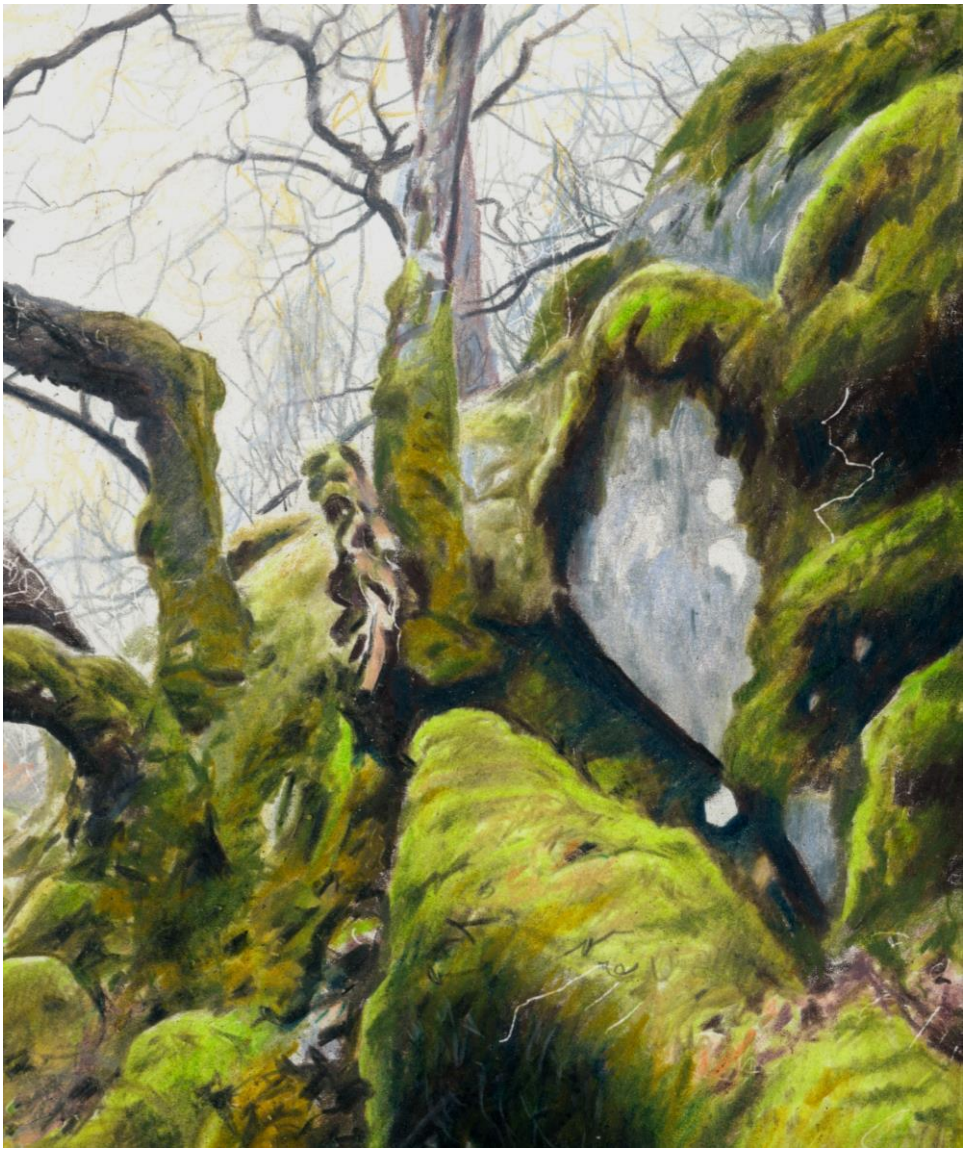
A Provisional Definition of **Temperate Rainforest** in Britain and Ireland



Ben Averis

2023

A Provisional Definition of Temperate Rainforest in Britain and Ireland; Ben Averis; 2023

Summary

This document presents a provisional definition of temperate rainforest in Britain and Ireland. This provisional definition is twofold:

Climatic

Various climatic measures and definitions are presented, using maps at the scales of Britain/Ireland and Europe. From comparisons of these with areas known to be rich in humidity-demanding plant and lichen species I suggest that the definition described by Alaback (1991) can be applied meaningfully to Britain and Ireland, and probably to Europe as a whole. This definition is as follows:

- at least 140 cm of precipitation annually; >10% of this during the summer months
- cool and frequently overcast summers; temperature of hottest month below 16°C
- fire infrequent and not an important evolutionary factor
- a dormant season that is caused by low temperatures and can include transient snow

In Britain and Ireland this definition appears to fit best if we add a winter cold limit:

- mean temperature of coldest month no lower than 2°C

Mapping of the above definition shows a rainforest zone that matches well with certain oceanicity indices: an index value of >15 calculated as annual rainfall (cm) divided by annual range of monthly mean temperatures (°C), or index value of >25 calculated as annual rainfall (cm) divided by maximum deviation of monthly mean temperatures from 9°C. It also correlates well with a summer potential water deficit of <1.27 cm. In N Britain areas with the coldest month below 2°C could be considered to have a more boreal type of rainforest climate, especially where the coldest month is below 0°C. Both temperate and boreal rainforests are globally scarce and of high international significance ecologically and botanically. Britain and Ireland (along with the Faroe Islands) has the most oceanic climate in Europe and is of major importance for temperate rainforest.

Botanical

From a comparison of species distributions with climate in Britain and Ireland a list is made of rainforest indicator species. These are mostly mosses, liverworts and lichens but also include some vascular plants and fungi. For the purpose of this provisional definition they are grouped into five categories:

R1 Very good rainforest indicators where they occur in native woodland: all current British and Irish records are from within the temperate rainforest climate zone (i.e. fitting the climatic definition of Alaback (1991) with an added lower limit of 2°C for the mean temperature of the coldest month).

R2 Good rainforest indicators where they occur in native woodland: almost all British and Irish records are from within the temperate rainforest climate zone; woodland occurrences elsewhere appear likely to indicate outliers of rainforest because the habitats of these species show a strong need for high humidity.

R3 Generally good rainforest indicators where they occur in native woodland (as for R2), but some of the outlier records appear to be, or are known to be, in less humid (semi-rainforest or non-rainforest) habitats.

R4 Generally good rainforest indicators where they occur in native woodland (as for R2 and R3), but with a more significant minority of records from outside the temperate rainforest climate zone and including less humid (semi-rainforest or non-rainforest) habitats.

R5 Commonest in the temperate rainforest climate zone but unreliable as indicators of rainforest because their frequency in this habitat appears to be related to non-rainfall factors at least as much as to rainfall. These other factors include temperature (mild winters, relatively cool summers or small annual temperature range perhaps just as important as humidity), air pollution ('R5p' lichens were previously more widespread, with occurrences in drier eastern parts of Britain from where they appear to have been largely or entirely lost since the Industrial Revolution as a result of pollution such as that from sulphur dioxide, leaving them now with mainly western/rainforest distribution patterns), or old growth forest with a long history of canopy cover (many western woods might have been less disturbed historically, or dependency on old growth forest might be lower and colonisation ability higher in areas with a rainforest climate).

Additional notes are given on other oceanic plant and lichen species (especially northern oceanic liverworts and southern oceanic lichens) that are of high biodiversity and conservation value and whose distributions overlap to some degree with rainforest.

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Ben Averis is a botanist and artist who lives near Edinburgh. Over the last few decades his botanical work has included surveys in more than 600 woods in Britain and Ireland, mostly in Scotland and with a particular focus on mosses and liverworts characteristic of western temperate rainforest.

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1. INTRODUCTION

It's great to see the interest people are showing in the temperate rainforest we have in Britain and Ireland. For many years there seemed to be very few of us focusing much on these places, but over the last decade or so that has changed and the fact that we have this wonderful habitat in our islands is much more widely known. This increased popularity has been helped a lot by the publication of books by Sandy and Brian Coppins (2012), Clifton Bain (2014), Eoghain Daltun (2022) and Guy Shrubsole (2022), information produced by Plantlife and the work of conservation groups such as the Alliance for Scotland's Rainforest (see Reference section for details of these publications and for online links to Plantlife, the Alliance for Scotland's Rainforest and Guy Shrubsole's "Lost Rainforests of Britain" website).

Some people have asked how we can define our temperate rainforest habitat or assess the rainforest status of a woodland site. Here is a provisional definition. I hope it helps people develop their understanding of this habitat, their appreciation of the botanical significance of our temperate rainforest sites, and their motivation to do whatever they can to help protect temperate rainforest in Britain and Ireland. Following useful feedback, this is the second version of this document. It is possible for future feedback to be incorporated into further revisions, in which case the latest version will keep the same filename and continue to be made available from http://www.benandalisonaveris.co.uk/resources/, with the revision date updated on the Contents page.

If we try to define our temperate rainforest in a very simple way (e.g. just one climatic variable, or a very short list of indicator species) it might seem encouragingly easy but we will soon find problems in that it doesn't accommodate the variation and complexity of the habitat. Temperate rainforest is variable, and there is no clear and simple separation between rainforest and non-rainforest. There are in-betweens of all sorts. Our temperate rainforest has diffuse climatic, geographical, ecological and floristic boundaries, and within it there are multiple gradients of ecological and floristic variation. (And, by the way, it's not just temperate rainforest. All habitats, and indeed everything about every aspect of nature, is overwhelmingly complex in reality! But that shouldn't temper our enthusiasm for studying temperate rainforest and doing our best to understand it.) If our approach to a definition of this habitat gets too complicated and technical, many people could find it difficult or confusing to work with and might be put off, so I've tried to reach a balance here. I have attempted to be not too simple and not too complicated.

I have started off with a section looking at climate in various ways, and followed that with a section looking at temperate rainforest plants and lichens, again in a number of ways. In the climate section I have presented a series of climate maps and chosen one of them (Map 15) as a map that is easily understood and can be referred to for an indication of the distribution of a temperate rainforest climate in Britain and Ireland. (Note the word "an" just there! This is not absolutely definitive, because it is impossible to be absolutely definitive on such a thing as this. But I hope it is workable.) For the botanical element of this provisional definition I have selected various plant and lichen species, and a few communities or assemblages of species, that can serve as indicators of a rainforest environment or at least elements of that environment. In a few cases I have suggested numerical thresholds, which should not be interpreted too literally; they are not the result of rigorous field testing which, if carried out, might suggest some future changes.

Ellis (2016) produced a list of epiphytic lichen rainforest indicators based on statistical analyses of their distributions in relation to climate. I have not carried out analyses of that kind, which would be a much larger task if done to include mosses, liverworts and vascular plants too, and in all habitats (Ellis's work was on epiphytic lichens only). The botanical material in this document is based on a more general assessment of the distributions and habitats of the species listed in Table 1. To this end I should say that I am more of a botanist and bryologist than a lichenologist, though I have recorded many macrolichen species during my botanical and bryological surveys of woods.

Nomenclature in this document follows that of Blockeel *et al*. (2021) for mosses and liverworts, the British Lichen Society website (see References section) for lichens and Stace (2019) for vascular plants. I have used scientific names throughout this document, but Table 1 includes their common/English names, except for some lichens that have scientific names only. I refer to "plant and lichen" species because lichens are not plants. A lichen is a multiple organism incorporating a symbiosis of fungal and algal (or in some cases bacterial) components.

I've put some photos into this document to give an indication of the general appearances of our temperate rainforest habitats and a selection of characteristic species. For information about the identification of species I can recommend these guides:

- *Mosses and Liverworts of Britain and Ireland: a field guide,* by Atherton *et al.* (2010)
- *Lichens: An Illustrated Guide to the British and Irish Species; 7th edition,* by Dobson (2018)
- *Collins Wild Flower Guide, 2nd edition,* by Streeter *et al.* (2016)

2. TEMPERATE RAINFOREST CLIMATE

Temperate rainforest is a broad category of woodland in parts of the world with a climate that is rainy and without extremes of hot or cold. This climate is reflected in the abundance and diversity of mosses, liverworts, ferns and lichens that thrive in damp, equable conditions.

Alaback (1991) described temperate rainforest areas as those with:

- at least 140 cm of precipitation annually; >10% of this during the summer months
- cool and frequently overcast summers; temperature of hottest month below 16°C
- fire infrequent and not an important evolutionary factor
- a dormant season that is caused by low temperatures and can include transient snow

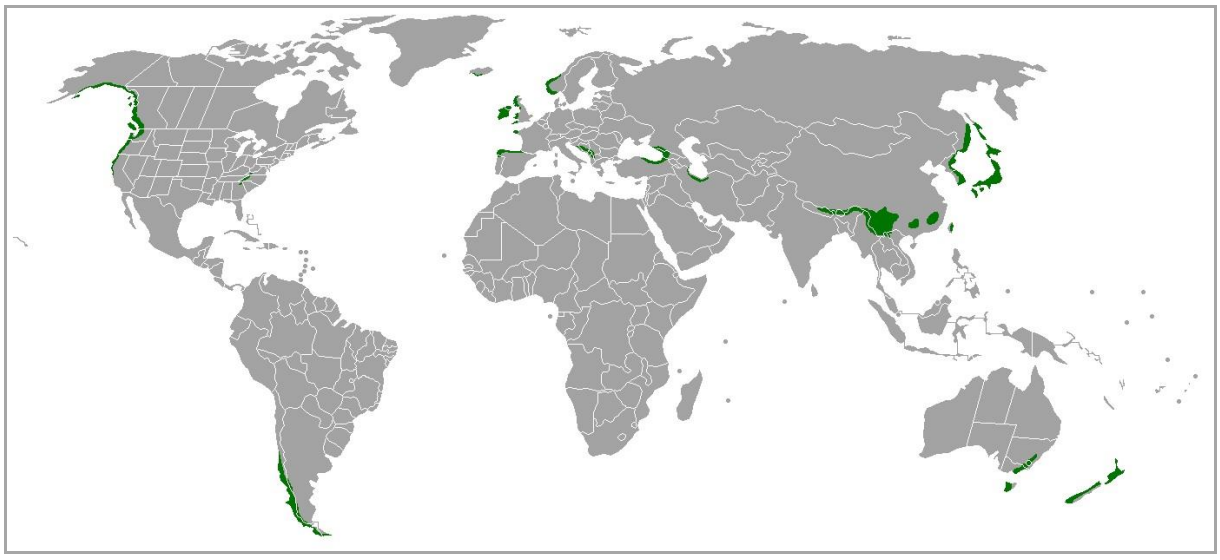
Alaback's (1991) paper discussed the distributions of temperate rainforest tree species in relation to climate, but with little mention of the other plant and lichen species that form a conspicuously significant part of the vegetation here.
In Australia, Floyd (1990) defined the habitat as *"forest in which a closed canopy of trees excludes at least 69% of the sky as well as being composed mainly of tree species which do not require fire for regeneration, but with seedlings able to regenerate under shade and in natural openings"* (text copied from https://en.wikipedia.org/wiki/Temperate_rainforest). This is understandable in Australia as a means of excluding environments where fire is a major natural ecological factor. Such environments are more or less absent from Britain and

Ireland, so Floyd's definition applied here would suggest that temperate rainforest occurs throughout our islands from the wet west to much drier eastern areas where the woods do not appear to be rainforest.

DellaSalla *et al.* (2011) described the climate and environment of temperate and boreal rainforests in different parts of the world, but with no single definition for temperate rainforest (reflecting its global variability) or for its separation from boreal (colder, more northern) rainforest. They also say that *"… a simple internet search for "temperate rainforest" yields inconsistencies in mapping locations due to gross differences in definitions and mapping techniques"*. Very true!

Wikipedia (https://en.wikipedia.org/wiki/Temperate_rainforest) states, as a general description and not a strict definition, that temperate rainforests are "*coniferous or broadleaf forests that occur in the temperate zone and receive heavy rain*" and that "*the moist conditions of temperate rain forests generally support an understorey of mosses, ferns and some shrubs and berries*", and also gives a map of the world distribution of temperate rainforest (see Map 1 below).

Map 1. A map of the world distribution of temperate rainforest



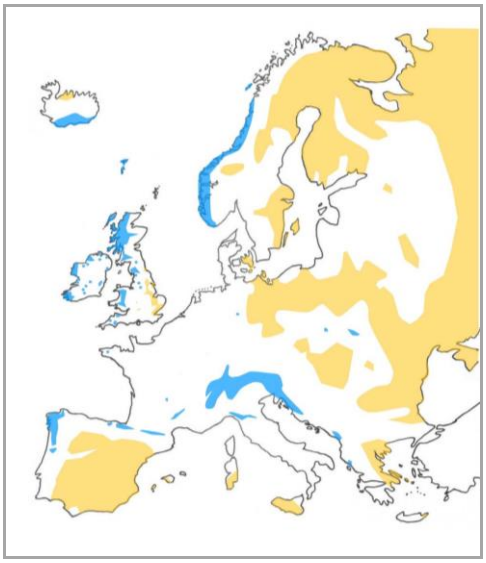
Map copied from https://en.wikipedia.org/wiki/Temperate_rainforest. Note: because of its scale, this map is very rough and omits small areas of temperate rainforest climate and habitat on mountains in South America, Africa and Indonesia, and on many small tropical islands. The map also lacks any definition of the green shaded areas.

A world map by DellaSalla *et al.* (2011) shows most of these areas as "temperate/boreal rainforest" and the Himalaya rainforest region as "tropical rainforest" (along with large areas in S and Central America, central Africa, SE Asia and Indonesia. Different maps, different distributions – hence my title for Map 1 begins with the word "A".

For consideration of temperate rainforest climate in Britain and Ireland it is helpful to look at some aspects of climate within Europe as a whole, so here are maps showing, in a simple way, the most rainy areas and patterns of geographical variation in annual mean temperature and annual temperature range. The areas with at least 140 cm of precipitation (Map 2) fit the rainfall element of Alaback's climatic definition of temperate rainforest. Very frequent precipitation (Map 3) has a more north-western distribution than that of high volume of precipitation. Annual mean temperature shows a general increase from north to south (Map 4). Annual temperature range increases from west to east (Map 5).

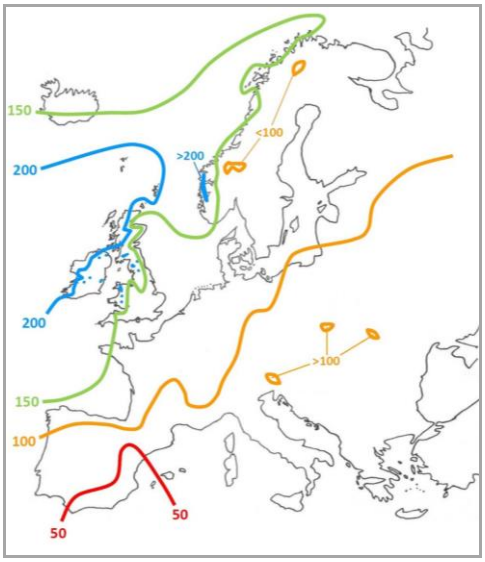
Map 2. Areas of Europe with >140 cm and <60 cm of precipitation annually

Blue = >140 cm. Orange = <60 cm.

