native species and later including larches and spruces (Anderson, 1967).

Conversion to agricultural land continued and tenants also made considerable demands on forests for wood for building, tools and fuel. Anderson (1967) also gives several reports of agricultural tenants damaging forests or opposing the efforts by landlords to protect and extend forests during the 17th and 18th centuries. The deforested land was used extensively for grazing. There are several reports of muirburn being introduced to improve grazing and causing damage to native forests during the 18th century (Anderson, 1967). The cattle trade built up during the late 18th century then declined again by the mid 1850s. Sheep husbandry began during the mid 18th century and grew steadily during the 19th century, declining after about 1870 when sporting began to develop. Sporting reached its zenith during the early part of this century. Grazing became, and has remained, the most important cause of the lack of regeneration in native forests.

Extensive felling of the last remnants occurred during the First and Second World Wars. The period since the Second World War presents a mixed picture, with the core areas of some pine remnants being protected, others (particularly birchwoods) being converted to exotic conifers, some declining from neglect and others (particularly birch) reinvading areas where grazing pressure was reduced. Bain (1987) states that 16% of the genuinely native pinewood area owned by the private sector and 50% of that owned by the Forestry Commission was destroyed by felling and underplanting between 1957 and 1987 (a loss in area of 3800 ha). Changes in the area of birch forest varied locally according to grazing pressure and other land use practices (Callander, 1986).

Conclusions on history

- Mankind was present in the boreal region from at least 6-7000 BP, so some of the forest development took place in the presence of mankind. Since then boreal forests have been subject to changes due to the influence of man and alterations to the climate.

- Deforestation began with the advent of agriculture 5-6000 years ago and proceeded as land was cleared for agriculture, trees were felled for timber, and regeneration was prevented by grazing animals. Serious deforestation probably began about 4000 years ago. The rate of deforestation is not known in detail, but it is thought to have taken place at varying rates such that the area of native forest had been dramatically reduced by 1600.

- Widespread felling for timber for iron smelting, charcoal production and ship building occurred after 1600 and led to further reductions in area. Losses of native forest continued this century with wartime fellings and conversion to agriculture and coniferous plantations; since 1987 the latter has ceased.

- Recent historical analyses suggest that past interpretations of the history of deforestation in Scotland placed undue emphasis on the role of the Romans, Vikings and exploitation during the 17th and 18th centuries, whereas the contribution of agricultural activities over a longer time period may have been underestimated.

- Only limited examples occur of management of forests; the history of Scotland's natural forests has generally been one of exploitation and neglect.

Chapter 8

Current status of Scottish boreal forests

Native forests

Extent

The native boreal forests of Scotland have been severely reduced in extent; more so than in any other part of the boreal zone (though a similar reduction occurred in the birchwoods of Iceland). The most recent estimates of the area of pinewoods suggest a gross area of 16-20 000 ha (Forestry Authority, 1994; MacKenzie and Callander, 1995). The total area of birch in the Highlands is estimated as 49 400 ha (MacKenzie and Callander, 1995). The proportion of this total which could be classified as boreal birchwood is unknown.

Some reduction in area of native woodlands has also occurred naturally during the historical period as a result of alterations in climate causing expansion in the area of bogs. Distinguishing between natural and man-induced reductions in the extent of forests is difficult.

The remaining areas of native boreal forest have been broken into relatively small discontinuous units. In many areas they are restricted to gorge sides and cliffs. The small size of these remnants restricts the value of the habitats for many woodland species of plant, birds and animals and reduces the possibilities for migration of woodland species and for genetic transfer. Treeline forest and shrub communities are conspicuously absent due to high grazing pressures (Mardon, 1991; Poore and McVean, 1957).

Tree species

The diversity of tree species in native woods in Scotland is thought to have been reduced. In pinewoods the abundance of pine is thought to have increased relative to broadleaves; this being a result of preferential treatment and the effect of grazing on sensitive broadleaved species such as aspen and willow (Stevens and Carlisle, 1959; Gimmingham, 1977; O'Sullivan, 1977; Rodwell, 1991). However, many pinewoods in western Norway which have been subject to relatively low levels of disturbance also have only limited representation of broadleaved species.

Many birchwoods are relatively recent in origin, colonising ground where grazing pressure has been temporarily reduced. The species composition and genetic status of such secondary woods is determined by the vagaries of the seed sources which happen to be represented in the area; frequently these bear only a limited likeness to natural forest. In recent secondary woods diversity of tree species and ground flora is reduced (Rodwell, 1991; Usher *et al.*, 1992). Underplanting of native woodland using exotic conifers has been widespread during this century, though this ended in the mid-1980s.

Regeneration

Regeneration in many Scottish native woodlands is absent or very sparse, even in open woodlands where regeneration may be expected (Stevens and Carlisle, 1959; Henman, 1961; Fenton, 1984). This is largely due to grazing pressure, but may be exacerbated by unfavourable ground conditions. Concern has also been expressed about the capacity of old trees in remnant woodlands to produce seed, but recent research suggests that even very old trees still produce considerable quantities of viable seed. In aspen and some montane willows the distance between clones of different sexes may restrict seeding (Soutar, personal communication; Mardon, 1991).

In most woodlands reduction of grazing pressure is frequently all that is needed to stimulate regeneration; though if uniform regeneration is required within a short time

period, ground preparation is frequently necessary. Grazing by red deer is the single most important factor limiting the regeneration of native forests (Callander and MacKenzie, 1991b).

