MOSSES AND LIVERWORTS OF THE MALHAM DISTRICT

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ON a map of Great Britain, Malham Tarn occupies a very nearly central position. It lies roughly midway between Land's End and John o' Groats, two miles east of the watershed between the Aire, flowing east to the North Sea, and the Ribble flowing west to the Irish Sea. From a plant-geographical point of view too, Malham occupies an interestingly central position; and species of diverse distribution types meet to produce an unusually rich and interesting flora. Some 300 species of mosses and liverworts occur within about fifteen miles of the Tarn. This can be compared with about 180 species in Cambridgeshire, and rather over 500 species in the much larger area of Devon.

It has been said that the most significant plant-geographical boundary in the British Isles runs diagonally from S. Devon to the Tees, dividing "highland Britain" to the north and west, built up of hard Palaeozoic rocks and with a cool rainy oceanic climate, from the geologically more recent and topographically more subdued lowlands to the south and east. Lying over 1,200 ft. above sea level in the northern Pennines, Malham Tarn is well in "highland Britain", and a number of quite markedly northern mosses are common near the Tarn and on the surrounding hills; but there is much, especially in the Dales, to remind the bryologist that lowland Britain is not far away.

In contrast to the flowering plants, bryophytes grow luxuriantly near the western seaboard of Europe, and the bryophyte flora of the British Isles (especially of the west coast) is rich by Continental standards. Several features of the Atlantic climate contribute to the luxuriant growth of bryophytes, among them the high rainfall and the mild climate without extremes of temperature; and undoubtedly no two species have the same requirements. Several indices of oceanicity have been devised, to give a general indication of the oceanicity of a climate. Amann's "index of hygrothermy" (first used for studying the distribution of Atlantic species in the Alps) has the merit of simplicity, and a map of its distribution in the British Isles is given by Greig-Smith (1950). The index of hygrothermy (H) for a locality is given by:

$$H=\frac{PT}{t_H-t_C}$$

where P=annual precipitation in cm., T=mean annual temperature in °C, and t_H and t_C are the mean temperatures, in °C, of the hottest and coldest months. Variations in this index correspond quite well with the distributions of many oceanic bryophytes. Many common Atlantic species begin to appear

in quantity where H exceeds 60-70. Values of well over 100 appear in the western Highlands and islands of Scotland, the west of Ireland, south-west England, and probably west Wales, and it is in these areas that the most restricted oceanic species occur (e.g. *Mastigophora woodsii*, *Colura calyptrifolia*).

When the position of Malham is considered several points stand out. Firstly, although Malham is only some 25 miles from Morecambe Bay, this stretch of the west coast has a much less oceanic climate than either the Lake District and the west coast of Scotland to the north, or west Wales to the south. Considering the heavy rainfall (about 58 in., 147 cm.), a value of about 85 for Amann's index at Malham Tarn is not particularly high. For an upland district, the temperature climate of the Tarn is rather "continental" by British standards, with a mean January temperature of 34·7 °F. (1·5°C.) and a mean July temperature

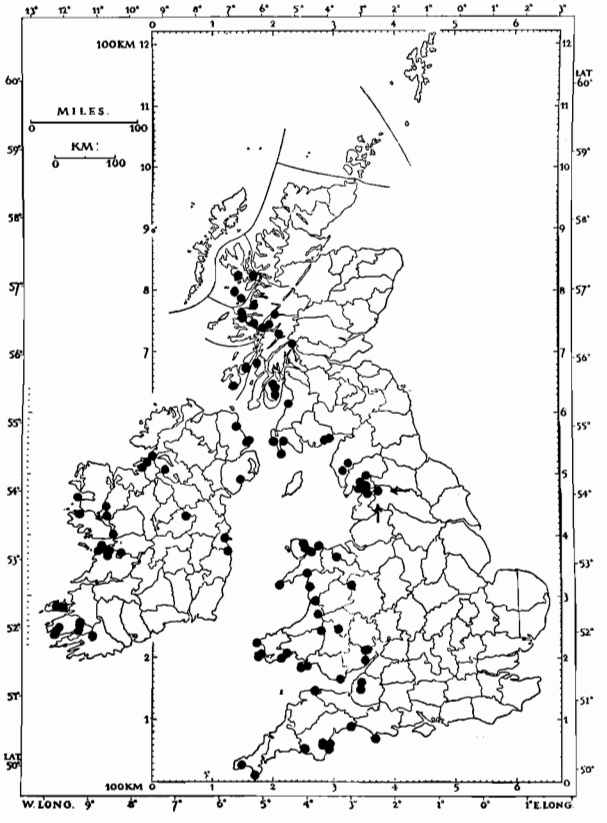

FIG. 1.

The distribution of *Marchesinia mackaii* in the British Isles (Recorded also from v.c. 39 (Staffs.), and H4 (Mid.-Cork)). The arrows indicate the Ingleton locality.

of 56·3°F (13·5°C.), giving an "annual range" of 21·6°F. (12·0°C). (Manley, 1957). In fact, although bryophytes grow luxuriantly round the Tarn, a number of common Atlantic species are notably sparse, though climate is probably not alone responsible for this; some other possible factors are mentioned below. The deep sheltered glens above Ingleton are probably the nearest places to the the Tarn where a strikingly oceanic bryophyte flora is to be seen. *Lejeunea ulicina*, a common small epiphytic liverwort over much of west and south -west Britain, is plentiful on tree-trunks at Ingleton. *Marchesinia mackaii* (Fig. 1) more strictly confined to the west coast (and restricted to calcareous, or at least base-rich, rocks), grows on shady vertical faces of limestone in the glens; and *Drepanolejeunea hamatifolia*, which grows in sheltered spots on the Ingletonian slates, is one of our most Atlantic liverworts.

One factor which has a profound influence on the character of the bryophyte flora round Malham is the preponderance of calcareous soils. A large part of the district surrounding the Tarn lies on Great Scar Limestone, and on the various Yoredale limestones; and the influence of these limestones is often apparent in the drift which blankets much of the outcrop of these and other rocks. As a result calcicole bryophytes figure largely in the Malham flora, and most of the rarer species are calcicoles. On the other hand many common calcifuge species are scarce and inconspicuous at Malham, and have to be looked for on the Millstone Grit or the areas covered with acid peat. This is one reason for the paucity of Atlantic species. The oceanic climate favours soil leaching, so that, by and large, oceanic bryophytes are adapted to acid soils. *Marchesinia mackaii*, mentioned above, is one of the few exceptions to this rule.