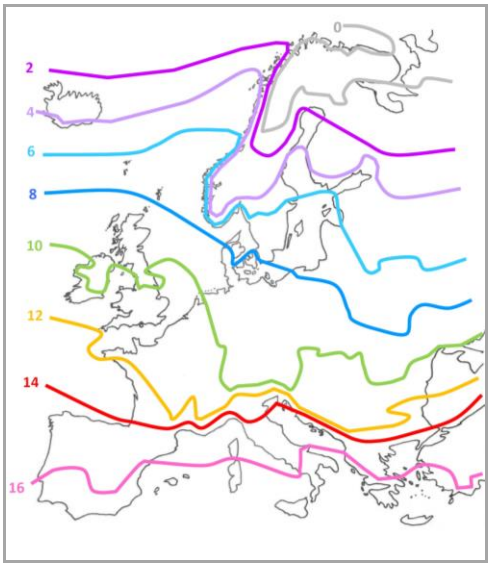


Map 3. Mean annual number of wet days in Europe

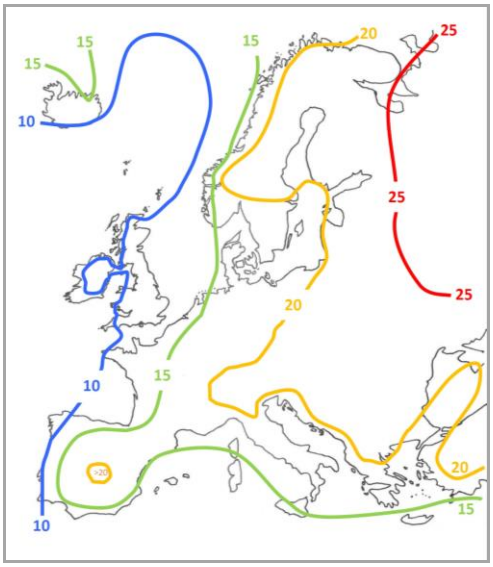
A wet day = a day with at least 1 mm of precipitation



Map 4. Mean annual temperature (ºC) in Europe. Shown in a simplified way with lines linking points along the northern limits of each temperature level



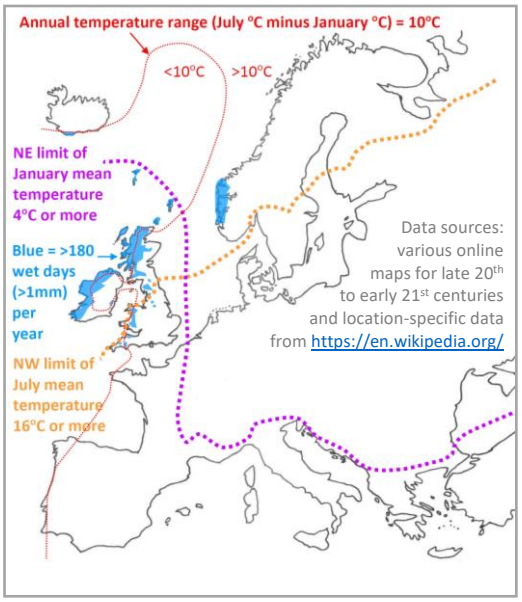
Map 5. Annual temperature range (ºC) in Europe (range of monthly mean temperatures)



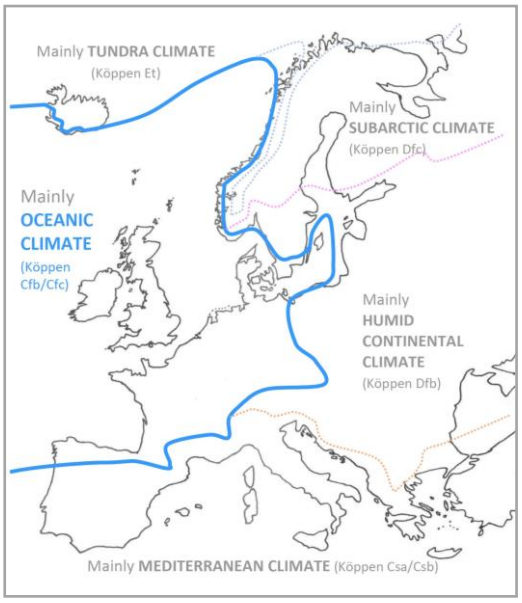
Data sources: various online maps for late 20th to early 21st centuries and location-specific data from https://en.wikipedia.org/

Map 6 shows that western and northern parts of Britain and Ireland, together with the Faroe Islands, have a combination of small annual temperature range, mild winters and relatively cool summers that is unique in Europe. The volume and frequency of rain is also high in these same areas, which can therefore be said to have the most strongly oceanic (wet and equable) climate in Europe. The global climate classification of Köppen (1936 + subsequent modifications) shows much of Europe to have an oceanic climate (Köppen types Cfb and Cfc) with rainfall at all times of year combined with the coldest month averaging above 0°C and the hottest month averaging between 10°C and 22°C. The approximate extent of the Köppen oceanic zone in Europe is shown in Map 7, which also shows the main Köppen categories found further north, east and south. The easternmost parts of the oceanic zone were formerly classed as humid continental but are now reclassified as a result of warmer average temperatures in recent decades.

Map 6. Combined climatic measures showing the extreme oceanicity of Britain and Ireland



Map 7. Distributions of Köppen broad climate types in Europe



Details of Köppen categories vary among published maps, and some people have used a coldest month threshold of -3°C (instead of 0°C) in the definition of the oceanic zone, but it is clear that the Köppen oceanic zone in Europe encompasses much variation in rainfall and temperature. Worldwide, Köppen's oceanic zone is important for temperate rainforest climates, but the two are not synonymous. In Europe most of the Köppen oceanic zone is too dry for rainforest. A rainforest climate occupies about 20% of Britain and Ireland.

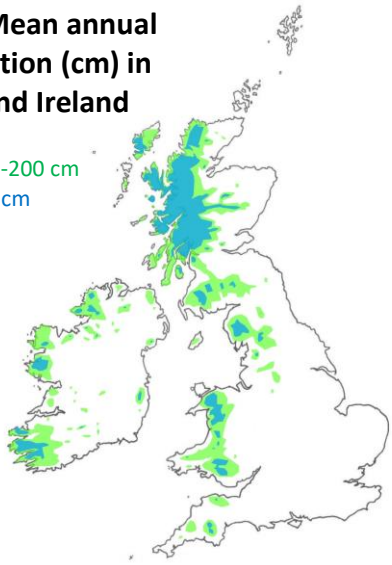
In Europe, many plant species are classed as oceanic (e.g. see Preston & Hill 1997 and Hill & Preston 1998) because they grow mainly or entirely in the oceanic zone. Rainforest and non-rainforest oceanic species and communities are important for biodiversity and conservation, especially as oceanic zones occupy just a small amount of the world's land area. Some oceanic species show a need for a very rainy climate and some do not; some evidently need very equable temperatures, some are mainly in the warmer south and others mainly in the cooler north. This whole group encompasses all sorts of requirements of different elements of the oceanic climate, hence the terms (for particular species) such as southern oceanic (lichens of this group being of notable conservation importance in southern Britain/Ireland, especially in S-SW England and NW Wales – see Sanderson *et al.* 2018), northern oceanic and hyperoceanic. There is insufficient space in this rainforest to do full justice to non-

rainforest oceanic species and assemblages, but it should be understood that they are all important for biodiversity and conservation value.

Here are two maps showing the most rainy areas of Britain and Ireland, as expressed by the volume (Map 8) and frequency (Map 9) of precipitation. Both measures show western distributions but they are not identical. Some areas such as Caithness and parts of western Ireland have a very high frequency but rather low volume of rainfall. The more strongly north-western distribution of a high frequency of wet days mirrors that seen a couple of pages back within Europe as a whole. In Map 8 the green and blue areas combined show areas whose annual rainfall of >140 cm qualifies as temperate rainforest according to Alaback's (1991) definition. Map 10 shows areas where hyperoceanic (very markedly western) moss and liverwort species make up >10% of the total bryophyte flora at the 10 km^2 scale (i.e. one way of showing areas with potential for bryophyte-rich temperate rainforest). This has a reasonably good degree of fit with the rainfall/wet days maps on this page, especially with Map 8.

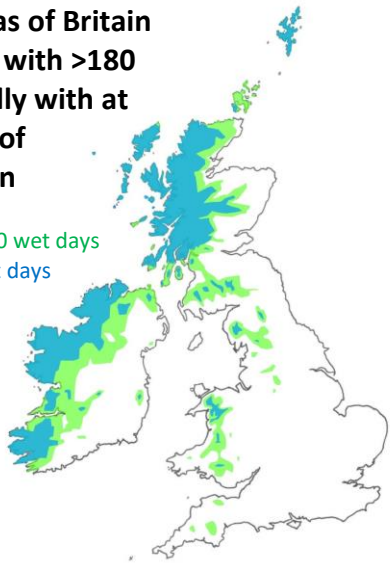
Map 8. Mean annual precipitation (cm) in Britain and Ireland

Green = 140-200 cm
Blue = >200 cm



Map 9. Areas of Britain and Ireland with >180 days annually with at least 1 mm of precipitation

Green = 180-200 wet days
Blue = >200 wet days



Data sources (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

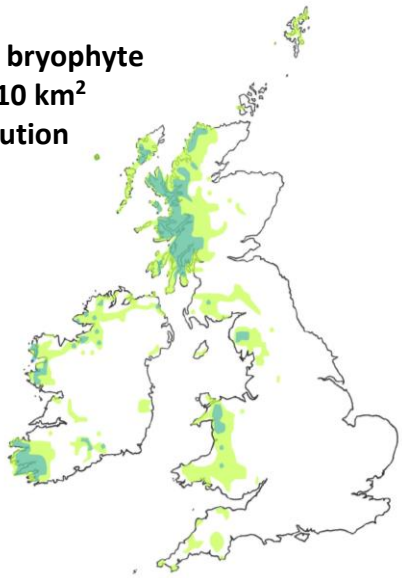
Map 10. Areas of Britain and Ireland where hyperoceanic bryophyte species make up >10% of the total bryophyte flora at the 10 km^2 scale: a potential indicator of temperate rainforest distribution

Green: hyperoceanic bryophytes make up 10-49% of all recorded bryophyte species per 10x10 km square.

Blue: hyperoceanic bryophytes make up >50% of all recorded bryophyte species per 10x10 km square.

Map drawn by Ben Averis, based on a 10km square dot map in Blockeel *et al.* (2014). Note that the bryophyte records contributing to this map are from all habitats – not just woodland.

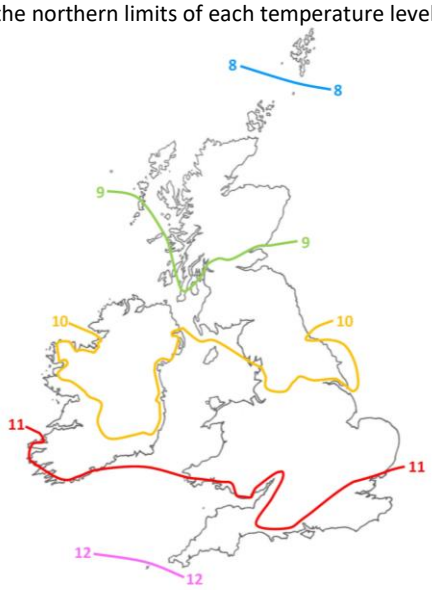
Hyperoceanic bryophyte species (*sensu* Hill & Preston 1997) are a subset of the oceanic group of species that in Europe are mainly or entirely confined to western areas with a rainy and/or equable climate.



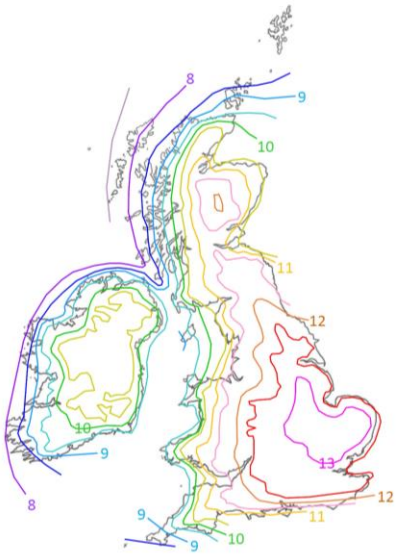
Here are four maps showing geographical variation in different measures of temperature in Britain and Ireland. Mean annual temperature increases from north to south (Map 11), annual temperature range is lowest in the west and highest in the south-east (Map 12), winters are mildest in the south-west (Map 13) and summer temperatures increase from NNW to SSE (Map 14).

Map 11. Mean annual temperature (°C) in Britain and Ireland

Shown in a simplified way with lines linking points along the northern limits of each temperature level

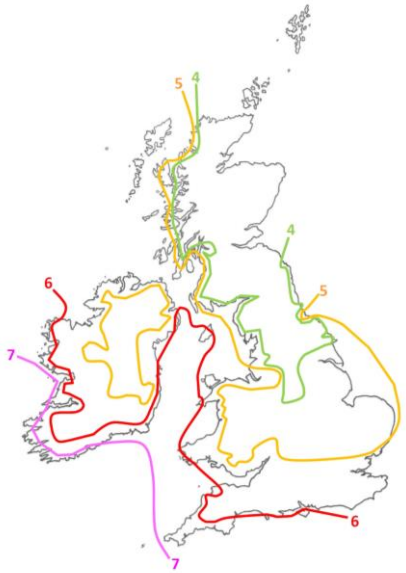


Map 12. Annual temperature range (July mean °C minus January mean °C) in Britain and Ireland



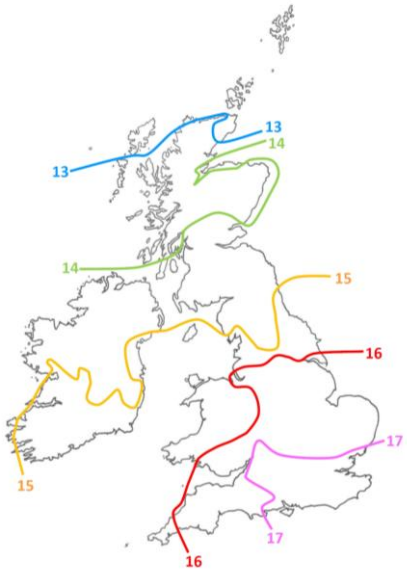
Map 13. Winter (December to February) temperature in Britain and Ireland

Shown in a simplified way with lines linking points along the northern limits of each temperature level



Map 14. Summer (June to August) temperature in Britain and Ireland

Shown in a simplified way with lines linking points along the northern limits of each temperature level



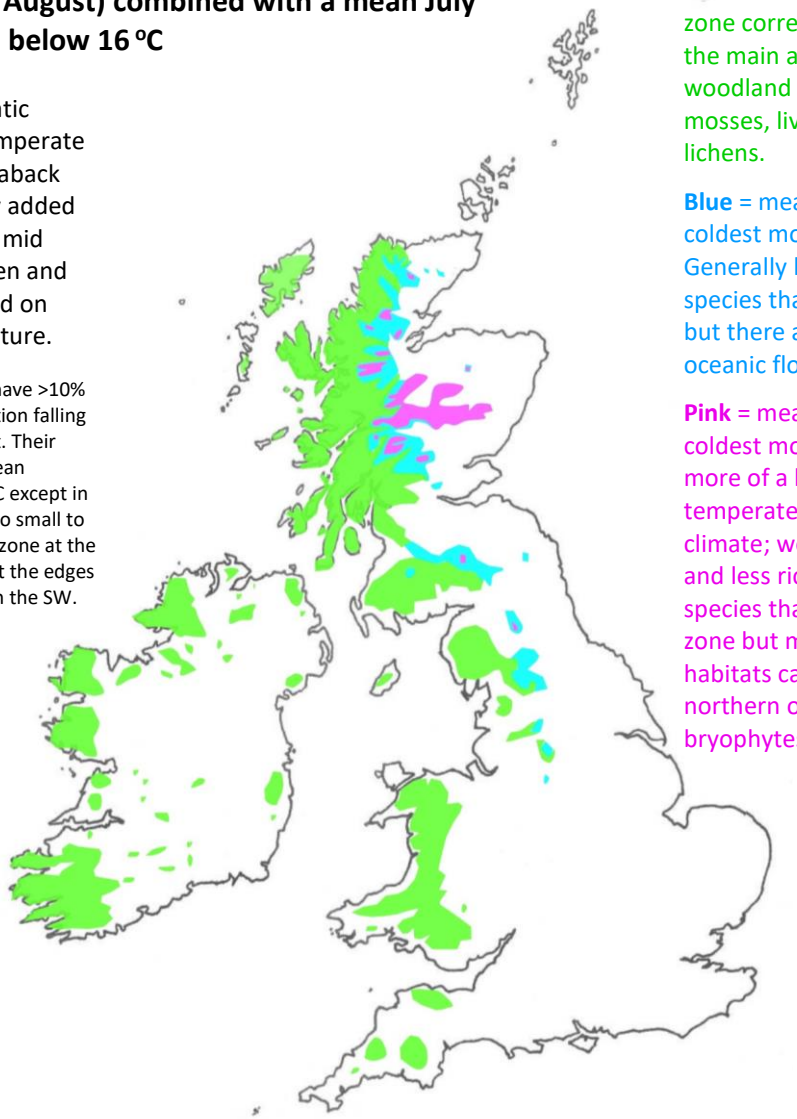
Data sources (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

Alaback's (1991) climatic definition shows a reasonable match with the hyperoceanic bryophyte map a couple of pages back, and with the distribution of woodland with a generally good abundance and diversity of western oceanic bryophytes, ferns and lichens, so here (Map 15) is a larger map showing areas with >140 cm of annual precipitation in Britain and Ireland. I have used different colours based on variation in winter temperature. In the north, the high rainfall zone extends east into areas with colder winters where there is a poorer representation of oceanic plant/lichen species. This difference in richness could be an effect of winter temperature but might be partly due to the relative scarcity of suitable woodland habitat in the colder eastern areas. Alaback's definition does not include a clearly stated cold temperature limit. A mean temperature of 2°C for the coldest month appears to give a reasonable fit with the distribution of woodland rich in oceanic species in Britain. 0°C is another option, noting that it has been used to mark the limit of winter cold in Köppen's oceanic zone globally.

Map 15. Areas of Britain and Ireland with >140 cm of precipitation annually (>10% of which falls in June/July/August) combined with a mean July temperature below 16 °C

This is the climatic definition of temperate rainforest by Alaback (1991), with my added separation into mid green, pale green and blue areas based on winter temperature.

All coloured areas have >10% of annual precipitation falling in June/July/August. Their hottest monthly mean temperature is 16°C except in very small areas (too small to affect the >140 cm zone at the scale of this map) at the edges of the green zone in the SW.



Green = monthly mean temperatures of coldest month = at least 2°C. This zone corresponds well with the main areas with woodland rich in oceanic mosses, liverworts and lichens.

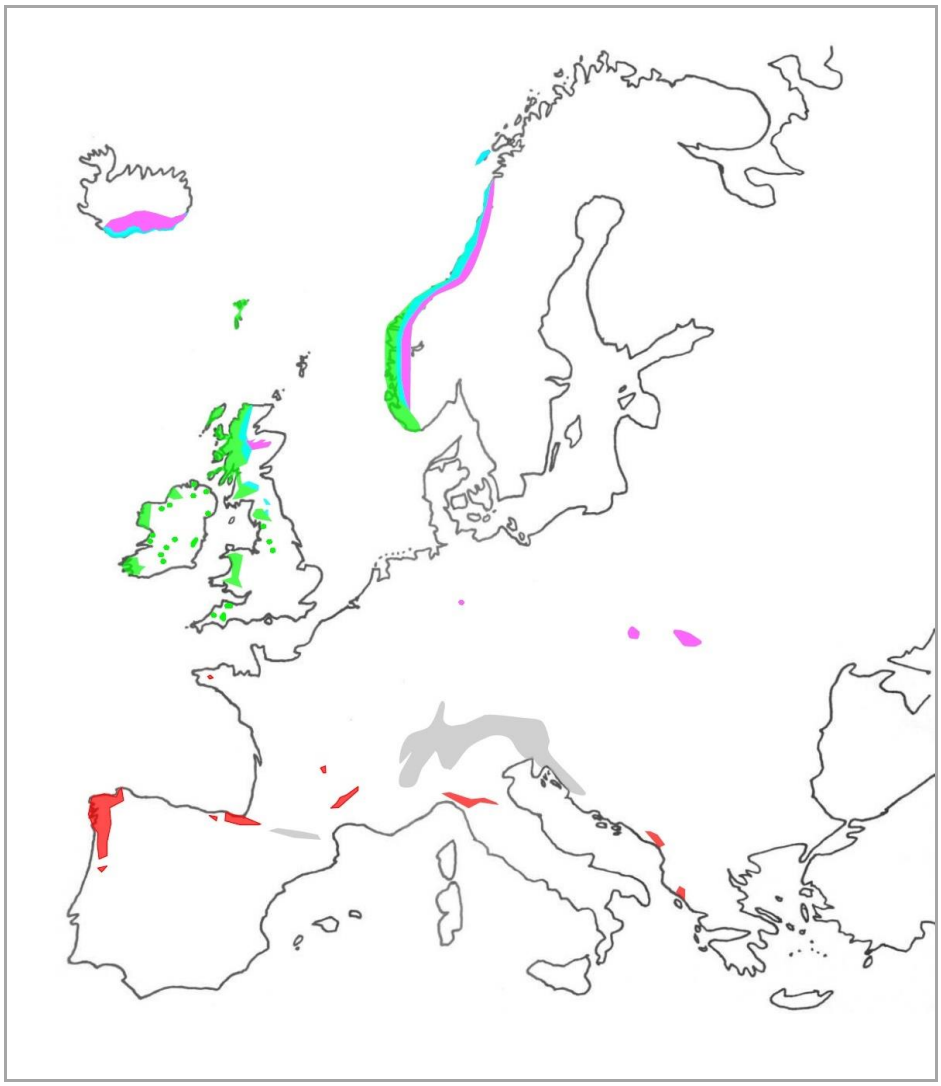
Blue = mean temperature of coldest month = 0-2°C. Generally less rich in oceanic species than the green zone, but there are some rich oceanic floras locally.

Pink = mean temperature of coldest month below 0°C, so more of a boreal than a temperate rainforest climate; woodland scarce and less rich in oceanic species than in the green zone but montane snowbed habitats can be rich in northern oceanic bryophytes.

Data sources (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

On this page we step back to the European scale again, to see how the areas with more than 140 cm of annual precipitation look when subdivided according to variation in temperature (Map 16). The most equable parts, with mild winters and cool summers, are coloured green. The blue and pink areas have colder winters. The pink areas have winters too cold for Köppen's oceanic category; this could preclude them from having a temperate rainforest climate. The red areas are at least partly with the mean temperature of the warmest month >16°C, which is too warm to fit Alaback's definition. The grey areas are more mountainous with a complex mix of pink, blue, green and red categories, variation depending mainly on altitude and only patchily fitting Alaback's definition.