Genetic status

Reduction in the extent of forest and preferential felling of timber quality trees has led to the loss of, or alterations to, many local tree populations in Scotland. Populations thought to have been particularly affected include aspen (Soutar, personal communication), silver birch of timber quality (Anderson, 1961) and high elevation populations of many species. In areas subjected to the most severe grazing pressures, the restriction of woodlands to cliff face habitats may have affected the gene pool by influencing selection pressures. Preferential felling has affected the timber quality of existing pinewoods (Stevens and Carlisle, 1959; Rodwell, 1991), but whether this has significantly altered the genetic structure of populations in this respect is unknown. Study of the genetic structure of Scots pine using monoterpene and isozyme analysis has shown that the genetic variation in native pinewoods is still high despite the severe contraction in range and numbers that they have undergone (Kinloch *et al.*, 1986).

Because of the limited extent of planting of native species, the introduction of stock derived from beyond the boreal region of Scotland has until recently been limited. However, pine of central European origin and east England provenance (though origin possibly Scottish) has been used for many years and may have caused local alteration to the genetic structure of some pinewoods; though in other areas non-native stock has only been sparingly used (Callander and MacKenzie, 1991a). The increase in broadleaved planting beginning in the mid-1980s has largely been carried out using continental stock (Worrell, 1992).

Age, stocking and form

Most Scottish pinewood stands are old and in some cases moribund. Stocking is low, particularly in western areas. Where pinewoods have been managed, stocking levels are higher; and in a few cases similar to managed woods in Scandinavia (notably Glen Tanar). Form is generally poor for timber production purposes, largely as a result of the low stocking and preferential felling of straighter trees. The age distribution and stocking of birchwoods is more varied (Forestry Commission, 1983; Fenton, 1984; Callander *et al.*, 1990), though old poorly stocked and moribund woods are also common. The form of birch is generally poor, though some stands of silver birch at low elevations in eastern Scotland show timber production potential (Lorraine-Smith and Worrell, 1991).

Old woodlands provide critical habitats for certain plants, fungi and invertebrates which are lacking in recent plantations (Nature Conservancy Council, 1986).

Soils

The soils under native woodland remnants probably represent the most natural, unaltered soil profiles in the boreal region of Scotland; with bogs providing the only other widespread semi-natural soil profiles. Removal of tree cover has led to decreased interception of precipitation and consequently increased soil wetness, runoff, leaching, organic matter accumulation, erosion and paludification (Malcolm, 1957; Pearsall, 1952; Dimbleby, 1976; Pyatt and Craven, 1979). Where birch dominated woodland has been replaced by heather moorland on acidic geology, podzolisation and acidification increases, iron pans frequently develop and soil fertility decreases. Dimbleby (1976) states that brown earth soils can be changed to podzols in as little as 100 years. Reduction of the broadleaved component in many pinewoods has probably promoted acidification and podzolisation of soils (Miles, 1986). However, where birchwoods have reinvaded old pinewood sites, the podzolisation and acidification appear to be reversed. Soil degradation may make regeneration of woodlands more difficult (Malcolm, 1957), particularly in high rainfall areas where erosion and peat accumulation may have been accelerated by the removal of forest cover. Many changes are, however, thought to be reversible by the establishment of trees (Miles, 1985, 1986).

Flora

The reduction in extent of native woodlands has drastically diminished and fragmented the distribution of woodland flora. Species whose range and abundance became restricted as a result of historical deforestation include:

- shrubs, e.g. *Juniperus communis, Salix cinerea, S. aurita*
- sub-shrubs, e.g. *Vaccinium* spp.
- herbs, e.g. *Goodyera repens, Linnaea borealis, Listera cordata, Melampyrum pratense, Monese uniflora, Oxalis acetosella, Pyrola* spp., *Trientalis europea*
- grasses/rushes, e.g. *Luzula* spp.
- ferns, e.g. *Dryopteris* spp.
- bryophytes, e.g. *Ptilium crista-castrensis, Thuidium* spp.

Epiphytic lichens and many species of fungus have also been reduced in abundance. Species which suffered the greatest decline are those which are specifically adapted to a stable woodland environment, notably herbs, some ferns, mosses, liverworts and lichens. Many of these are unable to survive in the absence of woodland and only recolonise adjacent areas of regenerating woodland slowly.

Species which could thrive in the absence of tree cover extended their range and abundance, notably ericaceous species, grasses and mire species, but some herbs (e.g. *Orchis* spp.) and some ferns (e.g. *Pteridium aquilinum*) also benefited by access to deforested land. These species form the semi-natural heathland and moorland communities which have become characteristic of the British uplands.

Fauna

The fauna of Scottish boreal forests is impoverished compared to boreal forests abroad, due to the failure of some species to (re-) colonise after the ice age (e.g. wolverine), natural extinctions (e.g. lynx) and man-induced extinctions. Deforestation of the Highlands probably contributed to the extinction of several mammals and birds typical of boreal forests (e.g. brown bear, elk, boar, beaver, wolf, osprey, goshawk, capercaillie) and reduced the ranges and abundance of many others (e.g. red squirrel, pine marten, black grouse, crossbill). Deforestation also adversely affected fish populations (Greer, 1979) and presumably many species of woodland invertebrate, most notably saproxylic insects (MacGowan, 1991).

Certain species proved to be well adapted to the moorland and grassland habitats which resulted from deforestation, and maintained or expanded their numbers (e.g. moorland birds such as red grouse, certain waders, raptors and, under management, red deer).

