PROJECT MUSE®

THE POTENTIAL NATURAL VEGETATION OF IRELAND

John R. Cross

Biology and Environment: Proceedings of the Royal Irish Academy,
Volume 106B, Number 2, August 2006, pp. 65-116 (Article)

Published by Royal Irish Academy

➔ For additional information about this article

<https://muse.jhu.edu/article/809809/summary>

THE POTENTIAL NATURAL VEGETATION OF IRELAND

J.R. Cross

ABSTRACT

A map of the potential natural vegetation of Ireland is presented. The concept of potential natural vegetation is briefly outlined, followed by a consideration of the factors affecting its development: these include climate, soil type, vegetation history, land use and biotic factors. This is followed by a brief overview of present day vegetation. Literature sources and methods used in the compilation of the map precede the main body of the text, which consists of a description of twenty vegetation units. The vegetation units, which fall within six Formations or Formation Complexes, include nine forest units, five mire units, two heath units, two sand dune units and one each of salt marsh and polder units. Minor vegetation types are also considered briefly. In conclusion, the general distribution and character of Irish potential natural vegetation and its relationship with the rest of Europe is discussed.

INTRODUCTION

Ireland (unless otherwise stated, Ireland refers to the island of Ireland) is one of the few areas in Europe that does not have a detailed map of the natural vegetation for the entire landmass. There have been numerous studies of Irish vegetation resulting in the production of maps at different scales. These include small-scale maps of specific vegetation types, e.g. agricultural grasslands (O'Sullivan 1982) and peatlands (Hammond 1979), as well as detailed maps of small areas, e.g. the Lough Corrib fens (Mooney 1990). However, no attempts at an overall synthesis of the natural vegetation have been published, with the exception of that of Noirfalise (1987). The need for and uses of vegetation maps are widely recognised on the European mainland, e.g. Germany (Bohn 1981), the Czech Republic (Neuhäuslová 1998; 2001). This conviction among botanists from many countries of Europe on both sides of the former Iron Curtain led to the international collaboration resulting in the production of a 'Map of the natural vegetation of Europe' at a scale of 1:2.5m (Bohn *et al.* 2000; 2003; 2004). The map of Ireland appearing in this map (Bohn *et al.* 2003; 2004) is presented in this paper, with an expanded and, where necessary, revised version of the descriptions of the vegetation units. It also elaborates on an earlier paper (Cross 1998). The classification system used in producing the 'Map of the natural vegetation of Europe' (Bohn *et al.* 2003) is retained. The concept of potential natural vegetation and the factors affecting its development are outlined. This is followed by a résumé of the present day vegetation, references for

the main sources of data, and a description of the methods used to compile the units and to construct the map of the natural vegetation of Ireland. The main text consists of details of the vegetation, habitat, land use and conservation status for each vegetation unit. Finally, the vegetation patterns within Ireland and the relationships of Irish vegetation to the rest of Europe are discussed.

A great deal more work is required for the production of a more detailed map that would adequately depict the heterogeneity of Irish vegetation. Interpretation of the map should, therefore, be undertaken with caution, bearing in mind that the units represent complexes in which only the principal vegetation type is depicted. Reference should be made to the description of the units that provide more information on the variations present, particularly the sections entitled 'Vegetation occurring in complex'. Throughout this paper nomenclature follows Stace (1997) for higher plants, Blockeel and Long (1998) for mosses and liverworts and Purvis *et al.* (1992) for lichens. Names of protected species are based on Curtis and McGough (1988).

THE CONCEPT OF POTENTIAL NATURAL VEGETATION

The concept of potential natural vegetation was introduced by Tüxen (1956), and it has given rise to much debate and many subsequent modifications, for example, see Kalkhoven and van der Werf (1988). As used in this paper, potential natural vegetation follows the definition of Westhoff and van der Maarel (1973), who describe it as '...the

J.R. Cross (e-mail: john.cross@environ.ie), National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, 7 Ely Place, Dublin 2, Ireland.

Received 30 August 2005. Read 30 November 2005. Published 31 July 2006.

vegetation that would finally develop in a given habitat if all human influences on the site and its immediate surroundings would stop at once and if the terminal stage would be reached at once'. The vegetation units therefore represent natural, more or less stable plant communities reflecting present day habitat conditions.

Over large areas of Ireland the original habitat conditions have been greatly and sometimes irreversibly altered by human activity, making predictions of potential natural vegetation difficult, especially as the effects of human influence may persist long after the activity has ceased. Edaphic and climatic changes, grazing pressure and the legacy of introduced species, for example, pose particular difficulties. It is possible to predict with a reasonable degree of certainty that, for example, grassland on calcareous clays in the midlands is likely to be replaced with some form of pedunculate oak–ash forest with hazel. It is also assumed that elements of the forest field layer will invade, even though this can be a very slow process (Peterken 1993). The extent to which changes in the soil following agricultural activities would influence species composition, however, is less predictable, although nitrophilous species may play a more important role in the herb layer than they did prior to the agricultural activity (Neuhäuslová 2001). Introduced species such as beech (*Fagus sylvatica*) and laurel (*Prunus laurocerasus*) may also form an element of the flora. It is, however, more difficult to predict the regenerated vegetation of cutaway bog; species-poor birch woodland has developed on many drier sites (van der Sleesen and Poole 2002), but we do not know whether this will be replaced eventually by oak–ash forest, or gradually revert to wet heath and subsequently bog.

While an attempt has been made to take these uncertainties into consideration, we can neither predict with certainty how the vegetation would evolve in the absence of human activity, nor determine what the terminal stage will be. The factors influencing the development of potential natural vegetation are examined in more detail below.

FACTORS INFLUENCING THE DEVELOPMENT OF POTENTIAL NATURAL VEGETATION

The natural vegetation that may develop at a specified site is influenced by a combination of several factors, including (1) climate, (2) soil type, (3) vegetation history and land use, (4) existing semi-natural vegetation and (5) biotic factors.

CLIMATE

Ireland lies at the north-west corner of the Eurasian landmass and is exposed to prevailing westerly winds and North Atlantic depressions, which determine its oceanic climate. Winters are mild, summers are cool and precipitation occurs throughout the year. The comprehensive network of meteorological stations around the island has enabled a detailed picture of the Irish climate to be assembled (Rohan 1986; Collins and Cummins 1996). Despite its small size, the climate of the island is characterised by regional variations that influence the distribution of species and plant communities. The most important regional variations are precipitation, temperature, sunshine, wind and altitude.

Precipitation

There is an increase in precipitation and a decrease in evapotranspiration from east to west. Mean annual precipitation varies from less than 700mm around Dublin to 1250mm in the lowlands of the west, and over 2000mm (and locally over 3000mm) in the mountains of Kerry, Connemara, Co. Galway and Donegal. Rain days (those with over 0.2mm rain per day) vary from 190 days near the east coast to about 250 days near the west coast. Rainfall exceeds evapotranspiration for eleven months and by more than 700mm per year in the west and for nine months and by 250mm per year in the east.

Temperature

There is an increase in temperature from north to south. For January, the mean temperatures vary from 3.5°C in the north-east to 6.5°C in the south-west, and for July they vary from 14.0°C on the north coast to 16.0°C around Cork and Dublin. The coastal fringes are particularly mild, and frost is infrequent.

Sunshine

There is an increase in sunshine from north-west to south-east, which reinforces the influence of precipitation and temperature, as already noted. There is also more sunshine on the coasts than inland. Mean annual sunshine totals vary from less than 3.5 hours per day over much of the midlands, north-west and south-west to 4.5 hours per day in the extreme south-east.

Wind

There is an increase in wind strength towards the coast, from south-east to north-west, and with altitude. Malin Head, Co. Donegal, has gales (Force 8 or greater on the Beaufort Scale) on more than 57 days per year, whereas many places inland and on the east coast have fewer than 10 days.

Table 1—Altitudinal limits of tree species. After Blackstock (1998) and Hart (1891).

Species	Altitude (m)	Location
<i>Quercus petraea</i>	330	Kerry
	100	Antrim
<i>Sorbus aucuparia</i>	730	Kerry, Mayo, Galway
<i>Ilex aquifolium</i>	490	Kerry
	230	Donegal
<i>Betula pubescens</i>	460	Kerry
	230	Donegal
<i>Alnus glutinosa</i>	< 330	—
	(Hart 1891)	
	< 240	—
	(Blackstock 1998)	
<i>Corylus avellana</i>	< 240	—

ALTITUDE

Precipitation and windiness increase with altitude, whereas temperature and sunshine decrease. Snow cover and incidence of frost also increase with altitude. Low summer temperatures—rather than low winter temperatures—and exposure may be important for the survival of the very impoverished arctic–alpine flora, and these temperatures also appear to dictate the tree line. There is little available information on the altitude of the tree line. Hart (1891) recorded all native tree species except alder above 330m: Blackstock (1998)

records that most native tree species regenerating within conifer plantations above 240m display a general north–south trend, with *Quercus petraea* and *Fraxinus excelsior* more common in the south-west and *Betula pubescens*, *Ilex aquifolium* and *Sorbus aucuparia* more common in the south-east. *Quercus petraea* was absent from plantations in the north, and *Alnus glutinosa* and *Corylus avellana* were not recorded anywhere in Ireland above this altitude. The highest woodland in the Killarney area is currently c. 330m, and in sheltered parts of County Wicklow trees occur above 330m. In the absence of grazing and burning, trees would grow at higher altitudes. The altitudinal limits of certain tree species are shown in Table 1.

SOIL TYPE

Detailed soil maps at the scale of 1:126,720 exist for eight counties. The general soil map of Ireland at a scale of 1:575,000 provides a useful overview of the complexity and considerable spatial variation present, and reflects the variation in parent material, climate and topography (Gardiner and Radford 1980). A summary of the major soil types is given in Table 2.

In general there is a pronounced increase in gleys and blanket peats and a decrease in soil depth, with a concomitant increase in rockiness, from south-east to north-west. Blanket peats are more common in the west and at high altitudes, whereas raised bog peats are concentrated in the central lowlands. Shallow soils over limestone occur principally in the western part of the midland

Table 2—The principal soil types according to major physiographic divisions and percentage area of land surface covered by that soil type. After Gardiner and Radford (1980).

Physiographic division	Principal soil types	% land area covered by soil type
Mountain and hill land above 365m	Peaty podzols	
	Peaty gleys	9.7
	Lithosols	
Hills between 150m and 365m	Brown podzolics	
	Grey-brown podzolics	5.4
	Rendzinas	
Rolling lowland below 150m	Acid brown earths	
	Podzols	26.6
	Gleys	
Flat to undulating lowlands	Grey-brown podzolics	
	Gleys	25.7
	Gleys	
Drumlins	Grey-brown podzolics	16.2
	Acid brown earths	
Mountains and lowlands	Blanket peats (mountain and lowland)	10.5
Basins	Basin peats (raised bogs)	5.1

plain, and brown earths and brown podzolics are most abundant south-east of the River Shannon. Within these broad soil units there is considerable variation, reflected in the presence of discrete vegetation types within the principal vegetation units.

VEGETATION HISTORY AND LAND USE

Mitchell (1976; 1987) and Mitchell and Ryan (1997) give masterly descriptions of the vegetation history of Ireland. They are not reiterated here, but a few salient points relating to the potential natural vegetation are highlighted below.

From *c.* 8000 BP onwards, mixed elm–oak forest covered much of the island, with some yew and ash and with hazel as an undershrub. Scots pine occurred on drier and poorer soils and at higher altitudes, and alder was present on wetter soils. As the climate became wetter, *c.* 7000 BP, alder became more widespread and pine declined. Elm (*Ulmus glabra*) declined dramatically *c.* 5900 BP, possibly as a result of disease. Humans first had an impact on the forests in Neolithic times *c.* 5500 BP, and from the Bronze Age onwards the history of Irish forests is one of intermittent but relentless decline, with the occasional development of secondary forests when human pressure on the land decreased (see, for example, McCracken 1971). From medieval times, the landscape appears to have consisted of scrubby woodland and rough pasture with local stands of dense woodland, although there was considerable regional variation (Hall 2000; 2003; Molloy and O'Connell 2004). Scots pine may have become extinct, or declined to very small, relict populations (Budd and von Engelbrechten 1999; Kelly and Connolly 2000; Molloy and O'Connell 2004; F. Kelly, pers. comm.), although it was subsequently reintroduced and is now widespread. By the beginning of this century, forest cover was probably less than 1% of the land surface (Rackham 1986). Cross (1987a) estimated that only *c.* 84000ha of native woodland and scrub—all of which has been greatly modified—remained in the Republic of Ireland, representing 0.8% of the land surface of the country. Recent analysis of Forest Service data indicates that *c.* 77000ha of native woodland (excluding scrub) occurs in the country (Higgins *et al.* 2004). Thus, the original forests in Ireland have been more thoroughly extirpated than in any other European country (Mitchell and Ryan 1997), and Ireland today is a landmass largely dominated by improved grassland.

Selective felling and planting have had a major impact on the abundance and distribution of the principal tree species. Sessile oak (*Quercus petraea*) is often the dominant species on well-drained acidic soils, where it forms near monodominant stands,

partly as a result of preferential selection. In contrast, pedunculate oak (*Q. robur*), which is found mostly on calcareous and poorly drained soils, is now relatively scarce outside old estates; woodlands on such soils today are often dominated by *Fraxinus excelsior*, which appears to have played a relatively minor role in ancient forests (e.g. Hall 2003; Molloy and O'Connell 2004; M. O'Connell, pers. comm.). Other species have also been selectively—but sometimes only locally—removed, for example, alder (*Alnus glutinosa*) from the valleys of County Wicklow for the British clog-making industry (Nisbett 1903). In addition to changes in species composition, woodland structure has also been profoundly altered, with many stands being even-aged and with a paucity of old and moribund trees.

In an attempt to reverse deforestation, a programme of tree planting began in the eighteenth century. This had little impact on the overall area under forest, but the introduction of exotic species, such as beech (*Fagus sylvatica*), sycamore (*Acer pseudoplatanus*) and larch (*Larix europaea*) had an important influence on the composition of the remaining forest stands, especially in old estates. Since the beginning of the twentieth century afforestation has concentrated on marginal upland soils and blanket peats and the emphasis has been overwhelmingly on conifers, with two North American species, sitka spruce (*Picea sitchensis*) and contorta pine (*Pinus contorta*), being particularly favoured in recent decades. Establishment of these forests requires deep ploughing (to break up the iron pan), drainage and fertilisation, radically altering the soils and resulting in the destruction of extensive areas of upland grassland, heath and blanket bog. It is not known how these coniferous plantations, which form *c.* 78% of the forest estate and cover *c.* 6% of the land surface, will develop in the future, although evidence suggests that as the canopy opens up, native species will gradually invade, at least on mineral soils and shallow peats (Blackstock 1998).

Important as the impacts of afforestation is, agricultural activity has played a far greater role in shaping the landscape and vegetation. Particularly rapid changes that have occurred since the accession of Ireland into the European Union (then the European Economic Community) in 1973 are discussed below.

Agricultural activity has caused a loss of native woodland and a reduction in the altitudinal limit of trees as a result of felling, grazing and burning. Overall species complement has declined, especially of woodland species, with a concomitant increase in weed and ruderal species. In recent decades ploughing and reseeded of grasslands and the widespread use of herbicides and fertilisers have

reduced species abundance still further, with a few high-productivity grasses and herbs being favoured. Many species are now confined to hedgerows, roadsides, railway embankments, cemeteries and other locations too inaccessible or remote to justify agricultural improvement.

Ploughing and fertilising have increased the fertility of lowland soils, which are consequently richer in nitrates, phosphates, calcium and other nutrients than undisturbed woodland (Peterken 1993; Hickie *et al.* 1999). Fertiliser drift may also have affected adjacent areas of non-agricultural land, nitrophilous species being particularly favoured. In contrast, grazing and burning of uplands have reduced soil fertility, encouraged the formation of iron pans and led to an expansion of heathlands.

Grazing by domestic animals and associated burning has played a key role in the development of anthropogenic heaths, species-rich grasslands and limestone heaths and has also influenced the development of sand dunes and salt marshes. Overgrazing, especially in the uplands of the west, has recently led to severe erosion of blanket peats and skeletal soils, so that the re-establishment of vegetation may be impossible in some areas (Bleasdale and Sheehy Skeffington 1995).

Drainage has altered the soil water regime and led to the loss of many wetland habitats and the moister facies of terrestrial communities. The impact has been greatest where the regional water table has been lowered—especially on the naturally better-drained soils—in the immediate vicinity of arterial drainage schemes and on raised bogs. On heavier clay soils and on blanket peats the impact has been less marked.

While human activity played a major role in forest decline, another important factor, often operating synergistically, was paludification, which led to the development and expansion of raised and blanket bogs. Raised bogs, which developed principally in the central lowlands and in the Bann Valley, at one time covered 5% of the island, while the blanket peats, which occur in the uplands and in the extreme west, formerly covered 12% of the land surface. Bogs traditionally provided domestic fuel, and extensive areas have been cut by hand over the centuries. Peat removal has greatly accelerated in the last 50 years with the introduction of mechanised cutting. More than 95% of raised bogs have been damaged or destroyed (Cross 1990a), 43% of blanket peats have been cut away (Foss *et al.* 2001) and *c.* 200,000ha have been afforested (Farrell and Boyle 1990; Stapleton *et al.* 2000). The approximate areas of land under different land uses throughout the island are given in Table 3.

Table 3—Land use in Ireland and approximate areas under each category of use.

<i>Land use</i>	<i>% area under use</i>
Improved agriculture (mostly grass-land)	66
Forest plantations	8
Semi-natural woodland and scrub	1
Blanket peat	9
Raised bog, including cutaway and substitute communities	5
Upland grassland and heath	4.5
Other vegetation (fen, sand dunes, salt marshes etc) and urban land.	6.5

Based on O'Sullivan (1982), Farrell and Boyle (1990), Hickie *et al.* (1999), Northern Ireland Biodiversity Group (2000).

To summarise, the overall effect of these changes has been to convert a largely deciduous-forested landscape, broken up by raised bogs in the lowlands and more extensive areas of blanket bog in the west and on the mountains, into a largely grassland-dominated landscape with small, scattered stands of native woodland and an increasing area of coniferous plantation. Paradoxically, the countryside still presents an impression of being well wooded because of the extensive network of hedges and shelter-belts, most of which were planted in the eighteenth century. These have to some extent acted as refugia for native woodland species and provide a valuable source of information for predicting potential vegetation.

EXISTING SEMI-NATURAL VEGETATION

Woodlands

Under present day climatic conditions and without human interference, much of Ireland—except for the peatlands, mountain tops and exposed coastal fringes—would be covered naturally in deciduous forest. The main extant woodland types are: sessile oak woodlands on acidic soils; mixed pedunculate oak–ash–hazel woodlands on base-rich soils; hazel scrub on shallow, limestone soil; various types of birch woodlands (often successional stands) on cutaway peat and in upland areas; and small areas of alder–ash–willow woods in river valleys, on lake shores and in wet depressions.

Over extensive areas, for example, the central and eastern lowlands, the drumlin belt of the north midlands, and the gleyed soils of the Kerry and Clare plateaux, sources of information for predicting the potential natural vegetation are

restricted to small, highly modified woodland fragments, hedgerows and patches of uncultivated land or palynological records (e.g. Hall 2003; Molloy and O'Connell 2004). Almost nothing remains of the high altitude woodlands, whose former presence can be inferred only from isolated trees or very small stands of secondary woodland and by limited extrapolation from the Scottish mountains. The paucity of woodlands means a shortage of seed sources and consequent slow recolonisation by some species.

Peatlands and other wetlands

Approximately 17% of the country was formerly covered in peatland (Hammond 1979) but much of this has now been cut away or afforested. Raised bogs have declined considerably with c. 95% seriously damaged or destroyed. Where they still remain, the variety of natural communities has been much reduced by a combination of drainage, cutting and burning and at least one species of higher plant has become extinct in the last 50 years (Cross 1990a). Where large-scale mechanised peat extraction has occurred, extensive areas almost devoid of vegetation have been created. Evidence from both Ireland and other countries in north-west Europe indicates that bog communities will not readily regenerate on such substrates, but the areas will be colonised by a complex mixture of woodland, fen and reed swamp communities or will become open water (see, for example, Streefkerk and Casparie 1989). Hand or small-scale mechanical cutting results in a complex of fen, bog and aquatic communities, which also develop into a mosaic of woodland and wetland communities. Remaining relatively intact raised bogs may survive to provide a 'seed' source and eventually expand, as the impact of artificial drainage is reduced and burning ceases.

Blanket mires, which are the most extensive remaining semi-natural vegetation communities in Ireland, have been grazed and burnt for centuries, resulting in a considerably modified structure and species composition (Doyle 1990). Large-scale mechanised peat extraction has been less extensive than on raised bogs but, combined with hand-cutting and afforestation, there has been considerable loss of this habitat. Farrell and Boyle (1990) estimated that c. 200,000ha of blanket bog and wet heath have been afforested.

Fen carr, reed swamp and other wetland communities have also declined in area as a result of drainage, although the lowering of lake levels has led to the development of new fens, swamps and stands of scrub on former lake beds and around lake margins. The reduction in water level fluctuations, however, means that they are not exactly comparable to the original communities. It is expected that such communities would expand as

drainage channels become blocked and water levels rise.

Other communities

Other vegetation types cover only a small fraction of the total area of the country. Of these, dunes and salt marshes would be expected to expand, although woodland and scrub communities may develop on the dunes and on polders, at least as long as the protective walls remain intact. Montane and coastal heaths would probably change the least as they are only slightly modified by present land use.

BIOTIC FACTORS

The influence of biotic factors on the potential natural vegetation is important but extremely difficult to predict. Excluding the possibility of a major outbreak of disease, such as Dutch Elm Disease, the two most critical factors are grazing and the impact of introduced plant species.

Grazing

Grazing by domestic animals, especially sheep and cattle as well as deer, plays a determining role in the character of present day vegetation. Extensive areas of upland heath are a direct result of grazing and associated burning and grazing is essential to maintain the diversity of dune, machair and unimproved grassland vegetation. Overgrazing is responsible for a decline in species diversity and regeneration in woodlands (Kelly 2000; Smith *et al.* 2003) and a cause of degeneration of upland vegetation. In the absence of human control, deer populations would expand and herds of feral sheep, cattle and goats might roam the countryside. In such a scenario, while forests would still develop on formerly unforested land, these grazers would have a major impact on the species composition and structure of the forests, and may retain areas of open grassland within the forests. In contrast, in the absence of systematic grazing, heath, scrub or coarse grassland may replace fixed dunes and machair vegetation (T. Curtis, pers. comm.).

Introduced species

Introduced plant species will also play a major role in the potential natural vegetation. Trees such as sycamore and beech, both shade-tolerant in their seedling phase but casting a heavy shade when mature, may inhibit regeneration of native species. Sitka spruce, Scots pine and western hemlock (*Tsuga heterophylla*) regenerate freely on better drained soils following disturbance and may become an integral part of the potential forests in upland areas. The regenerative ability of Sitka spruce and lodgepole pine on peats is less clear: many such forests do not thrive and it is probable

that without human intervention, modified blanket bog communities, with a large proportion of *Molinia caerulea*, would gradually develop as the trees die or are wind-thrown and the drainage deteriorates.

Rhododendron ponticum, on well drained acidic soils, and *Prunus laurocerasus* on base-rich soils may be important constituents of the shrub layer of the potential forests. Both are invasive, *R. ponticum* particularly so, and their presence leads to a reduction in diversity, the localised loss of native tree and shrub species and the formation of monodominant stands (Cross 1982; 2001). *Hippophae rhamnoides* may invade sand dunes. Other invasive exotics that may play an important role in the future potential vegetation include, *inter alia*, *Fallopia japonica* in woodlands, *Heracleum mantegazzianum* and *Gunnera tinctoria* alongside rivers and *Sarracenia purpurea* on raised bogs.

LITERATURE SOURCES USED FOR THE MAP AND VEGETATION DESCRIPTIONS

White (1982) gives a detailed history and bibliography of vegetation studies in Ireland and this provides a valuable source of information. A brief summary is given below.