Map 16. Areas of Europe with annual mean precipitation >140 cm, subdivided by temperatures of coldest and warmest months



Pink: coldest month below 0°C and warmest month below 16°C

Blue: coldest month between 0 °C and 2°C and warmest month below 16°C

Green: coldest month >2°C and warmest month below 16°C

Red: coldest month >2°C; warmest month partly <16°C and partly >16°C

Grey: coldest / warmest months: <0°C / <16°C at high altitude; >2°C / >16°C at low altitude

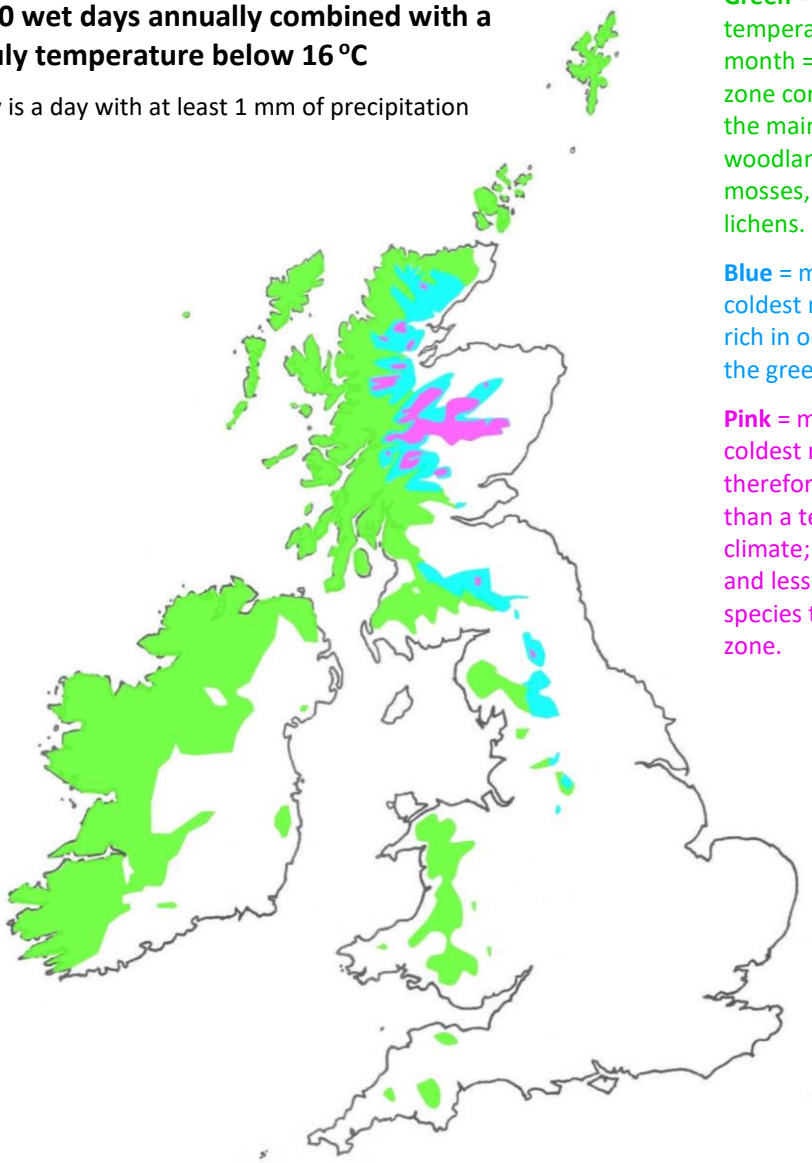
Data sources: various online maps for late 20th to early 21st centuries, and location-specific data from https://en.wikipedia.org/

See pages 18-19 for further discussion about differences in temperature among the areas of Europe with at least 140 cm of annual precipitation.

Map 17 uses the same measures as Map 15 but with the rainfall element expressed as frequency instead of volume: >180 days per year with >1 mm of precipitation. In the northernmost part of the British mainland the green and blue zones extend further east than in Map 15, into areas where woodland is scarce and less rich in oceanic/rainforest species than further west. The green (mild winter) zone is wider and more continuous in western Ireland (where it has a poorer fit with Map 10 than does Map 15, though it should be noted that native woodland is scarce through much of W Ireland), but slightly smaller in Wales and SW England. The green zone also includes Shetland, Orkney and the entire Outer Hebrides: areas with hardly any woodland, though some scrubby woodland probably existed in the past and perhaps could do so in future. Ratcliffe (1968) suggested that for oceanic bryophytes the frequency of rain could be more important than it total volume, but Map 17 (frequency) appears slightly less convincing than Map 15 (volume) as a map of a temperate rainforest climate in Britain and Ireland.

Map 17. Areas of Britain and Ireland with at least 180 wet days annually combined with a mean July temperature below 16 °C

A wet day is a day with at least 1 mm of precipitation



Green = monthly mean temperatures of coldest month = at least 2°C. This zone corresponds well with the main areas with woodland rich in oceanic mosses, liverworts and lichens.

Blue = mean temperature of coldest month = 0-2°C. Less rich in oceanic species than the green zone.

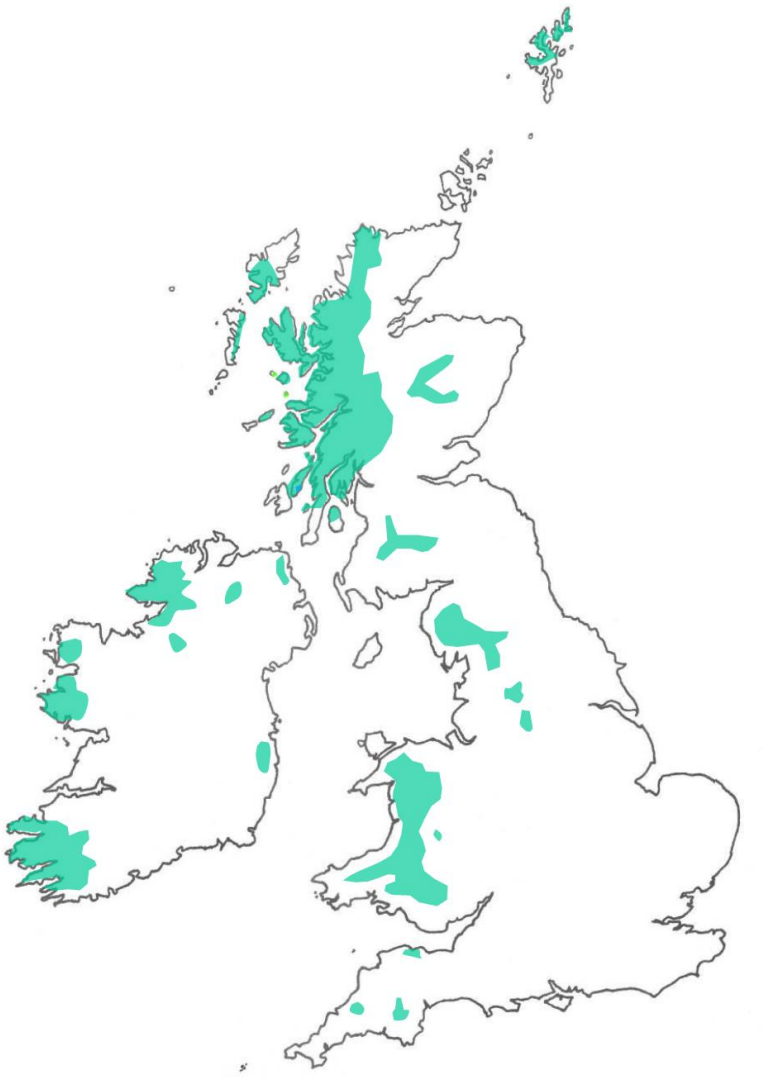
Pink = mean temperature of coldest month below 0°C and therefore more of a boreal than a temperate rainforest climate; woodland scarce and less rich in oceanic species than in the green zone.

Data sources (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

Another measure of wetness is potential water deficit. There seems to be a lack of recent maps of this measure available, at least from an online search, but Map 18, copied from a map by Page (1982), shows areas of Britain and Ireland with an average summer potential water deficit of less than 1.27 cm. These areas correspond well with the green zone in Map 15 (but also extending further east in the Scottish Highlands, as does the zone of >140 cm of annual precipitation) and the areas generally known to be rich in oceanic species (e.g. as shown in Map 10). The original copy of this map is not accompanied by information to indicate (a) exactly where the data came from, (b) the period of years to which those data refer, or (c) the definition of "summer", but I assume that the data are from a period of years in the mid to late 20th century and that "summer" probably means June, July and August collectively.

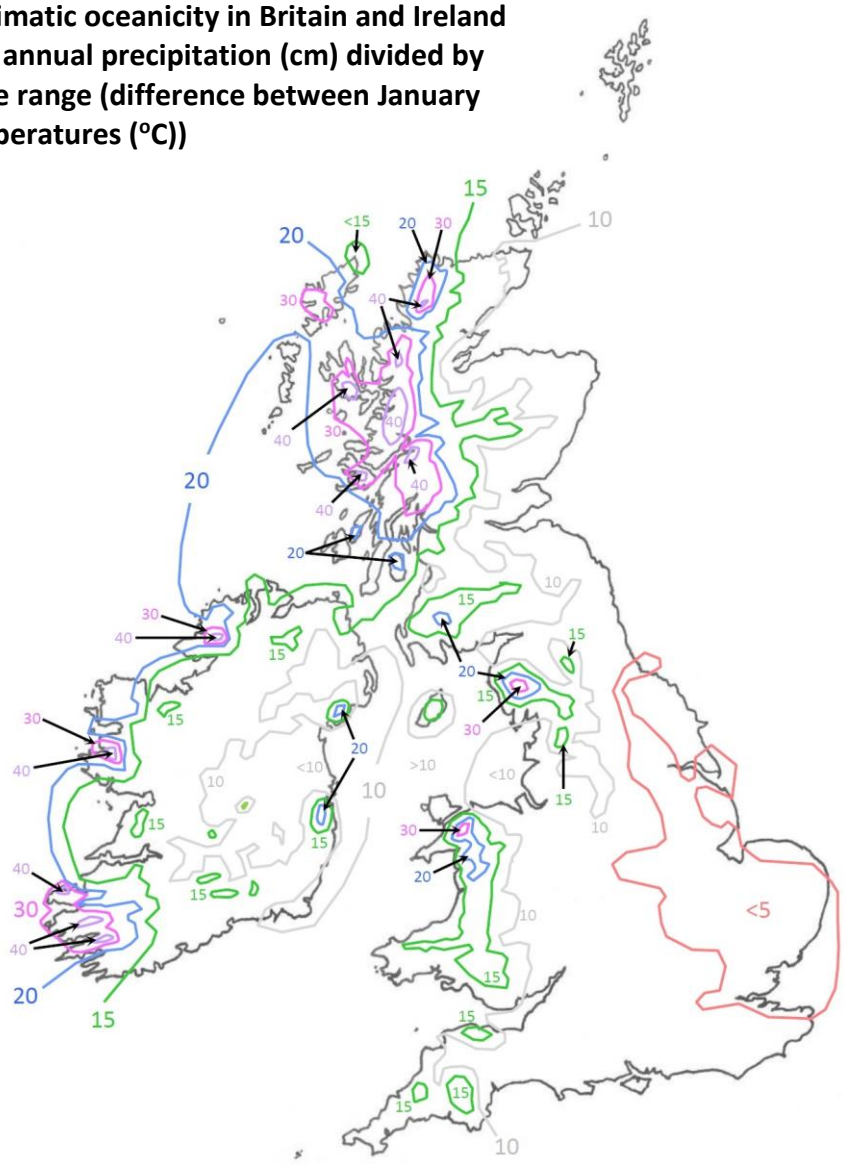
Map 18. Areas of Britain and Ireland with an average summer potential water deficit of less than 1.27 cm

Source: Page (1982)



The degree of oceanicity of a climate can be expressed by means of an index combining different measures. Temperature range in itself (see Maps 5 and 12) can be seen as an expression of oceanicity (lower range = more oceanic), as in Conrad's (1946) index of continentality which is based mainly on temperature range. However, one can combine different temperature and humidity elements in all sorts of ways to make a range of oceanicity indices. Map 19 shows a simple one calculated as annual rainfall divided by annual temperature range. An index value of 15 matches fairly closely with the boundary of the >140 cm zone in Map 15, except that it extends slightly less far east in the central and northern Highlands. Map 19 also shows the climate to be most strongly oceanic in the west Highlands, Hebrides and western Ireland, with small areas in the Lake District and NW Wales comparable though not reaching such high index values. This variation in oceanicity reflects the richness of the characteristic rainforest element of woodland vegetation, this being generally richer in areas with higher oceanicity index values. Gradients of oceanicity are steeper in and around western upland areas than in eastern and lowland areas.

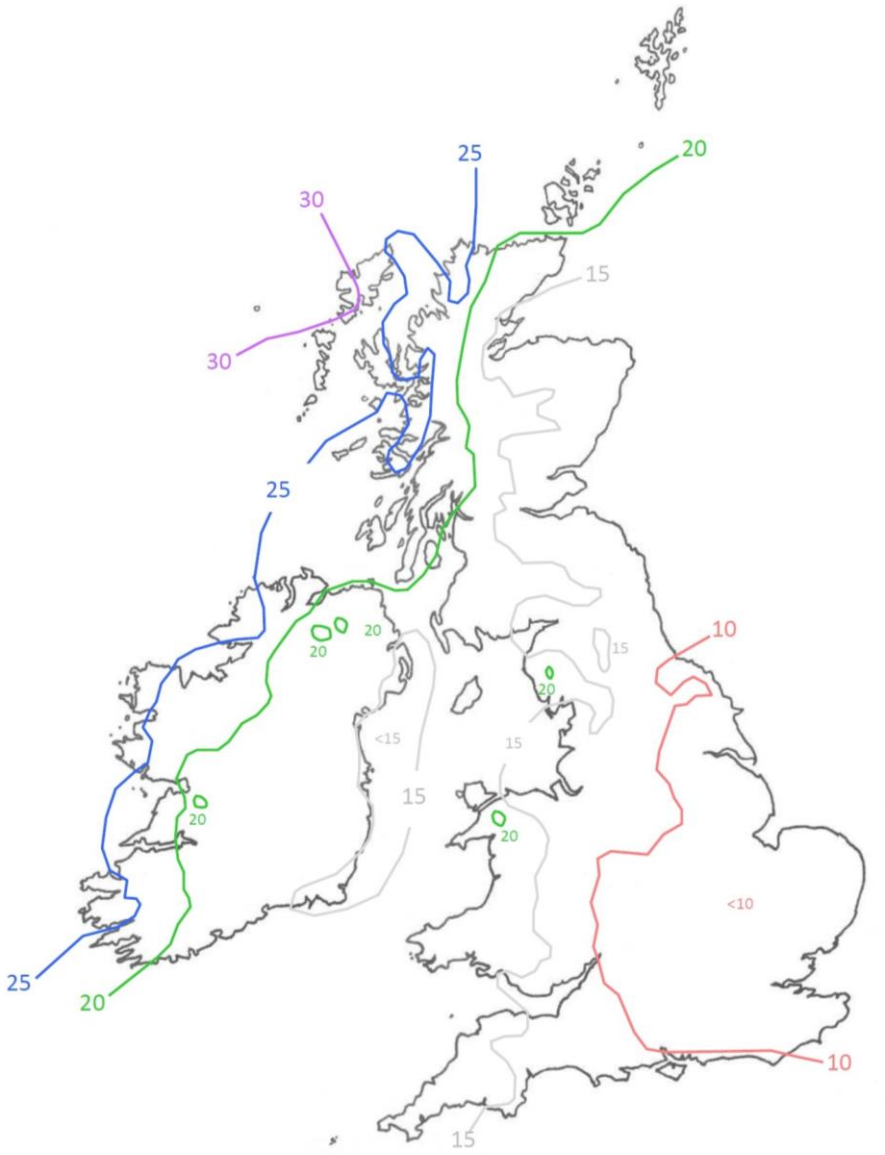
Map 19. Index of climatic oceanicity in Britain and Ireland calculated as mean annual precipitation (cm) divided by annual temperature range (difference between January and July mean temperatures (°C))



Data sources (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

Map 20 shows an index of climatic oceanicity calculated as rain frequency divided by annual temperature range. Western Scotland and western Ireland are shown to be the most oceanic areas in this map. An index value of 20 looks like a possible fit with temperate rainforest in the Highlands and western and northern Ireland (though it also includes Orkney and Shetland), but elsewhere it appears too restrictive, being confined to just two tiny areas in the Lake District and NW Wales. Overall, this map seems to give a poorer fit for rainforest distribution than Maps 15 and 19.

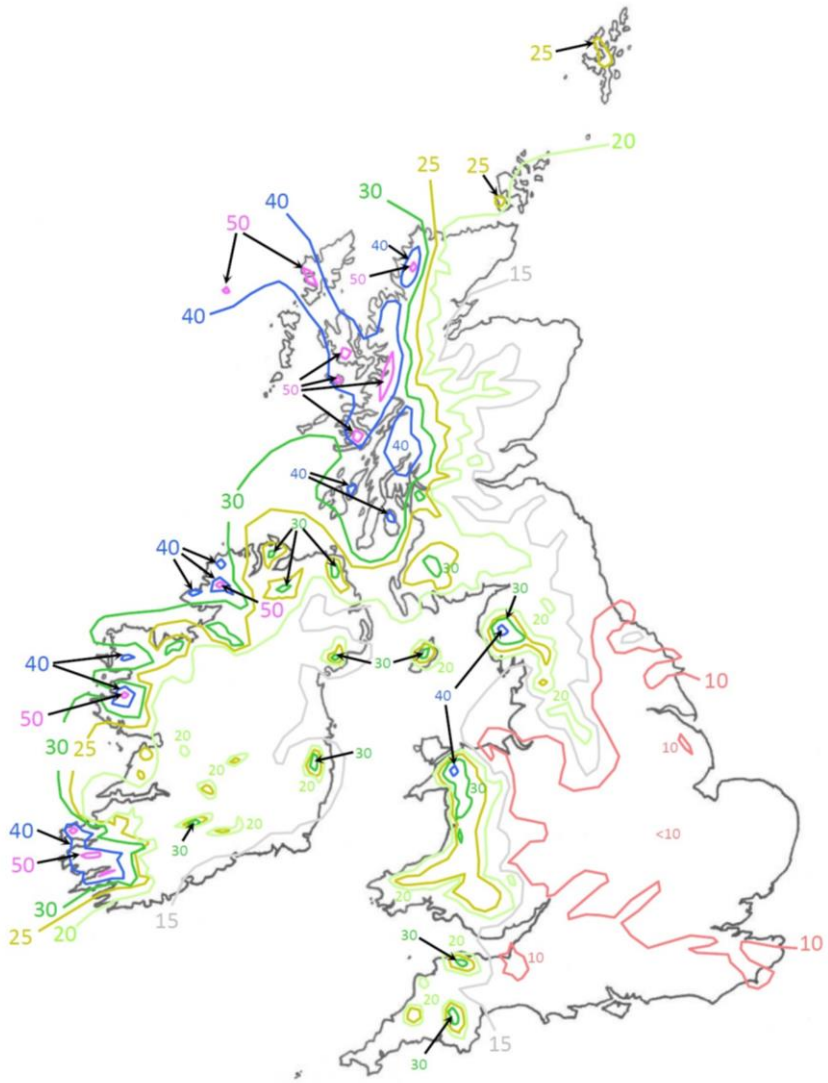
Map 20. Index of climatic oceanicity in Britain and Ireland calculated as mean annual number of wet days (= days with at least 1 mm of precipitation) divided by annual temperature range (difference between January and July mean temperatures (°C)).



Data sources (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

Map 21 shows an index of climatic oceanicity calculated as in Map 19 (rainfall/temperature range) but with temperature range expressed as the maximum deviation of January or July mean daily temperatures from 9°C (i.e. how much or how little it deviates from a 'middle' temperature of 9°C instead of just the amount of temperature range). Areas with an index value of 25 or more correspond well with the green zone in Map 15 and show a reasonable match with Map 10 too. As in Maps 19 and 20, this index shows a particularly high degree of oceanicity in the west Highlands, Hebrides and western Ireland (index value up to at least 50) and also in very small areas in the Lake District and NW Wales (index value up to at least 40).