Another chemical factor, of quite different character, is atmospheric pollution. Malham lies only some 25 miles from the industrial areas of Lancashire and the West Riding. Many bryophytes are sensitive to pollution, especially the corticolous species growing on the trunks and branches of trees and shrubs. In Europe, most of the damage to epiphytic bryophytes and lichens appears to be due to sulphur dioxide (see Barkman, 1958). Around Malham, the corticolous flora is decidedly poor, in contrast to the flora on limestone rocks, where atmospheric acids are neutralized by the calcium carbonate of the substratum. *Dicranoweisia cirrata* is a common epiphyte on trees around the Tarn. Although it avoids highly polluted areas, this species is more tolerant than most corticolous bryophytes, and probably often benefits indirectly from slight pollution by being freed from the competition of other more vigorous but more sensitive species. Measurements of pollution have been made at the Tarn House since October 1957. The figures in Table 1 give an indication of

Table 1. *Sulphur dioxide concentration in the atmosphere at Malham Tarn and other localities.*

(Expressed as mg. SO_3/cm.^{2}/day, measured by rate of sulphation of standard lead peroxide candle.)

Site	April-September 1958	September 1958-March 1959
Malham Tarn House	0·36	0·68
Leeds (Market Buildings)	2·28	4·21
Cambridge (Lammas Ground)	0·42	0·93
Brixham	0·13	0·36

the amount of sulphur dioxide in the air, estimated by the sulphation of a standard lead peroxide "candle". The effective sulphur dioxide concentration in the air at the Tarn is only a sixth of that in a large industrial town such as Leeds, and about two-thirds of that in Cambridge (where *Dicranoweisia cirrata* grows on trees in the Botanic Garden); but it is twice as high as in Brixham on the south Devon coast. Doubtless many country districts in the west would give figures lower again.

(1) *Woodland*

Woods are scarce on the limestone at the present day. Doubtless Craven was once well wooded. The climatic limit of tree growth probably lies between 2,000 and 2,500 ft. (in Snowdonia, frequent scattered rowans can be found in the cwms up to 2,200 ft. and occasionally higher), so we are probably justified in visualizing the whole countryside covered with woodland during most of the post-glacial period, except for the Tarn Moss, the cliffs, the higher summits and, in the latter part of the Post-Glacial, the blanket-bog. Certainly pollen-analysis shows that the country immediately round the Tarn was mostly covered with trees, or at least scrub, though the present preponderance of ash seems to be a product of human activity, and previously the woodland appears to have been much more diverse in composition (M. E. and C. D. Pigott, 1959).

Felling and sheep-grazing have left only fragments of this woodland, mainly on steep slopes and broken areas of limestone pavement. Several of the woods which do remain have rich floras. The most famous are Colt Park Wood near Ribblehead, and Grass Wood in Wharfedale, just above Grassington. Colt Park Wood (see Clapham, 1954) occupies a long narrow strip of limestone pavement (at c. 1,100-1,150 ft.) low on the north-eastern shoulder of Ingleborough. Most of the floor of the wood is made up of limestone blocks or *clints*, and the trees are rooted in the open crevices or *grikes* between them (Fig. 3a). The most abundant tree is ash, accompanied by rowan, hazel, *Salix caprea*, *Betula pendula*, and *Prunus padus*. *Hypnum cupressiforme* var. *lacunosum*, *Ctenidium molluscum*, *Thuidium* spp., and *Plagiochila asplenioides* are among the most conspicuous species in the moss carpet covering the clints. The grikes have a more moisture-loving and shade-tolerant flora, as exemplified by the highly characteristic miniature forests (see Gimingham and Birse, 1957) of *Thamnium alopecurum*. Grass Wood covers one of the terraced hillsides which are a common feature of the Great Scar Limestone, and is much more varied in character. Parts are very like Colt Park Wood, but in much of the wood the soil is deeper, and even locally somewhat acid, so that some mildly calcifuge woodland species are found, e.g. *Dicranum majus*, *Rhytidiadelphus loreus*. The clay rides in Grass Wood produce some interesting plants, e.g. *Fossombronia pusilla* and *F. wondraczekii*, *Archidium alternifolium*, and *Hypnum patientiae*. A number of woods of generally similar character exist in Wharfedale and Littondale. Surprisingly few bryophytes are confined to the woods; most can be found elsewhere either in grassland or about rock outcrops. *Brachythecium populeum* is perhaps the most obvious species round the Tarn which is more conspicuous in fragments of woodland than in other habitats. There is an interesting flora on the rock outcrops in the plantation west of Tarn House: the more notable species

include *Isopterygium depressum*, *Mnium stellare*, and *Seligeria doniana*. *Orthodontium lineare* is rather common on trees round the Tarn. It is a native of South Africa, and has extended its range very rapidly in Britain since it was first recorded near Greenfield, W. Yorks., in 1920.

(2) *Grassland*

Grasslands are the most extensive type of habitat over the Great Scar Limestone around Malham Tarn. The bryophyte flora of the grassland on shallow rendzina soils has much in common with that found in limestone grasslands elsewhere in Britain. Mosses are seldom very prominent, but a number of common calcicole species occur quite regularly, e.g. *Ctenidium molluscum*, *Fissidens cristatus*, *Tortella tortuosa*, *Weissia* spp., and *Hypnum cupressiforme* var. *lacunosum*. The cool climate and heavy rainfall are reflected in the frequency of such species as *Dicranum scoparium*, *Rhacomitrium langinosum*, *Lophocolea bidentata*, *Plagiochila asplenioides*, and *Mnium undulatum;* the last three are more familiar as woodland plants in southern England.

Passing into the *Agrostis-Festuca* and drier *Nardus* grasslands on rather deeper and somewhat leached soils, the strictly calcicole mosses disappear and are replaced by a group of common grassland species—*Pseudoscleropodium purum*, *Pleurozium schreberi*, *Rhytidiadelphus squarrosus*, and *Hylocomium splendens*. The wetter *Nardus* grasslands (with *Juncus squarrosus*) have a different flora again, often not far removed from that of burnt and grazed blanket bog, with *Ptilidium ciliare*, *Barbilophozia floerkii*, *Lophozia ventricosa*, *Dicranum scoparium*, and even *Polytrichum commune* and a little *Sphagnum*.