The first descriptions of Irish vegetation go back to the seventeenth century, for example, Boate (1652) and King (1685) cited in White and Doyle (1982), but it is the work of Pethybridge and Praeger (1905) that is acknowledged as being the first modern account of Irish vegetation (White and Doyle 1982). Since then there have been numerous studies of a variety of ecosystems ranging from the seminal, but relatively superficial, account of the 1949 International Phytogeographical Excursion (Braun-Blanquet and Tüxen 1952; Lüdi 1952) to more detailed descriptions, for example, for raised bogs (Bellamy and Bellamy 1966) and for acidophilous oak woodlands (Kelly 1975). Many studies have concentrated on a few well-known and floristically exceptional sites, for example: the Killarney oak woods (Rübel 1912; Richards 1938; Kelly 1975); the Burren (Ivimey-Cook and Proctor 1966; Kirby 1982); and the Connemara blanket peats (van Groenendael *et al.* 1979; 1983a; 1983b). The first comprehensive phytosociological study of a major ecosystem type, peatlands, was undertaken in the 1960s by Moore (1968), followed by surveys of agricultural grasslands (O'Sullivan 1965; 1968; 1982) and acidophilous woodlands (Kelly and Moore 1975).

During the last twenty five years this ad hoc research has continued with studies of native

woodland on calcareous soils (Kelly and Kirby 1982), wetland woods (Kelly and Iremonger 1997), salt marsh and sand dune systems (Jeffrey 1977; Ní Lamhna 1982), wetlands (O'Connell *et al.* 1984; Otte 2003), the Lough Corrib fens (Mooney 1990) and minerotrophic flushes in blanket bogs (Lockhart 1991), to name but a few. More systematic surveys include: work by Hammond, resulting in the production of the *Map of peatlands of Ireland* (1979); the surveys of raised and blanket bogs (Schouten 1984); and numerous national surveys undertaken by the National Parks and Wildlife Service (NPWS). The NPWS surveys include: the national surveys of raised bogs, lowland and mountain blanket mires (Douglas and Grogan 1985; 1986; 1987; Cross 1990a); sand dunes (Curtis 1991); shingle beaches (Moore and Wilson 2000); saltmarshes (Curtis and Sheehy Skeffington 1998); the Burren heathlands (McGough 1984); and native woodlands (Higgins *et al.* 2004).

A national vegetation survey was begun in the early 1970s, but unfortunately, like the subsequent survey begun for the Council of Europe, it was not completed and the considerable amount of data that were collected remain largely unpublished and inaccessible (White 1982). An unpublished map compiled by Professor J.J. Moore contains eight vegetation units and has similarities to the map presented in Fig. 1. Some of this information is contained in the 'Map of the natural vegetation of the member countries of the European Community and the Council of Europe' (Noirfalise 1987) at a scale of 1:3m, but with only seven vegetation units, it provides only a broad view of the natural vegetation of Ireland. Moreover, some of the units are of doubtful validity.

The work of Rodwell (1991a; 1991b; 1992; 1995; 2000) on British plant communities has some relevance to Ireland, even allowing for the differences in species complement and climate. Many Irish communities have close affinities to, or are variants of, British communities.

Thus, a considerable amount of data is available, but much remains in a fragmented form and is often unpublished. For Irish vegetation, there is nothing to compare with the extensive and often detailed surveys and maps of both actual and potential vegetation that have been produced in many European countries, for example, Bohn (1981) and Trautmann (1966) in Germany, Neuhäuslová (1998, 2001) in the Czech Republic, Falinski and Pedrotti (1990) and Catorci and Orsomando (2001) in Italy, which provide a foundation upon which to construct national potential vegetation maps.

Potential Natural Vegetation of Ireland

Fig. 1— The potential natural vegetation of Ireland compiled at a scale of 1:1.25m.

METHODS USED IN THE COMPILATION OF THE MAP

The methods used in compiling the map are similar to those used elsewhere, for example, by Neuhäuslová (2001). An indication of the potential natural vegetation is obtained from remnants of semi-natural vegetation (including hedges, scattered trees or shrubs) and the derived vegetation, for example, upland heaths indicate the potential occurrence of montane birch forests or sessile oak forests. The bases of the vegetation units

are constructed from a combination of relevé data, the literature, personal knowledge gained from field work over a period of c. 30 years, advice from colleagues and, where appropriate, by extrapolation from Britain.

A conscious decision was made not to map forest plantations. This decision may be criticised on the basis that the stands may persist for many decades but it is felt that they no more represent potential natural vegetation than a shorter-lived agricultural crop. As the stands mature and open it is anticipated that native species will become re-

THE POTENTIAL NATURAL VEGETATION OF IRELAND

1 Montane birch forests	10 Atlantic blanket bogs
2 Species-poor sessile oak forests	11 Montane blanket bogs
3 Sessile oak forests rich in bryophytes and lichens	12 Atlantic raised bogs
4 Sessile oak forests with <i>Hyacinthoides non-scripta</i>	13 Calcareous fens
5 Pedunculate oak-ash forests with hazel and <i>Circaea lutetiana</i>	14 Degraded raised bogs with alder carrs, ash-alder and birch forests
6 Hazel-ash forests on shallow calcareous soils	15 Montane heaths
7 Hazel-ash scrub in complex with <i>Sesleria</i> grassland and <i>Dryas</i> heath	16 Coastal heaths
8 Alluvial forests	17 Sand dune vegetation complexes
9 Alder-pedunculate oak-ash forests with <i>Salix cinerea</i> ssp. <i>oleifolia</i>	18 Salt marsh vegetation complexes
	19 Polder vegetation complexes

established, although some conifer species will probably remain as an integral part of the canopy.

The physical framework of the map was constructed from maps of climate, geology, glacial drift (all at the scale of 1:1m), soils (1:575,000), geomorphology, topography and land use capability (all at the scale of 1:1.25m). The boundaries of the vegetation units were added using maps of field boundary vegetation (hedges) (1:1.25m), anthropogenic grasslands (1:1.25m) and peatlands (1:1m). (All maps obtained from Haughton *et al.* (1979) with additional information on raised bogs from the map at a scale of 1:575,000 compiled by Cross (1990a)). There are, however, discrepancies between some of these maps that can only be resolved by additional fieldwork.

The twenty vegetation units mapped represent some of the *c.* 700 mapping units in the 'Map of the natural vegetation of Europe' (Bohn *et al.* 2000; 2003; 2004). These units are grouped into nineteen vegetation Formations and Formation Complexes based on physiognomic and ecological features of the natural plant cover. Each Formation is subdivided according to its most important features, such as the prevailing life forms, dominant species and groups of species. These are further subdivided according to edaphic, climatic and phytogeographical conditions, and the ultimate units correspond closely to the higher-ranking units of the Braun-Blanquet phytosociological system. These are further subdivided on the basis of soil type and, where appropriate, altitude. A more detailed explanation of the classification system and cartographic representation is given in Bohn *et al.* (2003; 2004). It should be emphasised that in the present paper some units (principally the woodlands) are more or less synonymous with Braun-Blanquet associations or sub-associations, while others are more broadly based and represent landscape units, e.g. blanket peats.

The resulting map (Fig. 1) is considerably more detailed than that of Noirfalise (1987). The twenty vegetation units are amalgamated into six Formations or Formation Complexes comprising: nine forest types—one high altitude birch forest, two acidophilous oak forests, four oak–ash forests with hazel and two forests of wet soils; five mire types—lowland and upland blanket mires, raised bogs, sedge mires (fens) and degraded cut-away raised bog; two heath types—montane and coastal; two sand dune types; one salt marsh type and one polder type.

DETAILS OF THE VEGETATION UNITS

Details of each vegetation unit are given below. For each unit the following information is given: the name and number of the unit (as it occurs in Fig. 1), followed by the number (in brackets) of the unit as it occurs in the 'Map of the natural vegetation of Europe' (Bohn *et al.* 2003; 2004). These details are followed by: (1) the scientific name of the plant communities and the most important synonyms, including, where they exist, the classification units of Fossitt (2000) (referred to as Fossitt units) and the habitats listed in the EU Habitats Directive (European Commission 1996) with the Natura code number in brackets (referred to as Natura units); (2) structure and species composition—species are listed alphabetically except where an indication of relative abundance is required; (3) floristic differences from closely related units (where appropriate); (4) ecological and geographical variations (where applicable); (5) other vegetation occurring in complex; (6) adjoining potential natural vegetation; (7) characteristic land use and most important substitute communities; (8) habitat characteristics—geology, landscape type, altitude, soil, and climate; (9) distribution of the vegetation

unit in Ireland; (10) importance of existing stands for nature conservation with the location and conservation status of representative stands; (11) most important literature. Some of these headings are abbreviated to avoid repetition. A map of the occurrence of each unit is also given with the relevant description.

FORESTS

The nine units of forest vegetation fall into three Formations: sub-arctic, boreal and nemoral-montane forests; mesophytic deciduous broad-leaved forests; and azonal alluvial and wet lowland forests of the nemoral zone.

FORMATION C—SUB-ARCTIC, BOREAL AND NEMORAL-MONTANE FORESTS

The only representative of this vegetation type that might occur in Ireland is montane birch (*Betula pubescens*) forest. Of the nine forest types this is the most speculative. It is almost totally absent from Ireland today except for a few small secondary stands, its potential sites being dominated by anthropogenic heathland and shallow blanket mire. It is also largely absent from England and Wales, and although birch woodland is widespread in Scotland, Rodwell (1991a) does not classify it as a separate unit but considers it to be an extension of acidophilous oak forests. However, *Betula pubescens* occurs at higher altitudes than *Quercus petraea* and it might be expected that it would form forests above the limit of oak, perhaps in mosaic with montane heath and blanket mire. The following description is based on inferences from upland heath and extrapolation from sessile oak woodland vegetation.

Unit 1. Montane birch forests (Betula pubescens) with Sorbus aucuparia and Ilex aquifolium (C16). Fig. 2.

Main communities and synonyms: This unit would probably belong to the *Vaccinio-Betuletum pubescentis* Tx. 1937 and falls within the *Quercus petraea-Betula pubescens-Oxalis acetosella* community (W11) of Rodwell (1991a).

Structure and species composition: Open birch woodland dominated by *Betula pubescens* with *Sorbus aucuparia* and, in sheltered locations, *Ilex aquifolium*. On rock outcrops and screes *Taxus baccata* and *Populus tremula* may occur, and at lower altitudes there may be scattered oak, principally *Quercus petraea*. The widely planted *Pinus sylvestris*, and possibly *Picea* species, may become an integral part of this community. The shrub layer would consist largely of saplings of the above trees with scattered individuals of *Salix* spp,

Fig. 2—The potential distribution of montane birch forest (Unit 1).

principally *Salix aurita*, *Salix cinerea* ssp. *oleifolia*. Lianes would be represented by *Hedera helix* and *Lonicera periclymenum*. Dwarf ericaceous shrubs, principally *Calluna vulgaris*, *Vaccinium myrtillus* and, especially at higher altitudes, *Empetrum nigrum* would be abundant. In drier localities *Erica cinerea*, and in wetter localities *E. tetralix*, may occur. Grasses, principally *Agrostis canina*, *Anthoxanthum odoratum* and *Deschampsia flexuosa* would be common in the field layer with *Blechnum spicant*, *Galium saxatile*, *Luzula sylvatica* and *Oxalis acetosella*. In sheltered localities at lower altitudes *Pteridium aquilinum* may be locally dominant. The moss layer would be relatively well developed but with a few species dominating, e.g. *Hylocomium splendens*, *Polytrichum* species, *Rhytidiadelphus loreus* and, in moist sites, species of *Sphagnum*. Around flushes, streams and wet rocks more species-rich communities could be expected.

Floristic differences: The general absence of oak and the dominance of birch (*B. pubescens*) combined with an abundance of *Calluna vulgaris*, *Deschampsia flexuosa*, *Pteridium aquilinum* and *Vaccinium myrtillus* would distinguish this high altitude woodland from other types.

Ecological and geographical variations: In the west *Juniperus communis* may be present.

Natural vegetation occurring in complex: Patches of *Calluna*-dominated heath would probably break up this woodland community on shallow soils with, in flushes and poorly drained areas, oligotrophic fen with *Eriophorum angustifolium*, *Juncus effusus*, *Molinia caerulea* and *Salix aurita*. Patches of montane blanket mire (11), oligotrophic fens and, at higher altitudes, montane heaths (15) would also occur.

Adjoining vegetation: Grades into acidophilous oak forests (2, 3) below and montane heath (15)

above, with montane blanket bog (11) on adjacent plateaux.

Habitat: Montane to sub-montane (400m to 700m) communities of siliceous uplands between acidophilous oak forests and montane heaths where the land is too steep for blanket bog formation. The underlying rock is mostly old red sandstone, slates, schists, granites and other acidic metamorphic rocks that produce oligotrophic, sandy to stony podzols, pH < 4.5, with a mor humus, mostly well drained but more or less permanently moist with local seepage areas. Although the summers are cool (mean temperature of warmest month *c.* 10°C), the winters are not severe (mean temperature of coldest month *c.* 1°C) and prolonged frost and snow cover are infrequent. Precipitation varies from 1200mm to 2400mm or more, with a high incidence of cloud cover and frequent strong winds.

Characteristic land use and substitute communities: Plantations of spruce and pine; montane heaths and species-poor grassland (*Nardetalia* Prsg. 1949) used for extensive rough grazing and burnt at irregular intervals. Some areas, especially in the west, are overgrazed and subject to erosion.

Distribution: Throughout Ireland at suitable altitudes, with the most extensive areas probably in the south-west (counties Cork and Kerry), in the Wicklow, Connemara, Donegal and Mourne Mountains. Small stands would probably occur on better-drained slopes within montane blanket bogs.

Importance for nature conservation: Cessation of grazing and burning would encourage the formation of the community. Substitute vegetation, principally wet heath and mountain grassland, is of some significance especially for certain bird species but is very widespread and common. Extensive areas within the altitudinal range of this unit have been planted with pine and spruce forests.

Most important literature: None known.

FORMATION F—MESOPHYTIC DECIDUOUS BROAD-LEAVED FORESTS

The majority of Ireland's forests fall into this Formation. The climax communities are dominated principally by oak (*Quercus petraea*, *Q. robur*) and/or ash. Following Dutch Elm Disease, Elm (*Ulmus glabra*) is now rare and usually present only as a shrub. Birch (principally *Betula pubescens*, but with some *B. pendula*) is common but, except on the most acidic soils, is probably part of the seral development of the forests. Alder and other species, such as cherry (*Prunus avium*), are only occasional components. There is greater species diversity in the shrub layer, with holly being dominant on

Fig. 3—The potential distribution of species-poor oak forests (Unit 2).

poor, acidic soils and hazel on more base-rich soils. Dwarf shrubs form an important component on acidic soils. Species diversity in the field layer is, broadly speaking, positively correlated with the base status of the soils. The abundance and variety of bryophytes and lichens is related to climate, especially rainfall.

Acidophilous oak forests

Unit 2. Species-poor oak (Quercus petraea) forests (F2). Fig. 3, Pl. I.

Main communities and synonyms: *Blechno-Quercetum typicum* Br.-Bl. et Tx. 1952; *Quercus petraea-Betula pubescens-Dicranum majus* woodland, typical and *Anthoxanthum-Agrostis* sub-communities (W17b, c) of Rodwell (1991a). Fossitt unit: oak-birch-holly woodland (WN1). Natura unit: old oak woods with *Ilex* and *Blechnum* in the British Isles (91AO).

Structure and species composition: Species-poor forests, up to 20m or more in height, dominated by *Quercus petraea* with *Betula pubescens* and *Sorbus aucuparia* and locally introduced *Fagus sylvatica*. Other tree species are rare. The shrub layer is dominated by *Ilex aquifolium*, with occasional saplings of the above species and *Cytisus scoparius* in clearings. There is a well-developed dwarf shrub layer of *Vaccinium myrtillus* and locally *Calluna vulgaris*. The field layer is species-poor, the principal species being *Luzula sylvatica* (sometimes dominant), grasses, e.g. *Agrostis capillaris*, *Anthoxanthum odoratum*, *Deschampsia flexuosa*, herbs, e.g. *Oxalis acetosella*, ferns, e.g. *Pteridium aquilinum*, which can be locally dominant, and *Blechnum spicant*. Dense stands of *Rubus fruticosus* sometimes occurs on slightly richer soil. *Hedera helix* and *Lonicera periclymenum* occur

Pl. 1—Species-poor oak forest (Unit 2). Summer aspect showing dominance of *Vaccinium myrtillus* and *Pteridium aquilinum* in the field layer. Tomnafinogue Wood, Co. Wicklow.

both as part of the ground layer and as lianes. The bryophyte flora is relatively species-poor, the principal species being *Eurhynchium striatum*, *E. praelongum*, *Polytrichum commune*, *Rhytidiadelphus loreus*, *R. squarrosus* and *Thuidium tamariscinum*.

Floristic differences: Largely distinguished by the absence of species characteristic of the succeeding two units.

Ecological and geographical variations: Westwards, elements of Unit 3 (*Q. petraea* forests rich in bryophytes and lichens) become increasingly common while elements of Unit 4 (ash–oak forest with *Hyacinthoides non-scripta*) occur on slightly richer soils. There is some evidence of differences between north- and south-facing slopes, with moisture-loving species being more abundant on north facing slopes.

Vegetation occurring in complex: Montane birch forests (1) at higher levels; mixed ash–oak forests with *Hyacinthoides non-scripta* on more fertile soil (4); small stands of montane alluvial forest with *Alnus glutinosa*, *Fraxinus excelsior* and *Salix* species in valley bottoms; small raised bogs (12). Seepage areas are characterised by stands of *Betula pubescens* with *Agrostis stolonifera*, *Juncus effusus*, *Molinia caerulea* and sometimes *Carex rostrata* and *Deschampsia caespitosa*: these correspond to the *Sphagnum palustre*–*Betula pubescens* community of Kelly and Iremonger (1997).

Adjoining vegetation: Grades into montane birch forests (1) at higher altitudes; on more fertile soil gives way to mixed ash–oak forests

with *Hyacinthoides* (4) and alluvial forests (8) in valleys.

Habitat characteristics: Occurs on sandy to loamy, well drained, sometimes shallow, acidic to strongly acidic (pH < 4.5) podzols and acidic brown earths with low nutrient status, over granites, slates, schists and sandstones in the drier parts of the country where rainfall is mostly below 1200mm. Mean minimum and maximum temperatures are *c.* 5°C and 15°C, respectively. The soils can become dry in the summer, especially on slopes with a southerly aspect.

Characteristic land use and substitute communities: In the past used for timber production, sometimes formerly managed as coppice or coppice with standards, but most of the forest areas have been converted to poor grassland or heath for rough grazing, mostly by sheep. In recent decades extensive areas on higher ground and steep slopes have been planted with plantations of *Picea abies*, *Pinus sylvestris*, *Pseudotsuga douglasii* and other conifers, while at lower levels many heath and grassland communities have been fertilised and reseeded. On steep slopes, *Pteridium* may dominate and abandoned grazing land is often dominated by *Ulex europaeus*.

Distribution: Occurs on the lower slopes and in valleys of siliceous uplands throughout the eastern half of the country and locally elsewhere.

Importance for nature conservation: This woodland type remains one of the most extensive in eastern Ireland because of its occurrence on poor

Fig. 4—The potential distribution of oak forests rich in bryophytes and lichens (Unit 3).

soils and/or steep slopes. Past management is responsible for the mostly even-aged, rather uniform stands. The variations in ground cover are more often a result of differences in grazing pressure than a response to edaphic factors. Several areas are protected, the most extensive being: Glen of the Downs, Deputy's Pass, Vale of Clara, Glendalough and Tomnafinnoge Wood, Co. Wicklow; Derrycrag Wood, Co. Galway; and Breen Wood, Co. Antrim. Extensive areas have been inter- and under-planted with conifers but are now being restored.

Most important literature: Kelly (1975); Kelly and Moore (1975).

Unit 3. Oak (Quercus petraea) forests rich in bryophytes and lichens (F1). Fig. 4, Pl. II.

Main communities and synonyms: *Blechno-Quercetum* subass. *Isothecium myosuroides* Br.-Bl. et Tx. 1952, *Blechno-Quercetum scapanietosum* Kelly and Moore 1975; *Quercus petraea* – *Betula pubescens* – *Dicranum majus* woodland, *Diplophyllum albicans* – *Isothecium myosuroides* sub-community (W17a) (Rodwell 1991a). Fossitt unit: oak–birch–holly woodland (WN1). Natura unit: old oak woods with *Ilex* and *Blechnum* in the British Isles (91AO).

Structure and species composition: Relatively species-rich forests dominated by *Quercus petraea*, 15–20m high, up to 25m in better locations but less than 10m in very exposed sites. *Betula pubescens* and *Sorbus aucuparia* also occur in the canopy, either admixed or forming a broken second layer. Other tree species are infrequent. Locally, the introduced *Fagus sylvatica* is co-dominant and potentially could become an important constituent. Alder (*Alnus glutinosa*) occurs locally in moister sites. A well-developed understorey of *Ilex aquifolium*, with birch

and rowan saplings, forms the shrub layer. The invasive introduced shrub *Rhododendron ponticum* has become the principal constituent of the shrub layer in certain areas to the exclusion of almost all native species. *Calluna vulgaris* and *Vaccinium myrtillus* form a dwarf shrub layer reaching a height of 1m in well-developed stands. The field layer consists of a mixture of grasses and herbs, while ferns are particularly prominent, especially *Blechnum spicant*, *Dryopteris aemula*, *D. dilatata* and *Pteridium aquilinum*, the last growing through and overtopping the dwarf shrub layer. *Hedera helix* and *Lonicera periclymenum* are abundant both as lianes and on the ground. Ivy, along with holly, winter-green ferns and the bryophytes and lichens give these woodlands a semi-evergreen appearance.

The most striking feature, however, is the abundance and richness of the bryophytes and lichens, which form thick carpets over rocks, boulders, fallen timber and among the dwarf shrubs and herbaceous plants, as well as forming luxuriant epiphytic communities. The most obvious species are the larger pleurocarpous and acrocarpous mosses, e.g. *Dicranum scoparium*, *D. majus*, *Eurhynchium striatum*, *Hylocomium brevirostre*, *H. splendens*, *Isothecium myosuroides*, *Polytrichum formosum*, *Rhytidiadelphus loreus*, and *Thuidium tamariscinum*. Filmy ferns (*Hymenophyllum* spp) are also important and there is a rich variety of smaller mosses and hepatics, e.g. *Bazzania trilobata*, *Diplophyllum albicans*, *Plagiochila spinulosa*, *Saccogyna viticulosa* and *Scapania gracilis*. The epiphytic communities, which are rich in lichens, mosses and hepatics, include ferns, e.g. *Polypodium* spp and even angiosperms, e.g. *Saxifraga spathularis* and small trees and shrubs.

Floristic differences: The abundance of *Dryopteris aemula*, filmy ferns, bryophytes and lichens, both on the ground and as epiphytes, distinguishes this unit from the preceding one. The absence of hazel and bluebell distinguish it from the following unit.

Ecological and geographical variations: In drier locations bryophytes are less abundant and the stands resemble the preceding unit (2). Elements of the succeeding unit (4) occur on slightly richer soils. Thermophilous species, e.g. *Arbutus unedo*, *Euphorbia hyberna*, *Saxifraga hirsuta* occur in the south-west; in Connemara, *Daboecia cantabrica* occurs locally.

Vegetation occurring in complex: Mixed ash–oak woodland with *Hyacinthoides non-scripta* (4) on more fertile soil; small stands of montane alluvial forest with *Alnus glutinosa*, *Fraxinus excelsior* and *Salix* species in valley bottoms; stands of *Betula pubescens* woodland in depressions and seepage areas; small raised bogs in depressions (12); lowland blanket bog on poorly drained sites (10).