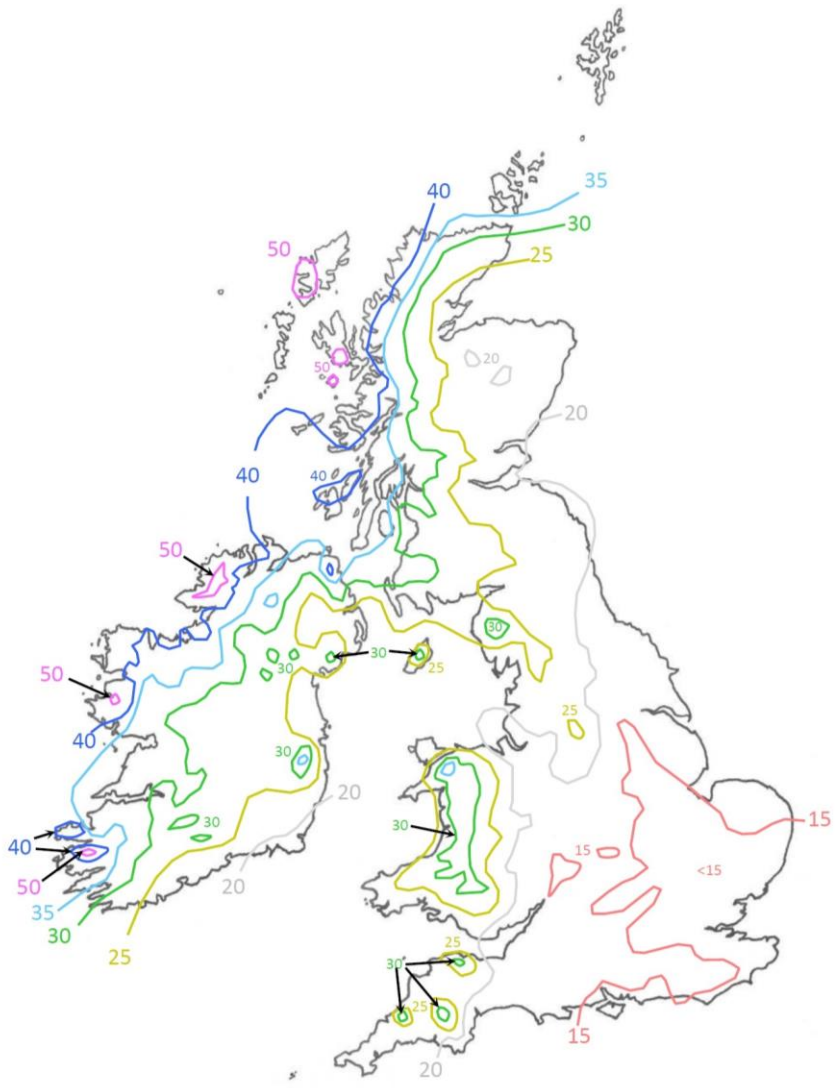
Map 21. Index of climatic oceanicity in Britain and Ireland calculated as mean annual precipitation (cm) divided by maximum deviation (°C) of January or July mean temperatures from 9°C.



Data sources (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

Map 22 shows an index of oceanicity calculated as in Map 21 on the previous page but with the wetness element expressed as frequency of rain (wet days) instead of volume. The line for an index value of 30 gives a moderately good fit with the boundary of the green zone in Map 15 and with the oceanic bryophyte distributions shown in Map 10, but it extends further east along the north coast of Scotland and in western Ireland. This map does not appear to reflect rainforest distribution quite as well as Maps 15, 19 and 21.

Map 22. Index of climatic oceanicity in Britain and Ireland calculated as mean annual number of wet days (= days with at least 1 mm of precipitation) divided by maximum deviation (°C) of January or July mean temperatures from 9°C.



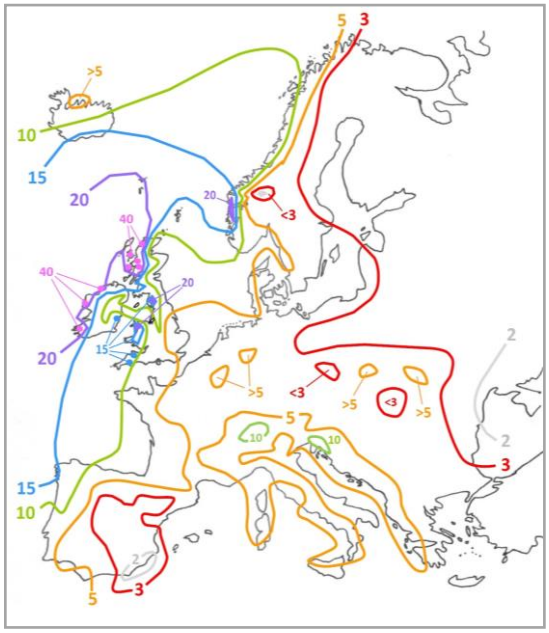
Data sources (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

Having seen indices of oceanicity mapped for Britain and Ireland over the last four pages it is relevant to see the distribution patterns of some of these in Europe as a whole, so here are European maps for indices calculated as annual rainfall divided by annual temperature range (Map 23) and the mean annual number of wet days divided by temperature range (Map 24).

Both maps show Britain and Ireland to have a particularly oceanic climate on a European scale. This is especially true of Map 24, in which the index calculated as wet days / temperature range shows western parts of Britain and Ireland, together with the Faroes, to have a much more strongly oceanic climate than any other part of Europe, even though the maps on the preceding pages show that within our islands rainfall volume has a slightly better correlation with temperate rainforest and oceanic bryophyte richness than does the number of wet days.

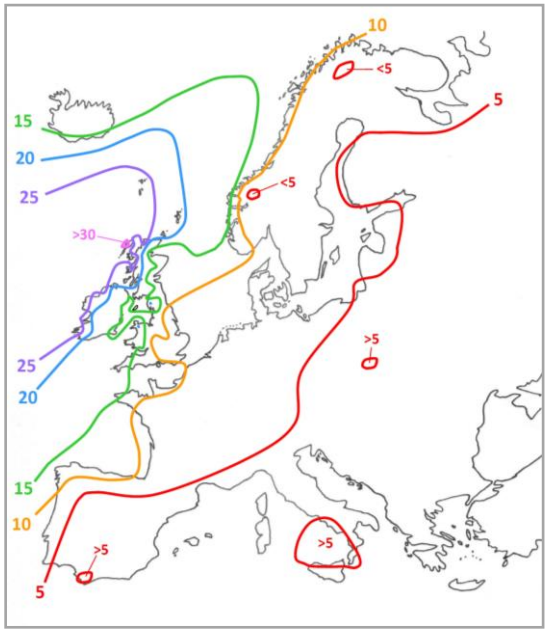
In these two maps, gradients of oceanicity are steepest in Britain, Ireland and southern Norway. There is a remarkably steep gradient of oceanicity in part of SW Norway, with variation form a very wet, oceanic climate on the west coast to a notably dry and continental climate (drier and with a much greater temperature range than anywhere in Britain) about 150 km inland; about the same distance as from Skye to the Cairngorms or from Mull to Perth.

Map 23. Index of climatic oceanicity in Europe calculated as mean annual precipitation (cm) divided by annual temperature range (difference between mean temperatures of warmest and coldest months (ºC))



Map 24. Index of climatic oceanicity in Europe calculated as mean annual number of wet days divided by annual temperature range (difference between mean temperatures of warmest and coldest months (ºC))

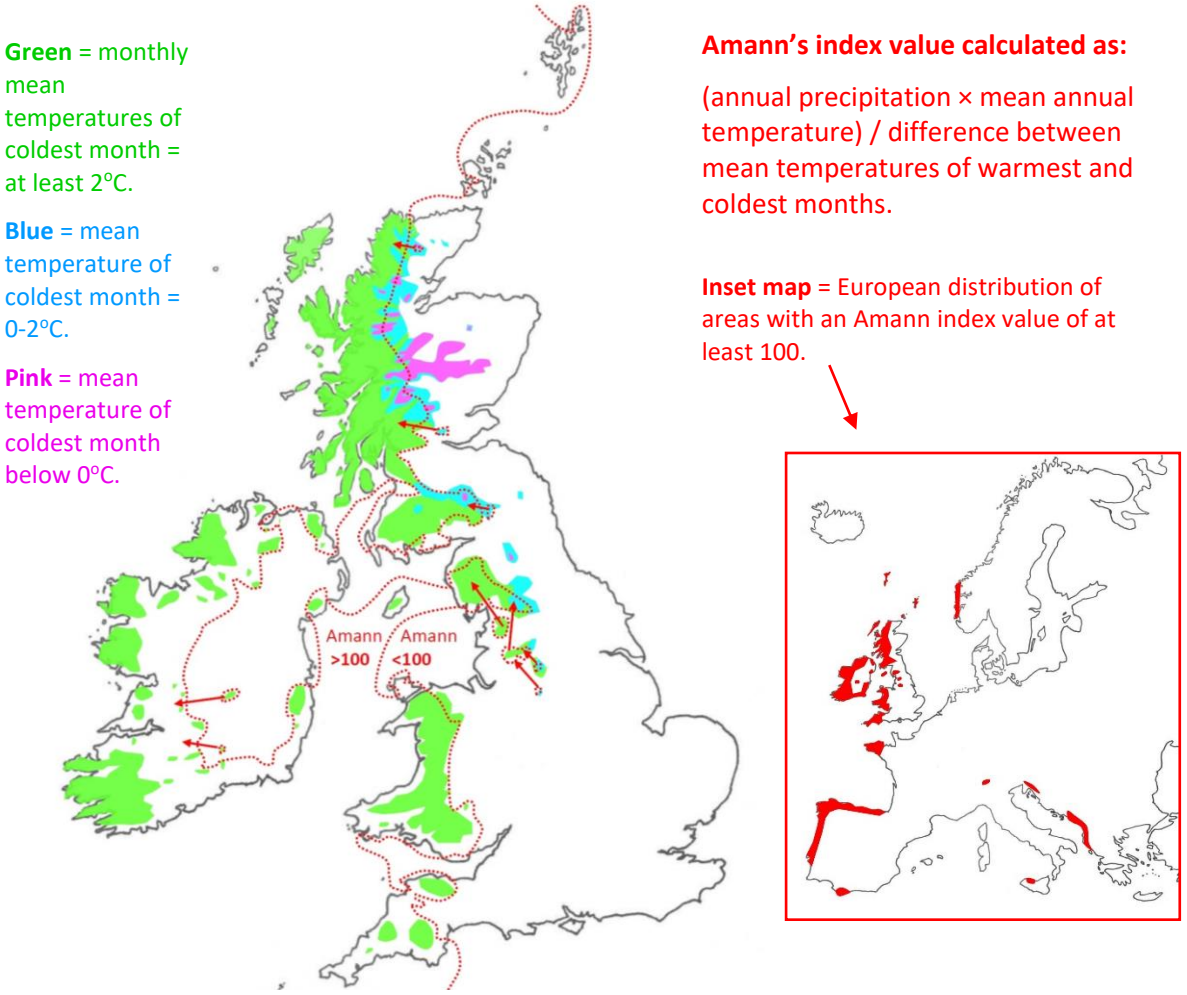
A wet day is classed here as a day with at least 1 mm of precipitation.



Data sources: various online maps for late 20th to early 21st centuries, and location-specific data from https://en.wikipedia.org/

Amann's index of hygrothermy has been used in some studies, with an index value of >100 suggested as an indication of an oceanic and/or rainforest climate. This is a triple-component index incorporating rainfall and temperature range, as in Map 21, but with an additional annual mean temperature element that pushes index values up in warmer areas. Map 25 shows an Amann index value of 100 superimposed onto a copy of Map 15. In the Scottish Highlands an Amann index value of >100 matches quite well with rainforest distribution and the green zone of Map 15, but further south this same index value extends into lowland areas with annual rainfall as low as 100 cm; these lowlands are probably too dry for rainforest in general, though it is possible that local variation in topography could produce small pockets of rainforest or semi-rainforest conditions there. Some humidity-demanding rainforest species extend east into parts of the Highlands where the Amann index is below 100. Some drier and warmer parts of SW Europe and NW Africa with annual rainfall below 80 cm (and locally even as low as about 40 cm) have Amann index values exceeding 100. With these points in mind I find, for current purposes, Amann's index to be less meaningful than climate measures that are not so weighted by overall temperature level.

Map 25. Copy of Map 15 (annual precipitation >140 cm) with superimposed red dotted line marking a value of 100 according to Amann's index of hygrothermy



Data sources for main map: (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf. Amann's index line for Britain copied from Shrubsole (2022). Amann's index line for Ireland calculated from maps in https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

Through this section I have presented maps showing wet and equable areas in different ways, based on various combinations of wetness (rainfall or rain frequency) and temperature range. All of these maps show quite similar patterns in a very broad sense, but with significant variation on at least a regional scale. Maps 15, 19 and 21 all have much in common and show a good degree of fit with the distributions of hyperoceanic bryophytes in Map 10 and of woods known more generally to contain a good representation of oceanic bryophytes, lichens or ferns.

Having looked at these climate maps and at species distributions I consider Alaback's (1991) definition to be a meaningful and easily understood indicator of a temperate rainforest climate in Britain and Ireland, especially if it can be given a lower temperature limit. Possibilities for a cold limit include a mean temperature of 0°C or 2°C for the coldest month, as in Maps 15 and 16. A cold monthly average limit of 2°C seems to have the best fit within Britain and Ireland, so in subsequent pages of this document I have referred to "the green zone in Map 15" as an indication of a temperate rainforest climate in Britain and Ireland.

If a lowest monthly mean of 2°C is proposed as a cold limit for temperate rainforest in Britain and Ireland, we may ask how this threshold would relate to woodland vegetation in Norway, where much of the rainy west has the coldest month below 2°C. Species distribution maps from Jørgensen's (1934) *Norges Levermoser* through to current online data (e.g. https://artsdatabanken.no/ and https://naturforskaren.se/ show many oceanic bryophyte and lichen species to be best represented in the green zone (coldest month >2°C). This lends support to the idea of using a lowest monthly mean temperature of 2°C for temperate rainforest in Britain and Ireland.

In the blue and pink zones of Map 15, which are wet but with colder winters (<2°C), the native woodland can be described as being of a more boreal nature, especially where native pine is abundant. A conifer canopy is much more characteristic of boreal rainforest than temperate rainforest (e.g. DellaSalla *et al.* 2011), and of course conifer canopies are widespread through boreal woodland generally, in both rainforest and non-rainforest climates. (DellaSalla *et al.* (2011) did not give a clear climatic distinction between temperate and boreal rainforest climates, and thought of latitude as playing a role in this separation, though variation in latitude does not consistently fit with variation in climate.)

A monthly mean temperature of 0°C matches that for the cold limit of Köppen's oceanic zone, so it seems reasonable to regard the pink zone (>140 cm of precipitation and coldest monthly mean below 0°C) as having a boreal rainforest climate.

The blue zone (>140 cm of precipitation and coldest month between 0°C and 2°C) could be considered to be at the milder winter end of a boreal rainforest climate or at the colder end of a temperate rainforest climate, or intermediate between boreal and temperate. If the blue and pink zones are considered not to be temperate, this does not reduce the interest of their climate and environment, especially as boreal rainforest is as scarce as temperate rainforest globally. Only a small portion of the world's boreal zone has annual precipitation exceeding 140 cm: these wetter areas are in Scotland, Norway, W Canada and S Alaska (inland from the western coastal oceanic zone), Japan (in Hokkaido and northern Honshu) and in the southern part of the Kamchatka peninsula in Russia. These areas receive significant amounts of snowfall, and deep snow can lie for a few to several months of the year. Despite the cold winters, deep snow prevents temperatures at ground vegetation level

from getting too seriously low, hence the assemblages of oceanic bryophytes in snowbeds in the Cairngorms and rich assemblages of ferns in gullies where snow lies late in mountain forests in Japan (Averis 2019) – floristic and climatological links between the oceanic and boreal zones. It is interesting that while prolonged and deep snow lie appears to be indicative of a colder and less temperate or less oceanic climate, this very same feature allows the survival of a floristic element that is intolerant of severe cold and has oceanic affinities.

Some parts of southern Europe (and very small areas in SW Britain) have more than 140 cm of annual rainfall, with >10% of this falling in June/July/August, but do not have a temperate rainforest climate in the sense of Alaback (1991) because the mean temperature of the hottest month is more than 16°C. It could be argued that because of their rainfall they still warrant recognition as having a kind of rainforest climate.

The Wikipedia map of temperate rainforest distribution (Map 1) has the whole of Japan coloured in for this habitat/climate, along with the southern half of Sakhalin, the eastern half of the Korean peninsula and the Russian coastal zone across the sea to the west of Hokkaido and Sakhalin. The Alaback definition of a temperate rainforest doesn't seem to fit well in that east Asian region because the large annual temperature range means that either the summers get too hot or the winters get too cold, and also because parts of these areas have annual precipitation well below 140 cm. There are also two areas in SE China coloured in for temperate rainforest in this same map, but summer temperatures there are too hot for the Alaback upper monthly limit. Subtropical rainforest seems quite possible in SE China and the SW half of Japan, given the warm and wet climate in those areas. Parts of NE Japan have much precipitation too, but the cold winters there mean that the climate is of a more boreal of humid continental type. There seems to be little room in Japan for a temperate rainforest climate in the Alaback sense.

Worldwide we can trace a series of rainy/rainforest climates from hot tropical (Köppen Af) at the warmest end, through to cold boreal (the wetter parts of Köppen Dfb/Dfc) via medium temperature areas in the wetter parts of Köppen climate types Cfa, Cfb and Cfc. Most of the temperate rainforest occupies the wetter parts of Köppen type Cfb.

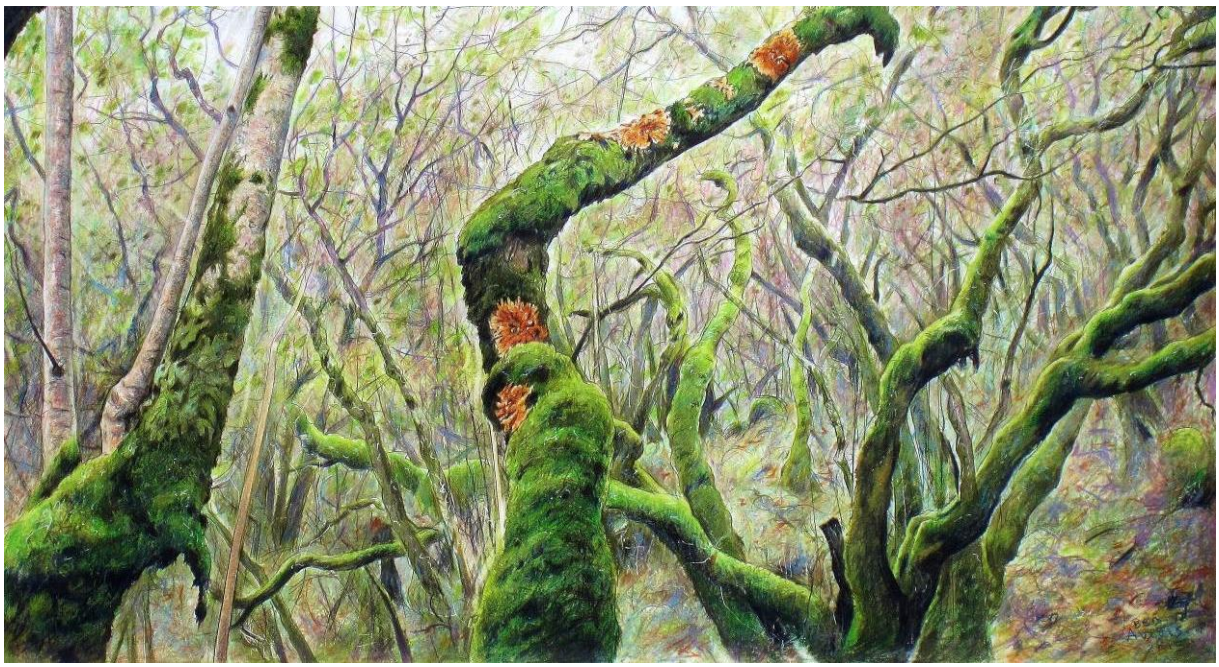
The climate information presented in this document relates to recent decades in the late 20th and early 21st centuries. These should not be considered to be stable. Geographical patterns of temperature, rainfall and climate type are likely to change in the future. Indeed, changes in the last 50 or so years have been sufficient to lead to recent reclassification of the broad Köppen climate type in some areas: for example parts of central Europe where the climate was classed as humid continental (Dfb) in the mid to late 20th century are now classed as oceanic (Cfb). Future changes cannot be predicted accurately enough for the maps in this document to be redrawn according to such changes. The purpose of the maps is to show the climate that has been a major influence on the recent and current distribution patterns of plant species and vegetation types.

3. TEMPERATE RAINFOREST VEGETATION IN BRITAIN AND IRELAND

It seems reasonable to expect that native woodland within those parts of Britain and Ireland that have a suitably wet and equable climate should be temperate rainforest. If we rely on climate alone for a definition of temperate rainforest in Britain and Ireland, we would ignore the potential role of vegetation as another element in definition and would also reduce the opportunity for identifying any sites of temperate rainforest (or sites with some elements of rainforest characteristics) that are outside the mapped zone of rainforest climate. A botanical element in our definition can help to identify such sites, and can also help to show variation in the abundance and diversity of characteristic rainforest species within rainforest environments. This is worthwhile because our temperate rainforests are very varied in their species composition and species-richness, and also show gradations (through what one might call semi-rainforest) to woodland that lacks rainforest features.