(3) *Limestone cliffs, pavements, and walls*

The limestone country is broken by innumerable outcrops and cliffs, ranging from a foot or so in height to the high scars which lend the Malham landscape much of its character. The bryophyte floras of these cliffs show some striking phytogeographical contrasts. Most of the more notable northern species in the Craven flora are saxicolous, e.g. *Pseudoleskea catenulata* (Fig. 5), *Distichium capillaceum*, *Orthothecium* spp., *Encalypta ciliata*, *Plagiopus oederi*, and *Mnium orthorrhynchum*. They occur in two main habitats; the cliffs formed by the thick bed of Yoredale limestone high on the slopes of Ingleborough and Pen-y-Ghent, and on many smaller cliffs (usually more or less north-facing) at rather lower altitudes in the higher parts of the Great Scar Limestone country. The Yoredale cliffs, favoured by *Pseudoleskea catenulata*, are rather exposed. They are the habitat of *Orthothecium intricatum* var. *abbreviatum*, which appears to be endemic to the Yoredale limestones in the north of England; whether it is genetically distinct from the normal form of the species is not known. *Plagiopus oederi*, *Orthothecium rufescens*, *Mnium orthorrhynchum*, and *Pedinophyllum interruptum* favour the more sheltered outcrops on the Great Scar Limestone, as in Penyghent Gill, and are scattered locally on rocky streamsides down into the dales. On all these cliffs *Tortella tortuosa* and *Gymnostomum aeruginosum* are conspicuous.

The bryophytes of rocks and cliffs also include some of the most notable southern species of the Malham Area. A visiting bryologist can hardly fail to be struck by the abundance of *Reboulia hemispherica*, which is one of the

commonest thalloid liverworts of dry habitats on the limestone outcrops: it is found even on the high Yoredale cliffs of Pen-y-Ghent. Other species are more restricted. *Isothecium striatulum* (Fig. 2), first recorded from Yorkshire in Gordale a few years ago, has its northern limit in Britain not far to the north-west on the limestone at the head of Morecambe Bay. The small leafy liverwort *Cololejeunea rossettiana*, a species of the Mediterranean and the Atlantic islands, thinly scattered over Britian as far north as southern Scotland, occurs on sheltered rock faces in Gordale.

The small bryophytes of sheltered crevices and overhangs in the limestone at all levels deserve mention. *Fissidens pusillus* is common in this habitat and on damp sheltered limestone faces, together with several species of *Seligeria*, of which *S. pusilla* is the commonest. Widely but thinly distributed is the liverwort *Cololejeunea calcarea*.

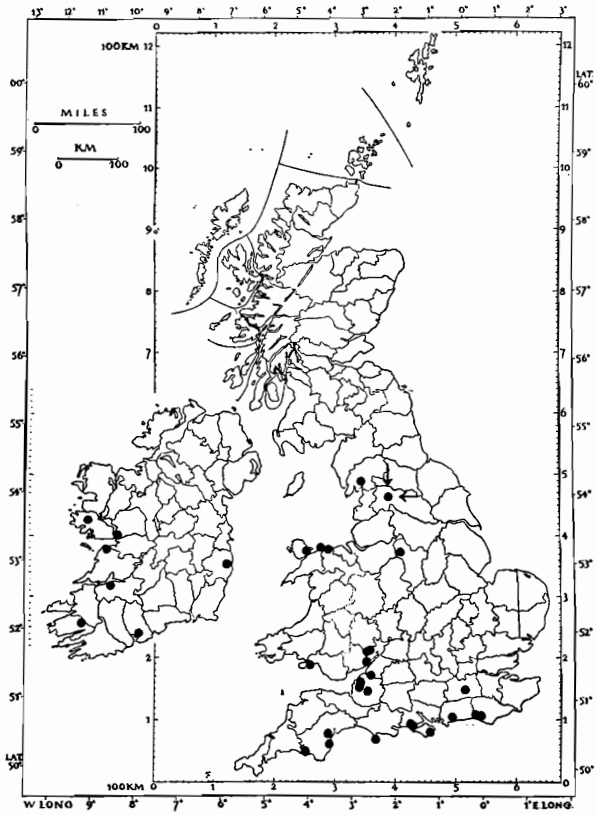

FIG. 2.

The distribution of *Isothecium striatulum* in the British Isles. The arrows indicate the Gordale locality.

In many places round the Tarn there are extensive limestone pavements: flat areas of bare limestone dissected along the joints by deep fissures. These pavements provide several sharply contrasting micro-habitats. The tops of the clints (see p. 64) are usually almost bare, or support only small tufts of such species as *Tortella tortuosa*, *Grimmia apocarpa*, and *Barbula recurvirostris* in crevices and hollows (Fig. 3b). The vertical sides of the grikes are sparsely covered with *Neckera* spp., *Ctenidium molluscum*, and *Camptothecium sericeum*. The deep shady bottoms of the grikes provide a suitable habitat for a range of woodland bryophytes, including *Thamnium alopecurum*, *Mnium undulatum*, and *Eurhynchium striatum*, usually accompanied by various woodland flowering plants, e.g.