Pl. II—Oak forests rich in bryophytes and lichens (Unit 3). Boulder covered in *Saxifraga spathularis*, *Hymenophyllum* species and bryophyte species. Derrycunihy Wood, Killarney National Park, Co. Kerry.

Adjoining vegetation: This community grades into montane birch woodland (1) on well-drained land at higher altitudes, species-poor oak forests (2) on drier sites at lower altitudes and mixed ash–oak forests (4) where it adjoins more fertile soils. An abrupt transition to lowland blanket bog (10) occurs on poorly drained surfaces, although the sharp boundaries may be a result of fires.

Habitat characteristics: This woodland type occurs in regions where rainfall exceeds 1200mm, wet days exceed 250 per year, humidity is constantly high and frosts are slight and infrequent (< 20 per year). Mean temperature of the coldest and warmest months are *c.* 6°C and *c.* 15°C, respectively. It is confined to acidic, often shallow, rocky, sandy to loamy podzols in mountainous areas, mostly over Old Red Sandstone and siliceous metamorphic rocks. The pH is usually below pH 4.5 and exchangeable phosphorus is particularly low. Grazing, principally by sheep and deer, is characteristic of many of these woodlands. Moderate grazing favours the development of grasses and *Luzula sylvatica* at the expense of *Calluna* and *Vaccinium*, but where it is severe only the bryophyte communities may survive.

Characteristic land use and substitute communities: As for the preceding unit most stands were formerly used for timber production and sometimes coppiced. Extensive areas have been cleared and replaced by wet heath and blanket bog as well as species-poor grasslands that are used for

sheep grazing. Stands of *Ulex* species occur on drier soils. In sheltered areas on well-drained slopes *Pteridium* may dominate. Coniferous plantations, especially of sitka spruce (*Picea sitchensis*) and contorta pine (*Pinus contorta*), have been widely planted.

Distribution: The headquarters for this woodland type is the extreme south-west, with the most extensive stands occurring in the mountainous regions of counties Cork and Kerry. Small stands occur in the mountains of Connemara, Donegal, Mayo and Sligo, on lake islands in blanket bogs and locally on high ground and in sheltered, humid valleys further east.

Importance for nature conservation: This is one of the best-represented forest types in Ireland today, and it includes the most extensive woodland stands in the country. They are particularly important for the abundance of bryophytes and lichens, some of which reach their most northerly distribution in Europe here (Birks 1996). The protected fern *Trichomanes speciosum* occurs locally in permanently moist locations, although it is not confined to these forests. Many stands, even protected areas, are under threat from overgrazing, the invasive *Rhododendron ponticum* and, locally, forest clearance. Important stands include: Derrycunihy and Tomies Woods (within the Killarney National Park) and Uragh Wood Nature Reserve, Co. Kerry; Glengariff Woods Nature Reserve, Co. Cork; Derryclare Wood

Nature Reserve, Co. Galway; Brackloon Wood, Co. Mayo; Glenveagh Woods, Glenveagh National Park, Co. Donegal; and Largalunny, Co. Fermanagh (including Correl Glen National Nature Reserve).

Most important literature: Richards (1938); Ratcliffe (1968); Kelly (1975); Kelly and Moore (1975); Kelly (1981).

Mixed oak–ash forests

Forests in which ash is either dominant or an important component, with hazel in the shrub layer and an often species-rich herb layer. There are four units.

Unit 4. Oak (mostly Quercus petraea) forest with bluebell (Hyacinthoides non-scripta). (F32). Fig. 5, Pl. III.

Main communities and synonyms: *Blechno–Quercetum coryletosum* Br.–Bl. et Tx. 1952, *Quercus robur–Pteridium–Rubus fruticosus* woodland, typical and *Holcus lanatus* sub-communities (W10a, d) (Rodwell 1991a). Fossitt unit: oak–birch–holly woodland (WN1). Natura unit: old oak woods with *Ilex* and *Blechnum* in the British Isles (91AO).

Structure and species composition: This oak forest type on more fertile, acidic soils is transitional between the acidophilous oak forests of the preceding units and the mixed oak–ash forests on calcareous base-rich soils. *Quercus petraea* (locally *Q. robur*) is dominant with small amounts of *Betula pubescens* and *Fraxinus excelsior*, locally with other tree species, for example, *Prunus avium*, and the introduced *Fagus sylvatica*, which regenerates spontaneously. The canopy is typically 20m or more in height. The shrub layer is dominated by *Corylus avellana* with lesser amounts of *Ilex aquifolium* and *Sorbus aucuparia*. Locally, species of elm may be important constituents of the shrub layer, e.g. *Ulmus procera*, possibly native in counties Wicklow and Wexford (T. Curtis, pers. comm.), and *U. glabra* elsewhere. Unlike the preceding two units, a dwarf shrub layer is mostly absent and the field layer is richer and characterised by an abundance, sometimes vernal dominance, of *H. non-scripta*, usually in association with *Holcus mollis* and *Stellaria holostea*. Locally *Silene dioica* and, on moist soils, *Anemone nemorosa* may be present. *Lonicera periclymenum* and *Rubus fruticosus* agg. often form a thick underscrub and a canopy of *Pteridium* is common by midsummer. *Oxalis acetosella* and ferns, e.g. *Dryopteris affinis*, *D. dilatata*, *D. filix-mas*, are common and elements of acidophilous oak forests, e.g. *Luzula sylvatica*, may be present. Bryophytes are relatively unimportant, apart from certain pleurocarpous mosses, e.g. *Eurhynchium striatum*, *Rhytidiadelphus loreus* and *Thuidium tamariscinum*.

Fig. 5— The potential distribution of oak forests with bluebell (Unit 4).

Floristic differences: The presence of *Corylus avellana*, *Fraxinus excelsior*, *Hyacinthoides non-scripta* and *Stellaria holostea* distinguish this unit from the two preceding units.

Ecological and geographical variations: None known, but possibly variations between north- and south-facing slopes.

Vegetation occurring in complex: Stands of acidophilous oak forests (2, 3) on shallower, more acidic soils; alluvial forests in river valleys (8); on more base-rich soil, pedunculate oak–ash forests (5); on wetter soils, mixed alder–oak–ash forests (9) or stands of birch woodland in wet hollows and seepage areas; and raised bogs (12) in depressions.

Adjoining vegetation: Adjoins mixed pedunculate oak–ash forests (5) on calcareous base-rich soils, acidophilous oak forests (2, 3) on poorer soils and alluvial forests (8) in river valleys.

Habitat characteristics: These forests occur in the lowlands, mostly below 200m, on relatively deep, acidic brown earths, pH 4.5–5.5, derived from acidic boulder clays, sandstones, shales and slates and, locally in the north-east, basalt. Following agricultural improvement they may contain high levels of nitrogen and phosphorus. Rainfall varies from c. 800mm in the east to over 1200mm in the west and north. Temperatures vary from a July mean of 14°C to 16°C to a February mean of 4.0°C to 6°C.

Characteristic land use and substitute communities: Nearly all this forest type has been cleared for agriculture, principally improved grassland for pasture or silage production or for crops, e.g. barley, wheat, sugar-beet and rape. Small areas have been reafforested with conifers or, more recently, beech, ash and oak. Bracken or gorse may dominate abandoned land.

Pl. III— Oak forest with bluebell (Unit 4). Vernal aspect with *Hyacinthoides non-scripta* dominating the field layer under a shrub layer of hazel. Near Lismore, Co. Waterford.

Distribution: Principally in the lowlands, low hills or lower slopes of uplands in the south, south-east and north, and locally elsewhere.

Importance for nature conservation: As this forest type occurs on good agricultural soils, only small fragments remain, often associated with other oak forests. Many stands have been interplanted with conifers. There is still a lack of information on this unit, and further research is required to identify and characterise it more precisely. It continues to be under threat from land reclamation. Small stands occur associated with areas dominated by acidophilous oak forests, e.g. Vale of Clara Nature Reserve, Co. Wicklow; Killarney National Park, Co. Kerry; Rosturra Wood Nature Reserve, Co. Galway; and Banagher Glen, Co. Derry. Kiltel Wood in Co. Kildare is an example of this unit in which *Quercus robur* is dominant.

Most important literature: Kelly (1975; 1981); Kelly and Moore (1975).

Mixed Quercus robur-Fraxinus excelsior forests on base-rich and calcium-rich brown earths and rendzinas

Unit 5. Pedunculate oak–ash forests with *Corylus avellana*, *Circaea lutetiana*, *Brachypodium sylvaticum* and *Veronica montana* (F28). Fig. 6, Pl. IV.

Main communities and synonyms: *Corylo-Fraxinetum veronicetosum* and *typicum* (in complex) Kelly and Kirby 1982. Closely related to *Fraxinus excelsior*–*Sorbus aucuparia*–*Mercurialis perennis*

communities (W9) (Rodwell 1991a). Fossitt unit: oak–ash–hazel woodland WN2.

Structure and species composition: A rather variable woodland type in which the canopy is formed principally from an admixture of *Fraxinus excelsior* and *Quercus robur*. Stands of *Betula pubescens* (occasionally *B. pendula*) are sometimes present. Other tree species, e.g. *Malus sylvestris*, *Prunus avium*, *Sorbus aria* agg. and *S. aucuparia* are occasional. *Ulmus glabra*, formerly present in the canopy, is now infrequent as a result of Dutch Elm Disease and is more often found in the shrub layer. *Fagus sylvatica* and *Acer pseudoplatanus* are often naturalised and may become important constituents. On drier sites, e.g. gravel ridges, the canopy may be less than 10m, but on deeper soils it exceeds 20m. The shrub layer is relatively species-rich but is dominated by *Corylus avellana* with *Crataegus monogyna* and occasionally *Ilex aquifolium*. Other shrub species include *Euonymus europaeus*, *Prunus spinosa* and *Viburnum opulus*.

The field layer is usually species-rich, with no one species dominant, although *Hedera helix* can be locally dominant under deep shade. *Brachypodium sylvaticum*, *Circaea lutetiana* and *Veronica montana* are constant, and there is often a well-developed vernal display of flowers with species such as *Anemone nemorosa*, *Fragaria vesca*, *H. non-scripta*, *Potentilla sterilis*, *Primula vulgaris*, *Ranunculus ficaria* and *Viola* species. Later in the season, *C. lutetiana* may be locally dominant, with *Geum urbanum*, *Geranium robertianum* and *Sanicula europaea* as well as several ferns, e.g., *Athyrium filix-femina*, *Dryopteris filix-mas*,

Pl. IV— Pedunculate oak–ash forest with hazel (Unit 5). Vernal aspect of the field layer with *Veronica montana*, *Ajuga reptans*, *Dactylis glomerata* and *Hyacinthoides non-scripta*. Raheen Wood, Co. Clare

Fig. 6— The potential distribution of pedunculate oak–ash forest with hazel (Unit 5).

Phyllitis scolopendrium and *Polystichum setiferum*. Nitrophilous species, e.g. *Anthriscus sylvestris*, *Heradium sphondylium* and *Urtica dioica*, occur on heavily fertilised land. *Rubus fruticosus* agg. is common, sometimes forming a separate and locally dense layer above the herbs. The bryophyte layer is variable but typically poorly developed, consisting principally of a few robust species, e.g. *Eurhynchium striatum*, *Rhytidiadelphus triquetrus*, *Thamnobryum alopecurum* and *Thuidium tamariscinum* and small colonies of *Fissidens taxifolia* and *Plagiomnium undulatum*.

Floristic differences: The presence of the above suite of species distinguishes this unit from the acidophilous oak forests, while the presence of *Athyrium filix-femina*, *Hyacinthoides non-scripta* and *Veronica montana* separate it from the following unit.

Ecological and geographical variations: Species such as *Allium ursinum* and *Anemone nemorosa* are more common on moister sites. Westwards, moisture-loving species increase in abundance. On drier soils, such as esker ridges, the flora is locally somewhat richer with relatively uncommon species, e.g. *Aquilegia vulgaris*, *Rhamnus catharticus*, *Sorbus aria* agg.

Natural vegetation occurring in complex: On shallower soils hazel–ash forests (6); alluvial forests in valleys (8); on heavy, poorly drained soils, alder–oak–ash forests (9); in depressions raised bogs (12) or cut-away raised bog communities (14); around lake shores various types of fens and reed swamps occur.

Adjoining vegetation: On shallower soils this community grades into hazel–ash forests and scrub (6). The vegetation types occurring in complex form a large-scale mosaic within the oak–ash forests across the central plain.

Habitat characteristics: These forests occur on flat to undulating glacial deposits over limestone. The soils are mostly deep, base-rich, well drained to moist, clay- and loam-rich brown earths and grey-brown podzols, with an acidity between pH 5.8

Fig. 7—The potential distribution of hazel-ash forest on shallow calcareous soils (Unit 6).

and pH 6.4, and a high amount of available calcium. Locally, on sands and gravels, the soils are shallow and dry. Widespread arterial drainage throughout the area means that the potential vegetation will contain fewer elements of wet soils than the original climax vegetation. The climate is typical for much of lowland Ireland, with rainfall mostly under 1000mm and fewer than 180 wet days per year. Late spring frosts are characteristic.

Characteristic land use and substitute communities: The fertile soils associated with this vegetation type are valuable for agriculture and most of the area is devoted to improved pasture, silage production or arable crops, e.g. barley and sugar-beet. Forest plantations are rare and consist principally of beech, although ash and oak are now being more frequently planted.

Distribution: Potentially one of the most extensive forest types in Ireland on the central lowlands and in broad valleys between the mountain ranges in the south and locally elsewhere.

Importance for nature conservation: Only small fragments of this woodland remain (the soil is highly suitable for agriculture) but they are very important for conservation. Some of the oldest known oak trees (more than 400 years old) in the country occur within this unit. Clear-felling is a constant threat and selective removal of larger trees, especially oak, is common. Small remnants of species-rich grassland occur as substitute vegetation, especially on esker ridges. The following species, which occur in stands belonging to this unit, are rare and protected: *Cardamine impatiens*, *Carex depauperata*, *Cladopodium arvensis*, *Galeopsis angustifolia*, *Hypericum hirsutum*, *Stachys officinalis*, and *Vicia orobus*. Important stands include Charleville Wood, Co. Offaly; St. John's Wood, Co. Roscommon; and

Marble Arch, Co. Fermanagh. A few small stands of drier facies occur on esker ridges, e.g. parts of Long Hill, Co. Westmeath. Small areas occur in the Killarney National Park, Co. Kerry. All these areas are designated Special Areas of Conservation (SACs) under the EU Habitats Directive.

Most important literature: Kelly and Kirby (1982); Cross (1992).

Unit 6. Hazel-ash forests on shallow calcareous soils, rich in bryophytes (F29). Fig. 7, Pl. V.

Main communities and synonyms: *Corylo-Fraxinetum* subassociation *neckeretosum* Kelly and Kirby 1982. *Fraxinus excelsior*-*Acer campestre*-*Mercurialis perennis*, *Geranium robertianum* sub-association (W8e) and the *Fraxinus excelsior*-*Sorbus aucuparia*-*Mercurialis perennis*, typical sub-community (W9a) are the closest comparable British communities (Rodwell 1991a). Fossitt units include: oak-ash-hazel woodland (WN2), yew woodland (WN3), scrub (WS1) and exposed calcareous rock (ER2). Natura units: limestone pavements (8240) and *Taxus baccata* woods (9580).

Structure and species composition: Forest and scrub communities in which ash is the dominant tree species. *Quercus robur* and other native trees are rare but *Taxus baccata* is locally important. *Fagus sylvatica* has been widely planted and regenerates readily. In sheltered locations the canopy may reach 15m or more in height with a well-developed stratification. More commonly, however, it is lower, and where the soil is very shallow the canopy may be formed from hazel with just a few emergent ash trees. The shrub layer is dominated by hazel with some *Crataegus monogyna*, *Ilex aquifolium* and *Prunus spinosa* and locally whitebeam (*Sorbus aria* agg.). The field layer is often poorly developed but, as in the preceding unit, it is typically species-rich and usually without dominants. The species composition is also similar to the previous unit, although *Athyrium filix-femina*, *Hyacinthoides non-scripta* and *Veronica montana* are largely absent and certain other species are less common, e.g. *Circaea lutetiana*. Where rock outcrops occur ferns such as *Asplenium trichomanes* and *Phyllitis scolopendrium* are present. In addition, the bryophyte layer is very well developed and often luxuriant and species-rich, with robust species such as *Ctenidium molluscum*, *Eurhynchium striatum*, *Hylocomium brevirostre*, *Neckera complanata*, *Rhytidiadelphus triquetrus*, *Thamnium alopecurum* and *Thuidium tamariscinum*.

Floristic differences: The presence of *Asplenium trichomanes* and *Solidago virgaurea* and the bryophytes *Ctenidium molluscum*, *Scapania aspera* and *Tortella tortuosa* and the paucity or absence of *Hyacinthoides non-scripta* help to distinguish it from the preceding unit.

Pl. V— Hazel—ash forest on shallow calcareous soil (Unit 6). Summer aspect with dominance of *Circaea lutetiana*, abundant *Polystichum setiferum*, *Phyllitis scolopendrium* and bryophyte-covered rocks. Slieve Carran Nature Reserve, Co. Clare.

Ecological and geographical variations: Moisture-loving species, e.g. *Allium ursinum*, occur locally around turloughs, where the forests are subject to irregular flooding, on pockets of clay and in seepage areas. The canopy may reach a

greater height in such locations. Yew stands may occur on limestone pavement.

Vegetation occurring in complex: Oak—ash forests (5) on pockets of deeper soil; mixed alder—oak—ash forests (9) on wetter soils;

grassland or scrub with *Rhamnus catharticus* in and around turloughs; calcareous fens (13) and willow and alder carr around lake shores, in wet depressions and turloughs; limestone heath on rock outcrops. Locally on limestone outcrops stands of yew with a well-developed bryophyte layer (e.g. *Neckera crispa*, *Tortella tortuosa*) but poorly developed shrub and field layer occur.

Adjoining vegetation: Oak–ash forests on deeper soils (5); raised bogs (12); calcareous fens (13); acidophilous oak forests (3) on adjoining siliceous rocks.

Habitat characteristics: Undulating to flat, often rocky lowlands over Carboniferous limestone with shallow brown earths, locally rendzinas, pH 6.8 or more with a high calcium content. Although the rainfall is relatively high, the soils dry out rapidly during dry spells and this may be a limiting factor for tree growth. The climate is somewhat wetter than in the preceding unit with rainfall between 1000–1200mm and wet days exceeding 180 per year.

Characteristic land use and substitute communities: The shallow soils are generally unsuitable for arable crops and most of the land is used for meadows or pasture (*Asperulo-Seslerietum* Br.-Bl. et Tx. 1952, *Centaureo-Cynosuretum* Br.-Bl. et Tx. 1952, *Seslerio-Mesobromium* Oberd. 1957). Traditionally, barley and potatoes were grown on deeper soils, but this is now rare. Generally unsuitable for forestry but occasional plantations of poorly growing larch, Scots pine and beech can be found.

Distribution. Principally in west-central Ireland on the western edge of the central plain and locally around Lough Ree and Lough Derg and south of Lough Sheelin, Co. Westmeath.

Importance for nature conservation: Stands of high forest are rare. More typically the stands are of scrub, which are maintained by selective felling of trees once they reach a certain size. Substitute vegetation includes species-rich calcareous grassland of very high conservation value. Land improvement, either by clearance of scrub and/or fertilising of the grasslands, poses a constant threat. Protected species include the very localised and rare *Carex depauperata* in woodland and *Sanguisorba officinalis* and *Viola hirta* in grassland communities. Several stands occur on the eastern edge of the Burren, e.g. the nature reserves of Coole-Garryland, Co. Galway and Dromore, Co. Clare, as well as locally within the Burren, for example, at Slieve Carron Nature Reserve and also around Lough Corrib, Co. Galway. There are also stands in the West Fermanagh Scarplands, including Hanging Rock National Nature Reserve. Stands of yew are of international significance; the most extensive occurs in Killarney National Park, Co. Kerry.

Fig. 8—The potential distribution of ash–hazel forest and scrub alternating with *Sesleria* grassland and limestone heaths (Unit 7).

Most important literature: Ivimey-Cook and Proctor (1966); Kelly and Kirby (1982); Perrin (2002).

Unit 7. Ash–hazel forest and scrub on shallow calcareous soils alternating with Sesleria grasslands and Dryas octopetala and limestone heaths (F30). Fig. 8, PI VI.

This unit represents the vegetation of the Burren region of County Clare and the Aran Islands. As a mixture of communities it presents problems regarding its classification and potential character. It is probable that in the absence of human activity and associated grazing low forest or scrub would dominate over extensive areas.

Main communities and synonyms: *Corylo-Fraxinetum neckerotosum* Kelly and Kirby 1982 in complex with *Prunetalia spinosae* Tx. 1952. The limestone heaths (*sensu* Etherington 1981) and grasslands include *Sesleria-Mesobromenion* Oberd. 1957; *Antennaria dioica-Hieracium pilosella* nodum Ivimey-Cook and Proctor 1966, *Dryas octopetala-Hypericum pulchrum* association Ivimey-Cook and Proctor 1966, *Arctostaphylo-Dryadetum* Ivimey-Cook and Proctor 1966. The corresponding British woodland communities are the *Fraxinus excelsior-Acer campestre-Mercurialis perennis* woodland, *Geranium robertianum* and *Teucrium scorodonia* sub-communities (W8e, g) and the *Fraxinus excelsior-Sorbus aucuparia-Mercurialis perennis*, typical sub-community (W9a) Rodwell (1991a). Fossitt units include oak–ash–hazel woodland (WN2), yew woodland (WN3), scrub (WS1) and exposed calcareous rock (ER2). Natura units: limestone pavements (8240) and *Taxus baccata* woods (9580).

Structure and species composition: This unit consists of a mosaic of ash–hazel forest and scrub,

Pl. VI— Typical aspect of Unit 7 showing hazel scrub invading *Sesleria caerulea* grasslands, *Dryas octopetala* heath and limestone pavement. Slieve Carran nature reserve, Co. Clare.

limestone heaths, grassland, bare limestone pavement and rocky outcrops. The forest and scrub communities are essentially the same as Unit 6 but, except for stands in sheltered locations on deeper soils, the canopy is low and the ash rarely exceeds the height of the hazel, which typically reaches only 8m or less. Die-back is common, especially on the shallowest soils.

Outcrops of rock and pavement are common and may be totally bare apart from the vertical fissures (grykes) that are typically colonised by *Phyllitis scolopendrium* and thorny shrubs such as *Rosa spinosissima*. More commonly, a very shallow soil covers the rocks supporting a mixture of grassland and heathland communities that display great variations depending on the depth, composition and pH of the soil, exposure and altitude. Species include *Antennaria dioica*, *Asperula cynanchica*, *Briza media*, *Calluna vulgaris*, *Carex flacca*, *Dryas octopetala*, *Festuca rubra*, *Galium verum*, *Gentiana verna*, *Hypericum pulchrum*, *Hieracium pilosella*, *Lotus corniculatus*, *Succisa pratensis*, *Thymus polytrichus*, and bryophytes such as *Breutelia chrysocoma*, *Ctenidium molluscum*, *Dicranum scoparium*, *Neckera crispa*, *Scapania aspera* and *Tortella tortuosa*. On exposed slopes and crests at higher altitudes, probably above the altitudinal limit for *Corylus*, a community dominated by *Dryas octopetala*, *Empetrum nigrum* and *Sesleria caerulea* occurs, and on the summit plateaux *Arctostaphylos uva-ursi*, *Dryas octopetala* and *Juniperus communis* form low-growing mats.

The extent to which these open communities at low altitudes are plagioclimaxes or full climax communities is still subject to debate. Grazing and possibly very occasional fires are certainly important, but feral goats and rabbits, combined with exposure and occasional drought, may be sufficient to prevent a complete tree and shrub cover from developing.

Ecological and geographical variations: On the coast and on the Aran Islands halophytic species occur, e.g. *Armeria maritima*, *Plantago maritima*.