Human social

The pattern of land use, settlement and the ownership of land have developed in a unique fashion in the Scottish Highlands. Population density is low compared to elsewhere in Britain and is lower now than for many centuries. It is similar to forested areas of southern Scandinavia but considerably higher than many of the boreal forest areas of Canada, Alaska and Russia. Deforestation in Scotland became more advanced than elsewhere on account of population pressure being greater and deforested land being suitable for agricultural use and sporting.

In the Scottish Highlands land is largely privately owned by a relatively small number of individuals whose forestry activities have traditionally been subordinate to sporting or sheep farming. The state Forestry Commission owns approximately 450 000 ha of land in the Highlands, making it the single largest landowner.

The history of land use in the Highlands means that unlike other boreal regions, forests have had little impact on current social structure and culture. In contrast to rural populations elsewhere in the boreal forest zone, rural communities in Scotland often have only a limited understanding and appreciation of native woodland and they derive only limited resources from them. Regions where destruction of native forests was less complete (e.g. Deeside and Strathspey) provide partial exceptions to these general rules.

Because a large proportion of the rural population do not own land, the influence they exercise over local land use decisions is restricted to the representation of their interests which they achieve through local and national government. This is similar in many ways to the situation experienced by rural communities in Canada, Alaska and Russia; though here the land is almost entirely state owned. Only in Scandinavia is ownership of land widely dispersed among private individuals, with rural communities exercising concomitantly greater control over rural resources.

Until recently, both private landowners and their tenants generally appear disinclined to manage or protect native woodlands, though several noteworthy exceptions to this occur. In contrast, considerable progress has been made in encouraging the establishment of conifer plantations by private landowners and the Forestry Commission. Since 1987 a significant increase in the planting of native species has occurred. Support to rural communities has been a policy objective of British forestry, though this has been largely interpreted as the provision of jobs, rather than using forests to achieve wider social objectives.

Management practices

In the first part of this century Scots pine was seen as an important tree species, alongside larch and spruce, both on private estates and in Forestry Commission forests, though the proportion of Scots pine planted diminished steadily until the 1980s. Native pinewoods attracted some attention during the 1930s when the Forestry Commission set up experiments to monitor regeneration. During the 1940s and 1950s, and particularly during the Second World War, felling took place in several native pinewoods. Others, particularly poorly stocked or fire-damaged remnants, were underplanted with introduced conifers. Some woods were, however, selected for protection, notably the Blackwood of Rannoch, part of Glen Affric, Glen Loy and parts of Achnashellach. Some planting with local provenance pine was carried out with timber production as an objective. Others survived intact because it was not practical and economic to manage them for timber production (Stevenson, personal communication). It is worth recording that sympathetic management of pinewoods can often be traced back to the enthusiasm and activities of particular forest managers.

Broadleaved woodland was extensively converted to conifers by felling and replanting, underplanting and interplanting, though the efficiency with which this was carried out varied considerably (Stevenson, personal communication). Only after the Wildlife and Countryside Act (1981) and the broadleaved policy review (1985) did broadleaved woodland, often previously termed scrub woodland, come to be assigned any value. The conversion of broadleaved woodland ceased after about 1986.

Starting in about 1985, the Forestry Commission has adopted a policy of encouraging the protection, rehabilitation and extension of native woodland (see Chapter 9) and this has been taken up enthusiastically by many estates.

Timber production

Native woodlands in the Highlands constituted an important component of Scotland's timber supply until well into the 18th century and in some places (notably Deeside and Speyside) into the 19th century (Miller and Ross, 1990). They also contributed to timber supplies during the First and Second World Wars. Currently timber production from native boreal forests is restricted to:

1. local production of sawnwood from a few pinewoods in Deeside and Speyside;

2. local production of firewood and some chipwood from birch (Callander *et al.*, 1990).

Timber production from native pinewoods has probably been in the range 1000-5000 m^3yr^{-1} during recent years (I. Ross, personal communication). Felling of birch for firewood is estimated to be approximately 16 000 m^3 for the whole of Scotland (Callander *et al.*, 1990) and therefore probably no more than about 5000-10 000 m^3 for the boreal birch forests. Timber production is limited by the poor condition of many woods, poor tree form, access problems, nature conservation designations and the lack of suitable management input and markets. If the area of native pine and birchwoods were substantially increased, significant timber production could be reinstated (Callander *et al.*, 1990; Lorraine-Smith and Worrell, 1991).

Nature conservation

The Scottish native boreal forests are a significant resource for the conservation of ecosystems and wildlife. They represent some of the most unaltered soils, plant communities and landscapes remaining in Britain. They are rare both nationally and internationally, and in some (but not all) senses are non-recreatable. They are therefore of national and international significance for nature conservation (Peterken, 1977, 1992). Management of such woods aims to conserve or promote 'naturalness', conserve reservoirs of specific woodland species and provide the public with the nearest approximation to a wilderness setting for recreation and observation of wildlife.

Livestock husbandry

Native woodlands in the Highlands, particularly birchwoods, are widely used as shelter for livestock. The grazing provided under birchwoods in early spring can be particularly valuable (Callander, 1991).

Field sports

Native woodlands provide winter shelter and early spring grazing for red deer. In common with planted woodland they also provide suitable habitat for roe deer and black grouse. Capercaillie can be an important gamebird in pinewoods and other bird species such as woodcock can form part of a day's mixed shooting. However, the presence of native woodland on grouse moors is seen as an impediment to shooting, and invasion of trees is often actively prevented by burning.