It is also possible that within the mapped areas of rainforest climate one might find examples of native woodland without characteristic rainforest species. This could be the result of local combinations of habitat features (e.g. open woodland on a wind-exposed SW-facing slope with few or no rocks), adverse land management (e.g. too much felling) or atmospheric pollution, or the site might be very small or it could be young woodland that has not yet acquired rainforest species. In places such as these it is worth looking more extensively at any other examples of native woodland in the general area.

Our temperate rainforest is very varied, encompassing a wide range of tree and shrub canopy species and ground layer plant communities. It cannot therefore be defined by the National Vegetation Classification (NVC; Rodwell 1991 *et seq*). It can include any of the NVC communities W2, W3, W4, W7, W8, W9, W10, W11, W15, W16, W17 and W18, though the commonest NVC communities in rainforest are W11 and W17. None of those NVC communities is specific to rainforest, though at NVC sub-community level W18e is a rainforest type, and W11b and W17a are mostly in rainforest environments.



Hazel-dominated temperate rainforest on the island of Seil, Argyll
Orange patches are the fungus Hypocreopsis rhododendri

Probably the most visually distinctive feature of our rainforests, reflecting the wet, equable climate, is the great abundance of mosses and liverworts on the ground, on rocks and on trees and shrubs. This photo shows some typical mossy temperate rainforest in the west Highlands of Scotland.

Mossy temperate rainforest in the west Highlands of Scotland

Of course, it's not as simple as 'mossy = rainforest'. Mosses and liverworts are generally less plentiful in drier eastern areas but can be locally abundant there. Some sheltered eastern valleys even have something of the 'classic' western temperate rainforest appearance, as seen in this photo taken in SE Scotland.

Mossy trees in woodland in a sheltered glen in the Lammermuir Hills, SE Scotland

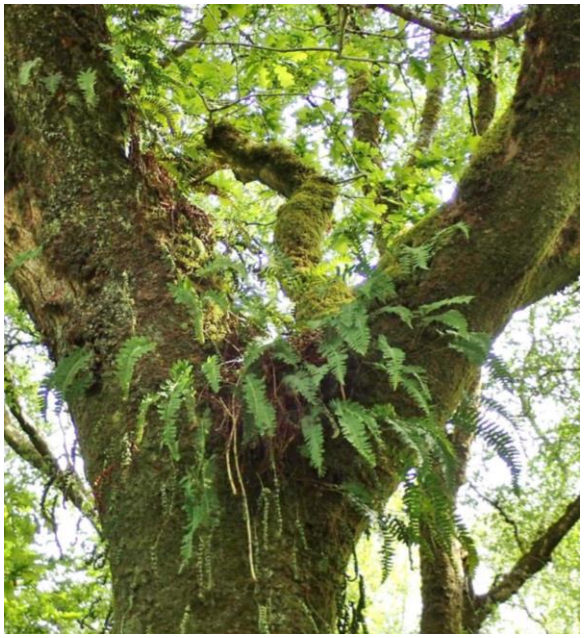
With so much moss, surely the woodland in the photo above is temperate rainforest? The abundance of moss reflects locally high shelter and humidity, but the woodland is not really rainforest because it lacks characteristic rainforest species such as those whose European and British/Irish distributions are mainly or entirely concentrated in western areas with a wet and equable climate (and are present in the upper photo). For rainforest assessment the species composition of the bryophyte cover is more important than its extent.

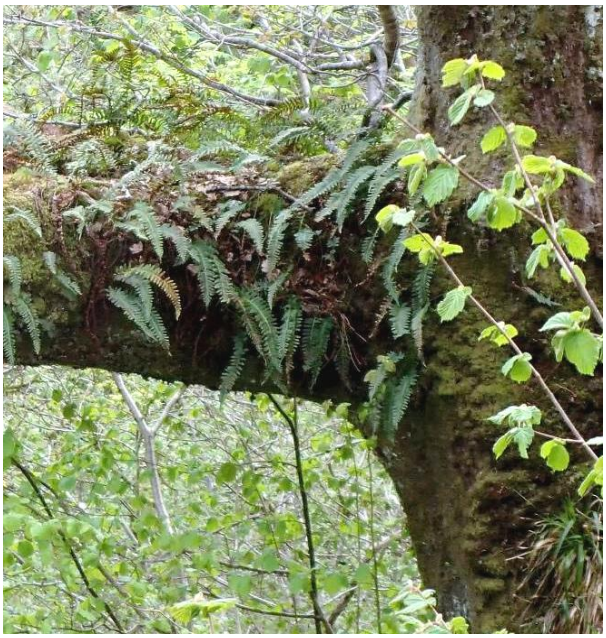
Lichens are common on trees and rocks in many British and Irish woods. They tend to show a slightly greater liking for light than do mosses and liverworts, but the habitats of all these groups overlap a lot. The photos below show abundant lichens on trees in west Highland rainforest (left) and in quite different east Highland woodland (right). Western species characteristic of the rainforest environment are present in the western photos but absent from the eastern ones. As with mosses and liverworts, the difference between rainforest and non-rainforest woodland lichen floras is more to do with species composition than with quantity.

West Highlands

East Highlands

Ferns in general like humid conditions and are common in western temperate rainforests, but are also common in many other woods further east. Polypody (*Polypodium*) is widespread on rocks and walls in Britain and Ireland. As an epiphyte on trees (lower two photos) it is common in the west in rainforests and in more open situations but also grows on trees in sheltered woods in drier eastern regions. A few fern species (not illustrated on this page) are found mainly in rainforest areas and are mentioned later in this document. For rainforest assessment purposes the species composition of the fern flora is more important than the quantity of ferns.





West Highlands

Eastern Scotland

The last few pages showed that the simple abundance of mosses, liverworts, lichens or ferns is not a reliable indicator of rainforest woodland. We need to look at which species are present, so I have put together the following provisional botanical definition. I have described a number of species-based criteria in order to provide more than one floristic approach to rainforest assessment, bearing in mind the variability of the habitat. For example, some rainforest is very rich in bryophytes but less so in lichens, while for other sites it is the reverse, or a site can be rich in both groups. The acidity of rock and bark substrates is another significant gradient of variation: acid rock and bark commonly support communities very different from those on more basic rock and bark.

The 'classic' temperate rainforest appearance is a very green one, with a deep and extensive cover of large mosses and liverworts on the ground, on rocks and on the trunks and branches of trees. There are also very different-looking assemblages of smaller bryophytes scattered on rock and bark, communities of large foliose lichens on trees and rocks, and small-scale communities of crustose lichens on smooth, relatively young stems of some tree and shrub species such as hazel.

As a group, bryophytes tend to be more demanding of shade, shelter and humidity than do lichens, though there is a great deal of overlap in this respect and for some species it is the reverse, with some mosses adapted to more dry and sunny habitats than some lichens. Many western bryophytes appear to be particularly demanding of high humidity; we can appreciate this by seeing their local abundance on rocks along streams in many western ravines. The filmy ferns (*Hymenophyllum* species) are very small ferns that look much like large, dark green liverworts and which typically grow with oceanic liverworts such as *Scapania gracilis* and *Plagiochila spinulosa*.

The moss, liverwort, lichen and fern species that are most useful for assessing rainforest status grow mainly on rocks and trees. Some can grow on dead wood. Most of them do not grow on the ground (where other mosses can be abundant) but some grow on very steep banks as well as rocks and trees.

British and Irish plant and lichen species vary greatly in their apparent needs for, or adaptations to, different aspects of climate. Some evidently need a rainy climate, others not; some grow mainly in drier regions. Some show a need for warm temperatures; others grow mainly or entirely in colder areas. Some appear to need a relatively small degree of temperature variation through the year and others can tolerate a wider temperature range.

Species with western oceanic distributions in Europe (*sensu* Preston & Hill 1997 and Hill & Preston 1998) appear to need (a) a wet climate and/or (b) a narrow temperature range, with winters relatively mild and summers not too hot. Some of them, such as the moss *Hageniella micans*, the liverworts *Leptoscyphus cuneifolius* and *Radula aquilegia*, and the lichen *Degelia cyanoloma*, show a particularly strong need for climatic wetness as well as an equable temperature regime and are very good indicators of a rainforest environment; they are found mainly in western Scotland and western Ireland but are also locally plentiful in the Lake District and NW Wales. Others such as the liverwort *Frullania teneriffae* and the lichen *Ricasolia virens* are not quite so demanding of wetness but show a strong need for an equable temperature regime and occur not only in very wet areas but also in slightly drier parts of the west. Some oceanic species such as the moss *Plenogemma phyllantha* and the liverwort *Myriocoleopsis minutissima* have distributions extending into much drier areas in

eastern Britain. There is also variation in adaptation to overall temperatures: some such as the liverworts *Lejeunea flava, Porella pinnata* and *Telaranea europaea* are thermophilous (warmth-loving) species with southern distributions, while others such as *Herbertus hutchinsiae, Plagiochila carringtonii* and *Scapania ornithopodioides* favour cooler conditions and have more northern distributions. Oceanic species also vary in their habitat preferences: some grow mainly on acidic substrates and others mainly where surfaces are more base-enriched; some are mainly in woodland and others mainly in open places; some favour south-facing slopes and others are mostly on cooler northerly aspects. It can therefore be seen that while all oceanic species have some things in common in terms of their broad climatic preferences and European distributions, they are a varied group in terms of their climate and habitat preferences and their use as rainforest indicators.

The west Highlands and Hebrides have the highest numbers of woodland sites with rich oceanic bryophyte floras: more than 400 sites with at least 10 oceanic species recorded, and more than 140 sites with at least 20 oceanic species recorded (Averis 1991 and later surveys). Sites with at least 20 oceanic species are very rare elsewhere in Britain: about 3 in the Lake District (data from surveys I have done in about 30 woods there) and probably about 5-10 in NW Wales (woods surveyed by various people). These very rich sites are within, or in a few cases just a very short distance outside, areas with an index value of at least 20 in Map 19 and at least 30 in Map 21. There are woods of similar richness in western Ireland, again in areas with similar oceanicity indices. The number of such woods in Ireland is unknown to me but is well below that for Scotland and probably higher than that for Wales. A limiting factor in Ireland is the scarcity of native woodland and the fact that so much of what little is left is badly affected by invasive rhododendron. Rhododendron has affected many woods in Britain too, and is a major problem for the conservation of our temperate rainforests. Another big problem is overgrazing, preventing natural regeneration of trees and shrubs. Anthropogenic climate change is another threat, perhaps especially to species that are adapted to generally cool conditions.

Non-oceanic species outnumber oceanic species and show even greater variation in adaptation to climate. British and Irish woodland occurrences of some non-oceanic species such as the moss *Hylocomiastrum umbratum* and the liverworts *Anastrepta orcadensis* and *Bazzania tricrenata* are mainly in temperate rainforest habitats or in places that appear to have at least some elements of a rainforest environment.

Added to all this variation are the effects of atmospheric pollution on the distributions of some species. This is well known for many lichens of the Lobarion community (see page 30), resulting in distributions that are now so strongly western and concentrated in rainforest areas as to give a false impression that these species are good indicators of rainforest.

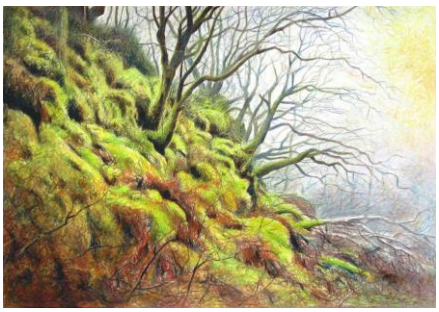
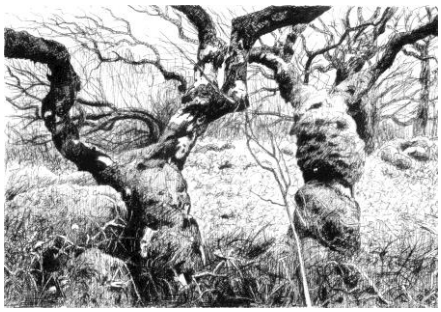
On the other hand, some species have become more widespread in recent decades. This includes some oceanic species such as the mosses *Daltonia splachnoides, Ulota calvescens* and *Plenogemma phyllantha*, and the liverworts *Colura calyptrifolia* and *Myriocoleopsis minutissima*. The most likely reasons for this appear to be the gradual reduction in sulphur dioxide pollution since the Clean Air Act of 1956 (though levels of atmospheric nitrogen deposition are high in many parts of Britain and Ireland nowadays), and gradually increasing temperatures; the relative roles of these two factors are unclear. There is the possibility that further changes in species distributions in future will affect the role of some of those species for assessment of rainforestness.

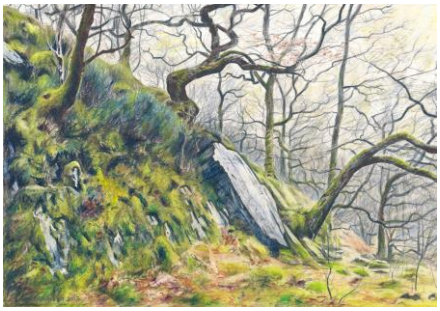
Other changes are not related to environmental change as much as to our understandings of taxonomy, which can lead to two or more species being merged together, or one species being split into two or more, potentially causing additions or reductions to the list of oceanic species.

There is also 'change' resulting from other aspects of new information. For example, the liverwort *Sphenolobopsis pearsonii* was considered to have an oceanic distribution in Europe until records from NW Russia led to 'demotion' to sub-oceanic status. ("Demotion" is perhaps inappropriate because a sub-oceanic species is worthy of great respect and admiration for having a greater range of environmental tolerance than an oceanic species!) But then, more recently, it was found that the Russian records of *S. pearsonii* were actually erroneous, so we now the species as oceanic again.

Some groups of species that can help us to assess the rainforest status of woodland are described in the following pages. Table 1 provides a list of all of these species, indicating their rainforest indicator categories (column 3) and whether or not they are oceanic in Europe (column 4). Most of these species also grow in some non-woodland habitats, but this does not reduce or prevent their relevance for assessment of rainforest status of woodland.

Some of the oceanic bryophytes found in British and Irish temperate rainforest – for example, the liverworts *Herbertus hutchinsiae, Mastigophora woodsii, Bazzania pearsonii* and *Plagiochila carringtonii* – also grow in oceanic heaths (UK NVC H20c and H21b) at higher altitudes, mainly on north-facing rocky hillsides in the west Highlands, Hebrides and western Ireland. These heaths have some floristic overlap with temperate rainforest, and some of them might once have been at least partly wooded and might have potential to become so in future. There is a continuum of floristic and ecological variation between these heaths and the rainforests, and in conservation terms the heaths are just as valuable as the rainforests. These heathland oceanic bryophyte assemblages also occur further east in places with late snow-lie (mainly NVC H20c but also some H22 and U18) in the central and eastern Scottish Highlands; these places are in the pink zone (coldest month <0^{o}C) in Map 15.



1. The strongest rainforest indicator species (categories R1 and R2 in Table 1)

These are species that in Britain and Ireland are known only, or almost only, from the green 'rainforest climate' zone in Map 15, and whose woodland occurrences are expected to indicate rainforest habitat. Future findings in woodland outside that zone would suggest the possibility of outliers of rainforest habitat (especially with several such species at a single site) and seem most likely in places where the local landscape setting and topography provide suitably rainforest-like conditions in an otherwise drier or less equable climate. These species are listed below. They are in the R1 and R2 categories in Table 1 (see suffixes 1 and 2 below): R1 = known only from the green zone in Map 15; R2 = green zone and a few non-green zone records, but sufficiently hygrophilous (humidity-demanding) that their woodland occurrences outside the green zone suggest outliers of rainforest habitat. The number of these species found at a site gives a measure of the richness of the rainforest floristic element there. These species vary from rare to locally common, and from small and inconspicuous to large and conspicuous. Many of them are oceanic in Europe as a whole.

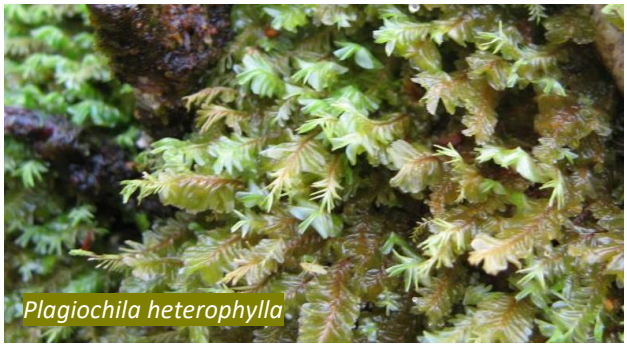
Mosses: *Campylopus setifolius*[1], *Chionoloma cylindrotheca*[1], *C. hibernicum*[1], *C. recurvifolium*[1], *Cyclodictyon laetevirens*[2], *Daltonia splachnoides*[1], *Dicranodontium subporodictyon*[1], *D. uncinatum*[2], *Fissidens polyphyllus*[1], *Hageniella micans*[1], *Hymenostylium recurvirostrum* var. *insigne*[1], *Hypnum uncinulatum*[1], *Rhabdoweisia crenulata*[2] and *Sematophyllum demissum*[1].

Liverworts: *Acrobolbus wilsonii*[1], *Bazzania pearsonii*[2], *Calypogeia suecica*[1], *Cephalozia crassifolia*[1], *Cololejeunea microscopica*[2], *Gymnomitrion crenulatum*[2], *Herbertus hutchinsiae*[1], *Lejeunea flava*[1], *L. hibernica*[1], *Leptoscyphus cuneifolius*[1], *Mastigophora woodsii*[2], *Metzgeria leptoneura*[1], *Plagiochila carringtonii*[2], *P. exigua*[1], *P. heterophylla*[1], *Pleurozia purpurea*[2], *Pseudomarsupidium decipiens*[1], *Radula aquilegia*[1], *R. carringtonii*[1], *R. holtii*[1], *R. voluta*[1], *Scapania ornithopodioides*[2], *Sphenolobopsis pearsonii*[2] and *Telaranea europaea*[2].

Lichens: *Arthothelium dictyosporum*[1], *A. lirellans*[1], *A. macounii*[1], *Bacidia caesiovirens*[2], *Bactrospora homalotropa*[1], *Crutarndina petractoides*[2], *Eopyrenula septemseptata*[1], *Fissurina alboscripta*[1], *Gomphillus calycioides*[1], *Lecanora caledonica* ined.[1], *L. cinereofusca*[1], *Lepra opthalmiza*[2], *Leptogidium dendriscum*[1], *Leptogium brebissonii*[1], *L. burgessii*[2], *L. coralloideum*[2], *L. hibernicum*[1], *L. juressianum*[1], *Melaspilea atroides*[2], *Menegazzia subsimilis*[2], *Micarea inopinula*[1], *M. longispora*[2], *Mycomicrothelia atlantica*[1], *Mycoporum sparsellum*[1], *Opegrapha brevis*[1], *Pectenia cyanoloma*[2], *Porina atlantica*[1], *Pseudocyphellaria citrina*[2], *P. intricata*[2], *P. norvegica*[1], *Pyrenula dermatodes*[1], *P. hibernica*[1], *P. laevigata*[2], *Thelotrema macrosporum*[2] and *Vezdaea stipitata*[1].

Vascular plants: *Saxifraga hirsuta*[1], *S. spathularis*[2] and *Stenogrammitis myosuroides*[1].

Fungi (all lichenicolous except those marked "Lv", which are parasitic on liverworts): *Abrothallus welwitschia*[1], *Arthonia sampaianae*[1], *Corticiruptor abeloneae*[1], *Filicupula suboperculata*[1] (Lv), *Hemigrapha atlantica*[1], *Nanostictis christiansenii*[1], *Nigromacula uniseptate*[1], *Skyttea pyrenulae*[1], *Stenocybe nitida*[1] (Lv) and *Unguiculariopsis manriquei*[1].


Plagiochila heterophylla


Pseudocyphellaria norvegica

2. Other good rainforest indicators (categories R3 and R4 in Table 1)

These are species whose woodland occurrences are mainly in the green zone in Map 15 and whose habitats suggest a need for at least moderately humid conditions, but which have a minority of records from outside the green zone and with these outlying records appearing to include some habitats that are not rainforest. They are in categories R3 and R4 in Table 1 (see suffixes 3 and 4 below): R4 species have a more significant minority of non-green zone records than do R3 species. As with the R1 and R2 groups, these species vary greatly in size and growth form, and many of them are oceanic in Europe as a whole.