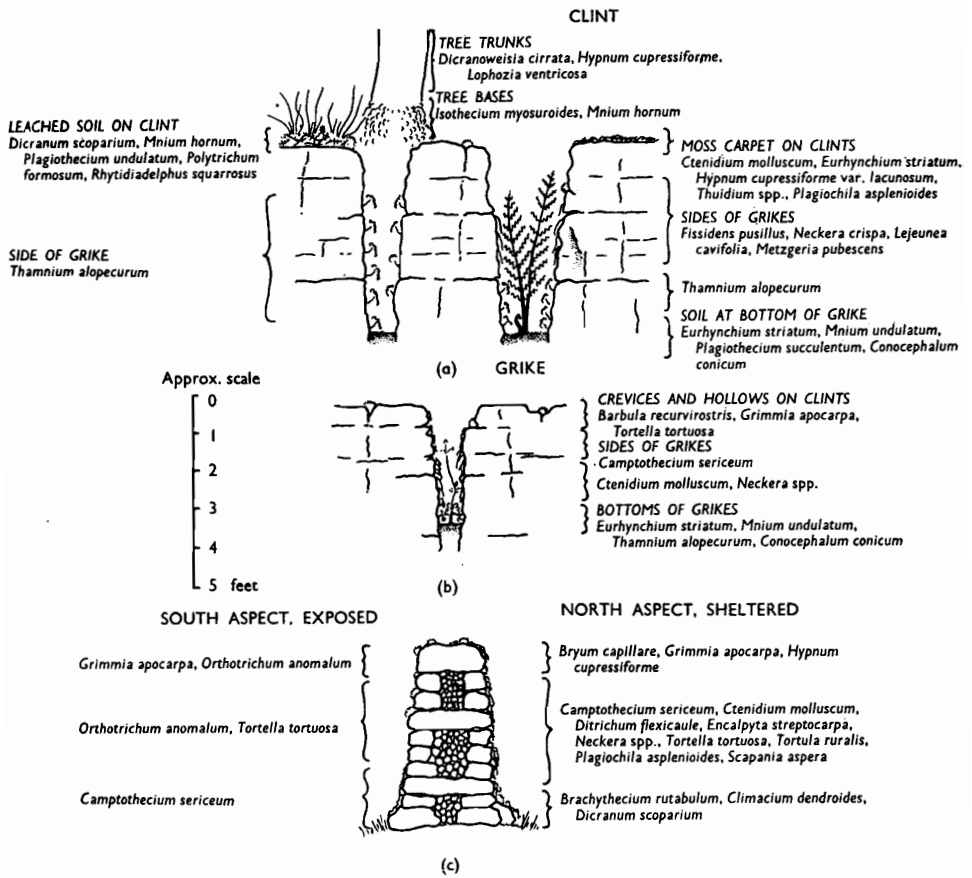

FIG. 3.

Diagrammatic sections of some limestone habitats, showing generalised distribution of typical bryophyte species. (a) Ashwood on limestone pavement. (b) Bare exposed limestone pavement. (c) Limestone dry wall.

Sanicula europaea. Residual patches of clayey soil in the bottoms of the grikes are often covered with luxuriant carpets of the big thalloid liverwort *Conocephalum conicum*. This species (like some others) has a very strong sweetish "liverwort" smell (variously described as being "resinous" or like China tea, fungi, or tobacco) which apparently not everyone can detect.

The flora of limestone walls varies very greatly with their position (Fig. 3c). Dry exposed walls have a poor bryophyte flora, including *Camptothecium sericeum* and *Grimmia apocarpa* among their commoner species. The richest floras are found on the north sides of walls in sheltered positions; two conditions which are met on many of the roadside walls just west of the Tarn House. The tops of these walls are generally dominated by *Hypnum cupressiforme*. *Bryum capillare*, and *Grimmia apocarpa*, and their sides are covered with masses of *Ctenidium molluscum*, *Neckera crispa*, *Tortella tortuosa*, *Anomodon viticulosus*, *Tortula ruralis*, *Camptothecium sericeum*, and many other species; there is often a marked zonation from the bottom of the wall to the top. A curious dark form of *Camptothecium lutescens* (intermediate in habit between this species and *C. sericeum*), perhaps the same as the plant mentioned by Dixon from Derbyshire, occurs on walls near the Tarn and locally elsewhere. Most of the species which grow on walls also occur quite commonly in other habitats, but some, e.g. *Encalypta streptocarpa*, *Tortula ruralis*, *Eurynchium murale*, *Zygodon viridissimus*, and *Scapania aspera* are perhaps more prominent in this habitat than elsewhere. The most notable moss in this habitat is *Zygodon gracilis*, of which Malham is the *locus classicus*;

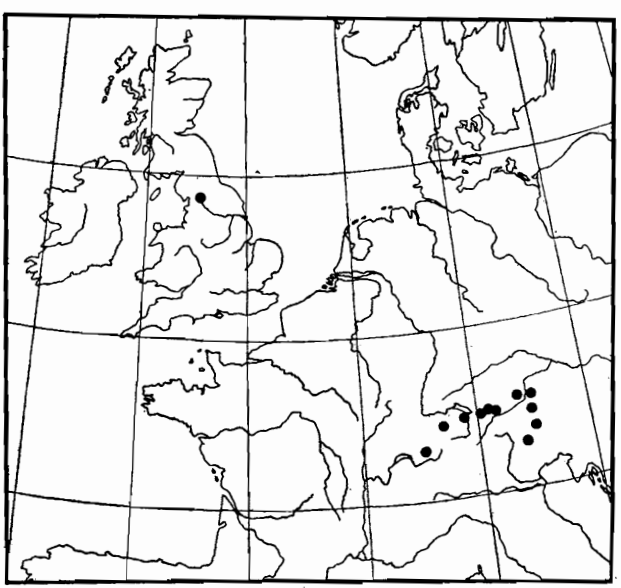

FIG. 4.
World distribution of *Zygodon gracilis* (from Malta, 1926).

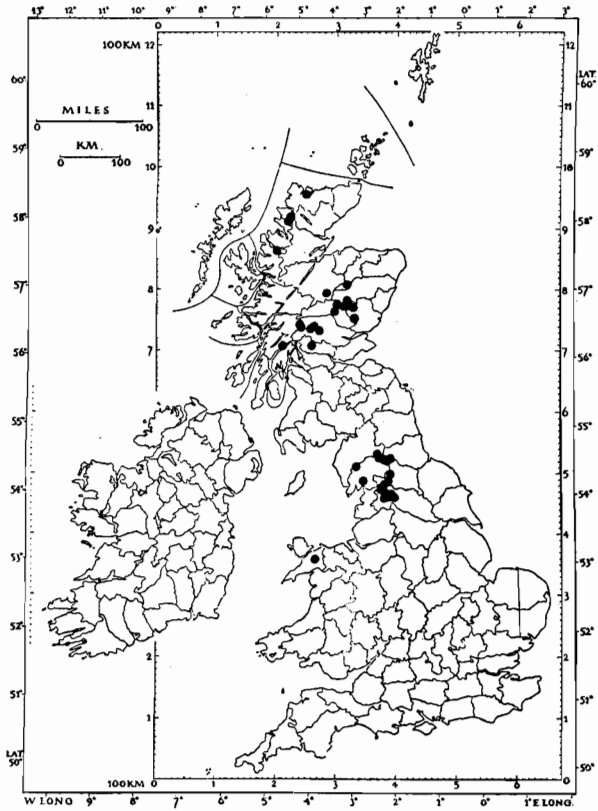

FIG. 5.

The distribution of *Pseudoleskea catenulata* in the British Isles. (Recorded also from v.c. 68 (Stirling).)

it is very local on walls and rock outcrops around Malham, Pen-y-Ghent, and Ingleborough. Elsewhere it is only found in a few scattered localities in Switzerland, Bavaria, and the eastern Alps (Fig. 4).