Vegetation occurring in complex: The forest and scrub margins are characterised by communities of spiny shrubs and sub-shrubs, such as *Juniperus communis*, *Prunus spinosa*, *Rosa pimpinellifolia* and *Rubus fruticosus* agg., which, in the absence of grazing, gradually invade the pavement. Depressions subject to periodic flooding (turloughs) contain scrub vegetation with *Crataegus monogyna*, *Rhamnus catharticus* and sometimes *Frangula alnus*, locally with *Potentilla fruticosa* at higher levels. Further development of this vegetation is probably limited by occasional summer flooding (Goodwillie 2003). At lower levels, which are more often flooded, species-poor grassland with *Elytrigia repens*, *Phalaris arundinacea* and *Potentilla anserina* would probably form the climax community in the absence of grazing (J. Ryan, pers. comm.). Permanent water bodies and seepage areas carry a

variety of fen communities, which also occur around temporary springs.

Adjoining vegetation: Hazel–ash forests (6) on deeper soils to the east; mixed alder–oak–ash forests (9) on the heavy clays that abut onto the limestone to the south; calcareous fens (13) in the lake-filled depression on the south-eastern edge of the Burren; montane blanket bog (11) on adjacent high ground over shales.

Habitat characteristics: An area of karst with pavements, cliffs, rock debris, dry valleys, depressions, springs and turloughs developed over Carboniferous limestone between sea level and 330m. The soils are mostly thin rendzinas, less than 25cm deep, or lithosols, and pH is 6.5–7.2, with a small clay and loess fraction. The mixture of calcareous and leached soils is responsible for the variety and intimate mixing of calcicole and calcifuge species (Etherington 1981). Outcropping rock occupies c. 75% of the area. Locally, pockets or drumlins of calcareous clays occur. Despite the high rainfall, which leads to leaching, the soils can dry out quickly. The climate is hyperoceanic with mild winters (January mean 5.5°C), cool summers (July mean 15°C), high annual rainfall (1200–1400mm) and more than 175 wet days per year. Strong, salt-laden winds, especially on the coast and on the Aran Islands, result in stunted and wind-shaped bushes and trees.

Characteristic land use and substitute communities: Cattle and, locally, goats browse the woody vegetation, but extensive areas have been cleared for pasture, which consists of species-rich grasslands and heaths, including the following communities: *Seslerio-Mesobromion* Oberd. 1957, *Antennaria dioica*–*Hieracium pilosella* nodum Ivimey-Cook and Proctor (1966), *Dryas octopetala*–*Hypericum pulchrum* association Ivimey-Cook and Proctor (1966) *int. al.* The proportion of scrub to grasslands/heathlands has waxed and waned over time depending on economic pressures. In recent decades considerable changes in land use have occurred with scrub and heath on deeper soils being converted to species-poor grassland for grazing and silage production, while extensive grazing is declining and the abandoned land is being invaded by hazel scrub (Dunford 2002).

Distribution: This unit occurs in the Burren area of north County Clare and south-west Galway, on the Aran Islands and locally elsewhere, e.g. around loughs Corrib and Mask.

Importance for nature conservation: This unit is remarkable for the variety and richness of the flora with species from diverse geographical regions growing together e.g. *Adiantum capillus-veneris*, *Dryas octopetala*, *Gentiana verna*, *Helianthemum canum* and *Neotinea maculata*. The very rare and localised species *Gymnocarpium robertianum* occurs in one site on open limestone pavement. The

Fig. 9—The potential distribution of lowland alluvial forests (Unit 8).

abundance of many of the above species and associated communities is a result of traditional grazing regimes and a reflection of the unimproved nature of much of the area. They will undoubtedly decline with land use changes but would presumably persist locally on cliffs, rock outcrops and over very shallow soils. Outstanding sites include Slieve Carran Nature Reserve, the Burren National Park, the Aran Islands, the coastal strip from Poulsallagh to Blackhead, Cappanawalla, Gleninagh and Moneen Mountains.

Most important literature: Ivimey-Cook and Proctor (1966); Kirby (1982); Kelly and Kirby (1982); McGough (1984); Dunford (2002).

FORMATION U—ALLUVIAL AND OTHER WETLAND FORESTS ON WET SOILS

These forests, dominated either by ash and oak with alder and a variety of willows, occur on flooded alluvial soils or on heavy, impermeable clays that remain wet for much of the year. Very few examples remain, making it more difficult to construct the potential vegetation compared with other woodland units.

Unit 8. Lowland alluvial forests of Quercus robur, Fraxinus excelsior and Salix species (U7). Fig. 9, Pl. VII.

Main communities and synonyms: This is a complex of communities in which the *Corylo-Fraxinetum deschampsietosum cespitosae* Br.-Bl. et Tx. 1952 is dominant on drier soils, the *Cari remotae-Fraxinetum* W. Koch 1926 occurs on water-logged sites and the *Salicetum albae* Issler 1926 forms gallery forests. However, the paucity of extensive alluvial forests makes it difficult to assign potential forests to particular syntaxa. Rodwell (1991a) classifies alluvial forests in Britain as *Alnus*

Pl. VII—Lowland alluvial forest (Unit 8). Vernal aspect with *Allium ursinum*, *Hyacinthoides non-scripta* and *Euphorbia hyberna*. Gearagh, Co. Cork.

glutinosa–*Urtica dioica* woodland (W6), but Irish stands do not fit readily into this community. Fossitt units include wet, pedunculate oak–ash woodland (WN4) and riparian woodland (WN5). Natura unit: residual alluvial forests (91EO).

Structure and species composition: Zoned vegetation in which forests of *Quercus robur* and *Fraxinus excelsior* up to 20m or more dominate. The introduced *Acer pseudoplatanus* may be locally abundant and *Alnus glutinosa* occurs in depressions. The shrub layer is relatively species-rich and dominated by *Corylus avellana* with *Crataegus monogyna*, *Ilex aquifolium* and shrub willows (principally *Salix cinerea* ssp. *oleifolia*). Other occasional species include *Euonymus europaea*, *Prunus spinosa*, *Sambucus nigra* and *Viburnum opulus*. The field layer is usually well developed and species-rich. In the spring, *Allium ursinum*, *Hyacinthoides non-scripta* and *Ranunculus ficaria* may be dominant, with some *Primula vulgaris*. Later in the year, species such as *Deschampsia cespitosa*, *Filipendula ulmaria* and *Urtica dioica* often form a tall, dense undergrowth. Other characteristic species include *Cardamine pratensis*, *Carex remota*, *C. sylvatica*, *Galium aparine*, *Poa trivialis*, *Ranunculus repens*, *Rubus fruticosus* agg. and the ferns *Athyrium filix-femina*, *Dryopteris affinis*, *D. dilatata* and *D. filix-mas*. The bryophyte layer includes *Brachythecium rutabulum*, *Calliergonella cuspidata*, *Eurhynchium praelongum*, *Hypnum cupressiforme* and *Thamnobryum alopecurum*.

Gallery forests of alder, tree and shrub willows, for example, *Salix alba* and *S. fragilis* (both introduced) and *S. cinerea* ssp. *oleifolia*, occur along the river channels. The layers are often indistinct as the trees vary considerably in height, with uprooted stems and fallen branches leading to an indistinct and tangled structure. There is a tall herbaceous layer, with species such as *Calystegia sepium*, *Carex riparia*, *Galium aparine*, *Oenanthe crocata*, *Phalaris arundinacea*, *Solanum dulcamara* and *Urtica dioica*. Locally, *Populus nigra* may colonise gravel and sandbanks in the Shannon, Liffey and Suir floodplains, where it is most abundant (Hobson 1991, 1993; D. Berridge, pers. comm.).

Floristic differences: The abundance of nitrogen and phosphorus-loving species, such as *Galium aparine* and *Urtica dioica*, along with *Carex riparia*, *Oenanthe crocata* and *Solanum dulcamara* distinguish this community from the following community (unit 9). However, the two vegetation units can be very similar, especially where flooding is infrequent.

Ecological and geographical variations: The zonation within the forests becomes less clearly defined westwards as the wetter climate enables moisture-demanding species to survive in areas that are infrequently flooded. This is particularly marked on poorly drained soils so that species such as *Alnus glutinosa*, *Deschampsia cespitosa* and *Salix cinerea* ssp. *oleifolia* become increasingly common. *Populus nigra* is largely confined to the floodplains of the rivers Shannon, Suir and Liffey.

Vegetation occurring in complex: Old river channels and pools provide habitats for aquatic communities, willow and alder carr, fens and reed swamps. On infrequently flooded but heavy, poorly drained soils alder–oak–ash forests (9) occur; on drier ridges stands of mixed oak–ash forests (4, 5) occur.

Adjoining vegetation: Grades into mixed oak–ash forests (4, 5) on drier soils, alder–oak–ash forests (9) on wetter soils, locally into raised bog (12) or degraded raised bogs (14).

Habitat characteristics: Alluvial forests occur on alluvium in the valleys of the major lowland rivers, most of which flow through calcareous or base-rich bedrock or glacial deposits, although some stands are fed by rivers flowing off poor, siliceous rocks. The more elevated areas are only briefly flooded, but the lower areas may be submerged for several weeks annually. Flooding can occur at any time of the year, although principally between October and March. Locally, there may be tidal, but not saline, influence. The unevenness of the surface and related variations in soil moisture are principally responsible for patterns in the vegetation, with swampy conditions in depressions and relatively dry conditions on low ridges. The soils, which are weakly acidic to neutral and rich in nitrates and phosphates, consist of silts with local fen peats and, in upper reaches, gravels. Alluvial forests occur across the complete spectrum of the lowland climate.

Characteristic land use and substitute communities: Most river systems have been drained or their hydrology modified for flood control purposes, as the land is highly suitable for agriculture. Except for the Shannon, the areas subject to flooding are now small. Much of the land is used for (largely improved) pasture, meadows or urban development. Small areas are planted with poplars and locally there are old osier beds for basket making. Within remnant stands grazing is occasional and sporadic clearance and felling helps to contribute to the uneven structure.

Distribution: Potentially along all the major lowland rivers, with the most extensive stands occurring along the Shannon and its tributaries and the lower and middle reaches of the Suir, Barrow, Nore, Slaney and Bann.

Importance for nature conservation: Only very small and highly modified examples of this forest type remain. Fens and meadows (calow land), especially along the Shannon, are very species-rich. Rare and protected species include *Campanula trachelium*, *Carex elongata*, *Leucjum aestivum*, *Oenanthe pimpinelloides*, and, in grassland, *Colchicum autumnale*. Representative stands include the Gearagh Nature Reserve, Co. Cork; Fiddown

Fig. 10—The potential distribution of alder–oak–ash forests (Unit 9).

Island Nature Reserve, Co. Kilkenny; Abbeyleix Wood, Co. Laois; and Hollymount, Co. Down.

Most important literature: White (1985); Kelly and Iremonger (1997); Browne *et al.* (2000); Cross and Kelly (2003); Heery (2003).

Unit 9. Alder–oak–ash forests with Salix cinerea subsp. oleifolia (U23). Fig. 10, Pl. VIII.

Main communities and synonyms: *Corylo–Fraxinetum deschampsietosum cespitosae* Br.–Bl. et Tx. 1952, *Carici remotae–Fraxinetum* Koch 1926. There are similarities with several of the units described by Rodwell (1991a), for example, *Alnus glutinosa–Fraxinus excelsior–Lysimachia nemorum* woodland, *Carex remota–Cirsium palustre* sub-community (W7b), *Fraxinus excelsior–Acer campestre–Mercurialis perennis* woodland, *Deschampsia cespitosa* sub-community (W8c) and *Fraxinus excelsior–Sorbus aucuparia–Mercurialis* woodland, typical sub-community (W9a). Fossitt unit: wet willow–alder–ash woodland (WN6).

Structure and species composition: This unit is a complex in which moisture-loving species occur in mosaic with species typical of forests of free-draining soils. Ash, with an admixture of oak (*Q. robur*), alder and birch (*B. pubescens*), dominates the canopy (up to 18m). Alder is concentrated on the wetter soils, i.e. at the top of drumlins or at the foot of slopes. *Acer pseudoplatanus* has been widely planted and potentially is an important constituent of this community. Oak is currently relatively rare, having been selectively removed. A lower layer of ash and alder saplings with *Salix cinerea* ssp. *oleifolia* also occurs. The shrub layer is formed from the above species, with hazel, *Crataegus monogyna*, *Ilex aquifolium* and locally *Prunus padus*. A layer of *Rubus fruticosus* agg., c. 1m high, often forms a sub-shrub

Pl. VIII — Alder–oak–ash forest with *Salix cinerea* subsp. *oleifolia*. (Unit 9). Alder-dominated stand with *Juncus effusus* and *Deschampsia cespitosa*. Crom Estate, Co. Fermanagh.

layer. The field layer is species-rich, with many species indicative of moisture-retentive or poorly drained soils, e.g. *Ajuga reptans*, *Carex remota*, *C. strigosa*, *C. sylvatica*, *Chrysosplenium oppositifolia*, *Circaea lutetiana*, *Crepis paludosa*, *Deschampsia*

cespitosa, *Filipendula ulmaria*, *Geum rivale*, *G. urbanum*, *Potentilla sterilis*, *Primula vulgaris*, *Ranunculus repens*, *Veronica montana* and the ferns *Athyrium filix-femina* and *Dryopteris dilatata*. The moss layer is relatively poorly developed, with

species such as *Brachythecium rivulare*, *Eurynchium praelongum*, *Plagiommium undulatum* and *Thuidium tamariscinum*.

Floristic differences: This unit is very similar to the preceding one, but it can be distinguished by the general paucity of nitrogen and phosphate-loving species, such as *Urtica dioica*, and aquatic species, such as *Oenanthe aquatica*.

Ecological and geographical variations: None known.

Vegetation occurring in complex: Mixed oak–ash forest on both drier calcareous (5) and acidic soils (4); fen communities (13), reed swamps and aquatic communities in small lakes; small raised bogs (12) in valleys and depressions.

Adjoining vegetation: Principally oak–ash forests (5) but locally acidophilous oak forests (3). At higher altitudes grades into mountain blanket bogs (11).

Habitat characteristics: These forests occur on lowlands, drumlins and low plateaux up to c. 200m over shales, slates, glacial tills and boulder clay. The heavy, wet, poorly-drained, mesotrophic, gleyed soils dry out on the surface for a short period in the summer but there is little or no tendency for peat to form. The pH is typically between pH 5–6, but locally higher, and the soil slightly calcareous. Flushing occurs locally on slopes. Annual precipitation is between 1000mm and 1200mm and there are usually more than 225 rain days per year. The incidence of cloud cover is high, especially in western areas. Mean annual temperature of the warmest and coldest months are c. 15°C and 4°C, respectively. The wetter communities occur in seepage areas, in valleys, inter-drumlin hollows, on the tops of drumlins and on flat ground where the soil is almost permanently wet but not subject to flooding. The drier communities occur principally on the better-drained slopes.

Characteristic land use and substitute communities: The soils are unsuitable for cultivation and largely support *Molinietalia* communities rich in *Juncus effusus* that are used for (mostly summer) grazing of cattle, less frequently as meadows. Plantations of *Picea sitchensis* also occur.

Distribution: Principally on drumlins in north-central Ireland, on plateaux in west Clare, Limerick and North Kerry, Castlecomer Plateau and locally elsewhere.

Importance for nature conservation: Only small stands remain, some of which contain relatively uncommon species, e.g. *Carex strigosa* and *Prunus padus*. They are under threat from felling and reforestation or attempts at land improvement. Areas of unimproved grassland, which are now very rare, are of considerable

value. Representative stands include Hughstown Wood, Co. Roscommon; Drumhierny Wood, Co. Leitrim; Drummin Wood, Co. Galway; and the Crom Estate, Co. Fermanagh.

Most important literature: Kelly and Iremonger (1997); Cross and Kelly (2003).

FORMATION S—MIREs

After forests, the mires, of which there are six units, are the second most extensive potential natural vegetation type in Ireland. Blanket bogs, which are the most extensive mire type, are classified into lowland and mountain types. A third type, highland blanket bog, has been recognised between 150m and 300m (Schouten 1984), but because of the limited extent of suitable topography at this altitude it covers relatively small areas. It is incorporated into the montane type on the map. Oceanic raised bogs, which once covered 5% of the land surface, have been drastically reduced in area, and most would potentially be classified as degraded raised bogs (Unit 14). Two types of raised bogs are recognised: the true Midland type and the Western type, but only a few remnants of the Midland type are large enough to map at this scale and the two types are not differentiated. The sedge mire communities have also been largely destroyed: most stands are very small and only two are mapped.

BLANKET BOGS

Blanket bogs are treeless landscape units in which a complex of vegetation communities occurs over peat of varying thickness, but traditionally accepted as greater than one metre in depth (Hammond 1979). They have developed under a very wet climate in association with a very long history of grazing and burning. The potential vegetation in the absence of these anthropogenic factors may not be fundamentally different from that occurring at present, although patches of scrub and woodland may develop on flushed sites, along rivers and on better drained slopes. The ability of blanket bog communities to redevelop on cut-away or former plantations—where drainage is no longer effective—is greater than on raised bogs, because of the higher rainfall and lower hydraulic conductivity of the peat (see, for example, the Bord na Mona site at Bellacorick, Co. Mayo). Such areas are mapped as blanket bog. Where severe overgrazing has led to the loss of the vegetation cover and subsequent erosion of the peat, recovery may be impossible or very slow. No attempt has been made to map these areas separately.

Fig. 11—The potential distribution of Atlantic blanket bog (Unit 10).

Unit 10. Atlantic (lowland) blanket bog (S5). Fig. 11.

Main communities and synonyms: *Pleurozium purpureae*–*Ericetum tetralicis* (Br.-Bl. et Tx., 1952) Moore 1968 in complex with *Rhynchosporion albae* Koch 1926. Rodwell (1991b) communities: *Scirpus cespitosus*–*Eriophorum vaginatum* blanket mire (M17) and *Sphagnum auriculatum* bog pool communities (M1). Fossitt units include lowland blanket bog (PB3), poor fen and flushes (PF2), transition mire and quaking bog (PF3). Natura units include blanket bog (7130), transition mires and quaking bogs (7140) and depressions on peat substrate (7150).

Structure and species composition: Lowland blanket bogs are a complex of treeless, oligotrophic mires occurring on deep (> 1m), waterlogged peat with relatively small inclusions of other vegetation types. Pools (occasionally displaying weak patterning) with aquatic communities, are an integral part of the complex. The vegetation is dominated by graminoid species, e.g. *Eriophorum angustifolium*, *E. vaginatum*, *Molinia caerulea*, *Schoenus nigricans* and *Scirpus cespitosus*, and short (< 20cm), poorly-developed, dwarf ericaceous shrubs, e.g. *Calluna vulgaris* and *Erica tetralix*. Other herbaceous species include *Narthecium ossifragum*, *Pedicularis sylvatica*, *Polygala serpyllifolia*, *Potentilla erecta* and *Rhynchospora alba*. There are constant but small amounts of *Sphagnum*, e.g. *S. magellanicum* and *S. papillosum*, forming lawns, *S. capillifolium*, *S. imbricatum* and *S. papillosum* forming hummocks and other bryophytes, e.g. *Campylopus atrovirens*, *Leucobryum glaucum*, *Pleurozia purpurea*, and lichens, e.g. *Cladonia uncialis*. Characteristically, deposits of mucilaginous algae (*Zygogonium ericetorum*) cover bare surfaces. Towards the edge of the deeper peat, where drainage and aeration is

better, there is a change in species composition, with a greater abundance of *Carex panicea*, *Molinia caerulea* and *Trichophorum cespitosus* with *Myrica gale*. On sloping, shallower (15–100cm deep) and drier peat wet heath communities occur. The *Rhynchosporion albae* community occurs in depressions with *Sphagnum denticulatum*, *S. cuspidatum*, *Menyanthes trifoliata* and *Rhynchospora alba*, sometimes forming Schwingmire communities. Oligotrophic fens, some of which contain rare boreal relict species, occur in association with water movement. In the absence of burning and grazing *Sphagnum* species and lichens would probably play a more important role in the potential mire vegetation, with a better development of dwarf shrubs, at least away from the wettest sites and on hummocks. Following drainage and/or fertilising, stands of *Molinia* develop.

Floristic differences: The presence of *Drosera anglica*, *Rhynchospora alba* and *Schoenus nigricans* and the absence of species characteristic of the following unit (Unit 11) distinguish it from mountain blanket bog. The presence of *Schoenus nigricans* with *Campylopus atrovirens*, *Molinia caerulea*, *Pinguicula lusitanica* and *Pleurozia purpurea* distinguish it from raised bogs.

Ecological and geographical variations: The lowland blanket bogs of Connemara are characterised by the presence of *Daboecia cantabrica* on shallow, drier peats, an abundance of rock outcrops, oligotrophic fens and rock basin lakes. Those in north-west Mayo are on deeper peat with numerous peat-bottomed pools. In counties Donegal and Kerry the bogs are more fragmented by the terrain.

Vegetation occurring in complex: A variety of oligotrophic fens occur, especially in seepage areas at the head of drainage channels. These include communities dominated by *Eriophorum angustifolium* and *Sphagnum fallax* or locally *Phragmites australis* and stands of willows (e.g. *Salix aurita*) or *Myrica gale*. Locally, *Betula pubescens* and *Salix aurita* may occur but in general flushed sites are too wet for tree and shrub growth (N. Lockhart, pers. comm.). Wet heath communities occur on shallow peat, with patches of dry heath, similar to Unit 16, on rock outcrops. These are dominated by *Calluna vulgaris*, *Erica cinerea* and, especially in coastal areas, *Ulex gallii*. Vegetation belonging to the *Isoeto-Lobelietum* Tx. 1937 em. Dierssen 1975 is present in pools and lakes. Alongside river channels narrow stands of alluvial forest or scrub, with alder, ash and shrub willow species may develop. Lake islands free from grazing carry acidophilous oak woodland (3) and such vegetation is likely to develop on patches of mineral soil elsewhere.

Adjoining vegetation: At lower altitudes acidophilous oak forests (3), locally alder–oak–ash forests (9). At higher altitudes this unit grades into montane blanket bog (11) or, on better-drained soils, birch forests (1).

Habitat characteristics: This unit occurs in areas with a hyperoceanic climate where rainfall (1200–2000mm) exceeds evapotranspiration by more than 700mm and falls on over 250 days per year. Summers are cool (July mean 14°C) and winters mild (February mean 6°C), with fewer than 20 frost days per year. Strong winds are common. The peat, which forms over acidic glacial drift or siliceous rocks, varies in depth from 1m to 7m, is highly humified (5–6 on the von Post scale), with an ash content of 1.2% to 2.4% dry weight and mean pH of 4.2–4.5. There are high values of marine-derived Cl, Mg and Na. Over much of the area the peat is waterlogged for most of the year except in the vicinity of lake shores, rock outcrops and steeper slopes. Grazing and associated burning are constant determining influences, and in their absence *Sphagnum* species and lichens would probably be more abundant. Overgrazing in recent years has led locally to the destruction of the vegetation and subsequent erosion of the peat.

Characteristic land use and substitute communities: Traditionally, these communities have been used for rough grazing by sheep or cattle. Together with the associated burning, this land use has determined the present day structure and species composition. Locally, attempts have been made to reclaim the land by draining, ploughing, fertilising and reseeding with grass, but invariably *Juncus effusus* invades quickly. Extensive areas have been drained, ploughed and planted with plantations of *Picea sitchensis* and *Pinus contorta*, but these seldom thrive. Peat cutting is common around the margins of the bogs and along roadsides, and a few extensive areas have been cut by machine.

Distribution: In the lowlands (up to 200m) along the Atlantic coast on flat ground and on slopes, locally up to 30°. The most extensive areas occur in Connemara, north-west Mayo and north-west Donegal.

Importance for nature protection: After Scotland, Ireland has the most extensive blanket bogs in the world. Floristically, however, Irish blanket bogs differ from the Scottish type and are thus unique and of global significance. Numerous rare plants, including boreal relict species, occur within the mire complexes, especially in flushes, with a high concentration of such sites occurring on the eastern edge of the north-west Mayo bog complex. These include; *Deschampsia setacea*, *Eriophorum gracile*, *Hammarbya paludosa*, *Saxifraga hirculus*, the liverwort *Leiocolea rutheana* (all of which are protected species), and the mosses

Fig. 12—The potential distribution of montane blanket bog (Unit 11).