Mosses: *Campylopus atrovirens*[4], *Heterocladium wulfsbergii*[4], *Hylocomiastrum umbratum*[4], *Isothecium holtii*[4], *Molendoa warburgii*[4] and *Rhynchostegium alopecuroides*[4].

Liverworts: *Anastrepta orcadensis*[4], *Anastrophyllum hellerianum*[4], *Bazzania trilobata*[4], *B. tricrenata*[4], *Colura calyptrifolia*[4], *Douinia ovata*[4], *Drepanolejeunea hamatifolia*[3], *Dumortiera hirsuta*[4], *Harpalejeunea molleri*[3], *Harpanthus scutatus*[4], *Jubula hutchinsiae*[4], *Lejeunea eckloniana*[3], *L. mandonii*[4], *L. patens*[4], *Lepidozia cupressina*[4], *L. pearsonii*[4], *Lophocolea fragrans*[4], *Plagiochila punctata*[4], *P. spinulosa*[4], *Porella pinnata*[4], *Saccogyna viticulosa*[4], *Syzygiella autumnalis*[4] and *Tritomaria exsecta*[4].

Lichens: *Arthopyrenia carneobrunneola*[3], *Bunodophoron melanocarpon*[4], *Calicium lenticulare*[4], *Cavernularia hultenii*[4], *Cetrelia olivetorum*[4], *Dictyonema coppinsii*[4], *Hypotrachyna endochlora*[3], *H. laevigata*[4], *H. sinuata*[4], *H. taylorensis*[4], *Leptogium cochleatum*[3], *Menegazzia terebrata*[4], *Micarea alabastrites*[4], *M. stipitata*[3], *Nevesia sampaiana*[3], *Parmeliella testacea*[3], *Parmotrema arnoldii*[4], *Pyrenula acutispora*[3], *P. occidentalis*[4], *Strangospora microhaema*[4] and *Usnea fragilescens*[4].

Vascular plants: *Hymenophyllum tunbrigense*[4], *H. wilsonii*[4] and *Trichomanes speciosum*[4].

Fungus: *Hypocreopsis rhododendri*[4].


Bazzania trilobata


Hymenophyllum wilsonii


Hypotrachyna laevigata

3. Species that are characteristic of rainforest but are not such good rainforest indicators (category R5 in Table 1)

These are commonest in the green zone in Map 15 but are unreliable as indicators of rainforest because their frequency in this habitat appears to be related to non-rainfall factors at least as much as to rainfall. These other factors include temperature (mild winters, relatively cool summers or small annual temperature range perhaps just as important as humidity), air pollution ('R5p' lichens were previously more widespread with occurrences in drier eastern parts of Britain from where they appear to have been largely or entirely lost since the Industrial Revolution as a result of pollution such as that from sulphur dioxide, leaving them with mainly western rainforest distribution patterns), or a need for old growth forest with a long history of canopy cover (many western woods might have been less disturbed historically, or dependency on old growth forest might be lower and colonisation ability higher where there is a rainforest climate).

Mosses: *Dicranum scottianum.*

Liverworts: *Frullania teneriffae, Plagiochila bifaria* and *Scapania gracilis.*

Lichens: *Arthonia ilicina, A. illicinella, Arthopyrenia nitescens, Gabura fascicularis, Gyalideopsis muscicola, Leptogium cyanescens, Lobaria pulmonaria, Lobarina scrobiculata, Nephroma laevigatum, N. parile, Opegrapha thelotrematis, Pannaria conoplea, P. rubiginosa, Parmeliella parvula, P. triptophylla, Pectenia atlantica, P. plumbea, Peltigera collina, Phyllopsora rosei, Ricasolia amplissima, R. virens, Sticta canariensis (*might be equally classifiable as R4)*, S. fuliginosa, S. limbata* and *S. sylvatica*.

Vascular plants: *Dryopteris aemula*

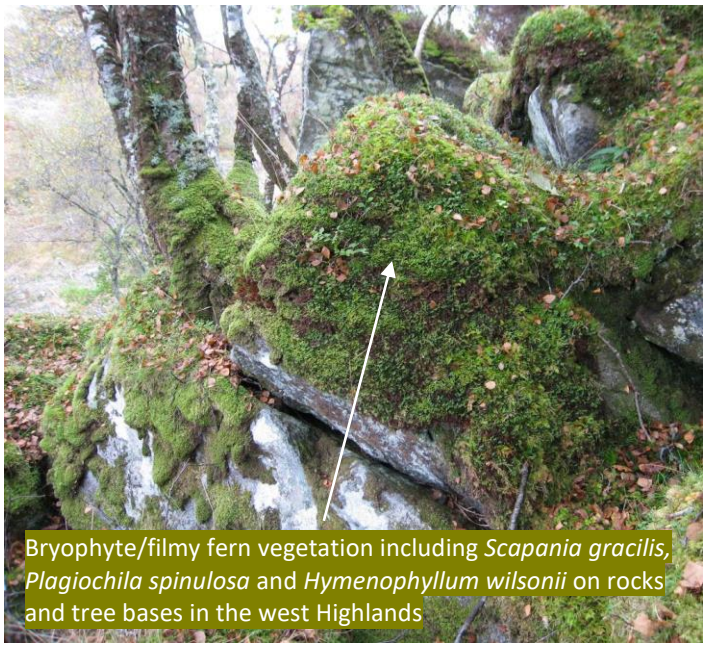

Scapania gracilis


Frullania teneriffae


Lobaria pulmonaria


Dryopteris aemula

4. Communities of small to large liverworts, filmy ferns and lichens on acid rock, bark and banks


Bryophyte/filmy fern vegetation including *Scapania gracilis, Plagiochila spinulosa* and *Hymenophyllum wilsonii* on rocks and tree bases in the west Highlands

On acid rock, bark and steep banks in temperate rainforest it is common to find small-scale communities including various combinations of the liverworts *Scapania gracilis, Bazzania trilobata, Plagiochila spinulosa* and *P. punctata*, the filmy ferns *Hymenophyllum wilsonii* and *H. tunbrigense* and the lichens *Hypotrachyna laevigata, H. taylorensis, H. sinuosa, H. endochlora, Cetrelia olivetorum, Menegazzia terebrata* and *M. subsimilis*. On rocks, banks or trees in woodland outside the green zone in Map 15 a small-scale community containing at least two of *B. trilobata, P. spinulosa, S. gracilis* and *H. wilsonii* growing in close proximity (within about 2-3 m^2) suggests that the habitat might be rainforest, or, alternatively, the presence of two or more of (A), (B), (C) and (D) below within about 0.25 hectares of woodland also suggests the possibility of rainforest habitat:

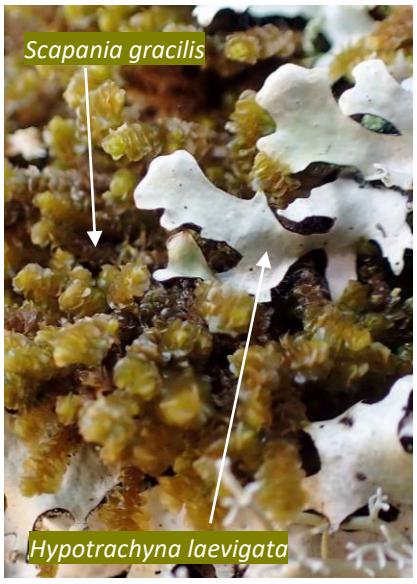
(A) At least two of the liverworts *Scapania gracilis, Plagiochila spinulosa* and *P. punctata* and the filmy ferns *Hymenophyllum wilsonii* and *H. tunbrigense*

(B) At least one of the lichens *Hypotrachyna laevigata, H. taylorensis, H. sinuosa* and *H. endochlora*

(C) The lichen *Cetrelia olivetorum*

(D) At least one of the lichens *Menegazzia terebrata* and *M. subsimilis*

Most of these species are listed on page 27 and have an "R3" or "R4" code in Table 1; *M. subsimilis* has an "R2" code in that table. Most of these species are oceanic in Europe, but *B. trilobata, M. terebrata* and *C. olivetorum* are not. The oceanicity status of *H. sinuosa* in Europe is unclear.


Scapania gracilis

Hypotrachyna laevigata


Hypotrachyna taylorensis


Plagiochila spinulosa

5. Communities of small Lejeuneacaea on rocks and trees

Small-scale communities including two or more of the oceanic liverworts listed below occur on rocks and trees in very humid situations (such as rocky ravines) in temperate rainforest in the green zone in Map 15, especially in western Scotland and western Ireland:

Cololejeunea microscopica
Colura calyptrifolia
Drepanolejeunea hamatifolia
Harpalejeunea molleri
Lejeunea patens

In native woodland outside the green zone in Map 15, findings of any of these species suggests that the site has at least some elements of a rainforest environment (rainforest or semi-rainforest – hence the inclusion of all of them under (2) above), and findings of two or more of them in close proximity to each other (within an area of about 1-2m^2) suggests that the site is an outlier of rainforest habitat.

Colura is fairly common in conifer plantations in western Britain. The shelter and shade in this habitat appears to boost humidity levels. The great majority of woodland occurrences of *Cololejeunea microscopica, Drepanolejeunea* and *Harpalejeunea* are in rainforest, hence they are in category R3 in Table 1; *L. patens* is in the R4 category). *Harpalejeunea* has been found on oaks in the New Forest (Neil Sanderson, pers. comm): a surprising and 'unrainforesty' area for it.

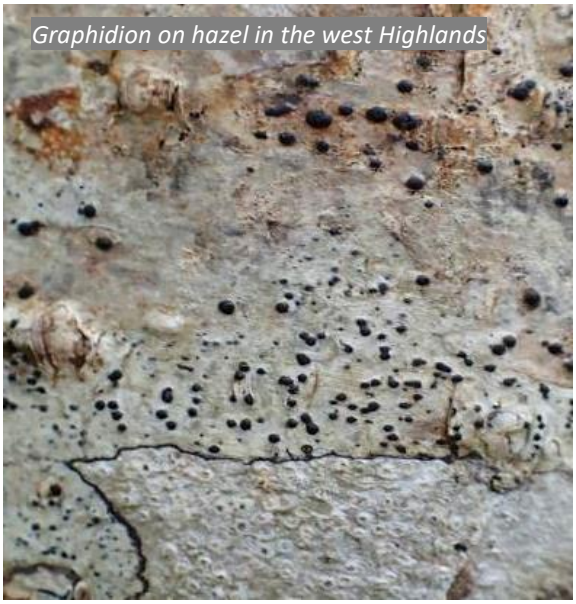
6. The Lobarion lichen community

The Lobarion is a distinctive community of relatively large lichens of genera such as *Lobaria, Lobarina, Ricasolia, Sticta, Pseudocyphellaria, Nephroma, Pectenia, Leptogium, Pannaria* and *Parmeliella*. It is found mainly on trees, especially ash, hazel, rowan and willows, but also oak, sycamore, aspen and other species, and least commonly on acid-barked species such as birch, alder and conifers. It also occurs on rocks. It is common in woodland in parts of western Scotland and western Ireland. Elsewhere in these islands it is scarce. The community and its constituent species are often seen as rainforest indicators, and indeed *Leptogium brebissonii, L. burgessii, L. coralloideum, L. dendriscum, L. hibernicum, L. juressianum, Pectenia cyanoloma, Pseudocyphellaria norvegica, P. citrina* and *P. intricata* are more or less restricted to the green zone in Map 15 and can be regarded as good rainforest indicators (= R1 and R2 categories in Table 1; most are also oceanic in Europe), but with many species in the R5 category the Lobarion in general is not a reliable indicator of rainforest habitat.

The community is vulnerable to atmospheric pollution, and *Lobaria pulmonaria, Lobarina scrobiculata, Nephroma laevigatum, N. parile, Pannaria conoplea, P. rubiginosa, Parmeliella triptophylla, Pectenia plumbea, Peltigera collina, Ricasolia amplissima, R. virens, Sticta fuliginosa, S. limbata* and *S. sylvatica* once grew in drier eastern areas from which they have largely gone since the Industrial Revolution. The current distribution of the Lobarion is now mainly western, overlapping considerably with that of a rainforest climate but also with occurrences in some drier areas such as the New Forest, coastal areas of Wales and SW England, and parts of NE Scotland. A long history of a relative lack of disturbance to woodland is another factor important for many Lobarion species.

Species-rich Lobarion with about five or more of *Gabura fascicularis, Lobaria pulmonaria, Lobarina scrobiculata, Nephroma laevigatum, N. parile, Nevesia sampaiana, Pannaria conoplea, P. rubiginosa, Parmeliella parvula, P. testacea, P. triptophylla, Pectenia atlantica, P. plumbea, Peltigera collina, Ricasolia amplissima, R. virens, Sticta canariensis, S. fuliginosa, S. limbata* and *S. sylvatica* within an area no larger than 0.25 hectares of woodland is mainly in the green zone in Map 15. Outliers of this richness are scarce but do not necessarily indicate rainforest conditions. For example, species-rich Lobarion occurs in the New Forest, where it is now very rare but was probably frequent in the 19th century before being affected by acidifying pollution, and by the Dornoch Firth near the east coast of northern Scotland (Neil Sanderson, pers. comm.).

7. The Graphidion lichen community


Graphidion on hazel in the west Highlands

The Graphidion is a group of small-scale communities of tiny crustose lichens on smooth bark. Many of these species look like tiny dots or squiggles. Young hazel stems are a particularly important Graphidion habitat, especially in western Scotland. Some forms of Graphidion are an important feature of British and Irish temperate rainforest; there might be a future description of a rainforest sub-type, with a name such as *Pyrenuletum laevigatae,* within the broader Graphidion (Neil Sanderson, pers. comm.). Many of the constituent species of rainforest Graphidion are included under (1) above (= R1 and R2 categories in Table 1), because their British and Irish records are all, or almost all, within the green zone in Map 15: *Arthothelium dictyosporum, A. lirellans, A. macounii, Bactrospora homalotropa, Crutarndina petractoides, Eopyrenula septemseptata, Fissurina (Graphis) alboscripta, Gomphillus calycioides, Melaspilea atroides, Mycomicrothelia atlantica, Opegrapha brevis, Pyrenula dermatodes, P. hibernica* and *P. laevigata*. Occurrences of these species in woodland outside the green zone suggest the possibility of a rainforest outlier.

Some other Graphidion lichen species are strongly western and placed in the R3, R4 and R5 categories in Table 1: *Pyrenula acutispora* (R3), *P. occidentalis* (R4), *Arthopyrenia carneobrunneola* (R3), *Arthonia ilicina, A. illicinella* and *Arthopyrenia nitescens* (all R5). Occurrences of three* or more of these species within an area of no more than 0.25* hectares of woodland outside the green zone in Map 15 might indicate an outlier of rainforest or semi-rainforest habitat (* = provisional figures that might warrant revision based on future field testing).

As with the Lobarion (see previous page) many Graphidion species are indicators of a long history of a relative lack of disturbance to woodland. The western forms of Graphidion have a higher proportion of good rainforest indicator species than does the Lobarion.


Hazel woodland in the west Highlands – a habitat type of outstanding importance for Graphidion lichens


Fissurina alboscripta – a rare hazelwood speciality known only from western Scotland

From consideration of the distributions of the species in this section, and geographical variation in climate, habitats and known woodland bryophyte/lichen floras, Map 26 shows approximate eastern limits of (a) temperate rainforest with very rich oceanic bryophyte/lichen floras and (b) possible outliers of rainforest or semi-rainforest, drawn onto a copy of Map 15. The Weald, in SE England, is interesting in having some elements of a rainforest flora in sheltered wooded valleys. The climate there is comparatively dry, but it is thought that gradual release of water from the porous sandstone rock helps to maintain conditions moist enough for a number of western and oceanic species including the moss *Dicranum scottianum*, the liverworts *Bazzania trilobata, Scapania gracilis* and *Saccogyna viticulosa*, and the filmy fern *Hymenophyllum tunbrigense*.

Map 26. Estimated approximate eastern limits of rainforest or semi-rainforest habitat drawn onto a copy of Map 15 (areas of Britain and Ireland with >140 cm of rainfall annually (>10% of this in June/July/August) + mean July temperature below 16 °C)

Green/blue/pink zones correspond to Alaback's (1991) climatic definition of temperate rainforest.

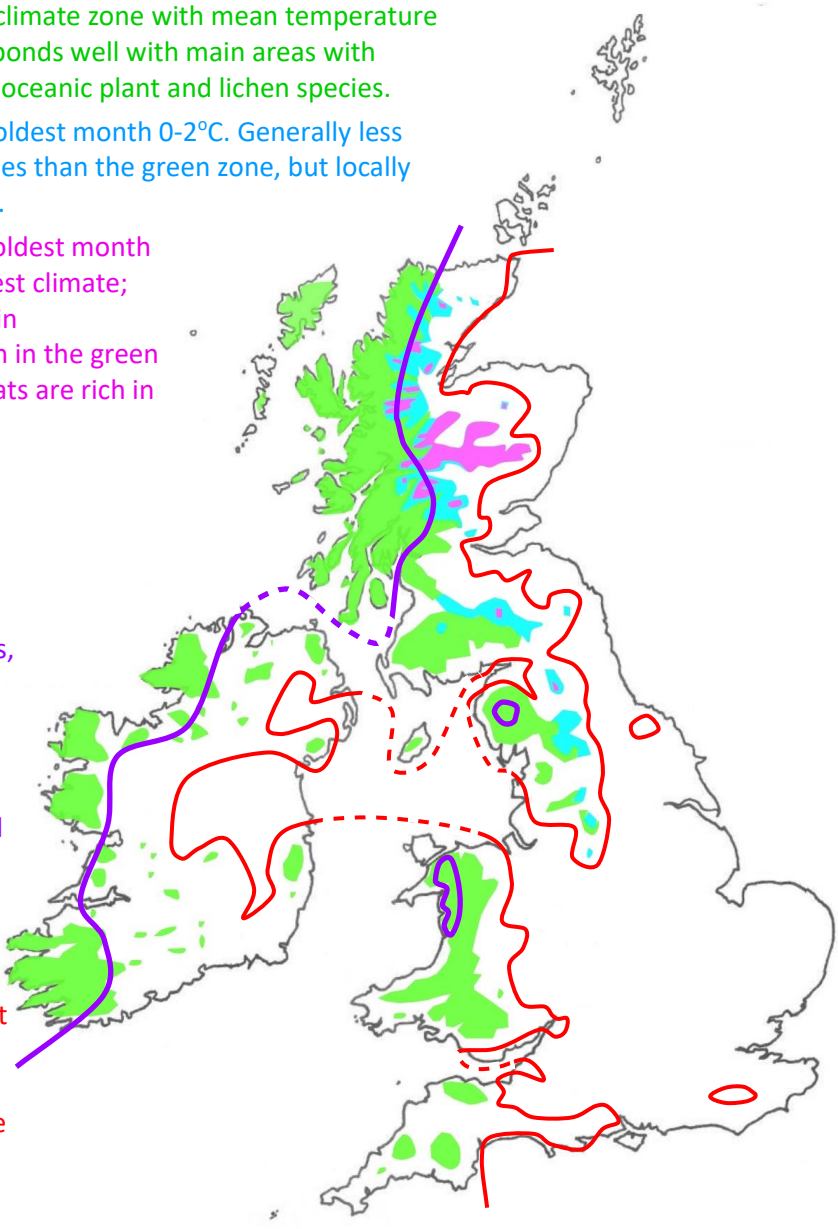
Green = temperate rainforest climate zone with mean temperature of coldest month >2°C. Corresponds well with main areas with woodland rich in hygrophilous oceanic plant and lichen species.

Blue = mean temperature of coldest month 0-2°C. Generally less rich in oceanic/rainforest species than the green zone, but locally with rich floras of such species.

Pink = mean temperature of coldest month <0°C; more of a boreal rainforest climate; woodland scarce and less rich in oceanic/rainforest species than in the green zone but some montane habitats are rich in northern oceanic bryophytes.

Purple line = approximate eastern limit of temperate rainforest that is very rich in rainforest and pollution-sensitive bryophytes and lichens, and, at higher altitudes, oceanic liverwort-rich heaths whose flora includes a rainforest element. Purple line has a reasonable fit with index value 20 in Map 19. Note small purple-outlined areas in the Lake District and NW Wales.