Landscape and informal recreation

Native woodlands are a highly cherished component of the Highland landscape. In well-wooded areas such as Strathspey, Deeside and Glen Affric they provide a varied forest landscape which is missing in most parts of Britain. Elsewhere they add variety to scenes dominated by arable or grazing land. The irregular internal structure of such forests can be a pleasing aspect for a visitor to native woodlands, providing unique views within the forest and increased opportunities to see the surrounding landscape (Thom, 1977). Native woodland, in common with open hill ground and planted forests, is used for informal recreation. Recreation in the form of walking and nature study is encouraged in relatively few native woodlands.

Planted forests

A large number of exotic tree species originating in oceanic boreal forests and temperate rainforests of Europe, Japan and North America have been grown for many years in the Scottish Highlands. These species grow faster than native Scottish species and, with the exception of lodgepole pine on some sites, have so far proved remarkably healthy. These forests replicate some of the characteristics of boreal forest ecosystems, but are significantly different in other respects.

The natural boreal forests of Scotland consist of light demanding species. Consequently, where light demanding tree species (pine and larch) have been planted, woodland conditions develop which have considerable affinities with native woodlands, particularly in terms of ground flora (Hill, 1986; NCC, 1986). This is most pronounced where Scots pine is used on old Scots pine sites. Affinities between forests of shade bearing spruce and fir and native boreal woodland are fewer.

Important differences between planted forests and natural boreal forests result from:

- Restricted species composition within individual stands, particularly the absence of a significant broadleaved and shrub component.
- Simplified forest structure.
- Curtailing of the natural cycle at the earliest phases of development.
- Lack of deadwood.
- Regular soil disturbance.

Although significant differences between planted forests and natural boreal forests are apparent, planted forests in Scotland do bear considerable resemblance to intensively managed forests in Scandinavia and elsewhere in the boreal zone.

Area

The most recent census (1979-82) shows that the total forest area of the Scottish Highlands is 650 000 ha, of which approximately 400 000 ha (62%) comprises introduced conifers and 130 000 ha consists of Scots pine (20%). Of the total area of planted conifer forest 24% is Scots pine, 16% is lodgepole pine and 9% is larch; hence approximately 50% consists of light demanding species (Forestry Commission, 1983). The Scots pine plantations are concentrated in the northern and eastern Highlands and are almost absent in western Scotland. The remaining 50% consists of shade bearing conifers: Sitka spruce (40%), Norway spruce (7%) and Douglas fir (2%). Planting since the last census will have increased the proportion of these species, particularly of Sitka spruce.

Soils

Most commercial planted forest has been established using soil cultivation and fertilising. Establishment of treecover has contributed to returning the water and nutrient status of soils more towards woodland soil conditions (Pyatt

and Craven, 1979). However, ground preparation has also disturbed soil profiles and frequently increased erosion (Moffat, 1991; Soutar, 1989). The widespread use of conifers has generally maintained the podzolic nature of soils where the previous vegetation was dominated by *Calluna* and pine; however, where conifers have been planted on brown earth soils, podzolisation has increased.

Flora

The effects of tree planting on ground flora depends to a large extent on the tree species used and the rotation length adopted (Hill, 1987). The use of shade tolerant conifers such as spruce leads to the virtual elimination of the semi-natural ground flora during the pole stage, though limited recolonisation of mosses, ferns and herbs takes place during the later years in thinned crops. Where light bearing species have been used, those elements of the natural woodland flora which have persisted in grassland or moorland communities quickly gain dominance (e.g. *Vaccinium*). Other woodland species follow at a variety of rates determined by the colonising ability of the species, the previous land use and proximity to native woodland. In common with other woodland species, some boreal woodland plants are extremely poor colonisers and require an undisturbed woodland environment; thus the prospects for such species to widely recolonise conifer plantations are poor.

Afforestation has mainly been at the expense of the moorland and grassland communities which developed on deforested land, though significant destruction of natural mire communities has occurred particularly in the Northern Highlands (NCC, 1986).

Fauna

Afforestation has provided habitats for several species of woodland birds and mammals, and while lacking many of the niches present in natural forests, plantations have allowed many Scottish woodland species to re-establish their ranges and increase in abundance. Conversely, the establishment of plantations has reduced the habitat available for many moorland species, particularly birds.

Timber production

Planted forests are currently managed for a range of benefits, but wood production is usually of highest priority. Wood production from coniferous plantations in Scotland is currently 2 million m^3 yr^{-1} (approximately 40% of Scottish consumption). The timber is suitable for a range of uses from construction timber to pulp, but generally excluding joinery grade timber. Wood production is maximised by attention to species choice, site preparation, fertilising, weeding, cleaning, thinning and felling, usually over a period between 40 and 55 years.

Other benefits

Planted forests present opportunities to realise other benefits, e.g. landscape enhancement, conservation, public recreation and watershed amelioration, though such opportunities decrease in proportion to the intensity of management for wood production. Many conservation organisations consider that when intensively managed plantations are established on open hill ground a net decrease in conservation value occurs and that alterations to soils and watercourses constitute serious environmental degradation (e.g. Nature Conservancy Council, 1986). However, under moderately intensive management regimes plantations have considerable potential for nature conservation, as illustrated by the recolonisation by certain mammals, birds (Avery and Leslie, 1990) and plants. Peterken (1992) has suggested that considerable conservation benefits may be achieved by extending rotation lengths on suitable sites, even to the extent of recreating 'old growth' conditions with introduced species.