Calliergon trifarium, *Tomentypnum nitens* and *Sphagnum warnstorffii*. The protected aquatic species *Najas flexilis* and *Pilularia globulifera* occur in oligotrophic lakes.

Overgrazing and associated peat erosion, peat extraction, agricultural improvement and afforestation have damaged extensive areas. Several areas are protected including Glenamoy International Biological Programme site, Knockmoyle–Sheskin Nature Reserve, the Owenduff Basin (Ballycroy Mayo National Park), Owenboy Nature Reserve, Co. Mayo; Lough Barra Bog, Co. Donegal; and Roundstone Bog complex and Lettershinnagh Nature Reserve, Co. Galway.

Most important literature: Moore (1968); Bellamy (1974); van Groenendael *et al.* (1979), Groenendael *et al.* (1983a; 1983b); Doyle (1982; 1990); Moore and Schouten (1984); Foss and McGee (1987); Douglas *et al.* (1989a; 1989b; 1989c; 1990); Lockhart (1989; 1991).

Unit 11. Montane blanket bog (S7). Fig. 12, Pl. VIII.

Main communities and synonyms: *Vaccinio–Ericetum tetralicis* Moore 1962; *Eriophorum angustifolium* bog-pool community (M3), *Carex echinata–Sphagnum recurvum/auriculatum* mire (M6), *Calluna vulgaris–Eriophorum vaginatum* mire (M19), *Eriophorum vaginatum* mire (M20) (Rodwell 1991b). Fossitt units include upland blanket bog (PB3), poor fen and flushes (PF2), transition mire and quaking bog (PF3). Natura units include blanket bog (7130), transition mires and quaking bogs (7140) and depressions on peat substrate (7150).

Structure and species composition: The vegetation of this unit is very similar structurally

Pl. IX—Montane blanket bog (Unit 11) showing typical pool systems, 'grassy' appearance with *Molinia caerulea*, *Eriophorum* species and hummocks of *Racomitrium lanuginosum*. Boleybrack, Co. Leitrim. (Photo Cáitríona Douglas.)

to the lowland blanket bogs, and there is no clear-cut transition but rather a gradual change in the species composition. *Calluna vulgaris*, *Molinia caerulea* and *Trichophorum cespitosum* persist but, with increasing altitude, *Rhynchospora alba* and *Schoenus nigricans* gradually disappear and are absent above c. 200m. *Empetrum nigrum* and *Vaccinium myrtillus*, rare at low levels, are important constituents. *Eriophorum vaginatum* is also more abundant and *Euphrasia micrantha* is typically present. *Sphagnum* species, principally *S. capillifolium* and *S. papillosum*, with the lichens *Cladonia portentosa* and *C. uncialis*, form luxuriant carpets where grazing and burning are absent or rare. Pools are characterised by *Menyanthes trifoliata*, *Sphagnum auriculatum* and *S. cuspidatum*. As in the lowland blanket bogs, there is a variety of oligotrophic fens in flushed areas: at higher altitudes some of these are probably climax, but at lower altitudes the potential vegetation is probably *Salix aurita* scrub. Areas of wet heath may potentially be montane birch forest (1).

Floristic differences: The presence of *Diplophyllum albicans*, *Empetrum nigrum*, *Euphrasia micrantha* and *Vaccinium myrtillus* distinguish this unit from lowland blanket bog.

Ecological and geographical variations: *Andromeda polifolia* and *Vaccinium oxycoccus* occur in central and eastern areas. *Sphagnum* species and lichens are also more common, but this may in part be a reflection of land use.

Vegetation occurring in complex: Oligotrophic fens, at lower levels with stands of *Salix aurita*; pools and lakes with aquatic vegetation; montane heath (15) on better drained slopes at the highest levels and on exposed ridges; montane birch forest (1) at lower levels.

Adjoining vegetation: Grades into montane heath (15) at higher altitudes and montane birch forests (1) in the east and midlands. At lower levels in the west grades into lowland blanket bog (10).

Habitat characteristics: This vegetation unit occurs over siliceous rocks (granites, sandstones, metamorphics) above 200m in the west and 400m in the east. The climate is characterised by high rainfall (1400mm to >2400mm), more than 250 wet days per year, strong winds, and high incidence of cloudiness and low temperatures, although prolonged frost and snow cover are rare, even at the highest altitudes. Peat composition is similar to Unit 10 but it is usually shallower, and Cl, Mg and Na are less abundant, especially away from the west coast. Grazing and associated burning are important influencing factors, and in recent years overgrazing has led to severe erosion, especially in the west.

Characteristic land use and substitute communities: Traditionally used for rough grazing by sheep, but extensive areas have been afforested with conifers (*Picea sitchensis*, *Pinus*

Fig. 13—The potential distribution of Atlantic raised bogs (Unit 12).

contorta). Peat cutting occurs locally, especially near larger towns and close to roads.

Distribution: Mountain slopes and plateaux throughout the country, with the most extensive areas in the west and north-west.

Importance for nature protection: As for the preceding unit (Unit 10), Ireland has outstanding examples of this vegetation type of international significance. Afforestation on lower slopes and overgrazing and erosion at all levels are major threats. Peat extraction is local but declining in importance. The following plants, all of which occur in Northern Ireland, are rare and protected: *Carex magellanica*, *C. pauciflora*, *Orthila secunda*, and *Rubus chamaemorus*. Representative stands include Easkey Bog Nature Reserve, Co. Sligo; Pettigo Plateau Nature Reserve, Co. Donegal; Sally Gap Bog, Co. Wicklow; Slieve Bloom Mountains Nature Reserve, counties Laois and Offaly; Cuilcagh Mountain, counties Cavan and Fermanagh; and the Garron Plateau, Co. Antrim.

Most important literature: Moore (1968); White and Doyle (1982); Schouten (1984); Douglas *et al.* (1989a; 1989b; 1989c; 1990).

Unit 12. Atlantic raised bogs (S8). Fig. 13, Pl. X. The mapped area represents a complex in which raised bog is the dominant vegetation in the landscape, interspersed with forest.

Main communities and synonyms: *Erico-Sphagnetum magellanici* (Oswald, 1923) Moore 1968 in complex with *Sphagno tenelli-Rhynchosporium albae* (Oswald, 1923) Koch 1926; *Erica tetralix-Sphagnum papillosum* and *S. cuspidatum/S. recurvum* communities (Rodwell 1991b). Fossitt units include raised bogs (PB1), poor fen and flushes (PF2), transition mire and quaking bog (PF3) and bog woodland (WN7).

Natura units include active raised bogs (7110) and bog woodland (91D0).

Structure and species composition: Isolated or, more commonly, complexes of flat, treeless raised bogs, dominated by *Sphagnum* species, dwarf ericaceous shrubs and herbs. Intact examples have well-developed hummock/hollow and pool complexes, sometimes displaying weak patterning, with lawns and carpets of *Sphagnum* species. Individual domes are separated by streams or rivers with marginal fen vegetation (laggs), now mostly absent or highly modified. Typically hummocks are formed from *Sphagnum capillifolium*, *S. imbricatum* and *S. papillosum* through and over which grow *Andromeda polifolia*, *Calluna vulgaris*, *Drosera rotundifolia*, *Erica tetralix*, *Eriophorum vaginatum*, *Trichophorum cespitosus* and lichens, e.g. *Cladonia ciliata* and *C. portentosa*. Lawns and hollows are characterised by *Sphagnum magellanicum*, *S. subnitens*, *S. tenellum*, *Drosera anglica*, *Eriophorum angustifolium*, *Menyanthes trifoliata*, *Narthecium ossifragum*, *Rhynchospora alba* and frequently *Vaccinium oxycoccus*. Pools contain *Cladopodiella fluitans*, *Eriophorum angustifolium*, *Menyanthes trifoliata*, *Sphagnum cuspidatum* and *Utricularia minor*.

Floristic differences: The presence of *Andromeda polifolia* and *Vaccinium oxycoccus*, as well as the greater abundance of *Sphagnum* species, distinguish raised bogs from lowland blanket bogs.

Ecological and geographical variations: In the west midlands, where rainfall exceeds 1000mm, the bogs increasingly take on characteristics of blanket bogs with *Campylopus atrovirens*, *Pleurozia purpurea* and *Carex panicea* becoming increasingly common. These are referred to as western raised bogs, as distinct from true midland raised bogs, which occur further east, in which these species are rare or absent.

Vegetation occurring in complex: *Calluna/Ulex europaeus* scrub with scattered *Betula pubescens* and *Pinus sylvestris* on the rand; tall sedge communities with stands of *Alnus glutinosa*, *Betula pubescens* and *Salix cinerea* ssp. *oleifolia* in the laggs; degraded raised bog communities (14) on cutaway; mixed oak-ash forest (5) or mixed alder-oak-ash forest (9) on mineral 'islands'. Larger bogs have internal drainage systems (soaks), with oligotrophic fen and sometimes small stands of *Betula pubescens* and *Pinus sylvestris* (*Salicetum auritae*).

Adjoining vegetation: Raised bogs occur mostly within forest communities (principally Units 5, 6, 8 and 9). Many are surrounded by cutaway with degraded raised bog communities (14).

Habitat characteristics: Lowland raised bogs occur in former depressions or lakes, principally

Pl. X— Atlantic raised bog (Unit 12) showing well-developed pool complex with hummocks and *Sphagnum* lawn. Garriskil Bog, Co. Westmeath.

over limestone or calcareous glacial deposits. Annual precipitation varies between 800mm and 1200mm, exceeds evapotranspiration by 250–700mm per year and falls on fewer than 250 days per year. The average temperature of the warmest and coldest months is *c.* 15.5°C and *c.* 4–5°C, respectively. Peat depth can exceed 15m but is typically 5–10m, pH is about 4.0, with an overwhelming dominance of chlorides and, to a lesser extent, sulphates in the water. The peat is usually poorly humified (<4 on the van Post scale). Typically the bogs are ungrazed but frequently burnt.

Characteristic land use and substitute communities: Raised bogs are principally used as a source of peat, which has been extracted over many centuries by hand and, in the last 50 years, by machine. Locally they have been drained and afforested. Hand-cut areas form complex mosaics of aquatic and terrestrial communities (14). Machine-cut bogs have lost their vegetation cover and form extensive areas of bare peat. Reclaimed areas consist of species-poor pasture or, locally, conifer plantations. Potentially, extensive areas will flood to form lakes or fens. Only very rarely are undrained bogs grazed.

Distribution: Formerly abundant in the central lowlands, in the Bann Valley and locally elsewhere (principally south Clare and north Kerry). The largest remaining examples occur in the midlands west of the Shannon in north Galway/Roscommon.

Importance for nature conservation: The oceanic raised bogs of Ireland represent some of the finest examples of their type in the world, even allowing for the extensive destruction. However, no intact bogs remain and even the best remaining examples are highly endangered ecosystems, which continue to be threatened by peat extraction, drainage and burning. *Sphagnum pulchrum*, *S. recurvum* var. *tenue* and stands of oligotrophic fen and birch woodland in soak systems are particularly rare. Most cutaway bogs have been replaced by species-poor pasture, fen, meadows, arable land or alder carr/birch woodland complexes (Unit 14). Representative stands include: Ardkill Bog, Co. Kildare; Carrowbehy Bog, Co. Roscommon; Clara, Mongan and Raheenmore Bog Nature Reserves, Co. Offaly; Garriskil Bog, Co. Westmeath; Lough Lurgan Bog, Co. Galway; Garry Bog, Co. Antrim; Fairy Water Bogs and Black Bog, Co. Tyrone.

Most important literature: Moore (1968); O'Connell and Mooney (1983); Mooney and Douglas (1984); Schouten (1984); Douglas and Grogan (1985; 1986; 1987); Cross (1987a; 1990a); Foss (1991).

Unit 13. Calcareous fens (S24). Fig. 14.

A complex of vegetation types dominated by sedges and determined by calcium-rich ground water.

Main communities and synonyms: *Schoenetum nigricantis* (Allorge, 1922) Koch 1926 in complex with *Juncetum subnodulosi* (Allorge, 1922) Koch

Fig. 14—The potential distribution of calcareous fens (Unit 13).

1926, *Cladietum marisci* (Allorge, 1922) Zobrist 1935; *Schoenetum nigricantis* mire (M13) (Rodwell 1991b). Fossitt unit: rich fen and flush (PF1). Natura units: calcareous fens with *Cladium mariscus* and *Carex davalliana* (7210), alkaline fens (7230).

Structure and species composition: Species-rich, usually treeless communities of small and tall sedges in mosaic, often of a rather open character with water runnels, bare soil and locally shallow pools. The *Schoenetum nigricantis* is dominated by *Schoenus nigricans* with *Molinia caerulea*. The *Schoenus* tussocks provide a relatively dry, acidic substrate that is colonised by calcifuge species, e.g. *Calluna vulgaris*, *Drosera rotundifolia*, *Erica tetralix*, *Narthecium ossifragum*, and the mosses *Bryum pseudotriquetrum* and *Rhizomnium punctatum*. The calcareous and relatively nutrient-rich, wet interspaces between the tussocks contain a rich bryophyte flora, e.g. *Aneura pinguis*, *Campylium stellatum*, *Palustriella commutata*, *Drepanocladus revolvens*, *Scorpidium scorpioides*, and aquatic vascular plants, e.g. *Menyanthes trifoliata* and *Utricularia intermedia*. Drier intertussock spaces provide niches for species such as *Agrostis stolonifera*, *Anagallis tenella*, *Carex flacca*, *Cirsium dissectum*, *Filipendula ulmaria*, *Hydrocotyle vulgaris*, *Parnassia palustris*, *Pinguicula vulgaris*, *Succisa pratensis*, *Ranunculus flammula* and a variety of orchids, e.g. *Dactylorhiza incarnata*, *Epipactis palustris*, *Gymnadenia conopsea*. When flowering, many of these species make a conspicuous contribution to the communities, although their overall cover is usually low.

The *Juncetum* is dominated by *Juncus subnodulosus* with associated *Carex lepidocarpa*, *Mentha aquatica* and *Molinia caerulea*. It is much more uniform than the *Schoenetum* as, in the absence of tussocks, the variety of niches is reduced. Dense stands of *Cladium mariscus*,

Phragmites australis and large sedges, e.g. *Carex acutiformis*, *C. elata* and *C. paniculata*, occur occasionally. Locally, where the ground water influence is reduced, there is a shift to more calcifuge plants and the early stages of raised bog formation. *Salix cinerea* ssp. *oleifolia* may also occur locally, but in general the soils are too wet and the pH too high for tree growth.

Floristic differences: The combination of the above species forms a unique community not readily confused with other vegetation types.

Ecological and geographical variations: None known.

Vegetation occurring in complex: Incipient raised bog communities (12), aquatic communities, reed swamps.

Adjoining vegetation: The most extensive communities occur today in areas bordering hazel-ash forest and scrub (7), but spring-fed systems also occur within the mixed oak-ash forests (6) and around raised bogs (12).

Habitat characteristics: Calcareous fens occur in limestone areas subject to a permanently high water table, frequent inundation of calcium-rich, oligotrophic water or in the neighbourhood of calcium-rich springs. The substrate is typically fen-peat or muds, often with marl, and with a pH between 6.5 and 8.0. Precipitation varies from 800mm to 1200mm. Mean temperature of the warmest and coldest months are c. 15°C and c. 5°C, respectively.

Characteristic land use and substitute communities: Many areas have been drained and converted into pasture, meadow or even arable land. Existing areas are mostly used for rough grazing, with a few small areas planted with coniferous forests, which do not usually thrive.

Distribution: The largest stands occur in association with karst areas in the west, especially on the eastern edge of the Burren and around loughs Corrib, Mask and Carra. Stands also occur around springs and seepage areas.

Importance for nature conservation: Although only small remnants remain, they are very valuable on account of their species richness. Substitute vegetation, which has arisen as a result of grazing or mowing, is also of considerable value. They continue to be under threat. Representative areas occur on the eastern edge of the Burren (e.g. Lough Bunny), the shores of Lough Corrib, Co. Galway; Magheraveely Marl Lakes, Co. Fermanagh; and Lecale Fens, Co. Down. A spring-fed example occurs in Pollardstown Fen Nature Reserve, Co. Kildare.

Most important literature: O'Connell *et al.* (1984); Ó Críodáin (1988); Mooney (1990);

Fig. 15—The potential distribution of degraded raised bogs (Unit 14).

Mooney and O'Connell (1990); Ó Críodáin and Doyle (1994; 1997).

Unit 14. Degraded raised bog with a mosaic of birch forests, alder and ash-alder carrs, fen and heath (T7). Fig. 15, Pl. XI.

This unit describes the extremely complex mosaic of vegetation that develops on cutaway bog. The complexity is a result of the small-scale variations in the substrate, which at this scale cannot be mapped. In the long term, it might be expected that with a gradual rise in water table there would be an expansion of fen and carr woodland and, eventually, the re-development of raised bog communities, i.e. a repetition of raised bog genesis that occurred following the last Ice Age.

Main communities and synonyms: *Alnetea glutinosae* Br.-Bl. et Tx. 1943 em Th. Müller et Görs 1958, *Osmundo-Salicetum atrocinereae* Br.-Bl. et Tx. 1952, *Betuletum pubescentis* (Hueck, 1929) Tx. 1937; *Salix cinerea-Betula pubescens-Phragmites australis* woodland (W2), *Betula pubescens-Molinia caerulea* woodland (W4) in complex with communities M8, M9, M16, M18 and M25 (Rodwell 1991b) and S4, S9, S13 and S24 (Rodwell 1995). Fossitt unit: cutover bog (PB4). Natura unit: degraded raised bogs (7120).

Structure and species composition: A complex of communities on drained and cutaway raised bog. The vegetation reflects the considerable spatial variation in the depth, pH and water relations of the substrate, previous land use and adjacent plant communities. In wetter areas subject to ground-water influence, tall fen, sedge fen and carr communities with *Alnus glutinosa* and *Salix cinerea* (mostly subsp. *oleifolia*) occur, with some *Betula pubescens* and, locally, *Fraxinus excelsior*. An ill-

defined shrub layer of the same species occurs but the cover of both the tree and shrub layer is often open and patchy allowing the development of a luxuriant and sometimes species-rich herb layer with many robust monocots. These include: sedges, e.g. *Carex acutiformis*, *C. diandra*, *C. nigra*, *C. paniculata* and *C. rostrata*; grasses and herbs, e.g., *Eupatorium cannabinum*, *Filipendula ulmaria*, *Lysimachia vulgaris*, *Lythrum salicaria*, *Molinia caerulea*, *Phragmites australis*, *Potentilla palustris* and *Valeriana dioica*; and horsetails and ferns, e.g. *Equisetum fluviatile*, *E. palustre*, *Dryopteris dilatata* and *Osmunda regalis*. Bryophytes play an important role, especially *Sphagnum palustre* and *S. fallax*, locally with *S. fimbriatum* and *S. squarrosum*. Stands of *Myrica gale* occur locally.

Where the ground-water influence is reduced, plants of oligotrophic soils become more important. Stands of *Betula pubescens*, often with *Pinus sylvestris*, occur with occasional holly, rowan and oak (usually *Quercus robur*). The shrub layer consists principally of various willow species, and the species-poor herb layer is frequently dominated by *Pteridium aquilinum* or *Rubus fruticosus* often with *Hedera helix* and *Lonicera periclymenum*. Other species present include a few grasses, e.g. *Anthoxanthum odoratum*, *Holcus lanatus*, *Molinia caerulea* and ferns, e.g. *Blechnum spicant* and *Dryopteris dilatata*. In wetter spots, remnants of the bog flora such as *Erica tetralix* and *Eriophorum vaginatum* may be present and there may be a luxuriant growth of *Sphagnum* species, e.g. *S. capillifolium*, *S. fimbriatum* and lichens, e.g. *Cladonia ciliata*. Typically, however, the bryophyte cover is dominated by *Eurhynchium praelongum*, *Hylocomium* species, *Hypnum* species, *Polytrichum formosum* and *Thuidium tamariscinum*.

Intermixed with these woodlands are ditches, depressions and holes carrying a variety of wetland vegetation depending on the substrate and ground-water influences. These allow for the development of various fen communities and regenerating bog complexes. Patches of the original bog surface may also remain with dried-out bog or heath communities.

Floristic differences: This complex of communities and species is unlike any other at low altitudes.

Ecological and geographical variations: None known.

Vegetation occurring in complex: Fragments of oak-ash forests (4, 5) raised bog (12), fens (13), reed swamps.

Adjoining climax vegetation: As for raised bogs (S5).

Habitat characteristics: These communities are characterised by sharp variations in soil type. Peat depth can vary from 1m or more to only a few

Pl. XI— Birch woodland, summer aspect, on former cutaway showing old face-bank and the sparse field layer dominated by *Rubus fruticosus* (Unit 14). (Photo Sasha Bosbeer).

centimetres, or it may be entirely absent. The underlying mineral soil varies from calcareous clays to acidic sands, and the peat may be of the fen or bog-type. The pH can vary from greater than pH 7 to less than pH 4. The soils may be permanently waterlogged or well-drained and fresh. Small areas of open water are also present. Climatically this vegetation unit occurs in the same areas as raised bogs.

Characteristic land use and substitute communities: The land is often too difficult and sometimes dangerous to utilise except for the occasional removal of trees. Flatter areas without deep holes are used for rough grazing. Areas that have been levelled are often converted to grassland or occasionally used for vegetable production or afforestation, but the very uneven depth and quality of the soil makes the land unattractive for agriculture.

Distribution: Widespread in association with raised bogs. Potentially these communities might be expected to cover extensive areas of cutaway bog in complex with reed swamps and open water.

Importance for nature protection: These communities have a general conservation value for plant and animal life in areas often devoid of

woodland. They will become increasingly valuable as refuges for fen and bog organisms as these habitats are destroyed elsewhere. Locally, incipient raised bogs and bog woodlands are developing. They provide habitat for some relatively rare species, e.g. *Frangula alnus*. Some areas are protected in association with protected raised bogs. The Peatlands Park, Co. Armagh, is an extensive site being actively managed.

Most important literature: There is little specific literature on these communities, but information can be found in Cross (1990a), Kelly and Iremonger (1997), O'Connell and Foss (1999), Browne *et al.* (2000) and van der Sleesen and Poole (2002).

FORMATION E— ATLANTIC DWARF SHRUB HEATHS

Heaths are extensive throughout the uplands, but they are mostly anthropogenic in origin. Cessation of grazing and burning would result in their decline, leaving only the montane communities at the highest levels and on very exposed, wind-swept ridges and summits. Elsewhere they would be replaced by birch woodland (1) and oak woodland (2, 3). In contrast, coastal heaths are

Fig. 16—The potential distribution of montane heath (Unit 15).

very restricted in area and have been further reduced by urban development and agricultural reclamation. Many areas of heath are too small to map at this scale.

Unit 15. Montane heath (E5). Fig. 16, Pl. XII.

Main communities and synonyms: *Lycopodium alpini*–*Racomitrium lanuginosi* (Armstrong, Calvert et Ingold, 1930) Br.–Bl. et Tx. 1952 in complex with *Nardo*–*Caricetum binervis* Br.Bl. et Tx. 1952; *Achillea*–*Festucetum tenuifoliae* Birse et Robertson 1976; *Herberteto*–*Polytrichetum alpinie* Mhic Daeid 1976; *Calluna vulgaris*–*Racomitrium lanuginosum* heath (H14), *Vaccinium myrtillus*–*Deschampsia flexuosa* heath (H18) (Rodwell 1991b). Fossitt unit: montane heath (HH4). Natura unit: dry heaths (4030).