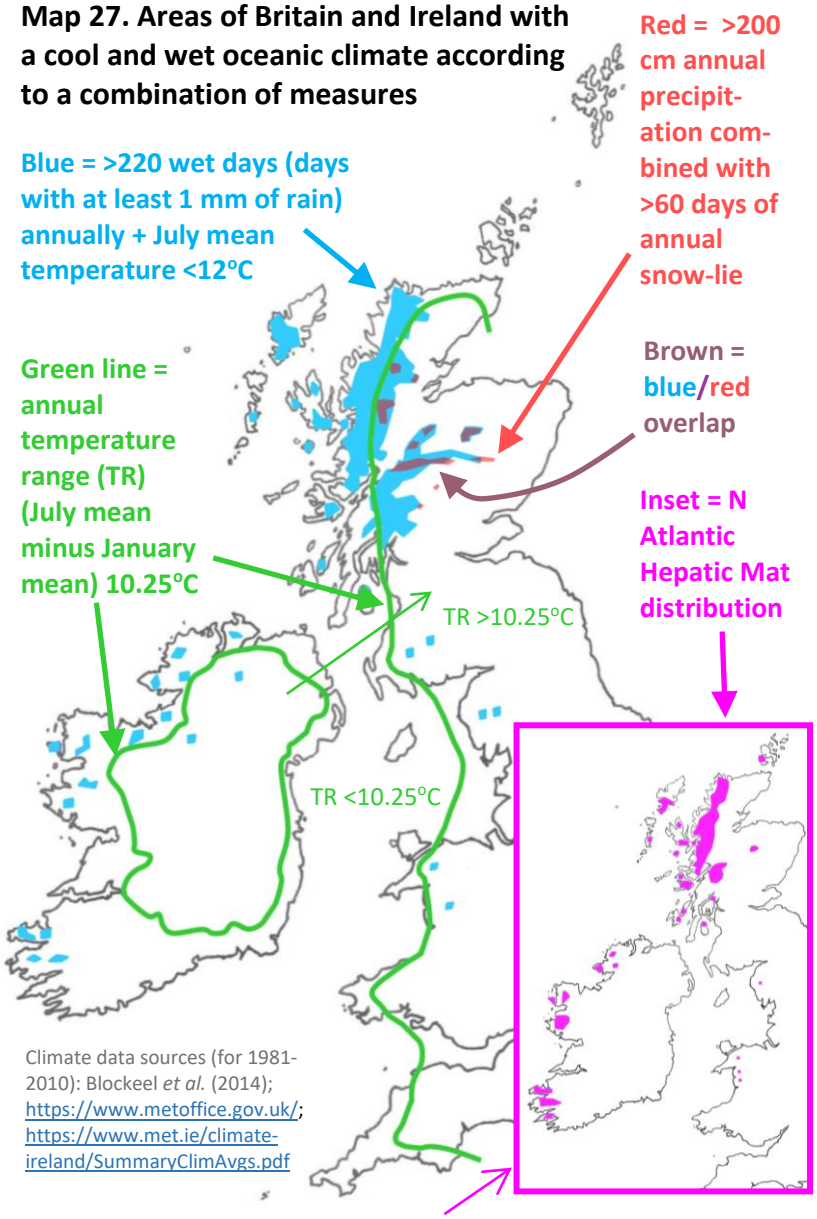
Red line = very approximate estimate of eastern limit of woodland with some rainforest characteristics ('semi-rainforest'); some actual rainforest outliers also possible (most likely to be not far from the green zone boundary). Note small red-outlined areas in NE and SE England.



Climate data sources (for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

This page and the next present two maps to follow on from Map 26. These show areas with a cool oceanic climate (Map 27) and a relatively warm oceanic climate (Map 28), to identify areas with a climate well suited to certain subgroups of oceanic plant and lichen species that are not necessarily rainforest species, though their distributions can overlap to some degree with rainforest areas and even with rainforest habitat.

Map 27. Areas of Britain and Ireland with a cool and wet oceanic climate according to a combination of measures

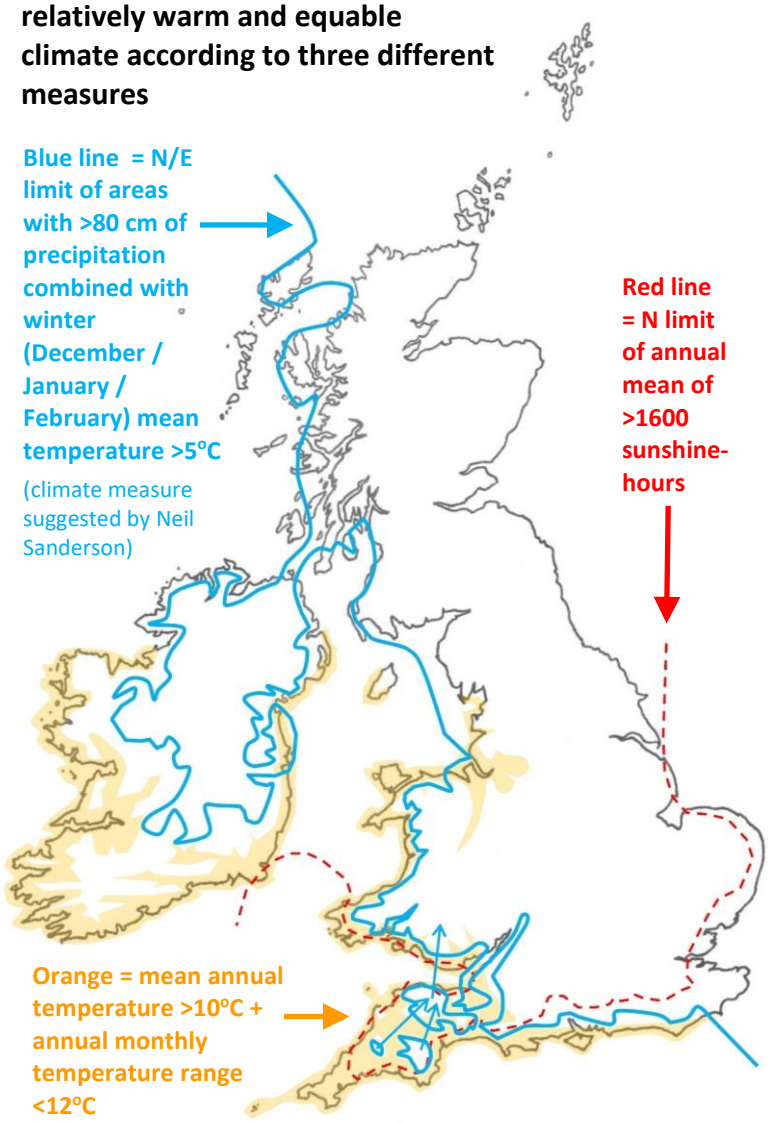


Data sources for N Atl. Hepatic Mat distribution map: Ratcliffe (1968), field observation by Ben & Alison Averis, and, for S. Uist, https://www.britishbryologicalsociety.org.uk/event/summer-meeting-1992-the-uists-benbecula/

The coloured areas in Map 27 match quite well with those that are richest in northern oceanic bryophytes, especially the liverwort community mentioned on page 26 (Northern Atlantic Hepatic Mat described by Ratcliffe, 1968) that is found mainly in N-facing hillside heaths (UK NVC H20c and H21b), but also lower down in some N-facing woods (W17), and higher up in some snowbeds (H20c/U18): see inset distribution map. These northern oceanic species are sufficiently hygrophilous as to indicate rainforest where they occur in woodland, though most of their populations are in open submontane to montane habitats. The richest of these liverwort communities (the Northern Atlantic Hepatic Mat described by Ratcliffe, 1968) are in N-facing heaths in the parts of the blue area with a low annual temperature range (i.e. W of the green line), especially the north-westernmost part of the Highlands together with the Hebrides. Occurrences in snowbeds are further east, in the red and purple zones in the map. The northern oceanic liverwort species that form this distinctive community are *Adelanthus lindenbergianus, Anastrophyllum donnianum, A. alpinum, A. joergensenii, Bazzania pearsonii, Herbertus hutchinsiae, H. borealis, Mastigophora woodsii, Plagiochila carringtonii, Pleurozia purpurea, Scapania nimbosa* and *S. ornithopodioides*. Accompanying species of interest include the mosses *Campylopus setifolius* and *Dicranodontium uncinatum*, the liverworts *Anastrepta orcadensis, Bazzania tricrenata, Lepidozia pearsonii, Mylia taylorii, Plagiochila spinulosa* and *Scapania gracilis*, and the filmy fern *Hymenophyllum wilsonii*.

Map 28 shows areas of Britain and Ireland with a relatively warm and equable, but not necessarily wet, climate. The orange areas and those S and W of the blue line (much overlap between them) have the richest concentrations of oceanic species that are relatively southern and warmth-loving but not markedly hygrophilous. These include southern oceanic lichens that contribute significantly to the biodiversity and conservation value of some non-rainforest woods in the south, especially in the New Forest, and overlap with rainforest as in some woods in NW Wales (and further N and E, as in the Lake District and W Highlands, especially in low altitude open S-facing woods) with rich floras of a combination of rainforest and other southern oceanic species (Neil Sanderson, pers. comm.).

Map 28. Areas of Britain with a relatively warm and equable climate according to three different measures



Data sources (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

Species of particular interest in the southern oceanic lichen assemblage include the following (list from Neil Sanderson, pers. comm.): *Agonimia allobata, Agonimia octospora, Arthonia invadens, Cresponea premnea, Enterographa sorediata, Inoderma subabietinum, Lecanographa lyncea, Micarea pycnidiophora, Mycoporum lacteum, Opegrapha corticola, O. fumosa, Parmelinopsis horrescens, P. minarum, Phaeographis dendritica, P. inusta, P. lyellii, Phyllopsora rosei, Porina coralloidea, P. hibernica, P. rosei, Rinodina isidioides, Schismatomma niveum, S. quercicola, Synarthonia astroidestera, Thelopsis rubella, Wadeana dendrographa, Usnea ceratina, U. florida* and *Varicellaria velata*.

Another group for which these warm southern and south-western areas are important, especially along coastlines, is that of species with Mediterranean-Atlantic distributions in Europe: for example, *Crithmum maritimum, Raphanus raphanistrum* subsp. *maritimus*, *Arbutus unedo,* the lichens *Parmelina carporrhizans* and *Teloschistes flavicans*, the mosses *Epipterygium tozeri* and *Leptodon smithii* and the liverworts *Fossombronia angulosa, F. cespitiformis* and *Petalophyllum ralfsii*.

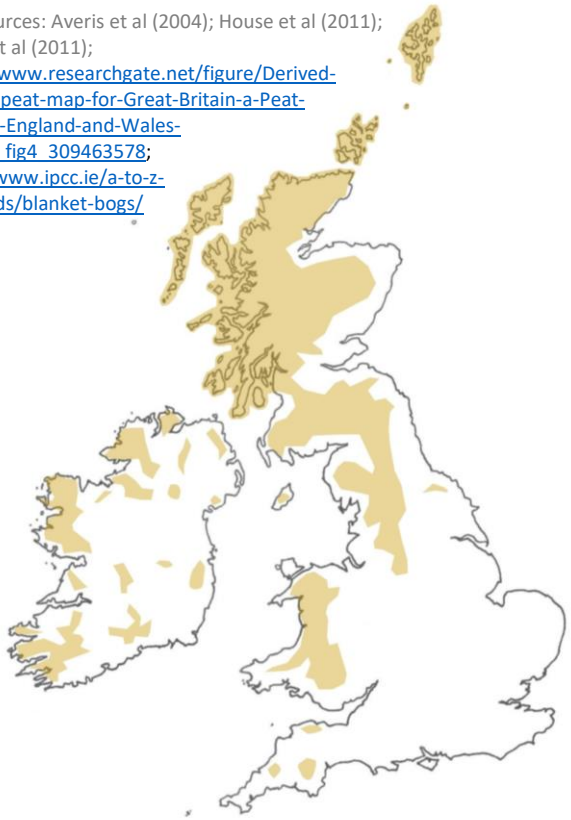
Finally, another habitat whose distribution has something in common with that of temperate rainforest is blanket bog. This is a habitat that is particularly extensive in parts of the world with a cool oceanic climate. In Britain and Ireland the distribution of blanket bog (Map 29) is predominantly upland and western, overlapping considerably with that of temperate rainforest. However, blanket bog extends further east and is not so confined to the very wettest areas. Its distribution is matched quite well with that of a climate defined by at least 100 cm of annual precipitation combined with a summer (June, July and August) mean temperature not exceeding 14°C (Map 30).

Some plant and lichen species are characteristic of both blanket bog and temperate rainforest: for example *Calluna vulgaris, Vaccinium myrtillus* and widespread mosses such as *Hypnum jutlandicum, Pleurozium schreberi, Hylocomium splendens, Rhytidiadelphus loreus* and *Sphagnum capillifolium*, but many other species are common in bogs and rare in the rainforests, or vice versa. Among the oceanic species the liverwort *Pleurozia purpurea* is common in many western bogs and also grows in some northern temperate rainforests.

Note: Blanket bog is a less varied and more well-defined habitat than temperate rainforest – hence the better availability of information on its distribution and the inclusion here of Map 29. It corresponds mainly with UK National Vegetation Classification communities M17 and M19, and also includes some M1, M2, M3, M18, M20 and M21, and forms of M15, M16 and M25 on deep peat.

Map 29. Main areas within which blanket bog has been found in Britain and Ireland

Data sources: Averis et al (2004); House et al (2011); House et al (2011); https://www.researchgate.net/figure/Derived-blanket-peat-map-for-Great-Britain-a-Peat-map-for-England-and-Wales-derived_fig4_309463578; http://www.ipcc.ie/a-to-z-peatlands/blanket-bogs/



Map 30. Areas of Britain and Ireland with >100 cm annual rainfall combined with summer (June-August) mean temperature <14°C

Data sources (climate data for the period 1981-2010): Blockeel *et al.* (2014); https://www.metoffice.gov.uk/; https://www.met.ie/climate-ireland/SummaryClimAvgs.pdf

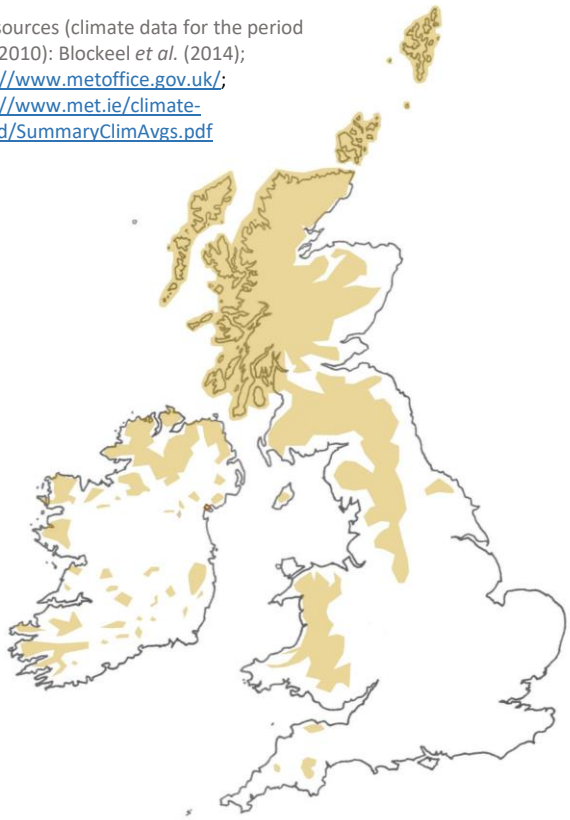


Table 1 – Plant and lichen species list. This is a list of all plant and lichen species included in the botanical rainforest assessment described in this document.

Key to codes in 'Rainforest indicator code' column:

R1 Very good rainforest indicators where they occur in native woodland: all current British and Irish records are from within the green zone in Map 15.

R2 Good rainforest indicators where they occur in native woodland: almost all British and Irish records are from within the green zone in Map 15; woodland occurrences elsewhere appear likely to indicate outliers of rainforest because the habitats of these species show a strong need for high humidity.

R3 Generally good rainforest indicators where they occur in native woodland (as for R2), but some of the outlier records appear to be, or are known to be, in less humid (semi-rainforest or non-rainforest) habitats.

R4 Generally good rainforest indicators where they occur in native woodland (as for R2 and R3), but with a more significant minority of records from outside the rainforest climate zone and including less humid (semi-rainforest or non-rainforest) habitats.

R5 Commonest in the green zone in Map 15 but unreliable as indicators of rainforest because their frequency in this habitat appears to be related to non-rainfall factors at least as much as to rainfall. These other factors include temperature (mild winters, relatively cool summers or small annual temperature range perhaps just as important as humidity), air pollution ('R5p' lichens were previously more widespread, with occurrences in drier eastern parts of Britain from where they appear to have been largely or entirely lost since the Industrial Revolution as a result of pollution such as that from sulphur dioxide, leaving them now with mainly western/rainforest distribution patterns), or old growth forest with a long history of canopy cover (many western woods might have been less disturbed historically, or dependency on old growth forest might be lower and colonisation ability higher in areas with a rainforest climate).

'Oceanic in Europe?' column: O = oceanic (including Hyperoceanic) according to Preston & Hill (1997) for vascular plants, Hill & Preston (1998) for bryophytes and the brief European/world distribution notes in Smith *et al.* (2009) for British and Irish lichens; there is not yet a formal European phytogeographical classification of British and Irish lichen species.

'ID+' column: + = reasonably straightforward to identify in the field and not rare in woodland in Britain and Ireland.

Scientific name	**Common name** (some lichens do not have common names)	**Rainforest indicator code**	**Oceanic in Europe?**	**ID +**
MOSSES				
Campylopus atrovirens	Bristly Swan-neck Moss	R4	O	+
Campylopus setifolius	Silky Swan-neck Moss	R1	O	+
Chionoloma cylindrotheca	Irish Crisp-moss	R1		
Chionoloma hibernicum	Irish Crisp-moss	R1	O	
Chionoloma recurvifolium	Drooping-leaved Beard-moss	R1	O	
Cyclodictyon laetevirens	Bright-green Cave-moss	R2	O	
Daltonia splachnoides	Irish Daltonia	R1	O	
Dicranodontium subporodictyon	Rusty Bow-moss	R1	O	
Dicranodontium uncinatum	Curve-leaved Bow-moss	R2		
Dicranum scottianum	Scott's Fork-moss	R5	O	+
Fissidens polyphyllus	Many-leaved Pocket-moss	R2	O	
Hageniella micans	Sparkling Signal-moss	R1	O	
Heterocladium wulfsbergii	Wulfsberg's Tamarisk-moss	R4	O	
Hylocomiastrum umbratum	Shaded Wood-moss	R4		+
Hymenostylium recurvirostrum var. *insigne*	Robust Tufa-moss	R1	O	
Hypnum uncinulatum	Hooked Plait-moss	R1	O	
Isothecium holtii	Holt's Mouse-tail Moss	R4	O	+
Molendoa warburgii	Warburg's Moss	R4	O	
Rhabdoweisia crenulata	Greater Streak-moss	R2	O	
Rhynchostegium alopecuroides	Portuguese Feather-moss	R4	O	+
Sematophyllum demissum	Prostrate Signal-moss	R1	O	
LIVERWORTS				
Acrobolbus wilsonii	Wilson's Pouchwort	R1	O	
Anastrepta orcadensis	Orkney Notchwort	R4		+
Anastrophyllum hellerianum	Heller's Notchwort	R4		
Bazzania pearsonii	Arch-leaved Whipwort	R2	O	

Scientific name	**Common name** (some lichens do not have common names)	**Rainforest indicator code**	**Oceanic in Europe?**	**ID +**
Bazzania tricrenata	Lesser Whipwort	R4		+
Bazzania trilobata	Greater Whipwort	R4		+
Calypogeia suecica	Swedish Pouchwort	R1		
Cephalozia crassifolia	Irish Pincerwort	R1	O	
Cololejeuna microscopica	Long-leaved Pouncewort	R2	O	+
Colura calyptrifolia	Fringed Cowlwort	R4	O	+
Douinia ovata	Waxy Earwort	R4	O	+
Drepanolejeunea hamatifolia	Toothed Pouncewort	R3	O	+
Dumortiera hirsuta	Dumortier's Liverwort	R4	O	
Frullania teneriffae	Sea Scalewort	R5	O	+
Gymnomitrion crenulatum	Western Frostwort	R2	O	+
Harpalejeunea molleri	Pointed Pouncewort	R3	O	+
Harpanthus scutatus	Stipular Flapwort	R4		
Herbertus hutchinsiae	Juniper Prongwort	R1	O	+
Jubula hutchinsiae	Hutchins' Hollywort	R4	O	+
Lejeunea eckloniana	Holt's Pouchwort	R3	O	
Lejeunea flava	Yellow Pouchwort	R1	O	
Lejeunea hibernica	Irish Pouchwort	R1	O	
Lejeunea mandonii	Atlantic Pouchwort	R4	O	
Lejeunea patens	Pearl Pouncewort	R4	O	+
Lepidozia cupressina	Rock Fingerwort	R4	O	+
Lepidozia pearsonii	Pearson's Fingerwort	R4	O	+
Leptoscyphus cuneifolius	Wedge Flapwort	R1	O	+
Lophocolea fragrans	Fragrant Crestwort	R4	O	
Mastigophora woodsii	Woods' Whipwort	R2	O	
Metzgeria leptoneura	Hooked Veilwort	R1	O	+
Plagiochila bifaria	Killarney Featherwort	R5	O	+
Plagiochila carringtonii	Carrington's Featherwort	R2	O	
Plagiochila exigua	Petty Featherwort	R1	O	+
Plagiochila heterophylla	Western Featherwort	R1	O	+
Plagiochila punctata	Spotty Featherwort	R4	O	+
Plagiochila spinulosa	Prickly Featherwort	R4	O	+
Pleurozia purpurea	Purple Spoonwort	R2	O	+
Porella pinnata	Pinnate Scalewort	R4	O	
Pseudomarsupidium decipiens	Deceptive Featherwort	R1	O	+
Radula aquilegia	Brown Scalewort	R1	O	+
Radula carringtonii	Carrington's Scalewort	R1	O	
Radula holtii	Holt's Scalewort	R1	O	
Radula voluta	Pale Scalewort	R1	O	
Saccogyna viticulosa	Straggling Pouchwort	R4	O	+
Scapania gracilis	Western Earwort	R5	O	+
Scapania ornithopodioides	Bird's-foot Earwort	R2	O	
Sphenolobopsis pearsonii	Horsehair Threadwort	R2	O	
Syzygiella autumnalis	Autumn Flapwort	R4		+
Telaranea europaea	Irish Threadwort	R2	O	
Tritomaria exsecta	Cut Notchwort	R4		
LICHENS				
Arthonia ilicina		R5	O	
Arthonia ilicinella		R5	O	
Arthopyrenia carneobrunneola		R3	O	
Arthopyrenia nitescens		R5	O	