Sustainability

The time period during which plantation forestry has been practised in Britain is too short for the long-term effects on sites and soils to be determined. Second rotation crops are generally showing no signs of reduced productivity. On the other hand, elevated levels of erosion have been observed throughout the rotation of some upland plantations established using early cultivation techniques. Soil compaction can occur due to the use of heavy machinery, and nutrient loss due to harvesting may be a concern on the poorest sites where whole tree harvesting is used. Modern guidelines and practices are intended to reduce or eliminate these impacts.

Human social

Plantation forestry has gained a prominent, though rather ambiguous, place in the rural culture of the Scottish Highlands during the relatively short period of its existence. Forestry created jobs and added to the variety of landscapes and habitats; the desirability of these changes has been the subject of continual debate. Awareness of forests and forestry continues to increase.

Conclusions on current status

- The natural boreal forests of Scotland have been severely reduced in extent, more so than in any other part of the boreal zone. Only small discontinuous areas remain and woodland composition and structure have been extensively modified by man.

- Treeline forest and shrub communities are notably absent.

- Regeneration in many Scottish native woodlands has been absent or very sparse for a long period.

- Soils under native woodland remnants are relatively undisturbed; elsewhere deforestation has led to considerable changes in soil properties.

- Woodland plant and animal communities have been severely restricted in range and abundance due to deforestation; several species of animal have become extinct. Plants and animals able to thrive in the absence of woodlands have flourished.

- Rural communities in Scotland often have only a relatively limited understanding and appreciation of native woodland; they derive only limited resources from them and exert only a small influence on their present and future status.

- Native woodlands are well suited for multi-purpose forestry in the Highlands. If the area of native pine and birchwoods was substantially increased, significant timber production could be reinstated, albeit generally with lower timber production than from many non-native forests.

- Scottish native boreal forests represent a significant resource for conservation of ecosystems, wildlife and landscapes. An increase in their area would confer considerable benefits for nature conservation.

- A large number of tree species originating in oceanic boreal forests and temperate rainforests of Europe, Japan and North America have been grown for many years in the boreal region of Scotland. In some respects these forests have affinities with natural boreal forest, however management for wood production has resulted in clear differences.

Chapter 9

Current policy and initiatives

Native woodland

It is now widely, though not universally, accepted that the area of native woodland remaining in Scotland is less than optimal for the needs of society, both rural and urban. Foresters, scientists and conservationists have all advocated measures to protect and restore existing woodland, and to increase its area by planting and natural regeneration (Stevens and Carlisle, 1959; Frazer Darling and Morton Boyd, 1964; McVean and Ratcliffe, 1962; Ratcliffe, 1977; Bunce and Jeffers, 1977; Nature Conservancy Council, 1986; Forestry Commission, 1981; Forestry Commission, 1985; House of Commons, 1990; Peterken *et al.*, 1992). Such measures are now part of Government policy and are underpinned by international commitment.

Several decades elapsed between concern for the status of native woodland in the Highlands first being expressed and those concerns achieving sufficiently high political priority to be addressed by government. The mechanisms currently adopted to promote restoration of native woodland are based primarily on voluntary management agreements with private owners, where agreed operations are subsidised by substantial grant payments.

Government initiatives which have helped to secure the future of privately owned native woodlands in Scotland include: the Native Pinewood Grant Scheme (Forestry Commission, 1981) and the New Native Pinewood Grant Scheme (1989) which provided private owners with guidelines for and funding towards management, regeneration and creation of native pinewoods. The Broadleaved Woodland Policy Statement and Grant Scheme (Forestry Commission, 1986) and the Woodland Grant Scheme provided similar incentives for broadleaved woodland. The *Forest nature conservation guidelines* (Forestry Commission, 1990) encourage the planting of native species. Recently several interagency projects have been established in the Scottish Highlands to encourage owners to take advantage of avail-able grants for native woodland rehabilitation. In addition the Forestry Commission has established an Advisory Panel on Native Woodland in the Highlands.

Currently 9500 ha of new native pinewoods have been planted/regenerated. In Highland Region the planting of broadleaves by the private sector has increased from 1% of grant-aided planting (36 ha) in 1987 to 60% in 1994 (Dunsmore, personal communication). The practice of converting native woodlands to commercial conifer crops by felling and replanting or underplanting stopped in 1987. Substantial areas of semi-natural woodland have been fenced with a view to restoring them and extending their area. Forest Enterprise (FE) is prioritising the restoration of remnants of semi-natural woodland on its landholdings and proposes to extend the area of native broadleaved woodlands by 1000 ha and restore all significant areas of underplanted native woodland (Stevenson, personal communication). In addition FE intends to set up Caledonian Forest Reserves covering a gross area of 18000 ha. FE is affording the establishment of new native woodland on its own land relatively low priority, partly because funds for such work are divided between a wide range of other conservation and recreation objectives, and such woodlands do not meet financial targets set by Treasury.

Several areas of native woodland have been bought and are now being managed by nature conservation organisations; the most notable being Creag Meagaidh owned by Scottish Natural Heritage and Abernethy owned by the Royal Society for the Protection of Birds. Other similar land purchases have been proposed, e.g. Mar Lodge.

Statistics are not available to allow a clear assessment of the current location, area, timber volume, growth, or composition of native woodlands to be made, mainly because they are not specifically distinguished in forest inventories (Callander *et al.*, 1990). Inventories of native woodlands have been carried out by the Nature Conservancy Council (now represented by Scottish Natural Heritage) which distinguished between woods on the basis of their antiquity and several interagency initiatives are carrying out surveys of native woodland.