Structure and species composition: A complex of low, wind-trimmed heath, grassland and bryophyte communities, rarely more than a few centimetres high and often forming mosaics with bare rock and frost-shattered stones. Ericaceous species such as *Calluna vulgaris*, *Erica cinerea*, *Empetrum nigrum* and *Vaccinium myrtillus* dominate the dwarf shrub layer with locally, *Arctostaphylos uva-ursi*, *Salix herbacea* and *Vaccinium vitis-idaea*. Grasses include species such as *Agrostis capillaris*, *Deschampsia flexuosa*, *Festuca vivipara* and *Nardus stricta* occurring with herbaceous species, such as *Euphrasia* spp, *Galium saxatile*, *Thymus polytrichus* and *Viola riviniana*. Other local species include *Armeria maritima*, *Carex bigelowii*, *Diphasiastrum alpinum* and *Plantago maritima*. Mat-forming bryophytes, especially *Hypnum cupressiforme* and *Racomitrium lanuginosum* along with *Dicranum scoparium*, *Herbertus aduncus*, *Hylocomium splendens*, *Pleurozium schreberi*, *Polytrichum alpinum*, *P. juniperinum* and *Rhytidiadelphus loreus* are important components of these communities. In

sheltered localities, bryophyte-rich communities occur along with *Luzula sylvatica* and, locally, *Hymenophyllum wilsonii* and *Saxifraga spathularis*.

Floristic differences: This is the only non-mire vegetation type occurring above the tree line.

Ecological and geographical variations: There is some indication of a difference between the mountains of the north and east and those of the west; for example, *Diphasiastrum alpinum* is more common in the northern half of the country, *Vaccinium vitis-idaea* is commoner in the north-east and *Juniperus communis* ssp. *nana* in the west. Isolation of the communities appears to have resulted in considerable floristic variation between sites. Bare rocky sites and areas subject to flushing by base-rich water provide habitat for more nutrient-demanding species, e.g. *Polygonum viviparum* and *Rhodiola rosea*.

Vegetation occurring in complex: Small areas of montane blanket bog (11); cliffs and rock outcrops, wet gullies and ledges.

Adjoining vegetation: Grades into montane blanket bog (11) on gentle slopes where drainage is impeded and birch forests (1) on well-drained, more sheltered slopes at lower altitudes.

Habitat characteristics: Communities of exposed summits and ridges of the montane to subalpine belt (>500m) representing the altitudinal limit to vegetation in Ireland. The climate is cool, wet, windy, misty and cloudy. Although no detailed data are available, mean winter temperatures are close to 0°C, but snow cover is rarely prolonged and is blown off exposed sites. Precipitation is >1600mm per year in the east and exceeds 3000mm in the west, where rain days exceed 250 per year. The granites, sandstones, slates, schists and other acidic metamorphic rocks produce shallow, stony podzols, rankers and lithosols subject to frost heave and freeze-thaw action, with a pH between 4 and 5, although locally there is slight flushing.

Characteristic land use and substitute communities: This community is too high and exposed to be of any economic importance apart from sheep grazing. Recreational use is increasing.

Distribution: On the highest mountain-tops and exposed ridges, occurring at lower levels in exposed sites in the west and north. Most of the stands are small and cannot be mapped at this scale.

Importance for nature protection: In most areas these communities are modified by grazing or recreational pressure. Representative stands occur throughout the country on most of the higher, exposed mountain-tops. The following protected areas contain stands: Wicklow, Killarney, Glenveagh and Connemara National Parks; Mount Brandon, Co. Kerry; Eastern Mourne Mountains, Co. Down. Montane heaths and associated cliff communities are the centres for

Pl. XII— Montane heath (Unit 15). *Calluna vulgaris* and *Empetrum nigrum*-dominated sward with *Juncus squarrosus* tussocks. Djouce Mountain (725m), Co. Wicklow.

numerous rare and protected arctic-alpine species, e.g. *Alchemilla alpina*, *Cryptogramma crisa*, *Polygonum viviparum* and *Polystichum lonchitis*.

Most important literature: Mhic Daeid (1976); White and Doyle (1982); Curtis (1993).

Unit 16. Coastal heath in mosaic with Festuca grassland (E11). Fig. 17, Pl. XIII.

Main communities and synonyms: *Calluno-Scilietum vernae* Malloch 1971; *Ulici-Ericion cinereae* Géhu 1973; *Calluna vulgaris-Scilla verna* heath

Fig. 17— The potential distribution of coastal heath (Unit 16).

(H7), *Calluna vulgaris*–*Ulex gallii* heath (H8) Rodwell (1991b). Fossitt unit: dry siliceous heath (HH1). Natura unit: dry heaths (4030).

Structure and species composition: Short (rarely more than 1m), often dwarfed and wind-pruned vegetation of ericoid shrubs and gorse (*Ulex gallii*), usually in mosaic with grassland. *Calluna vulgaris*, *Erica cinerea* and *Ulex gallii* dominate the dwarf shrub communities. The grassland is typically dominated by *Festuca ovina* and *F. rubra*, accompanied by other grasses, e.g. *Agrostis capillaris*, *Anthoxanthum odoratum*, *Dactylis glomerata*, *Danthonia decumbens*, *Holcus lanatus*, and various herbs, e.g. *Anthyllis vulneraria*, *Armeria maritima*, *Carex flacca*, *Lotus corniculatus*, *Plantago lanceolata*, *P. maritima*, *Thymus polytrichus* and *Viola riviniana*.

Floristic differences: The combination of the above species and absence of plants of wet peat distinguish this unit from lowland blanket bog.

Ecological and geographical variation: *Scilla verna* occurs on the east coast indicating affinities with British communities. *Daboecia cantabrica* occurs in Connemara. *Ulex gallii* is mostly confined to the southern half of the country and is rare in the north.

Vegetation occurring in complex: Seawards, communities of *Festuca rubra*/*Armeria maritima*/*Silene maritima*-dominated grassland occur with *Crithmum maritimum*/*Spergularia rupicola* communities on rocks.

Adjoining vegetation: Landwards, this vegetation grades into acidophilous oak woodlands (2, 3, 4), locally mixed oak–ash forests (5) or, in the west, lowland blanket bogs (10).

Habitat characteristics: Largely confined to a narrow fringe on rocky coasts of sandstones,

shales, granites and other resistant metamorphic rocks, sometimes thinly overlain by calcareous tills or sands. The climate is characterised by strong winds, especially on the west coast, and is mostly frost-free, with the mean of the coldest and warmest months being 5.5–6.5°C and 14–16°C, respectively. Annual rainfall varies from c. 700mm on the east coast to over 1600mm on the west coast. Compared with inland areas there is considerably more sunshine. The soils are shallow, sandy or loamy rankers and brown earths, mostly acidic and oligotrophic to oligomesotrophic, pH 4.5 to pH 5.5, locally enriched by guano. Exposure, salt spray, occasional drought and grazing by rabbits contribute to the maintenance of the zonation and grassland communities.

Characteristic land use and substitute communities: Mostly used for rough grazing or recreation (footpaths). On flat ground coastal heath has been locally reclaimed for agriculture.

Distribution: This vegetation type occurs all around the coast in suitable locations, but the stands are narrow and small in extent and many cannot be mapped at this scale.

Importance for nature conservation: Coastal heaths are part of a continuum of heaths restricted to the north-west coast of Europe. Locally they are threatened by reclamation for agriculture and recreational developments. A few species occurring in this vegetation are protected, e.g. *Lotus subbiflorus*, *Ornithopus perpusillus*. Representative stands occur on Capel Island/ Knockadoon Head and Old Head of Kinsale Nature Reserves, Crookhaven, Co. Cork; Ballylack, Co. Waterford; Howth Head, Co. Dublin; Bray Head, Co. Wicklow.

Most important literature: None known.

FORMATION P—SAND DUNE AND SALT MARSH VEGETATION COMPLEXES

Azonal vegetation of sand dunes, shingle and gravel banks and salt marshes. These are mostly narrow, linear vegetation types restricted to the geomorphological features to whose formation they contribute.

Unit 17a. Dune complexes of the north-east, east, south and south-west coasts (P6). Fig. 18, Pl. XIV.

Main communities and synonyms: This complex consists of various communities including associations of the *Cakiletea maritimae* Tx. et Prsg.1950 in the pioneer dunes, *Ammophilietea* Br.-Bl. et Tx. 1943 on the main dunes and the *Viola curtisii*–*Tortuletum ruraliformis* Br.-Bl. et Tx. 1952 and *Ulici gallii*–*Ericetum cinereae*

Pl. XIII— Coastal heath (Unit 16) with *Erica cinerea*, *Calluna vulgaris*, *Potentilla erecta* and *Succisa pretensis* on rocky outcrop Ballyconneely, Co. Galway.

Fig. 18— The potential distribution of dune complexes of the northeast, east, south and southwest coasts (Unit 17a).

Géhu 1973 on stabilised dunes. In addition, the stabilised dunes carry *Festuco-Galietum maritimi* (Onno, 1933) Br.-Bl. et De Leeuw 1936, *Festuco rubro-Rosa pimpinellifolia* Nooren et Schouten 1976 and *Hippophaeo-Berberidetum* Moor 1958. A variety of communities described by Rodwell (2000) are included within this unit, principally *Honkenya peploides*-*Cakile maritima* strandline community (SD2), *Ammophila arenaria* mobile dune community (SD6), *Ammophila arenaria*-*Festuca rubra* semi-fixed dune community (SD7), *Festuca rubra*-*Galium verum* fixed dune community (SD8), *Salix repens*-*Calliergon cuspidatum* dune-slack

community (SD15) and *Hippophae rhamnoides* dune scrub (SD18). Fossitt unit: sand dune ecosystems (CD1-6). Natura units include annual vegetation of drift lines (1210), perennial vegetation of stony banks (1220), embryonic shifting dunes (2110), shifting dunes with *Ammophila arenaria* (2120), fixed dunes ((2130), decalcified fixed dunes (2150), dunes with *Salix arenaria* (2170) and humid dune slacks (2190).

Structure and species composition:

Communities of mobile and stabilised dune systems displaying a certain degree of zonation. The pioneer communities are characterised by *Cakile maritima* and *Salsola kali*, with *Polygonum oxyspermum* ssp *raii* occasional on shingle deposits. The vegetation of the fore-dunes is typically characterised by *Elytrigia juncea* with *Carex arenaria*, *Calystegia soldanella*, *Euphorbia paralias*, *Glaucium flavum* and *Honkenya peploides*. The main dunes are dominated by *Ammophila arenaria* with *Festuca rubra* and an abundance of yellow flowering Asteraceae, e.g. *Leontodon taraxacoides*, *Senecio vulgaris*, *S. jacobaea* and *Taraxacum officinale*. The fixed dune vegetation is characterised by a high cover of the moss *Tortula ruraliformis* and the lichen *Peltigera canina*, with *Galium verum* and *Viola tricolor* ssp. *curtisii* being prominent constituents. Several leguminous species are of particular importance, e.g. *Anthyllis vulneraria*, *Lotus corniculatus*, *Ononis repens* and various *Trifolium* species. Other species frequently present include *Anacamptis pyramidalis*, *Cerastium semidecandrum*, *Erodium maritimum*, *Euphrasia curta*, *Myosotis ramosissima*, *Thymus*

Pl. XIV— Birch and willow scrub with *Pteridium aquilinum* on fixed dunes (Unit 17a). Buckrooney, Co. Wicklow.

polytrichus and *Vulpia fasciculata*. Inland, on older, leached dunes, *Festuca* grassland dominates often with *Rosa pimpinellifolia*. Where grazing is absent *Pteridium aquilinum* and *Rubus fruticosus* become dominant and scrub or low woodland consisting of *Betula* species, *Crataegus monogyna*, *Ilex aquifolium*, *Prunus spinosa*, *Salix cinerea* ssp. *oleifolia*, *Ulex europaeus* and the introduced *Acer pseudoplatanus* occur. The introduced and invasive *Hippophae rhamnoides* is locally important. Very occasionally, where leaching has reduced the soil pH to sufficiently low levels, *Calluna vulgaris* and *Erica cinerea* form patches of heath. Low carpets of *Salix repens* characterise the slacks, typically with *Agrostis stolonifera*, *Carex nigra*, *Hydrocotyle vulgaris* and *Potentilla anserina*. Locally, *Fraxinus excelsior* and *Salix cinerea* ssp. *oleifolia* may occur where grazing is absent.

Floristic differences: See following unit.

Ecological and geographical variations: In the south-east corner of the country several species with southern affinities occur, e.g. *Asparagus officinalis* ssp. *prostratus*, *Juncus acutus* (in slacks). From Co. Cork to Galway Bay the systems are intermediate between this and the following unit. They are subject to more active erosion, some communities are reduced or absent and the species diversity is also reduced. In contrast, however, the slacks are more extensive.

Vegetation occurring in complex: Small areas of salt marsh occur locally, and some dune systems are associated with shingle banks (see section entitled Other Communities).

Adjoining vegetation: Salt marsh vegetation (18), aquatic communities and reed swamps in lagoons, mixed oak–ash forests with *Hyacinthoides non-scripta* (4), acidophilous oak forests (2, 3), mixed oak–ash forests (5).

Habitat characteristics: The drier, sunnier, warmer and more sheltered climate on the east and south coast is responsible for the greater range of habitats and species than on the west coast. The temperature of the warmest and coldest months varies between 14°C in the north-east and 16°C in the south and 5°C and 7°C, respectively. Rainfall varies from <700mm on the east coast to c. 1400mm in Kerry. Rain days vary between 140 days on the east coast to 240 days in the south-west. The soils, formed from wind-blown sand (locally with shell fragments), have a wide pH range from greater than pH 7.2 on some pioneer dunes to less than pH 4.5 on some back-dunes. They can become very dry in summer.

Characteristic land use and substitute communities: Used predominantly for grazing (although this is far less intense than in the following unit) and recreation (caravan sites, bathing beaches, golf courses). Some areas have been planted with conifers (mostly *Pinus* spp).

Fig. 19—The potential distribution of dune complexes with machair grassland (Unit 17b).

Distribution: Principally on the north, east, south and south-west coasts from Co. Derry to Co. Clare.

Importance for nature conservation: Intact sites are important for the variety of species and communities and especially for the presence of a number of rare and protected species, which include *Asparagus officinalis*, *Centaureum pulchellum*, *Lathyrus japonicus*, *Polygonum maritimum*, *Otanthus maritimus* (very local on shingle in Co. Wexford), *Saxifraga granulata*, and *Pyrola rotundifolia* ssp. *maritima*. Increasing recreational pressure is the main threat. Afforestation has damaged a few sites. Dune systems play an important role in coastal defences. Representative stands include Inch and Rossbeigh, Co. Kerry; North Bull Island Nature Reserve, Co. Dublin; Raven and Ballyteige Burrows Nature Reserves, Co. Wexford; Murlough, Co. Down; and Magilligan, Co. Derry.

Most important literature: Nooren and Schouten (1976); Jeffrey (1977); Ní Lamhna (1982); Curtis (1991).

Unit 17b. Dune complexes with machair grassland on north-west coasts (P5). Fig. 19, Pl. XV.

Main communities and synonyms: As in the preceding unit, this complex contains various communities, including associations of the *Cakiletea maritimae* Tx. et Prsg. 1950 in the pioneer dunes and *Ammophilieta* Br.-Bl. et Tx. 1943 on the main dunes. On stabilised dunes and machair the *Viola curtisii*–*Tortuletum ruraliformis* Br.-Bl. et Tx. 1952, *Camptothecium*–*Asperuletum* Br.-Bl. et Tx. 1952 and *Ulici gallii*–*Ericetum cinereae* Géhu 1973 associations occur; *Molinio*–*Arrhenantheretea* occurs in moister situations. The principal units of Rodwell (2000) are: *Honkenya peploides*–*Cakile maritima* strandline community (SD2), *Ammophila arenaria* mobile dune

community (SD6), *Ammophila arenaria*–*Festuca rubra* semi-fixed dune community (SD7), *Festuca rubra*–*Galium verum* fixed dune community (SD8), *Salix repens*–*Calliargon cuspidatum* dune-slack community (SD15) and *Hippophae rhamnoides* dune scrub (SD18). Fossitt unit: sand dune ecosystems (CD1–6). Natura units include annual vegetation of drift lines (1210), perennial vegetation of stony banks (1220), embryonic shifting dunes (2110), shifting dunes with *Ammophila arenaria* (2120), fixed dunes (2130), decalcified fixed dunes (2150), dunes with *Salix arenaria* (2170), humid dune slacks (2190) and machair (21AO).

Structure and species composition: A complex of open and closed communities of mobile and stabilised dune systems (the latter mostly in sheltered bays) often, but not always, with plains or machair grassland. The pioneer dune systems and associated communities have a similar species composition to Unit 17a but are often poorly developed because of erosion. The *Ammophila arenaria*-dominated main dunes are consequently often truncated. The fixed dune communities are characterised by a high percentage cover of mosses, especially *Brachythecium albicans* and *Tortula ruraliformis*, and the presence of *Viola tricolor* ssp. *curtisii*, but these communities are not always clearly developed.

The machair is an extremely dynamic system in which erosion and deposition result in a mosaic of winter-wet and dry grassland communities, merging imperceptibly into one another. Sand-binding species are unimportant. The drier communities are characterised by a mixture of grasses, e.g. *Festuca rubra*, *Poa subcaerulea*; herbs, e.g. *Bellis perennis*, *Thymus polytrichus*, *Trifolium repens*; and mosses, e.g. *Brachythecium albicans* and *Tortula ruraliformis*. Wet grassland communities with *Agrostis stolonifera*, *Carex flacca*, *Dactylorhiza incarnata*, *Lotus corniculatus*, *Parnassia palustris*, *Potentilla anserina* and *Succisa pratensis* occur in depressions or slacks. In the absence of intensive grazing dwarf scrub dominated by *Corylus avellana*, *Crataegus monogyna*, *Rosa spinosissima* and *Rubus fruticosus* agg. with *Pteridium aquilinum* may develop, although rabbits and deer may ensure continuity of patches of open vegetation.

Floristic differences: Differences from preceding unit are ones of degree rather than kind. Some species, for example *Glaucium flavum* on pioneer dunes and *Cerastium semidecandrum*, *Erodium maritimum*, *Myosotis ramosissima*, *Ononis repens* and *Vulpia fasciculata* on fixed dunes, are mostly absent, and there is a paucity of winter annuals. The *Ammophila* dune communities are often poorly developed. Where machair is present both the landscape and vegetation communities are very distinctive.

Pl. XV— Machair vegetation (Unit 17b) showing the characteristic flat to undulating topography and very closely grazed vegetation. Doogort, Co. Donegal. (Photograph by Karen Gaynor.)

Ecological and geographical variations: On the inland side of dune systems where the sand has been decalcified or where sand has been blown onto acidic rocks, heath with *Calluna vulgaris*, *Erica cinerea* and *Ulex* species develops. Exposure may prevent further development into scrub.

Vegetation occurring in complex: Aquatic vegetation (*Potametea*) and stands of reeds (*Phragmitetea*) associated with lagoons, calcareous-rich brown-moss fens, salt marsh vegetation (18), dune heath, shingle vegetation (see section on Other Communities).

Adjoining vegetation: Dune complexes of Unit 17a, salt marshes (18), coastal heaths (16), Atlantic blanket mires (10), oak forests rich in bryophytes and lichens (3).

Habitat characteristics: These communities are characterised by a cool, wet and very windy climate. The mean temperature for January is *c.* 5.3°C and for August is 14.2°C, and the mean daily range is only *c.* 5°C. Rainfall is between 1000–1100mm, falling on average on 240 days per year. The most distinctive feature, however, is the occurrence of strong winds throughout the year with mean annual wind speeds reaching 7m sec⁻¹ and frequent gales (Malin Head, Co. Donegal, records a mean of 69 gales per year). This results in strong erosion of the dunes and an almost continuous ‘rain’ of sand onto the plains, which counteracts leaching. The soils are a mixture of

pure sand and sandy rankers, often with a high content of shell fragments and calcium, pH between 6.6 and 8.8, and a low level of organic matter. The frequent rainfall keeps them fresh, but in depressions and slacks the soils are wet, especially in winter.

Characteristic land use and substitute communities: The machair is a product of a long tradition of land use in which grazing, mostly by cattle, and local cultivation for cereals and hay production were the principal activities. Increasingly, however, the land is being used for uncontrolled grazing and recreation, e.g. caravan sites and golf courses. The dune ridges are also grazed and locally more sheltered sites have been planted with conifers.

Distribution: Confined to the north-west coast between Galway Bay and Malin Head.

Importance for nature conservation: These distinctive communities have a very limited distribution and are very important at a European level, occurring only in north-west Ireland and west and north-west Scotland. They are increasingly under threat from overgrazing, land division and recreation. The following species are protected: *Astragalus danicus*, *Lathyrus japonicus* and the liverwort *Petalophyllum ralfsii*. The habitats are important for rare species of fauna, e.g. Chough (*Pyrrhocorax pyrrhocorax*) and species of *Vertigo* snails. Representative stands occur at Aillebrack, Co.

Fig. 20— The potential distribution of salt marshes (Unit 18).

Galway; Dooaghtry and Termoncarragh, Co. Mayo; Sheskinmore and Tranarossan, Co. Donegal.

Most important literature: Ackeroyd and Curtis (1980); Bassett and Curtis (1985); Curtis (1991); Crawford *et al.* (1996).

Unit 18. Salt Marsh vegetation complexes (P19).

Fig. 20.

Main communities and synonyms: The following syntaxa are listed approximately in order from the longest to the shortest period of submergence: *Salicornietum strictae* Knauer 1952, *Spartinetea maritimae* (Tx., 1961) Beefink, Géhu, Ohba *et al.* 1971, *Puccinellietum maritimae* (Warming, 1906) Christiansen 1927, *Halimionetum portulacoides* Kunholtz-Lordat 1927, *Juncus-maritimi*-*Oenanthe lachenalii* Tx. 1937 and *Armerion maritimae* Br.-Bl. *et de Leeuw* 1936. The principal Rodwell (2000) units are: transitional low-marsh vegetation with *Puccinellia maritima* (SM10), *Puccinellia maritima* salt marsh (SM13), *Halimione portulacoides* salt marsh (SM14), *Juncus maritimus*-*Triglochin maritima* salt marsh (SM15), *Festuca rubra* salt marsh (SM16) and *Juncus maritimus* salt marsh (SM18). Fossitt unit: salt marshes (CM1, CM2). Natura units: *Salicornia* and other annuals colonising mud and sand (1310), *Spartina* swards (1320) and Atlantic salt meadows (1330).

Structure: A complex of mud flats, true salt marsh communities and natural drainage channels often displaying a distinct zonation, depending on the period of submergence. At the lowest levels the mud flats may be covered almost permanently, except briefly during the lowest spring tides (submergent marsh) while conversely, at the highest levels, the vegetation may be exposed for much of the time, except for a brief period during

the highest spring tides (emergent marsh). In general, four main vegetation zones can be distinguished, related as much to topography as to distance from the sea. The lowest zone is characterised by stands of the annual *Salicornia europaea* agg. or the introduced *Spartina anglica*. Above this occur more species-rich communities often dominated by *Puccinellia maritima* with *Aster tripolium*, *Cochlearia* species, *Limonium humile* and *Spergularia media*. Above this zone *Armeria maritima* and *Plantago maritima* form a mixed sward accompanied by *Glaux maritima* and *Triglochin maritima*. In the upper marsh, communities dominated by *Festuca rubra* occur with *Glaux maritima* and *Juncus gerardii* and, at the highest levels, *J. maritimus*. Along drainage channels and around the edge of pools *Atriplex portulacoides*-dominated communities occur, although this species is more or less absent from the west and north coasts.

Ecological and geographical variations: The zonation is less clearly developed on the west coast, where grazing intensity is higher, the climate is milder and wetter and the salinities consequently lower than on the drier and warmer east coast. These factors are believed to contribute to the presence of turf fucoids that occur mostly in the upper submergent marsh. The most common species are *Ascophyllum nodosum*, several *Fucus* spp and *Pelvetia canaliculata*. The west coast marshes also have a higher incidence of grasses and *Oenanthe lachenalii* occurs locally. *Atriplex portulacoides* and *Puccinellia distans* are almost absent from the west and north coasts. The absence of *A. portulacoides* is partly a response to grazing, but its sensitivity to frost also appears to limit its occurrence in the north. *Blysmus rufus*, in contrast, is more abundant in the north. Locally on the east coast, the distinctive *Limonium binervosum* association occurs. A few thermophilous species occur on the south-east coasts, e.g. *Sarcocornia perennis* and *Juncus acutus*, representing a South Atlantic element in the flora.