Scientific name	**Common name** (some lichens do not have common names)	Rainforest indicator code	Oceanic in Europe?	ID +
Arthothelium dictyosporum		R1	O	
Arthothelium lirellans		R1	?	
Arthothelium macounii		R1	O	
Bacidia caesiovirens		R2	O	
Bactrospora homalotropa		R1	O	
Bunodophoron melanocarpum	Black-eyed Susan	R4		+
Calicium lenticulare		R4		
Cavernularia hultenii		R4		
Cetrelia olivetorum	Speckled Sea-storm Lichen	R4		+
Crutarndina (Thelotrema) petractoides		R2	O	
Dictyonema coppinsii		R4	?	
Eopyrenula septemseptata		R1	?	
Fissurina alboscripta	White Script Lichen	R1	O	
Gabura fascicularis	Octopus Suckers	R5	?	+
Gomphillus calycioides		R1	O	
Gyalideopsis muscicola		R5	?	
Hypotrachyna endochlora		R3	O	
Hypotrachyna laevigata	Smooth Loop Lichen	R4	O	+
Hypotrachyna sinuosa	Green Loop Lichen	R4	?	+
Hypotrachyna taylorensis	Tailed Loop Lichen	R4	O	+
Lecanora caledonica ined.		R1	O	
Lecanora cinereofusca		R1	?	
Lepra opthalmiza		R2	?	
Leptogidium dendriscum		R1	O	
Leptogium brebissonii	Blobby Jelly-skin Lichen	R1		+
Leptogium burgessii	Frilly-fruited Jelly-skin Lichen	R2	O	+
Leptogium cochleatum		R3		+
Leptogium coralloideum		R2	O	
Leptogium cyanescens	Blue Jelly-skin Lichen	R5		+
Leptogium hibernicum		R1	O	
Leptogium juressianum		R1	O	
Lobaria pulmonaria	Tree Lungwort	R5p		+
Lobarina scrobiculata	Textured Lungwort / Lob Scrob	R5p		+
Melaspilea atroides		R2	?	
Menegazzia subsimilis	Tree Flute	R2	O	
Menegazzia terebrata	Tree Flute	R4		+
Micarea alabastrites		R4	O	
Micarea inopinula		R1	O	
Micarea longispora		R2	O	
Micarea stipitata		R3	O	
Mycomicrothelia atlantica		R1	?	
Mycoporum sparsellum		R1	O	
Nephroma laevigatum	Mustard Kidney Lichen	R5p	O	+
Nephroma parile	Powdery Kidney Lichen	R5p		+
Nevesia sampaiana	Brown Shingle Lichen	R3	O	+
Opegrapha brevis		R1	O	
Opegrapha thelotrematis		R5	O	
Pannaria conoplea	Mealy-rimmed Shingle Lichen	R5p		+
Pannaria rubiginosa	Red-eyed Shingle Lichen	R5p	O	+
Parmeliella parvula		R5	?	+
Parmeliella testacea		R3	?	+

Scientific name	**Common name** (some lichens do not have common names)	Rainforest indicator code	Oceanic in Europe?	ID +
Parmeliella triptophylla	Black-bordered Shingle Lichen	R5p		+
Parmotrema arnoldii		R4	?	
Pectenia atlantica	Felt Lichen	R5	O	+
Pectenia cyanoloma		R2	O	+
Pectenia plumbea	Plum-fruited Felt Lichen	R5p		+
Peltigera collina	Floury Dog-lichen	R5p		
Phyllopsora rosei		R5	O	
Porina atlantica		R1	O	
Pseudocyphellaria citrina (= P. crocata)	Yellow Specklebelly	R2	O	+
Pseudocyphellaria intricata		R2	O	+
Pseudocyphellaria norvegica	Norwegian Specklebelly	R1	O	+
Pyrenula acutispora		R3	O	
Pyrenula dermatodes		R1	O	
Pyrenula hibernica	Blackberries in Custard	R1	O	
Pyrenula laevigata		R2	?	
Pyrenula occidentalis		R4	?	
Ricasolia amplissima	Parchment Lichen	R5p		+
Ricasolia virens	Green Satin Lichen	R5p	O	+
Sticta canariensis		R5 (or perhaps R4?)	O	+
Sticta fuliginosa	Peppered Moon Lichen / Stinky Sticta	R5p	O	+
Sticta limbata	Floury Sticta	R5p		+
Sticta sylvatica	Wood Pitted Lichen / Stinky Sticta	R5p	O	+
Strangospora microhaema		R4		
Thelotrema macrosporum		R2	O	
Usnea fragilescens *	Inflated Beard Lichen	R4	O	
Vezdaea stipitata		R1	?	
VASCULAR PLANTS				
Dryopteris aemula	Hay-scented buckler fern	R5	O	+
Hymenophyllum tunbrigense	Tunbridge filmy fern	R4	O	+
Hymenophyllum wilsonii	Wilson's filmy fern	R4	O	+
Saxifraga hirsuta **	Kidney Saxifrage	R1	O	+
Saxifraga spathularis **	St Patrick's Cabbage	R2	O	+
Stenogrammitis myosuroides	Kerry Mousetail Fern	R1	O	
Trichomanes speciosum (sporophyte)	Killarney Fern	R4	O	
FUNGI				
Abrothallus welwitschii	A lichenicolous fungus species	R1	?	
Arthonia sampaianae	A lichenicolous fungus species	R1	?	
Corticiruptor abeloneae	A lichenicolous fungus species	R1	?	
Filicupula suboperculata	Parastitic on liverworts	R1	?	
Hemigrapha atlantica	A lichenicolous fungus species	R1	?	
Hypocreopsis rhododendri	Hazel Gloves	R4	O	+
Nanostictis christiansenii	A lichenicolous fungus species	R1	?	
Nigromacula uniseptata	A lichenicolous fungus species	R1	?	
Skyttea pyrenulae	A lichenicolous fungus species	R1	?	
Stenocybe nitida	Parastitic on liverworts	R1	O	
Unguiculariopsis manriquei	A lichenicolous fungus species	R1	?	

* The map for *Usnea fragilescens* shows many records from drier parts of Britain and Ireland, but this species is thought to have been over-recorded in the past and the post-2000 records (more concentrated in the west) are considered to show a more truthful picture of its distribution (Brian Coppins and Neil Sanderson, pers. comm.).

** Native occurrences in W & S Ireland only; garden escape plants elsewhere in Ireland and in Britain excluded).

4. ACKNOWLEDGMENTS

Firstly I thank those people who, through asking about rainforest definition, or even just expressing an interest in the subject, have encouraged me to write this document. I hope they and others find it of interest or use.

I thank my lichenologist friends Brian and Sandy Coppins for productive and encouraging discussions about rainforests, their specialist plant and lichen species and their relationships with climate, habitats, and so on. That acknowledgement goes back many years, by the way, as we (and others) have been looking at these habitats and discussing them with each other since the old days before the internet and mobile phones.

I am very grateful to the lichenologist Neil Sanderson for detailed feedback on earlier versions of this document, especially with regard to the habitats, ecology, distributions and classification of rainforest and southern oceanic lichen species. Three-way email discussions of these matters with Neil and Brian Coppins has made an invaluable contribution to this document.

I thank my wife Alison for discussions about rainforests and other western habitats and their vegetation. We both share a great interest in western woods and uplands, and have spent a lot of time out together in these wonderful habitats. I also thank Alison for reading through earlier drafts of this document.

I thank Guy Shrubsole for interesting discussions about various aspects of rainforests while he was writing his *Lost Rainforests of Britain* book. Alison and I had a good couple of days with him and his partner Louisa in woods in Argyll in autumn 2021. It's great that his book and campaign are bringing temperate rainforest to the attention of more people.

Thanks too to those who gave me feedback from my 2020 document *Drizzle, Midges, Misery and Moss*. This has helped to encourage me to write this definition document. I wrote *DMMM* during the first Covid lockdown – something to be borne in mind if my writing style was interpreted as a sign of madness! It was actually a *sort of* serious attempt to use a conversational and humorous approach to convey information about these wonderful places and all the stuff within them. I've taken something of a more 'normal' approach here in this document!

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British Lichen Society website: https://britishlichensociety.org.uk/

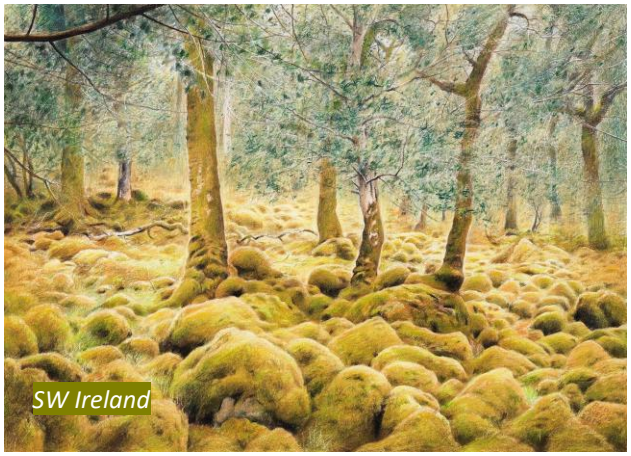
British Bryological Society website: https://www.britishbryologicalsociety.org.uk/

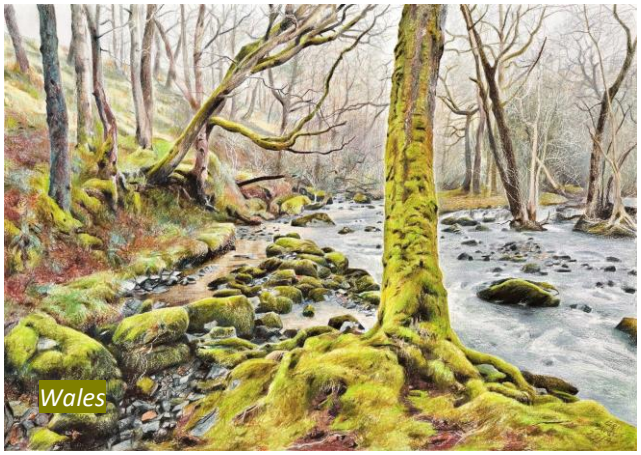
Lost Rainforests of Britain website: https://lostrainforestsofbritain.org/

6. PHOTOGRAPHS OF EXAMPLES OF RAINFOREST HABITATS AND SPECIES

Temperate rainforest in western Scotland:

Temperate rainforest in England, Wales and Ireland (including two drawings at bottom of page):





Rainforest of a more boreal nature, in areas with colder winters: Scottish Highlands (upper four; in blue and pink zones in Map 15) and Hokkaido, Japan (lower three; winters cold and very snowy).







Species (pages 48-54) – a selection, spanning categories R1 through to R5 in Table 1. Not all to the same scale.

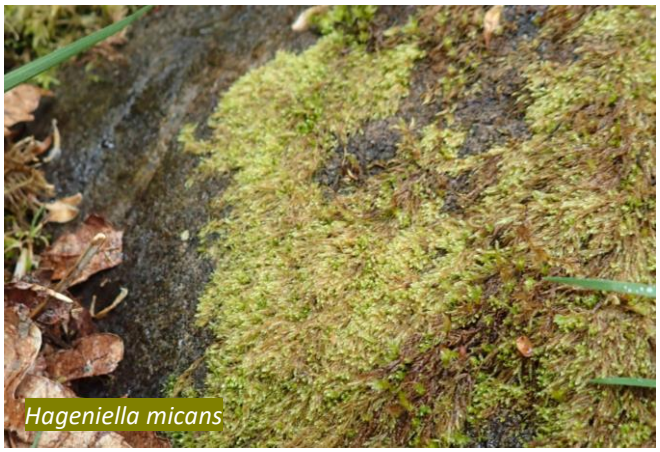
Some rainforest mosses:


Campylopus setifolius


Hyocomium armoricum


Dicranum scottianum


Daltonia splachnoides


Hageniella micans


Dicranodontium subporodictyon


Isothecium holtii


Rhabdoweisia crenulata

Some rainforest liverworts (1):


Scapania gracilis


Plagiochila spinulosa


Plagiochila punctata


Saccogyna viticulosa


Pseudomarsupidium decipiens


Herbertus hutchinsiae


Bazzania tricrenata


Plagiochila carringtonii


Scapania ornithopodioides


Lepidozia cupressina

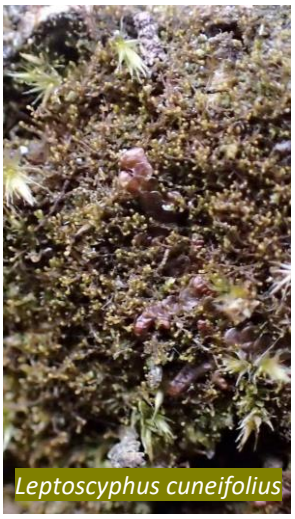

Lepidozia pearsonii


Bazzania trilobata

Some rainforest liverworts (2):


Lejeunea patens


Acrobolbus wilsonii


Leptoscyphus cuneifolius

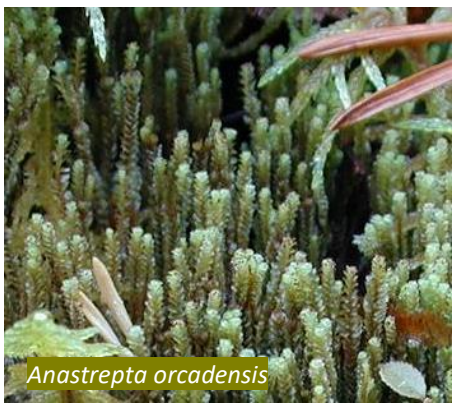

Jubula hutchinsiae


Radula aquilegia


Radula voluta


Radula holtii


Syzygiella autumnalis


Anastrepta orcadensis


Metzgeria leptoneura


Dumortiera hirsuta


Cololejeuna microscopica

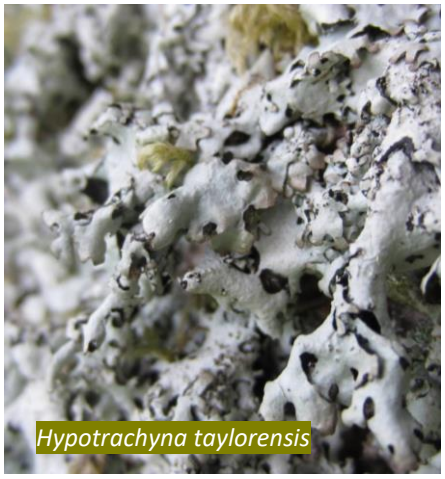

Drepanolejeunea hamatifolia

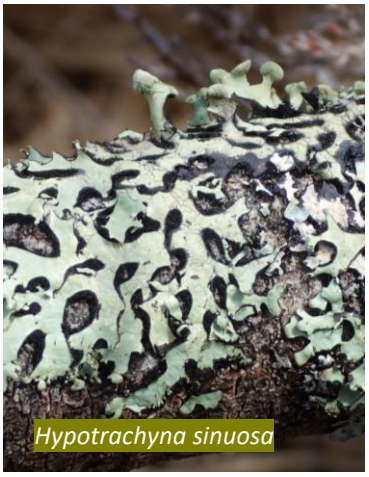

Harpalejeunea molleri

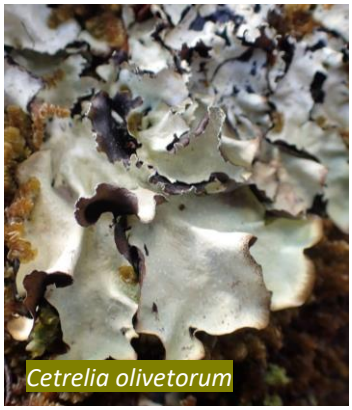

Colura calyptrifolia

Some rainforest lichens (1):


Hypotrachyna laevigata


Hypotrachyna taylorensis


Hypotrachyna sinuosa


Cetrelia olivetorum


Menegazzia terebrata


Menegazzia subsimilis


Bunodophoron melanocarpum


Lobaria pulmonaria


Lobarina scrobiculata


Ricasolia virens


Ricasolia amplissima

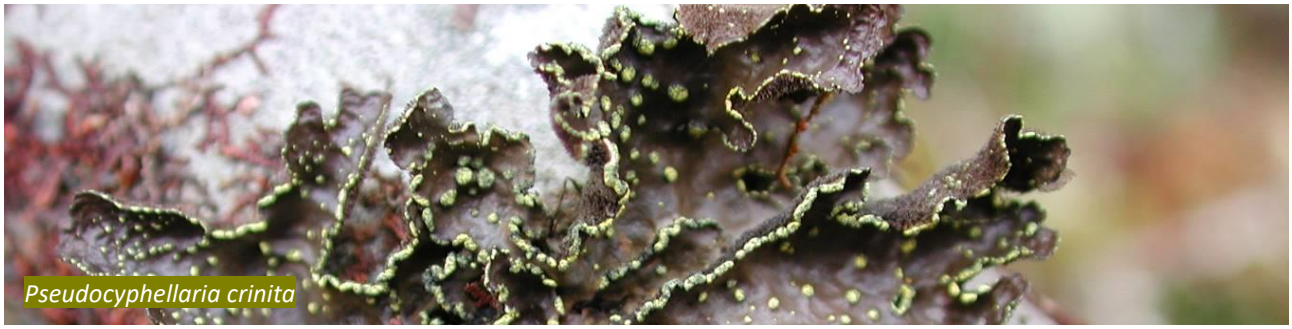

Sticta sylvatica


Sticta fuliginosa


Sticta limbata

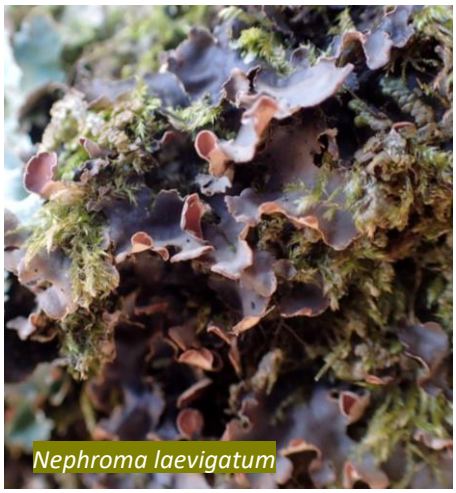

Sticta canariensis

Some rainforest lichens (2):


Pseudocyphellaria crinita


Pseudocyphellaria norvegica


Pseudocyphellaria intricata


Nephroma laevigatum


Nephroma parile


Peltigera collina


Pectenia atlantica


Pectenia cyanoloma


Pectenia plumbea


Leptogium burgessii


Collema fasciculare

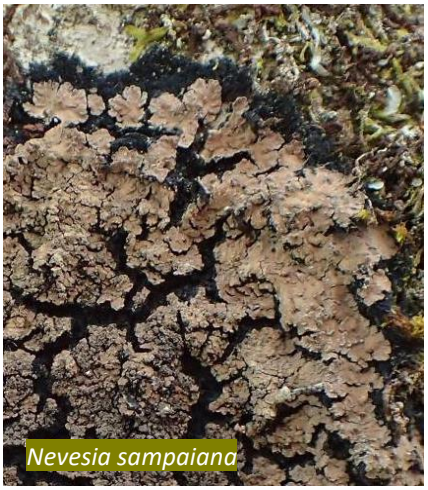
Some rainforest lichens (3) (Graphidion species on hazel – these photos taken in the W Highlands):

Some rainforest lichens (4), ferns (third row) and a fungus (bottom photo):


Pannaria rubiginosa


Pannaria conoplea


Leptogium brebissonii


Nevesia sampaiana


Leptogidium dendriscum


Hymenophyllum wilsonii


Hymenophyllum tunbrigense


Dryopteris aemula


Hypocreopsis rhododendri