It is clear that prospects for arresting the decline of native woodlands in the Highlands have improved greatly since 1987. A sustained period in which regeneration of existing woods and establishment of new ones is required before a significant improvement in the status of native boreal forests in Scotland can be considered to have been achieved.

Several important factors limiting restoration and expansion of native woodlands can be identified:

1. A lack of motivation on the part of some private landowners and their agents, partly based on an unwillingness to undertake forms of woodland management largely for public benefit.

2. Legal difficulties in establishing trees on tenanted farms (Rural Forum, 1991).

3. Inappropriate management: many native woodlands are still subject to overgrazing, burning and neglect, and this continues to cause local reduction in their area. The high populations of red deer are seen as a particularly serious problem (Callander and MacKenzie, 1991b).

4. Limitations resulting from the allocation of funds to FE, and the rules under which FE can undertake planting of forests.

5. Limitations imposed by the poor condition of existing woodland, and the limited opportunities for timber production on many sites.

6. Use of broadleaved planting stock from outwith the boreal region may be causing changes to the genetic character of Scottish boreal tree populations.

Planted forests

The need to continue to increase the area of planted forests is widely, though not universally, accepted and is supported by provision of Government grants to private landowners. The activities of Forest Enterprise are limited by Government rules preventing them from acquiring substantial amounts of land.

Forest management practices have evolved during the last 10 years to take greater account of benefits other than timber production, and such changes are now underpinned by the Government's commitment to sustainable forestry and the Biodiversity Convention (Forestry Commission, 1994; Department of the Environment, 1994). Changes in practice include: increasing the component of native species, improved guidelines for cultivation, roading, landscaping and harvesting practices, retaining a small proportion of stands beyond the commercial rotation age, improving landscaping practices, retaining dead timber at clear felling, and the proposed use of silvicultural systems other than clear felling.

Some of these modifications to silvicultural practice will lead to the establishment of planted forests which in certain respects are closer to natural boreal forests than plantations established during the period 1960-80 (more diversity, more native species, retention of deadwood). At present there is no consensus on exactly what form any further modifications to silviculture should take.

Research effort has also been increased on:

- natural regeneration and the application of silvicultural systems other than clear felling;
- the use of native species in plantations;
- prospects for replicating certain attributes of north American natural forests.

Chapter 10

Conclusions: the future

Native woodlands

One of the values of describing the biogeography and history of Scottish boreal forests is that it allows their future management to be conceived in a wider geographical context and as part of a longer historical time sequence. This wider context may usefully supplement conventional analysis of what are justifiable objectives for the management of forests for the public good.

Consideration of the biogeography of Scottish boreal forests identifies them as a unique oceanic version of boreal forests. They are situated at the extreme north-west of the European landmass where climatic conditions exhibit usually rapid clines, both in terms of oceanity and with altitude. As a result, an unusually diverse range of forest types and transitions between types occurs within a comparatively small area in the Highlands. The only closely similar forests are located in a limited part of southern Norway. These Norwegian forests have also been severely disturbed by man and examples of primary oceanic boreal pine–birch forest in Norway are rare. This heightens the perception of the cultural and conservation value of the remnants of Scottish boreal forest.

The future of native woodland in Scotland can be seen as a Scottish contribution to what is now widely conceived as an international problem: that of establishing a satisfactory future for forest ecosystems throughout the world. This Scottish contribution requires the conservation and extension of existing native woodlands to provide significant reserves of the major types of forest native to Scotland.

The history of the Scottish boreal forests is one of an unparalleled reduction in area. While this has bequeathed a few unique and extraordinary opportunities (sheep farming, sporting, the conservation of unique moorland ecosystems and afforestation with introduced conifers), it has also left a legacy of regret; regret for lost forest landscapes, extinct species of mammal, bird and probably plants, reduced soil fertility, increased erosion, and lost opportunities to utilise a native forest ecosystem. The current status of existing native woodlands compounds this sense of regret; they are often degraded and mismanaged, surviving precariously as tattered remnants, frequently despite the efforts of man.

Native forests are capable of demonstrating links with past natural and human history in a way which few other land uses can claim. Stevens and Carlisle (1959) state this very aptly; 'to stand in them is to feel history', and natural woodlands have frequently been likened to historical monuments. As Anderson (1967) states, it also comes as a surprise to many people today to realise the former extent of the forests and how closely the lives of people were bound up with them. The influence of the native forests on rural culture has now largely dissipated, but in regions such as Deeside and Speyside where significant tree cover has persisted, traces of a forest culture akin to that encountered in Scandinavia, can still be perceived.

Afforestation has also only partially rectified the sense of regret occasioned by the loss of the native forests. Successes achieved in wood production have not been accompanied by significant progress in restoring natural forest ecosystems and landscapes. Seen with the benefit of hindsight, the level of activity and successes of plantation forestry during this century makes the absence of progress in restoring native woodlands seem all the more remarkable.

Afforestation during this century has paid only sporadic attention to social and cultural aspects of forestry. Strengthening links between communities and Scottish forests could be well served by a significant expansion of native woodland.

New native woodlands

These are some of the specific points that need attention in developing areas of new native woodland.