Natural vegetation occurring in complex: sand dune vegetation (17a and 17b), coastal lagoons and reed swamps.

Adjoining climax vegetation: Various, depending on the substrate and climate, e.g. sand dune vegetation (17a and 17b), various forest communities, locally (in the west) blanket bog (10).

Habitat characteristics: The structure and floristics of salt marshes are determined partly by the length of time that the sea covers the deposits, but the climate is an important factor responsible for east-west differences. Where the tidal range is great the marshes tend to be more clearly zoned and more extensive. Salinity levels are higher in the relatively warmer, drier and sunnier climate on the east and south coasts, and this also contributes to the

Pl. XVI— Saltmarsh vegetation (Unit 18) with *Atriplex portulacoides* along the edges of the channels and a sward of *Limonium* species, *Aster tripolium*, *Armeria maritima* and *Spartina anglica* in the background. Rogerstown Estuary, Co. Dublin. (Photo Karen Gaynor).

clearer zonation. On the west coast, high rainfall, combined with the input of large volumes of fresh water from rivers, reduces salinity. The substrate varies from fine marine or alluvial silt to coarser material originating from glacial deposits. In places on the west coast, partly buried blanket-bog peat occurs. Wind-blown sand from adjacent dune systems may be locally important, especially in association with machair grassland.

Characteristic land use and substitute communities: Principally used for rough grazing by cattle and sheep, especially on the west coast but much less so on the east coast today. A reduction in grazing pressures on the west coast may result in a decline in the abundance of turf fucoids and increase in the occurrence of *Atriplex portulacoides*. Locally, areas have been reclaimed and converted into polders with species-poor grassland and arable land. Some attempts at reclamation in the nineteenth century failed with the subsequent redevelopment of salt marsh. Peat extraction and cultivation on the marshes themselves has occurred locally. Reclamation for building land, especially for port facilities, occurs in the vicinity of towns. Salt marshes serve important functions as coastal defences.

Distribution: Salt marshes occur around the entire coast, but the most extensive communities occur in

estuaries, sheltered, shallow bays, or behind extensive dune systems. Narrow, fringing salt marshes occur along sheltered rocky bays.

Importance for nature conservation: Ungrazed or lightly grazed salt marsh vegetation is probably close to the potential vegetation as there are no salt-tolerant trees or shrubs in Ireland. Salt marshes are particularly important for wild geese and other birds that overwinter in Ireland. Overgrazing and, locally, reclamation are the principal threats. *Sarcocornia perennis*, *Carex divisa*, *Hordeum secalinum* and *Puccinellia fasciculata* (confined to the south-east coast) are rare and protected species. Several sites are recognised as being of very high conservation value, for example: Rogerstown Estuary Nature Reserve, North Bull Island Nature Reserve, Boldoyle Estuary and Malahide Island, Co. Dublin; Ballyteigue Burrow Nature Reserve, Co. Wexford; and Carlingford Lough and Strangford Lough, Co. Down. A few large sites are included in Special Areas of Conservation complexes, e.g. Bannow Bay, Co. Wexford, and Castlemaine Harbour and Tralee Bay, Co. Kerry.

Most important literature: Jeffrey (1977); Ní Lamhna (1982); Sheehy Skeffington and Wymer (1991); Curtis and Sheehy Skeffington (1998); Sheehy Skeffington and Curtis (2000); McCorry *et al.* (2003); Curtis (2003).

Fig. 21—The potential distribution of polders (Unit 19).

OTHER COMMUNITIES

POLDERS

Unit 19. Vegetation of newly established polders (U28). Fig. 21.

Small areas reclaimed from the sea occur locally around the coast, the largest being around the mouth of the Slaney, Co. Wexford, along the Shannon estuary and around Lough Swilly, Co. Donegal. The heavily fertilised soils are rich in nitrogen and phosphates. Potentially, these polders may develop into mixed oak (*Quercus robur*)–ash forests, perhaps with alder in wetter places. However, oak is rare in the vicinity of these areas and, at least initially, the more readily dispersed ash and sycamore would probably be the main components, with a shrub layer of shrub willows and elder (*Sambucus nigra*). Tall, nitrogen and phosphate-loving herbs, e.g. *Anthriscus sylvestris*, *Galium aparine*, *Urtica dioica* and thickets of *Rubus fruticosus* agg., would be expected to form the herb layer. However, if the embankments are breached they would probably develop into saltmarsh communities or *Bulboschoenus* marsh.

REED, SEDGE SWAMPS AND AQUATIC COMMUNITIES (R)

Sheltered lake shores, the margins of slow-flowing rivers, shallow infilling lakes and coastal lagoons are characterised by a variety of mostly species-poor communities of the *Phragmitetea* Tx et Prsg. 1942 (see, for example, O'Connell *et al.* 1984). Typically, they are dominated by a few tall, clonal, perennial helophytes, the most extensive

stands being formed by *Phragmites australis* and *Scirpus lacustris* and, around the coast, *Bulboschoenus maritimus*. Accompanying species include *Alisma plantago-aquatica*, *Berula erecta*, *Iris pseudacorus*, *Mentha aquatica*, *Equisetum fluviatile*, *Glyceria* spp, *Lycopus europaeus*, *Myosotis scorpioides*, *Rorippa amphibia*, *Typha* spp and various free-floating and aquatic plants, e.g. *Lemna trisulca*, *Nymphae alba*, *Potamogeton* spp. They are often associated with a variety of other aquatic communities, tall sedge communities (*Magnocaricion* Koch 1926) and, locally, stands of *Cladium mariscus*. In a few places there is a tradition of cutting *Phragmites* for thatching and drier stands may be grazed. In the absence of cutting and grazing they may develop into willow and alder carr.

SHINGLE BEACHES

Shingle beaches occur around the entire coastline of Ireland but are concentrated on the north-west, west and south coasts. Particle size of the shingle varies from 2mm to 250mm in diameter, but is locally up to 1.5m (boulder beaches). They may form a simple ridge or, more commonly, occur in complexes with other geomorphological features, e.g. dune systems, lagoons.

The vegetation varies according to particle size and stability of the system. Unstable systems have open vegetation with a limited flora, with species such as *Tripleurospermum maritimum*, *Rumex crispus* and *Sonchus arvensis*. Stable systems carry *Plantago lanceolata*, *Festuca rubra*, *Lotus corniculatus*, *Rubus fruticosus* and *Geranium robertianum*. The most species-rich sites are those with *Festuca*-dominated grassland in which additional species, e.g. *Crepis capillaris*, *Anthyllis vulneraria* and *Hieracium pilosella* also occur. Sandy substrates are characterised by *Ammophila arenaria* and *Carex arenaria*, for example.

Shingle beaches are of high conservation value and have an important protective function. Rare species include *Mertensia maritima*, *Crambe maritima* and *Lathyrus japonicus*. Important sites include Whitestrand Bay–Coolart, Port bun an Inbhir, Co. Donegal; Tramore/Keel, Co. Mayo; Maherabeg, Co. Kerry; Ballyteige and Lady's Island, Co. Wexford; and the Murrough, Co. Wicklow (Moore and Wilson 2000).

CHASMOPHYTIC VEGETATION OF CLIFFS, ROCK CREVICES AND SCREES

The area covered by cliffs and screes is very small and cannot be mapped at this scale. Inaccessible cliffs probably represent the nearest to truly natural vegetation in the country. They are

particularly important at high altitudes for the impoverished Irish arctic-alpine flora, which includes *inter alia*, *Arenaria ciliata*, *Arabis petraea*, *Cryptogramma crista*, *Epilobium alsinifolium*, *Minuartia recurva* and *Polygonum viviparum*. At lower levels, cliffs and screes may carry scattered individuals or clumps of species associated with forest vegetation, e.g. *Ilex aquifolium*, *Sorbus aucuparia*, *Taxus baccata*, *Luzula sylvatica* and various grasses. Damp, north-facing slopes often carry species-rich bryophyte and lichen communities. Rock faces and deep, shaded ravines with cliffs subject to running or dripping water are often characterised by communities dominated by *Chrysosplenium oppositifolia* and various ferns, including locally the rare and protected *Trichomanes speciosum*. Sea cliffs are characterised by species such as *Armeria maritima*, *Aster tripolium*, *Crithmum maritimum* and *Spergularia rupicola* (White and Doyle 1982).

DISCUSSION

GENERAL DISTRIBUTION AND CHARACTER OF THE POTENTIAL VEGETATION IN IRELAND

With the cessation of agricultural activity and reduced grazing by domestic animals, forests would regenerate rapidly over most of Ireland, with probably more than 85% of the land surface being covered in some form of woody vegetation. The most extensive forest types would be the mixed oak-ash formations (Units 4, 5, 6). Forests on calcareous soils would dominate the central lowlands from Galway Bay to the Irish Sea and extend into the broad valleys in the south. Forests on relatively base-rich acidic soils (Unit 4) would occur in the lowlands of the south and north, as well as on the higher ground of the north midlands and on the basalt plateau of the north-east.

The second most extensive forest type would be the alder-oak-ash forest on heavy gley soils (Unit 9). These are concentrated in the drumlin belt of the north-west midlands and on the shale plateaux of Clare, Limerick and Kerry, coinciding with the climatically wetter parts of the country. Smaller areas occur further east, e.g. the Castlecomer plateau, and variations in the species composition are almost certain to occur. However, further surveys are required before these communities can be characterised more precisely.

The acidophilous oak forests (Units 2 and 3) have a more scattered distribution but are concentrated on the Old Red Sandstone mountains of the south-west, extending east across the mountain ridges of the south and into the Wicklow Mountains. They occur also on the Mourne Mountains and adjacent areas of sandy

soils and are scattered in other siliceous mountain areas, for example, Connemara and Donegal. They are closely associated with the montane birch forests, which may be considered as an altitudinal extension. Lowland alluvial forests (Unit 8) would expand along all the major river valleys and narrow bands of alluvial forest with alder, ash and shrub willows would develop along upland rivers and streams.

An east-west climatic gradient can be seen in all these forests as Rodwell (1991a) has also noted for Britain. It is most clearly observed in the acidophilous forests, with the species-poor sessile oak forests of the east (Unit 2) being replaced by the more species-rich forests of the climatically wetter south-west and west, with their luxuriant bryophyte, lichen and fern floras (Unit 3). A similar pattern occurs in the mixed oak-ash forest formations, which become increasingly rich in bryophytes and ferns westwards.

Altitudinal variations are clearly visible, although, for reasons of scale, these cannot all be mapped. In general, sessile oak forests with bluebell (Unit 4) are replaced by species-poor sessile oak forests (Unit 2) on the poorer podzolic soils in drier areas, e.g. the Wicklow mountains, and by bryophyte-rich acidophilous oak forests (Unit 3) in wetter areas, e.g. the Kerry and Connemara mountains. Above this zone the oak forests grade into birch forests or, where the topography is suitable, upland blanket bogs. Montane heath occurs at the altitudinal limit. Alder-oak-ash forests grade directly into mountain blanket bog where there is altitudinal continuity. Within the lowland blanket bogs, where topography allows, there is a direct transition from lowland to upland blanket bog with no intervening forest zone. In areas of steeper topography, oak or birch forest would probably replace the existing wet heath communities.

The potential distribution of peatlands closely reflects present-day patterns. A reduction in burning and grazing of the blanket peats would lead to changes in species composition and abundance. Willow and birch scrub would probably become more widespread on the oligotrophic fens within blanket bogs, while narrow belts of alluvial forest would develop alongside rivers. East of the Shannon the map shows the almost total absence of raised bogs, which are largely replaced by degraded raised bog (Unit 14). Raised bogs are mapped west of the Shannon, however, as the majority have been less severely damaged and are more likely to regenerate in the wetter climate.

East-west variations can also be observed in the remaining units. These differences are particularly pronounced in the sand dune vegetation complexes, with machair being

confined to the cool, wet and very windy climate of the north-west. The species variations in the salt marsh complexes and the coastal heaths also reflect temperature and rainfall gradients. Grazing, which is much more prevalent in the west than the east, is also an important factor, and a reduction in grazing pressure would probably result in a reduction in diversity of vegetation communities. For example, in the absence of grazing by domestic animals, machair may develop into low scrub.

SPECIES COMPOSITION OF THE FORESTS

The relative abundance of individual species in the potential forests is difficult to predict. The composition of secondary woodland (and hence potential natural woodland) depends on small variations in soil type, availability of seeds, condition of the land at the time of abandonment and chance events, for example, mast years, seed dispersal and disease (Peterken 1994). Elm, for example, following Dutch Elm Disease, is now scarce, at least as a tree, although in places it does appear to be re-establishing itself as a shrub. Selective removal of species has resulted locally in their virtual absence. In contrast, some introduced species, particularly beech, sycamore and certain conifers, which have been widely planted and which regenerate spontaneously, may play an important role in potential forests, e.g. sitka spruce or the reintroduced Scots pine in montane birch woodlands, or beech in mixed oak–ash woodlands. Introduced species will also play an important role in the shrub layer, e.g. *Rhododendron ponticum* on well drained acidic soils, and *Prunus laurocerasus* on more fertile soils.

The herb layer will probably also differ considerably from present day forest remnants. Some species, such as *Rubus saxatilis* and *Thelypteris oreopteris*, are now so restricted that their expansion into new forests is likely to be very slow. Other species, such as *Anemone nemorosa* and *Hyacinthoides non-scripta*, which are locally common, are slow colonisers and are therefore initially likely to play a relatively minor role. In contrast, certain species that have survived in the agricultural landscape and benefit from the increased nutrient status of the soil, will be much more abundant than they would be in natural stands, e.g. *Anthriscus sylvestris*, *Heracleum sphondylium*, *Sambucus nigra* and *Urtica dioica*. Introduced species, e.g. *Impatiens glandulifera*, may also be important in alluvial forests.

RELATIONSHIPS WITH THE VEGETATION OF THE REST OF EUROPE

The potential vegetation of Ireland differs from that of Britain and nearby parts of the continent in three

major respects. Firstly, the impoverished flora, and in particular the absence of certain important forest trees, results in floristically less diverse forest communities. Secondly, the mild, moist climate results in the widespread occurrence of Atlantic and sub-Atlantic species, in particular bryophytes and lichens. Thirdly, the area of mires in Ireland is greater than in any other European country at these latitudes (Ratcliffe and Oswald 1988). In addition, the extensive area of calcareous soils and the unique communities of the Burren karst region are of particular note.

Of the twenty vegetation units, four are more or less confined to Ireland: pedunculate oak–ash forests with hazel (Unit 5); the vegetation of the Burren (Unit 7); alder–oak–ash forests with *Salix cinerea* ssp. *oleifolia* (Unit 9); and Atlantic blanket bogs (Unit 10). Two units have their headquarters in Ireland but also occur in Britain: hazel–ash forests on shallow calcareous soils (Unit 6) and Atlantic raised bogs (Unit 12). Seven units are more or less confined to Ireland and Britain: species-poor oak forest (Unit 2); oak forests rich in bryophytes and lichens (Unit 3); oak forest with bluebell (Unit 4); lowland alluvial forest (Unit 8); montane blanket bog (Unit 11); montane heath (Unit 15); and dune complexes with machair grassland (Unit 17b).

The acidophilous oak forests are an extreme oceanic manifestation of a forest type that extends from the Atlantic into eastern Europe. The hyperoceanic, bryophyte-rich forests of the west (Unit 3) are particularly noteworthy. They include many southern Atlantic bryophytes and lichens with a Macronesian–Tropical world distribution, here reaching their most northerly known localities in the world (Birks 1996). Elsewhere in Europe similar hyperoceanic forests only occur in north-west Spain, but there the species complement is considerably richer in thermophilous species.

The absence of beech as a native species in Ireland, and also northern Britain, sets these areas apart from southern Britain and the continent. Beech forests are replaced by mixed oak–ash forests and, except for a restricted area of northern Spain and a very small area in Normandy, these forests are confined to Ireland and Britain. *Fraxinus excelsior* is a moisture-loving species that does not thrive on dry soils in the continental interior. Dierschke (1982) considered ash forests in Ireland as being a vicarious climax association of the more demanding beech forests of the continent, and, while beech may become an integral part of our potential forests, evidence from existing forests suggest that ash will continue to play an important role. The ash–oak forests with bluebell (Unit 4) occur extensively across central and northern Britain but, in contrast to Ireland, *Quercus robur*, rather than *Q. petraea* is the dominant species, and several species, e.g. *Tilia cordata*, *Carpinus betulus*, are absent from Ireland. It

should also be noted that bluebell is largely restricted to the north-west Atlantic fringes of Europe and is most abundant in Ireland and Britain. These so-called 'bluebell' woods may therefore be considered as almost endemic to these islands.

The mixed pedunculate oak–ash forests on calcareous soils (Unit 5) also occur in Britain, but, in the absence of several important species such as *Acer campestre*, *Carpinus betulus* and *Mercurialis perennis*, and with the greater abundance of moisture-loving species, the Irish communities are quite distinct. This applies also to the hazel–ash forests and the mixed alder–oak–ash forests on wet gleyed soils (Unit 9), which reach their greatest extent in Europe within Ireland.

Irish blanket bogs differ floristically from their Scottish counterparts, and they are more fragmented by the topography; only north-west Mayo has landscapes comparable to the Flow Country of Caithness and Sutherland (Ratcliffe and Oswald 1988). In the lowland blanket bogs, *Eriophorum vaginatum* is much less important in Ireland than in Scotland, while conversely, *Schoenus nigricans* is more or less absent in Scotland. In addition, several northern elements occur in Britain, both in the lowland and mountain blanket bogs, that are absent, or very scarce, in Ireland.

The oceanic raised bogs, which formerly occurred widely in north-west Europe (Goodwillie 1980), have been destroyed over much of their former range. Despite their extensive destruction, however, Ireland still has the greatest concentration of this type of bog in Europe (Cross 1990a; 1990b). The degraded raised bog communities (Unit 14) arising from their destruction cover extensive areas and have the potential to develop into unique communities.

The coastal communities, in contrast to the forests, are principally part of a north–south continuum along the west coast of Europe, although east–west variations can also be discerned. The dune systems are some of the largest and most intact in western Europe. Of particular significance are the machairs of the north-west coast, which occur elsewhere only in similar situations in Scotland. The coastal heaths are intermediate between northern and southern European types, those communities occurring in Ireland being limited to adjacent coasts of England, Wales and north-west France. Their distribution is determined by the intolerance of low temperatures displayed by two of the principal species, namely *Ulex gallii*—on the northern edge of its range from Galicia to southern Scotland—and *Erica cinerea*, which, while having a slightly wider distribution, is also frost-sensitive and does not occur east of Jutland or north of southern Norway.

The principal feature of interest in Irish salt marshes is the east–west variation arising from the oceanic climate and the associated lower salinity of the seawater on the west coast. This characteristic is superimposed on a north–south gradient, exemplified by minor changes in the species composition. A similar pattern can be seen in Scotland.

APPLICATION OF THE MAP OF POTENTIAL NATURAL VEGETATION

The diversity of the Irish landscape and vegetation is a product of natural variations in rock type, soil and climate overlain by millennia of human activity. This has resulted in a fine-grained mosaic of semi-natural and anthropogenic vegetation types. At the scale presented here, the map of the potential natural vegetation of Ireland clearly has limitations. However, used in conjunction with the descriptions of vegetation units provided here, it can provide an indicative guideline for land use and planning. Bohn *et al.* (2000) have discussed the use of such maps. They include:

- use as a baseline for a pan-European habitat and landscape classification, assessment and mapping system for nature conservation purposes;
- determination and evaluation of the degree of naturalness of the actual vegetation and landscape;
- establishment of representative national and international networks of protected areas;
- establishment of an international network for comparative observations of processes and changes in ecosystems, for example, for monitoring air pollution and climate change; and
- planning and restoration programmes, e.g. selection of appropriate species for afforestation.

CONCLUSION

The peculiarities and uniqueness of the Irish flora arising from its geographical location and relative isolation have been the subject of considerable discussion in the past (Praeger 1934; Webb 1983). The map of potential natural vegetation indicates that this applies not only at a species level but also at a community level. Some communities, for example, Atlantic raised bogs and bryophyte- and lichen-rich sessile oak forests, have their European headquarters in Ireland while others, such as alder–oak–ash forests, may be unique to Ireland. Production of a more detailed map will require considerable effort, even with modern methods of remote sensing. However, natural vegetation is a basic resource of a country that should be incorporated more fully into land-use and planning policies. It is hoped that the indicative

and practical value of the map and descriptions will be recognised and that it will stimulate further discussion and research, eventually leading to the production of a more detailed and accurate map, comparable to those available for other countries.

ACKNOWLEDGEMENTS

Many people have helped me with the production of this paper. I am especially grateful to Dr Jim White, University College, Dublin, who first encouraged me to attempt the task of mapping the potential natural vegetation of Ireland in the context of the 'Map of the natural vegetation of Europe'. I would like to thank all my present and former colleagues in the National Parks and Wildlife Service of the Department of the Environment, Heritage and Local Government, in particular Dr T. Curtis, Ms K. Gaynor and Mr M. Neff, for their advice and constructive criticism of the text and for drawing my attention to inaccuracies and mistakes. I am also grateful to the following people: Dr D.L. Kelly, Trinity College, Dublin; Mr R. Weyl and Mr P. Corbett for information on Northern Ireland; Dr Zdenka Neuhäuslová, Botanical Institute of the Czech Academy of Science, Prague, for useful discussions on the concept of potential natural vegetation; Dr Udo Bohn, Bundesamt für Naturschutz, Bonn, for his encouragement and help; and H. Weber, Bundesamt für Naturschutz, Bonn, for the preparation of the map and legend. Ms G. Weir helped me with the production of Figs 2–21.