(4) *Streams and rivers*

Almost all the streams round Malham are fast-flowing and calcareous. Although many streams rise on the Millstone Grit and acid drift, they generally possess a typically calcifuge flora only in the headwaters, where *Rhacomitrium aciculare*, *Scapania undulata*, and *Nardia compressa* are conspicuous, as they are in the mountain torrents of the Lake District. On reaching the Yoredale limestones the character of the flora changes (Table 2). The stream often goes wholly or partly underground into a bed of limestone, to reappear at the next impermeable band of shale. The water becomes calcareous; the two most

Table 2. *Water composition and bryophyte flora in Crooke Gill, Pen-y-Ghent, 7 January 1960.*

Altitude (ft.)	pH	Ca mg./l	K mg./l	Na mg./l	Principal bryophytes
2,050	3·9	1·7	0·5	3·6	A little *Scapania undulata*
1,850	4·0	3·8	0·2	3·6	*Scapania undulata, Nardia compressa*
1,750	4·6	5·9	0·3	3·6	*Scapania undulata*, a little *Rhacomitrium aciculare*
1,600	4·4	5·5	0·3	3·6	*Scapania undulata*
1,500	5·8	10·6	0·3	3·6	*Scapania undulata, Rhacomitrium aciculare, Hygrohypnum luridum*
1,450	7·4	18·7	0·5	4·4	*Brachythecium rivulare*
1,350	7·6	19·5	0·5	4·4	*Brachythecium rivulare*
1,300	7·7	21·6	0·5	4·4	*Eurhynchium riparioides, Fontinalis antipyretica, Brachythecium rivulare.*

pH measured with glass electrode, calcium by titration with EDTA, sodium and potassium by flame photometer.

The uppermost bed of Yoredale limestone at c. 1,900 ft. is almost covered by drift. The stream is flowing over limestone at 1,500 ft., and receives a tributary, issuing from the limestone, just above 1,450 ft.

striking mosses on the boulders are now generally *Brachythecium rivulare* and *B. plumosum*, often with *Hygrohypnum luridum*, *Eurhynchium riparioides*, and *Grimmia alpicola*. In the water *Cinclidotus fontinaloides* is often conspicuous in all but the fastest streams, and *Fontinalis antipyretica* is also widespread. The two species of *Hygroamblystegium* both occur on rocks in streams round Malham, but both are rare. Two species, *Dichodontium pellucidum* and *Barbula spadicea*, are particularly characteristic of sandy stream sides. One of the most notable species of Craven, *Fissidens rufulus*, is locally abundant on stony and rather sandy stream beds, usually where it is submerged for the greater part of the year. It is a common plant in the Wharfe, but occurs also, for instance, in Gordale and the stream below Malham Cove. Curiously it seems to be more frequent in Craven than *F. crassipes*, which is very much commoner in the country as a whole.

Even as large a river as the Wharfe has a flora much like the hill streams in its fast-running stretch at Ghaistrills Strid above Grassington. But the slower-flowering reaches nearby are much more reminiscent of rivers in lowland England. The roots and trunks of trees along the bank, reached by occasional floods, have a very characteristic flora, including *Leskea polycarpa*, *Tortula latifolia*, and *Orthotrichum rivulare*.

At Bolton Abbey the Wharfe, still highly calcareous, flows over Millstone Grit, producing a striking contrast between the rocks by the river, periodically flooded or sprayed with calcareous water, and the calcifuge flora of the surrounding woodland. The rocks for some distance above the normal level of the river are thickly carpeted with *Thamnium alopecurum*, *Brachythecium* spp. etc.; rocks less densely covered with vegetation carry an interesting flora including *Distichium capillaceum*, *Mnium orthorrhynchum*, *Pedinophyllum interruptum*, and *Cololejeunea calcarea*. A similar state of affairs is found in the Ingleton Glens, where *Cololejeunea calcarea* is frequent within reach of calcareous spray on the Ingletonian slates.

Some streams, especially those whose courses lie largely over the Great Scar Limestone or calcareous drift, contain so much dissolved calcium bicarbonate that calcium carbonate is readily deposited from solution as *tufa*. Tufa formation seems always to be associated with the presence of either bryophytes or algae. The Gordale Beck, and the small streams flowing northwards into the Cowside Beck, are good examples of such streams. They have a characteristic flora, in which *Pellia fabbroniana*, *Cratoneuron filicinum*, *C. commutatum* var. *virescens*, *Eurhynchium riparioides*, *Cinclidotus fontinaloides* and *Bryum pseudotriquetrum* are prominent. The bryophytes on the beds of the streams are often thickly encrusted with calcium carbonate, but the most spectacular tufa-formation is seen in waterfalls. The shape of the curtains of tufa, following the profile of the cascading water, is often very striking; the examples at Gordale Scar are well worth looking at carefully. At Janet's Foss, a little further down Gordale, a small cave has been left behind the screen of tufa. Tufa often shows a banded structure. The origin of this banding and its periodicity probably vary from one example to another, and in many ways are still obscure. The bands are probably rarely annual; the most usual mechanism is likely to be the successive overgrowth of pendulous sheets of moss stems (C. A. Sinker, *in litt.*). A considerable number of species of bryophytes may deposit tufa, but the four most important round Malham are *Eurhynchium riparioides*, *Cratoneuron commutatum*, *Pellia fabbroniana* and *Barbula tophacea*. *Eucladium verticillatum*, an important tufa-former in many parts of the country, is surprisingly rare round Malham; though it does, for instance, form quite an impressive patch of tufa by the path in Swilla Glen, Ingleton. Two other common tufa-forming species round Malham are *Gymnostomum aeruginosum* and *G. curvirostre*, growing as dark green cushions usually marking slight seepages from limestone outcrops and cliffs; but the results of their activities are on a smaller scale than those of the previous species. Tufa flushes, forming a half-way stage between damp cliffs and calcareous springs, are a very characteristic habitat of *Orthothecium rufescens*, e.g. at Mastiles Bridge and by the Cowside Beck.