- *At least some areas need to be large scale enough to: be considered as significant representatives of the boreal forest ecosystem; be ecologically resilient; display their natural dynamics; recreate past forest landscapes; provide the basis for at least local industries; and to provide for a degree of forest 'wilderness experience'. Such areas are best based on existing areas of native woodland.*

- *Where little native woodland currently exists, attention needs to be paid to creating new core areas.*

- *High elevation woodlands and treeline communities which are conspicuously absent in Scotland are in particular need of expansion. These present special technical difficulties.*

- *Natural regeneration is the preferred method for expanding woodlands.*

- *Genetic integrity of boreal tree populations needs to be safeguarded by using planting stock of local origin. There is little to be gained and much which may be lost by using plants from outwith the boreal region (Worrell, 1992).*

- *Social and cultural aspects of forestry could be enhanced by greater community participation, in a similar way to that envisaged for lowland areas.*

While not all the features of a boreal forest can be recreated, 'new native' woods allow combinations of benefits to be realised which are not available from existing types of forest. These values emphasise the importance of landscape, ecological restoration, cultural history and wilderness experience. Opportunities to realise the more familiar outputs from forests, including wood production, are also present to a greater or lesser extent, particularly in new native pinewoods.

Establishment of natural forests clearly presents the flora and fauna which evolved within boreal forests with opportunities to flourish. In a countryside which is dominated by non-natural ecosystems and radically altered animal and plant communities, this clearly has special value. One of the important attributes of such forests is the fact that they require relatively low inputs and therefore their inclusion in a 'portfolio' of more intensive forest types presents future generations with wider range of opportunities and a greater degree of flexibility.

The strategic approach

Serious consideration needs to be given to the future extent, location and composition of such forests. The strategic approach to forest planning has been widely accepted both within the forest industry (Forestry Commission, 1992; FICGB, 1992; Harding, 1992) and elsewhere (RSPB, 1991; Wightman, 1992), and this could usefully be extended to native woodlands. Peterken (1992) has suggested that the conservation interests would be well served if the extent of native woodland was increased at least twofold, and three to fivefold in the Scottish Highlands. He proposes that a number of key areas be identified where native woodlands may be clustered to give coverage of 25-30% of the land area, thereby creating an ecologically resilient woodland landscape. He also advocates the recreation of riparian woodlands.

Native woodlands also need to be integrated with plantation forestry in a way which maximises benefits. Conservation organisations have suggested a pattern of zones of forest managed under different regimes (Wightman, 1991). The concept of native forest forming a matrix in which more intensively managed forests are located appears to be widely accepted as an objective.

There is a need to identify priority areas for establishing new native woodlands and to consider how such woodlands may be designed to integrate satisfactorily with existing land use interests. On this basis government policies and incentives will need to continue to evolve.

Wider policy issues

Native forests provide opportunities for multi-purpose forestry in which some of the benefits are private (wood production, shelter for stock), but where the majority are public. The current situation, in which private landowners can receive government incentives for creating new native woodland but the involvement of the

public sector is limited, has elements of illogicality and requires addressing. The future of native woodlands would be enhanced with wider involvement of the public sector.

The future for native woodlands is also influenced by other land use policies. Current practices on sporting estates which lead to burning and overgrazing also need to be addressed to secure a future for native woodland. The positive aspects of the relationship between deer management and native forests need to be developed.

Planted forests

The history of forestry in boreal countries is one in which clearance and exploitation of natural forests has gradually given way to plantation forestry. The management of plantations has become increasingly refined since its inception about 150 years ago and the production of wood has become particularly efficient. In recent years the objectives of plantation forestry have been widened to include not only wood production but a range of other benefits. This has been done in order to take increased account of landscape and nature conservation. In Scotland this has required that silviculture be altered by making a number of individual modifications to intensively managed plantations.

Such modifications might usefully be refined and developed by emulating more of the natural structures and processes exhibited by natural boreal forests. Two main forest ecosystems suggest themselves as models for Scottish quasi-natural boreal forests: (a) Scandinavian and (b) northern British Columbian/southern Alaskan (choosing the appropriate transitional zone between rainforest and continental boreal forest). Promoting quasi-natural composition, structures and processes could be achieved by:

- Matching species to site and using different species during different phases of the rotation in ways which are modelled on natural forests.

- Increasing rotation length with some areas left to develop 'old growth' characteristics (Peterken, 1992).

- On sites where this is possible, timing and designing felling to emulate the pattern of disturbance encountered in natural forests, i.e. designing the distribution and size of felling coups to emulate to a greater or lesser extent that observed in natural forests.

- Relying on natural regeneration and increasing natural forms of tree succession.

- Increasing efforts to recreate specific woodland habitats and niches.

- Limiting intensive site preparation.

Possible advantages of emulating aspects of forest ecosystems

The fact that one has a natural model to follow, albeit in another country, might suggest that changes due to natural phenomena (e.g. the pattern of windthrow, regeneration) may be more predictable than in forests which have been modified in an *ad hoc* fashion. There is also a case to argue that such diverse forests may be more stable in the long term than intensively managed plantations (e.g. to insect attack or windblow). On the other hand, intensively managed plantations are also in some senses inherently predictable because they are uniform; whereas natural forests are diverse and complex. If it could be established that quasi-natural forests were either more stable or in some respects more predictable , there would be some virtue in introducing them into the suite of forest types we bequeath to future generations. Long-term stability and predictability are essential components of the concept of sustainability.

Ecological theory would suggest that such quasi-natural forests may be more suitable for the range of wildlife which evolved within boreal forests, thus contributing to the maintenance of biodiversity. In addition, the likelihood of overstepping ecological thresholds and causing environmental damage decreases the closer one comes to 'following nature'. For example, sedimentation of watercourses is least likely to occur in forests where felling and restocking emulated the natural pattern of disturbance and regeneration. Avoiding environmental damage is also an important aspect of sustainable management.