REFERENCES

- Ackeroyd, J.A. and Curtis, T.G.F. 1980 Some observations on the occurrence of machair in western Ireland. *Bulletin of the Irish Biogeographical Society* **4**, 1–12.
- Bassett, J.A. and Curtis, T.G.F. 1985 The nature and occurrence of sand-dune machair in western Ireland. *Proceedings of the Royal Irish Academy* **85B**, 1–20.
- Bellamy, D.J. and Bellamy, R. 1966 An ecological approach to the classification of the lowland mires of Ireland. *Proceedings of the Royal Irish Academy* **65B**, 237–51.
- Birks, H.J.B. 1996 Contributions of Quaternary palaeoecology to nature conservation. *Journal of Vegetation Science* **7**, 89–98.
- Blackstock, P. 1998 Broad-leaved tree and shrub invasion of conifer plantations in Ireland. Unpublished PhD thesis, University of Ulster.
- Bleasdale, A. and Sheehy Skeffington, M.J. 1995 The upland vegetation of northeast Connemara in relation to sheep grazing. In D.W. Jeffrey, M.B. Jones and J.H. McAdam (eds), *Irish grasslands — their biology and management*, 110–24. Dublin. Royal Irish Academy.
- Blockeel, T.L. and Long, D.L. 1998 *A check-list and census catalogue of British and Irish Bryophytes*. Cardiff. British Bryological Society.
- Bohn, U. 1981 Vegetationskarte der Bundesrepublik Deutschland 1:200 000 — potentielle natürliche vegetation. Sheet cc5518 Fulda. *Schriftenreihe Vegetationskunde* **15**, 1–130.
- Bohn, U., Gollub, G. and Hettwer, C. 2000 *Map of the natural vegetation of Europe*. Bonn-Bad Godesberg. Federal agency for Nature Conservation.
- Bohn, U., Gollub, G., Hettwer, C., Neuhäuslová, Z., Schlüter, H. and Weber, H. 2003 *Map of the natural vegetation of Europe* 1–3. Bonn-Bad Godesberg. Federal Agency for Nature Conservation.
- Bohn, U., Gollub, G., Hettwer, C., Neuhäuslová, Z., Schlüter, H. and Weber, H. 2004 *Map of the natural vegetation of Europe*. Interactive CD-ROM (S. Hennekens). Bonn-Bad Godesberg. Federal Agency for Nature Conservation.
- Braun-Blanquet, J. and Tüxen, R. 1952 Irische pflanzengesellschaften. In W. Lüdi (ed.), *Die pflanzenwelt Irlands. Veröffentlichung Geobotanisches Institute Zürich* **25**, 224–415.
- Browne, A., Dunne, F. and Roche, N. 2000 A survey of broadleaf woodlands in three SACs: Barrow-Nore, River Unshin and Lough Forbes. Internal report for the National Parks and Wildlife Service. Dublin. Dúchas The Heritage Service.
- Budd, R. and von Engelbrechten, S. 1999 Fossil pollen analyses of a sediment core from St. John's Wood, County Roscommon. Internal report to the Heritage Council.
- Catorci, A. and Orsomando, E. 2001 Note illustrative della carta della vegetazione del foglio nocera umbra. *Braun-Blanquetia* **23**, 1–108.
- Collins, J.F. and Cummins, T. 1996 *Agroclimatic atlas of Ireland*. Dublin. Agmet.
- Crawford, I., Bleasdale, A. and Conaghan, J. 1996 Biomar Survey of Irish machair sites, 1996. *Irish Wildlife Manuals, No. 3*. Dúchas, The Heritage Service, Dublin.
- Cross, J.R. 1982 The invasion and impact of *Rhododendron ponticum* in native Irish vegetation. *Journal of Life Sciences of the Royal Dublin Society* **3**, 209–20.
- Cross, J.R. 1987a Status and value of native broadleaved woodland. *Irish Forestry* **44**, 81–8.
- Cross, J.R. 1987b Unusual stands of birch on bogs. *Irish Naturalists' Journal* **22**, 305–10.
- Cross, J.R. 1990a The raised bogs of Ireland: their ecology, status and conservation. Internal report to the Minister of State at the Department of Finance. Dublin. Stationery Office.
- Cross, J.R. 1990b Survey and selection of peatland sites for conservation in the Republic of Ireland. In G.J. Doyle (ed.), *Ecology and conservation of Irish peatlands*, 175–88. Dublin. Royal Irish Academy.
- Cross, J.R. 1992 The distribution, character and conservation of woodlands on esker ridges in Ireland. *Biology and the Environment: Proceedings of the Royal Irish Academy* **92B**, 1–19.

- Cross, J.R. 1998 An outline and map of the potential natural vegetation of Ireland. *Applied Vegetation Science* **1**, 241–52.
- Cross, J.R. 2001 The invasion and control of *Rhododendron ponticum* L. in native Irish vegetation. In I. Kowarik and U. Starfinger (eds), *Biologische Invasionen: Herausforderung zum Handeln*. *Neobiota* **1**, 329–37.
- Cross, J.R. and Kelly, D.L. 2003 Wetland woods. In M.L. Otte (ed.), *Wetlands of Ireland*, 160–72. University College Dublin Press.
- Curtis, T.G.F. 1991 The flora and vegetation of sand dunes in Ireland. In M.B. Quigley (ed.), *A guide to the sand dunes of Ireland*, 42–66. Dublin. European Union for dune conservation and coastal management.
- Curtis, T.G.F. 1993 *Polygonum viviparum* L. in Ireland with particular reference to the flora and vegetation of the Mount Brandon Range, Co. Kerry. *Irish Naturalists' Journal* **24**, 274–80.
- Curtis, T.G.F. 2003 Salt marshes. In M.L. Otte (ed.), *Wetlands of Ireland*, 31–43. University College Dublin Press.
- Curtis, T.G.F. and McGough, H.N. 1988 *The Irish red data book*. Dublin. Stationery Office.
- Curtis, T.G.F. and Sheehy Skeffington, M.J. 1998 The salt marshes of Ireland: an inventory and account of their geographical variation. *Biology and Environment: Proceedings of the Royal Irish Academy* **98B**, 87–104.
- Dierschke, H. 1982 The significance of some introduced European broad-leaved trees for the present potential natural vegetation of Ireland. In J. White (ed.), *Studies on Irish vegetation*. *Journal of Life Sciences of the Royal Dublin Society* **3**, 199–207.
- Douglas, C. and Grogan, H. 1985 Survey to locate raised bogs of scientific interest in Counties Galway (East) and Roscommon. Part II. Dublin. Internal report to the Forest and Wildlife Service.
- Douglas, C. and Grogan, H. 1986 Survey to locate raised bogs of scientific interest in Counties Longford, Westmeath and Mayo. Dublin. Internal report to the Forest and Wildlife Service.
- Douglas, C. and Grogan, H. 1987 *Survey to locate raised bogs of scientific interest in Counties Clare and Kerry*. Dublin. Internal report to the Forest and Wildlife Service.
- Douglas, C., Garvey, L., Kelly, L. and O'Sullivan, A. 1989a A survey to locate blanket bogs of scientific interest in counties Kerry and Sligo. Dublin. Internal Report to the Wildlife Service, Office of Public Works.
- Douglas, C., Garvey, L., Kelly, L. and O'Sullivan, A. 1989b A survey to locate blanket bogs of scientific interest in County Galway. Dublin. Internal Report to the Wildlife Service, Office of Public Works.
- Douglas, C., Garvey, L., Kelly, L. and O'Sullivan, A. 1989c A survey to locate blanket bogs of scientific interest in County Mayo. Dublin. Internal report to the Wildlife Service, Office of Public Works.
- Douglas, C., Dunnells, D., Scally, L. and Wyse Jackson, M. 1990 A survey to locate blanket bogs of scientific interest in Counties Donegal, Cavan and Leitrim. Dublin. Internal report to the Wildlife Service, Office of Public Works.
- Doyle, G.J. 1982 The vegetation, ecology and productivity of Atlantic blanket bog in Mayo and Galway, western Ireland. In J. White (ed.) *Studies on Irish vegetation*. *Journal of Life Sciences of the Royal Dublin Society* **3**, 147–164.
- Doyle, G.J. 1990 Phytosociology of Atlantic blanket bog complexes in north-west Mayo. In G.J. Doyle (ed.), *Ecology and conservation of Irish peatlands*, 75–90. Dublin. Royal Irish Academy.
- Dunford, B. 2002 *Farming and the Burren*. Dublin. Teagasc.
- Etherington, J. 1981 Limestone heaths in south west Britain: their soil and the maintenance of their calcicole-calcifuge mixtures. *Journal of Ecology* **69**, 277–94.
- European Commission 1996 *Interpretation manual of European Union habitats*. Brussels. European Commission, DGXI.
- Falinski, J.B. and Pedrotti, F. 1990 The vegetation and dynamical tendencies in the vegetation of Bosco Quarto, Promantario del Gargano, Italy. *Braun-Blanquetia* **5**, 1–31.
- Farrell, E.P. and Boyle, G. 1990 Peatland Forestry in the 1990s. 1. Low-level blanket bog. *Irish Forestry* **47**, 69–78.
- Foss, P.J. (ed.) 1991 *Irish Peatlands, the critical decade*. International Mire Conservation Group excursion and symposium proceedings. Dublin. Irish Peatland Conservation Council.
- Foss, P.J. and McGee, E. 1987 A survey to locate blanket bogs of scientific interest in County Mayo. Dublin. Internal report to the Wildlife Service.
- Foss, P.J., O'Connell, C. and Crushell, P.H. 2001 *Bogs and fens of Ireland—Conservation Plan 2005*. Dublin. Irish Peatland Conservation Council.
- Fossitt, J. 2000 *A guide to habitats in Ireland*. Kilkenny. The Heritage Council.
- Gardiner, M.J. and Radford, T. 1980 *Soil associations of Ireland and their land use potential—Explanatory Bulletin No. 36 to the Soil Map of Ireland*. Dublin. National Soil Survey of Ireland.
- Goodwillie, R. 1980 *European peatlands*. Nature and Environment series No. 19. Strasburg. Council of Europe.
- Goodwillie, R. 2003 Vegetation of turloughs. In M.L. Otte (ed.), *Wetlands of Ireland*, 135–144. University College Dublin Press.
- Hall, V.A. 2000 The documentary and pollen analytical records of the vegetation history of the Irish landscape AD 200–1650. *Peritia, Journal of the medieval academy of Ireland* **14**, 341–71.
- Hall, V.A. 2003 Vegetation history of mid-to western Ireland in the 2nd millennium AD; fresh evidence from tephra-dated palynological investigations. *Vegetation History and Archaeobotany* **12**, 7–17.
- Hammond, R.F. 1979 *The peatlands of Ireland*. Soil Survey Bulletin No. 35. Dublin. An Foras Taluntais.
- Hart, H.C. 1891 On the range of flowering plants and ferns on the mountains of Ireland. *Proceedings of the Royal Irish Academy* **1**, 512–70.

- Haughton, J.P., Andrews, J.H., Breathnach, M.S., Gardiner, M.J., Jones Hughes, T., Kirk, W., Walsh, M.C. and Williams, C.E. 1979 *Atlas of Ireland*. Dublin. Royal Irish Academy.
- Heery, S. 2003 Callows and floodplains. In M.L. Otte (ed.), *Wetlands of Ireland*, 109–23. University College Dublin Press.
- Hickie, D., Bohnsack, U., Scott A. and Baldock, D. 1999 A report on the impact of agriculture schemes and payments on aspects of Ireland's Heritage. Kilkenny. The Heritage Council.
- Higgins, G.T., Martin, J.R. and Perrin, P.M. 2004 National Survey of Native Woodland in Ireland. Dublin. Internal report to the National Parks and Wildlife Service.
- Hobson, D.D. 1991 The status of *Populus nigra* L. in the Republic of Ireland. *Watsonia* **18**, 303–5.
- Hobson, D.D. 1993 *Populus nigra* L. in Ireland – an indigenous species? *Irish Naturalists' Journal* **25**, 244–7.
- Ivimey-Cook, R.B. and Proctor, M.C.F. 1966 The plant communities of the Burren, Co. Clare. *Proceedings of the Royal Irish Academy* **64B**, 211–301.
- Jeffrey, D.W. (ed.) 1977 *North Bull Island, Dublin Bay: a modern coastal natural history*. Dublin. Royal Dublin Society.
- Kalkhoven, J.T.R. and van der Werf, S. 1988 Mapping the potential natural vegetation. In A.W. Küchler and I.S. Zonnenveld (eds), *Handbook of Vegetation Science* **10**, Vegetation Mapping, 375–86. Dordrecht. Kluwer Academic.
- Kelly, D.L. 1975 Native woodland in western Ireland, with especial reference to the region of Killarney. Unpublished PhD thesis, University of Dublin, Trinity College.
- Kelly, D.L. 1981 The native forest vegetation of Killarney, south-west Ireland: an ecological account. *Journal of Ecology* **69**, 437–72.
- Kelly, D.L. 2000 Charting diversity in a Killarney oakwood: level of resolution in floristic recording and the effects of fencing and felling. In B. S. Rushton (ed.), *Biodiversity: the Irish dimension*, 76–94. Dublin. Royal Irish Academy.
- Kelly, D.L. and Connolly, A. 2000 A review of the plant communities associated with Scots Pine (*Pinus sylvestris*) in Europe, and an evaluation of putative indicator/specialist species. *Investigación Agraria, Sistemas y Recursos Forestales; Fuera de Serie* **1**, 15–39.
- Kelly, D.L. and Iremonger, S.F. 1997 Irish wetland woods: the plant communities and their ecology. *Biology and the Environment; Proceedings of the Royal Irish Academy* **97B**, 1–32.
- Kelly, D.L. and Kirby, E.N. 1982 Irish native woodlands over limestone. In J. White (ed.), *Studies on Irish vegetation. Journal of Life Sciences of the Royal Dublin Society* **3**, 181–98.
- Kelly, D.L. and Moore, J.J. 1975 A preliminary sketch of the Irish acidophilous oakwoods. In J.-M. Géhu (ed.), *La végétation des forêts caducifoliées acidophiles*, 375–87. Vaduz. Cramer.
- Kirby, N. 1982 An ecological and phytosociological study of *Corylus avellana* L. in the Burren, Western Ireland. Unpublished PhD thesis, National University of Ireland, Galway.
- Lockhart, N.D. 1989 *Leiocolea rutheana* (Limp.) K. Muell. new to Ireland. *Journal of Bryology* **15**, 525–9.
- Lockhart, N.D. 1991 Phytosociological and ecological studies of lowland blanket bog flushes in west Galway and north Mayo. Unpublished PhD thesis, National University of Ireland, Galway.
- Lüdi, W. 1952 Fragmente zu waldstudien in Irland. In W. Lüdi (ed.), *Die pflanzenwelt Irlands. Veröffentlichung Geobotanisches Institute Zürich* **25**, 214–23.
- McCorry, M.J., Curtis, T.G.F. and Otte, M.L. 2003 *Spartina* in Ireland. In M.L. Otte (ed.), *Wetlands of Ireland*, 44–50. University College Dublin Press.
- McCracken, E. 1971 *The Irish woods since Tudor times*. Newtown Abbot. David and Charles.
- McGough, H.N. 1984 A report on the grasslands and closely related vegetation types of the Burren region of western Ireland. Dublin. Internal Report to the Forest and Wildlife Service.
- Mhic Daeid, C. 1976 A phytosociological and ecological study of the vegetation of peatlands and heaths in the Killarney Valley. Unpublished PhD thesis, University of Dublin, Trinity College.
- Mitchell, G.F. 1976 *The Irish landscape*. London. Collins.
- Mitchell, G.F. (ed.) 1987 *The book of the Irish countryside*. Dublin. Town House.
- Mitchell, G.F. and Ryan, M. 1997 *Reading the Irish landscape*. Dublin. Town House.
- Molloy, K. and O'Connell, M. 2004 Holocene vegetation and land-use dynamics in the karstic environment of Inis Oírr, Aran Islands, western Ireland: pollen analytical evidence evaluated in light of the archaeological record. *Quaternary International* **113**, 41–64.
- Mooney, E.P. and Douglas, C. 1984 Survey to locate raised bogs of scientific interest in Counties Galway (East) and Roscommon. Part I. Dublin. Internal Report to the Forest and Wildlife Service.
- Mooney, E.P. 1990 A phytosociological and palaeoecological study of the wetlands of the lower Corrib basin, Co. Galway, Ireland. Unpublished PhD thesis, National University of Ireland, Galway.
- Mooney, E.P. and O'Connell, M. 1990 The phytosociology and ecology of the aquatic and wetland plant communities of the lower Corrib basin, County Galway. *Proceedings of the Royal Irish Academy* **90B**, 5–97.
- Moore, D. and Wilson, F. 2000 *National shingle beach survey*. Dublin. Internal Report for National Parks and Wildlife Service, Dúchas, The Heritage Service.
- Moore, J.J. 1968 A classification of the bogs and wet heaths of northern Europe. In R. Tüxen (ed.), *Pflanzensoziologische systematik*, 306–20. Den Haag. Junk.
- Moore, P.D. and Bellamy, D.J. 1974 *Peatlands*. London. Elek Science.
- Neuhäuslová, Z. (ed.) 1998 *Map of the potential natural vegetation of the Czech Republic*. Prague. Academia.
- Neuhäuslová, Z. 2001 Potential natural vegetation of the Czech Republic. *Braun-Blanquetia* **30**, 1–80.
- Ní Lamhna, E. 1982 The vegetation of saltmarshes and sand-dunes at Malahide Island, County Dublin.

- In J. White (ed.), Studies on Irish vegetation. *Journal of Life Sciences of the Royal Dublin Society* **3**, 111–29.
- Nisbett, J. 1903 Interim report regarding inspection of woods and plantations in County Wicklow. Dublin. Internal report to the Department of Agriculture and Technical Instruction.
- Noirfalise, A. 1987 *Map of the natural vegetation of the member countries of the European Community and the Council of Europe*. Luxembourg. Office of the Official Publications of the European Communities.
- Northern Ireland Biodiversity Group. 2000 *Biodiversity in Northern Ireland*. Norwich. The Stationery Office.
- O'Connell, C. and Mooney, E.P. 1983 Survey to locate raised bogs of scientific interest. Dublin. Internal report to the Forest and Wildlife Service.
- O'Connell, C. and Foss, P. 1999 *A survey of cutover and cutaway bog habitats of the Irish Midlands*. Dublin. Irish Peatland Conservation Council.
- O'Connell, M., Ryan, J.B. and MacGowran, B.A. 1984 Wetland communities in Ireland. In P.D. Moore (ed.), *European mires*, 303–64. London. Academic Press.
- Ó Críodáin, C. 1988 Parvocaricetea in Ireland. Unpublished PhD thesis, National University of Ireland, Dublin.
- Ó Críodáin, C. and Doyle, G.J. 1994 An overview of Irish small-sedge vegetation: syntaxonomy and a key to communities belonging to the *Scheuchzeria-Caricetea nigrae* (Nordh. 1936) Tx. 1937. *Biology and Environment: Proceedings of the Royal Irish Academy* **94B**, 127–44.
- Ó Críodáin, C. and Doyle, G.J. 1997 *Schoenetum nigricantis*, the *Schoenus* fen and flush vegetation of Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy* **97B**, 203–18.
- O' Sullivan, A.M. 1965 *A phytosociological survey of Irish lowland meadows and pastures*. Unpublished PhD thesis, National University of Ireland, Dublin.
- O' Sullivan, A.M. 1968 Irish *Molinietalia* communities in relation to those of the Atlantic region of Europe. In R. Tüxen (ed.), *Planzensoziologische systematik*, 273–80. Den Haag. Junk.
- O' Sullivan, A.M. 1982 The lowland grasslands of Ireland. In J. White (ed.), Studies on Irish vegetation. *Journal of Life Sciences of the Royal Dublin Society* **3**, 131–42.
- Otte, M.L. 2003 *Wetlands of Ireland*. University College Dublin Press.
- Perrin, P.M. 2002 The ecology of yew (*Taxus baccata*) in Ireland. Unpublished PhD thesis, University of Dublin, Trinity College.
- Pethybridge, G.H. and Praeger, R.L. 1905 The vegetation of the district lying south of Dublin. *Proceedings of the Royal Irish Academy* **25B**, 124–80.
- Peterken, G. 1993 *Woodland conservation and management*. London. Chapman and Hall.
- Praeger, R.L. 1934 *The botanist in Ireland*. Dublin. Hodges Figgis.
- Purvis, O.W., Coppins, B.J., Hawksworth, D.L., James, P.W. and Moore, D.M. 1992 *The lichen flora of Great Britain and Ireland*. London. Natural History Museum.
- Rackham, O. 1986 *The history of the countryside*. London. Dent.
- Ratcliffe, D.A. 1968 An ecological account of Atlantic bryophytes in the British Isles. *New Phytologist* **67**, 365–439.
- Ratcliffe, D.A. and Oswald, P.H. 1988 *The Flow Country: the peatlands of Caithness and Sutherland*. Peterborough. Nature Conservancy Council.
- Richards, P.W. 1938 The bryophyte communities of a Killarney oakwood. *Annales Bryologici* **XI**, 108–30.
- Rodwell, J.S. 1991a *British plant communities 1: Woodland and scrub*. Cambridge University Press.
- Rodwell, J.S. 1991b *British plant communities 2: Mires and heath*. Cambridge University Press.
- Rodwell, J.S. 1992 *British plant communities 3: Grasslands and montane communities*. Cambridge University Press.
- Rodwell, J.S. 1995 *British plant communities 4: Aquatic communities, swamps and tall herb fens*. Cambridge University Press.
- Rodwell, J.S. 2000 *British plant communities 5: Maritime communities and vegetation of open habitats*. Cambridge University Press.
- Rohan, P.K. 1986 *The climate of Ireland*. Dublin. Stationery Office.
- Rübel, E.A. 1912 The International Phytogeographical Excursion in the British Isles. V. The Killarney woods. *New Phytologist* **11**, 54–8.
- Schouten, M.G.C. 1984 Some aspects of the ecogeographical gradient in the Irish ombrotrophic bogs. *Proceedings of the 7th International Peat Congress, Dublin* **1**, 414–32. Dublin. Irish National Peat Committee.
- Sheehy Skeffington, M.J. and Curtis, T.G.F. 2000 The Atlantic element in Irish salt marshes. In B.S. Rushton (ed.), *Biodiversity: the Irish dimension*, 179–96. Dublin. Royal Irish Academy.
- Sheehy Skeffington, M.J. and Wymer, E.D. 1991 Irish salt marshes—an outline review. In M.B. Quigley (ed.), *A guide to the sand dunes of Ireland*, 77–91. Dublin. European Union for Dune Conservation and Coastal Management.
- Smith, G.F., Kelly, D.L. and Mitchell, F.J.G. 2003 Establishing native woodlands in former upland conifer plantations in Ireland. In J. Humphrey, A. Newton, J. Latham, H. Gray, K.J. Kirby, E. Podsom and C. Quine (eds), *The restoration of wooded landscapes*, 37–46. Proceedings of a conference held at Heriott Watt University, Edinburgh, 14–15 September 2000. Edinburgh. Forestry Commission.
- Stace, C. 1997 *New Flora of the British Isles*. Cambridge University Press.
- Stapleton, L., Lehan, M. and Toner, P. 2000 *Ireland's environment: a millennium report*. Wexford. Environmental Protection Agency.
- Streefkerk, J.G. and Casparie, W.A. 1989 *The hydrology of bog ecosystems; guidelines for management*. Utrecht. Staatsbosbeheer.
- Trautmann, W. 1966 Erläuterungen zur Karte der potentiellen natürlichen Vegetation der Bundesrepublik Deutschland 1:200 000. Blatt 85 Minden. *Schriftenreihe Vegetationskunde* **1**, 1–137.

- Tüxen, R. 1956 Die heutige potentielle natürliche vegetation als gegenstand der vegetationskartierung. *Angewandte Pflanzensociologie* **13**, 5–42.
- van der Sleesen, S. and Poole, A. 2002 A survey of the woodlands of County Offaly. Dublin. Internal report for the National Parks and Wildlife Service, Dúchas, The Heritage Service.
- van Groenendaal, J.M., Hochstenbach, S.M.H., van Mansfeld, M.J.M. and Roozen, A.J.M. 1979 *The influence of the sea and of parent material on wetlands and blanket bog in west Connemara, Ireland*. Nijmegen. Catholic University.
- van Groenendaal, J.M., Hochstenbach, S.M.H., van Mansfeld, M.J.M. and Roozen, A.J.M. 1983a Plant communities of lakes, wetlands and blanket bogs in W. Connemara, Ireland. *Journal of Life Sciences of the Royal Dublin Society* **4**, 103–28.
- van Groenendaal, J.M., Hochstenbach, S.M.H., van Mansfeld, M.J.M. and Roozen, A.J.M. 1983b Soligenous influences on wetlands and blanket bogs in western Connemara, Ireland. *Journal of Life Sciences of the Royal Dublin Society* **4**, 221–42.
- Webb, D.A. 1983 The flora of Ireland in its European context. *Journal of Life Sciences of the Royal Dublin Society* **4**, 143–60.
- Westhoff, V. and van der Maarel, E. 1973 The Braun-Blanquet approach. In R.H. Whittaker (ed.), *Handbook of Vegetation Science*, Part V: Ordination and classification of communities, 617–726. The Hague. Junk.
- White, J. 1982 Introduction to the excursion report. A history of Irish vegetation studies. In J. White (ed.), *Studies on Irish vegetation*. *Journal of Life Sciences of the Royal Dublin Society* **3**, 199–207.
- White, J. 1985 The Gearagh woodland, Co. Cork. *Irish Naturalists' Journal* **21**, 391–6.
- White, J. and Doyle, G.J. 1982 The vegetation of Ireland: a catalogue raisonné. In J. White (ed.), *Studies on Irish vegetation*. *Journal of Life Sciences of the Royal Dublin Society* **3**, 280–368.