(5) *Fens and raised bogs*

The Tarn Moss and its neighbouring fens are of great ecological interest, and rich in bryophytes. The water entering Malham Tarn drains from the Great Scar Limestone, and from calcareous drift, and the Tarn water is highly calcareous. When this water is close to the surface of the soil, so that the ground is waterlogged for much of the year, calcareous fens have developed with a very characteristic flora. Often fens develop as part of the *hydrosere*, or natural succession from open water to dry-land vegetation. To begin with, fine silt and mud is washed into a lake from the surrounding countryside, and this sediment accumulates on the bottom together with the remains of the plants and animals living in the lake. In time, the water becomes shallow enough for the growth of reedswamp plants, which with increasing rapidity build up a layer of reedswamp peat over the waterlogged mud. As the peat approaches the surface of the water, reedswamp gives place to fen, and it is at this point that bryophytes begin to play an important role in the vegetation: occasional bands of fen peat may consist almost wholly of bryophyte remains.

As the peat becomes higher and drier, so that it suffers no more than winter flooding, woody plants become established; at Malham mainly species of *Salix* (especially *S. cinerea*, *S. aurita*, and *S. pentandra*), though in other parts of the country alder and the two buckthorns may be important. This *fen carr* often makes an all but impenetrable thicket; on its floor twigs and other plant remains gradually accumulate as brushwood peat.

The fate of fen carr depends on various circumstances. In favourable places the ground may become progressively drier as the peat accumulates, and the carr may give place to something approaching ordinary woodland. But in large expanses of fen and fen carr the water cannot drain away. The ground remains waterlogged, though now out of reach of flooding by calcareous water; and the rainy climate of north-west Europe favours the leaching away of bases from the upper layers of the peat. In time, the surface of the peat locally becomes

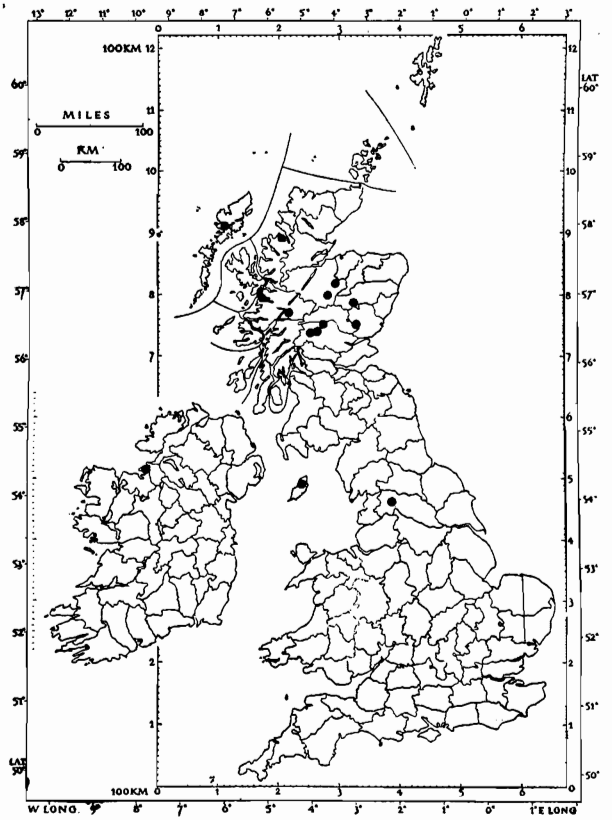

FIG. 6.

The distribution of *Barbilophozia kunzeana* in the British Isles. The single record in the north of England is from Malham Tarn Moss.

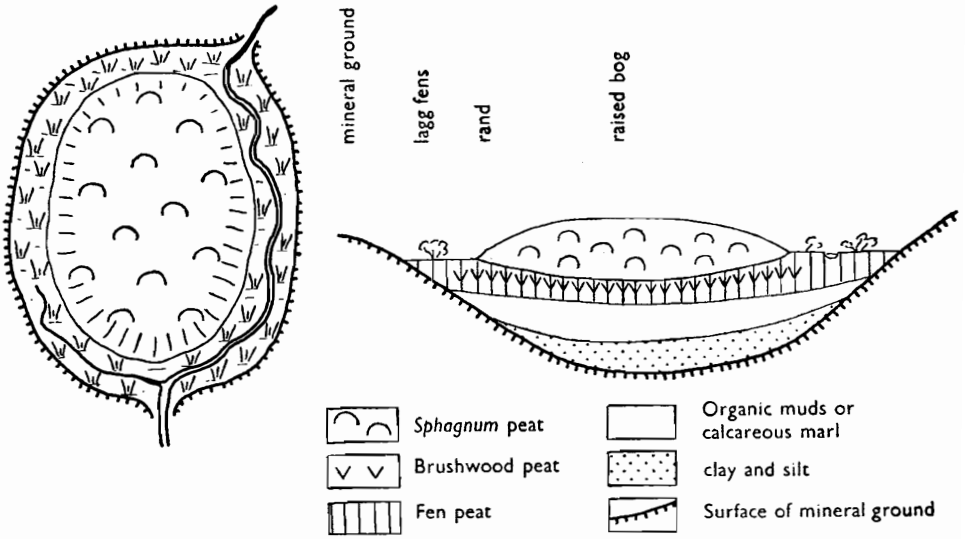

FIG. 7.
Diagrammatic plan and profile of a raised bog. (Vertical scale greatly exaggerated).

acid enough to support species of *Sphagnum*, especially *S. fimbriatum*, *S. squarrosum*, and *S. palustre*, which form a blanket over the ground. Often the growing *Sphagnum* seems to have killed the carr; the carr Sphagna are replaced by the vigorous peat-forming species of unshaded habitats, and a rapidly growing *Sphagnum* bog is formed which soom accumulates a substantial mass of peat. A bog of this kind is called a raised bog. The growing *Sphagnum* surface slopes down on every side to the remaining areas of calcareous fen along the streams and the margins of the neighbouring mineral ground. In Fig. 7 are shown the belt of fen separating the bog from the surrounding mineral ground, called the *lagg* (from the Swedish); and the steeper edge of the bog abutting the fens, the *rand* (from the German). Often, as at Malham, the change to raised bog conditions followed the change to a warm moist oceanic climate at the opening of the Atlantic period, about 7,500 years ago.

Raised bogs were once to be seen almost throughout the British Isles, but peat cutting and drainage have left only traces of those that once existed in the East Anglian Fenland, the Somerset Levels, and the Cheshire-Lancashire plain. Good actively growing raised bogs are now rare in Great Britain; Tregaron Bog in mid-Wales (Godwin and Conway, 1939), and the Silver Flowe in Galloway (Ratcliffe and Walker, 1958), are National Nature Reserves. Raised bogs are one of the most characteristic features of the landscape in the central plain of Ireland, where superb examples can be seen (Tansley, 1939; Osvald 1948).