However, it is not immediately apparent that modelling plantations on natural forests is necessarily the optimal approach. Quasi-natural forests would be complex and expensive to manage. Other approaches which suggest themselves include:

- Managing forests to produce pleasing effects and to reduce environmental impacts with little reference to or similarities with specific natural forest ecosystems.

- Managing extensive areas of forest primarily for timber production and concentrating efforts to provide natural forest conditions on areas of native forest.

Whether quasi-natural plantations are ultimately preferred by society remains to be seen.

Information requirements

Information on the attributes of boreal forest ecosystems can be used to supplement guidelines for establishing 'new native' boreal forest. The species composition and structure of native boreal woodlands is known about in general terms but considerably better information is required before we can claim to understand and be able to manage boreal forest ecosystems in Scotland. The most obvious information requirements relate to:

- The frequency, types and patterns of disturbance, species composition and structure at the site level.

- The upper altitude limits for the different native tree species in different parts of the country, together with establishment of treeline communities.

- The dynamics of regeneration and succession after various forms of disturbance, colonisation by ground flora and fauna.

- Integration with other forms of forestry and other land uses.

Some of this information may be available by studying Scandinavian forests; the rest will be gained only by experience. Gathering this information and establishing a satisfactory framework in which to apply it could be greatly enhanced by international contacts. This would constitute a significant contribution to developing a flexible, productive and sustainable forest resource in Scotland.

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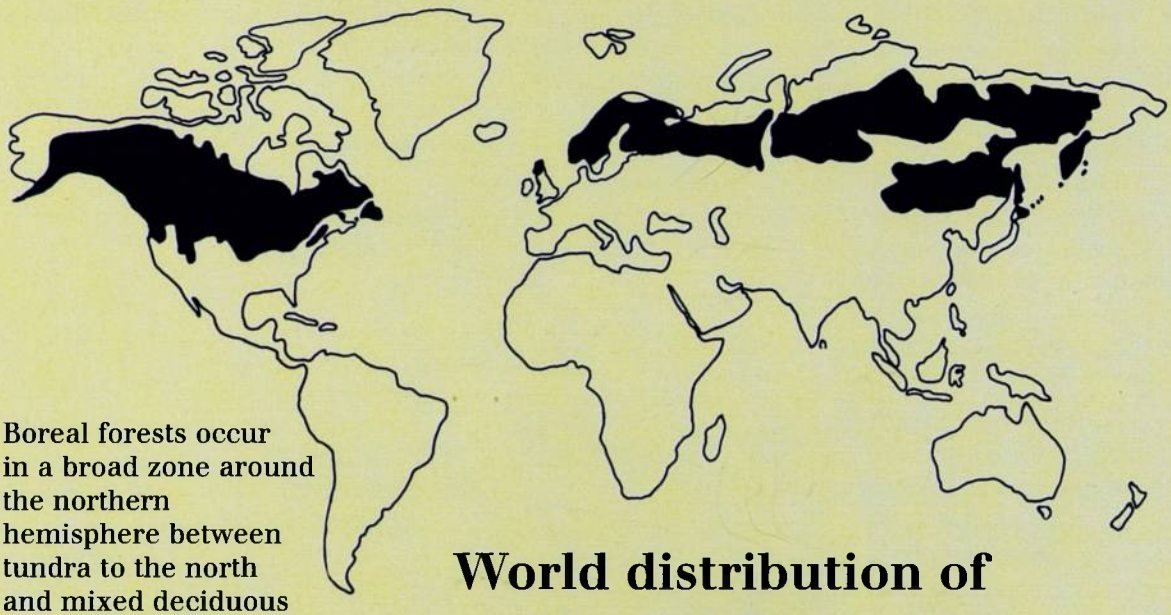
Appendix 1

The division of *Pinus sylvestris-Hylocomium* woodland into subcommunities according to the National Vegetation Classification, and the relationships between this and some previous classifications

National Vegetation Classification		Equivalent in other classifications	
		Stevens and Carlisle (1959)	(a) McVean and Ratcliffe (1962) (b) McVean (1964)
Pinus sylvestris–Hylocomium splendens woodland	*Erica cinerea–Goodyera repens* subcommunity	Community 1	(a) *Pinetum Hylocomieto–Vaccinietum triquetrosum* (b) Pinewood *Vaccinium*–moss association. *Hylocomium–Rytidiadelphus* phase
	Vaccinium myrtillus–Vaccinium vitis-idaea subcommunity	Community 3	(a) *Pinetum Hylocomieto–Vaccinietum myrtillosum* (b) Pinewood *Vaccinium*–moss association. *Vaccinium* phase
	Luzula pilosa subcommunity	Communities 3,4,5	
	Sphagnum capillifolium/quinquefarium subcommunity	Communities 2,6,8,9	(a) *Pinetum Vaccineto–Callunetum* (b) Pinewood *Vaccinium–Calluna* association
	Scapania gracilis subcommunity	Community 2	(a) *Pinetum Vaccineto–Callunetum* (b) Pinewood *Vaccinium–Calluna* association



Boreal forests occur in a broad zone around the northern hemisphere between tundra to the north and mixed deciduous forest or steppe/prairie to the south.

World distribution of boreal forest

The pine and birch forests of the Scottish Highlands are regarded as an extreme oceanic variant of boreal forests by many ecologists. Some published maps of their world distribution include Scotland, while others do not.

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