Malham Tarn Moss is quite a good example of a small raised bog, though it is no longer actively growing. The stratigraphy of the peat has been worked

out by M. E. and C. D. Pigott (1959), and shows that the bog has grown up in much the way outlined above. One interesting feature (which it shares with many bogs in England and Wales) is that the great bulk of the peat is formed of the easily recognizable remains of *Sphagnum imbricatum*, which is no longer to be found on the Moss at the present day. *Sphagnum* species are only locally common on the Moss: much of the surface is covered with tussocks of *Eriophorum vaginatum*, and the most conspicuous species in its bryophyte flora are the leafy liverworts *Lophozia ventricosa*, *Mylia anomala*, *Odontoschisma sphagni*, and *Calypogeia* spp. Species characteristic of burnt or decaying peat, e.g. *Pohlia nutans*, *Tetraphis pellucida*, although common, have become less prominent since the Moss has been protected from burning and other human activities. The most notable species of the raised bog, *Barbilophozia kunzeana* (Fig. 6), occurs locally in some quantity among the *Molinia* tussocks on the rand along the inflow stream, as well as on patches of acid peat north of the stream. Helwith Moss, in Ribblesdale, is another small raised bog. It has better developed *Sphagnum* communities than the Tarn Moss, but its surroundings do not compare in interest with the Malham Tarn fens.

Good examples of calcareous fen are not common, and in fact much of the fen at Malham has grown up over peat cuttings which were flooded when the level of the Tarn was raised in 1791. Spiggot Hill Fen and parts of the North Fen may be little-altered parts of the original lagg of the Moss; but much of the North Fen is a mosaic of varied patches of vegetation ranging through the whole gamut from calcareous fen to raised bog (see Fig. 8). It is interesting to consider this diversity in the light of the classification of bog and fen vegetation proposed in Sweden by Du Rietz (1949). Bryophytes are often very sensitive indicators of habitat conditions, and Du Rietz makes much use of them in constructing his classification. He makes a primary distinction between ombrogenous *moss* or *bog* communities, which depend entirely on rain falling on their surfaces for their water supply, and soligenous *fens* whose water has drained at least partly from mineral ground. The fens fall into two main classes (though the various types intergrade, as Sjörs (1950) emphasizes): *poor fens* which are acid and characterized by species of *Sphagnum*, especially *S. recurvum*; and *rich fens* which are generally calcareous and dominated by true mosses (largely Hypnaceae), of which *Scorpidium scorpioides* is best rich fen indicator. *Scorpidium* is present in the calcareous fens at Malham, but the most abundant species are *Drepanocladus revolvens*, *Campylium stellatum*, *Acrocladium cuspidatum*, and *A. giganteum; Mnium pseudopunctatum*, *M. seligeri*, *Bryum pseudotriquetrum*, *Fissidens adianthoides*, and *Marchantia polymorpha* are also common.

The fen carr has quite a different flora, with at least as much in common with wet woodland as with the fen from which it is derived. Common species in the ground flora are *Climacium dendroides*, *Acrocladium cuspidatum*, *Mnium punctatum*, *Mnium seligeri*, and locally *Acrocladium cordifolium*; the carr shares *A. giganteum* and *Mnium pseudopunctatum* with the open fen. The densest growth of bryophytes is seen on the stumps and bases of the willows. often covered with a thick carpet of *Hypnum cupressiforme*, *Brachythecium rutabulum*, *Drepanocladus uncinatus*, and other species. Higher up the stems lichens form the most conspicuous part of the epiphytic flora, though *Dicranoweisia cirrata* and (more locally) *Ptilidium pulcherrimum* are scattered through the carr.

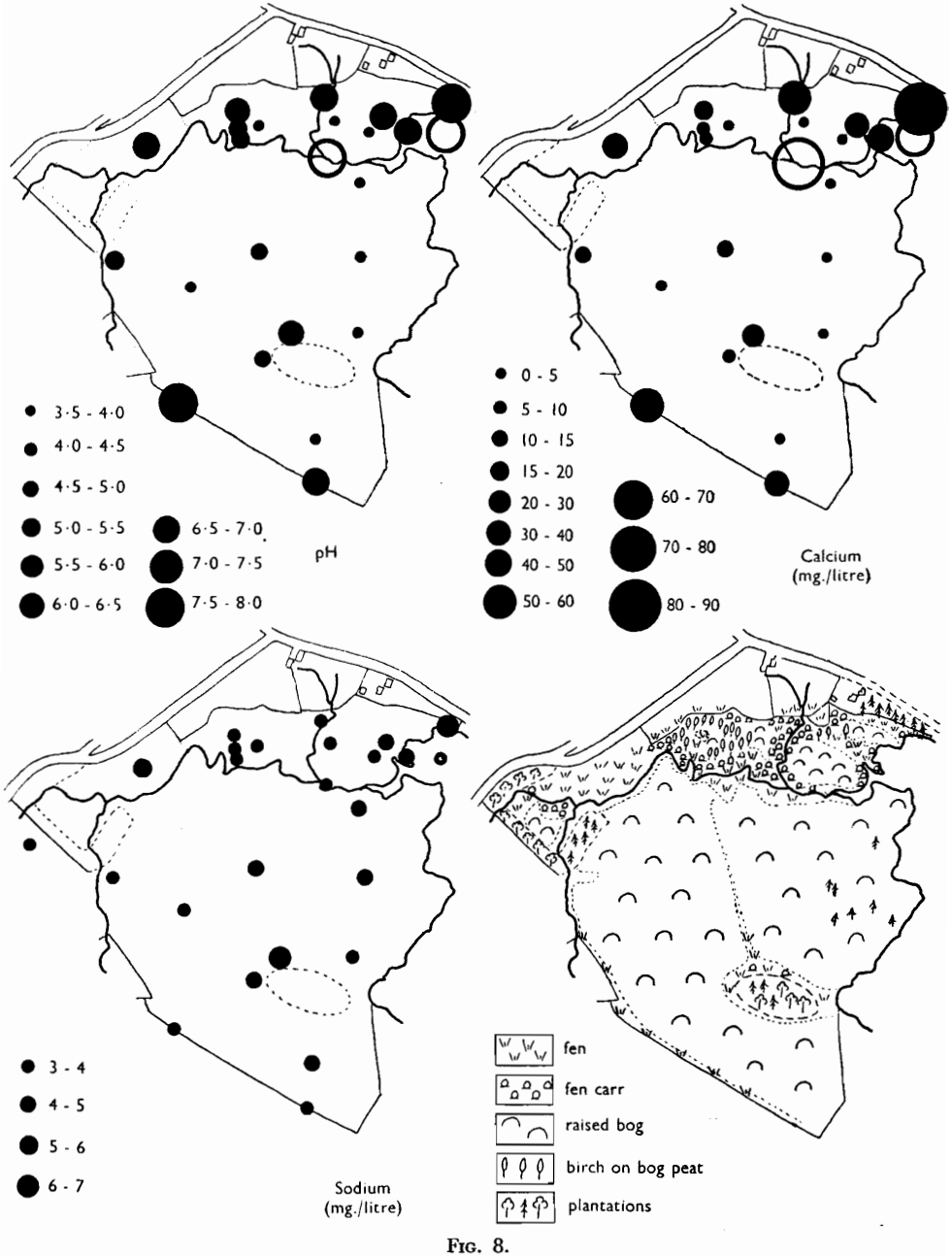

FIG. 8.

The distribution of pH, calcium, and sodium in surface water on the Tarn Moss. Notice the correspondence of fen areas with high values of pH and calcium concentration round the margins of the Moss, and the uniformly low values in the raised bog areas. Sodium, probably brought in largely by rain, is much more evenly distributed than calcium and pH. Open circles represent samples from the inflow stream and Tarn.

Of the Sphagna, apparently none is confined to the Tarn Moss itself. Species common on the Moss, but occurring also in the more acid patches of the North Fen are *S. papillosum*, *S. rubellum*, and (in pools) *S. cuspidatum*. *S. magellanicum* grows in similar habits to *S. papillosum* but is much rarer. *S. recurvum** probably needs a rather higher base-status, and occurs mainly in ditches and peat cuttings on the Moss, and especially the more acid parts of the fen; *S. plumulosum* is another rather base-demanding species forming hummocks in somewhat similar situations. Of the remaining species, *S. fimbriatum* is rather more tolerant of calcareous water than the last two, and grows both in the open fen and under a tree canopy. *S. squarrosum* and the related *S. teres* are particularly characteristic of the transitional areas between rich and poor fen, where they often grow with *Acrocladium stramineum*. Undoubtedly the most tolerant of calcareous water of all the Sphagna is *S. contortum*, scattered here and there forming low carpets among characteristic rich fen species.

The "mires" on calcareous drift to the east of the Tarn and round the upper reaches of the Gordale Beck, of which Great Close Mire is the largest and best known, deserve at least a passing mention. They are perhaps best called "spring fens". Similar communities occur in Westmorland (Holdgate, 1955) and in upper Teesdale (see Pigott, 1956). There is little or no development of peat, but the ground is kept more or less permanently wet by a continual seepage or trickle of water. Generally these mires are gently sloping, flattish areas, dotted with small hummocks. The really characteristic bryophyte of the wet ground between the hummocks is *Cratoneuron commutatum* var. *falcatum*; but *Scorpidium scorpioides* and *Drepanocladus revolvens* are also common. Many of the hummocks are small residual hummocks of drift, and the larger ones are capped by fragments of damp grassland which may show obvious results of leaching. Very locally, substantial tufa hummocks have grown up, perhaps around the sites of active springs. The sides and bases of both the drift hummocks and the tufa hummocks possess an interesting bryophyte flora, including *Riccardia pinguis*, *Gymnostomum aeruginosum*, *Fissidens adianthoides*, *Philonotis calcarea*, *Preissia quadrata*, *Solenostoma* spp., *Leiocolea bantriensis*; and, more rarely, *Moerckia flotowiana* and *Amblyodon dealbatus*.

A number of species occur round Malham Tarn which are scarce in the country as a whole, and grow only in widely scattered and isolated localities, e.g. *Camptothecium nitens* (map in Pigott, 1960), *Cinclidium stygium* (Fig. 9), *Amblyodon dealbatus* (Fig. 10), and *Rhytidium rugosum* (map in Pigott, 1956). *Catoscopium nigritum* and *Helodium blandowii* which occurred near the Tarn in the past are in the same category. On various grounds it is probable that at least some of these species are relics from late-glacial and early post-glacial times. Together with the common fen and limestone grassland species, these plants must have been very much more widespread before the spread of forest and bog began to restrict open calcareous habitats to progressively smaller and smaller areas (Pigott and Walters, 1954). *Camptothecium nitens* is a very common plant in fens in northern Scandinavia at the present day, and is often abundant in

* *S. recurvum* often has the leaves distinctly five-ranked on the branches, and may simulate *S. pulchrum*, which has much broader-pointed leaves, longer and thicker branches, and a darker stem. *S. pulchrum* is a much rarer plant in Britain, common in the regeneration complex of actively growing raised bogs, but very local elsewhere.

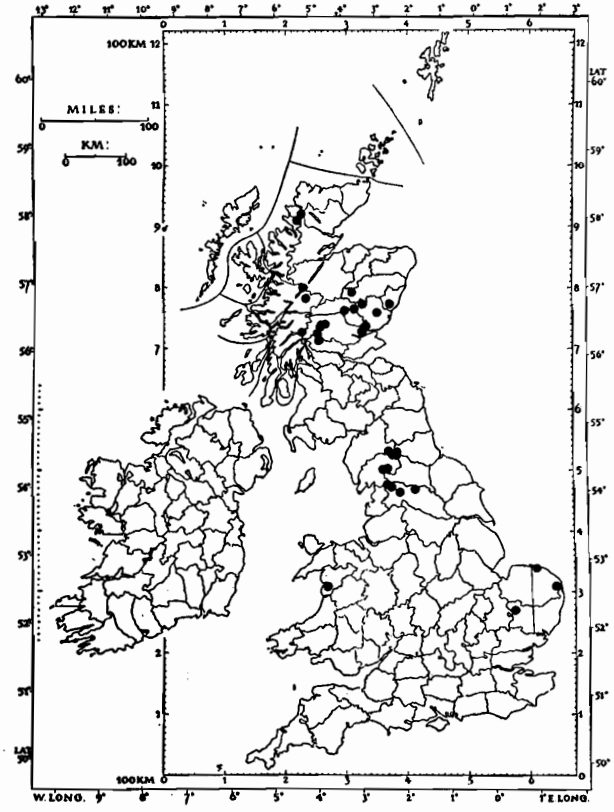

FIG. 9.
The distribution of *Cinclidium stygium* in the British Isles.

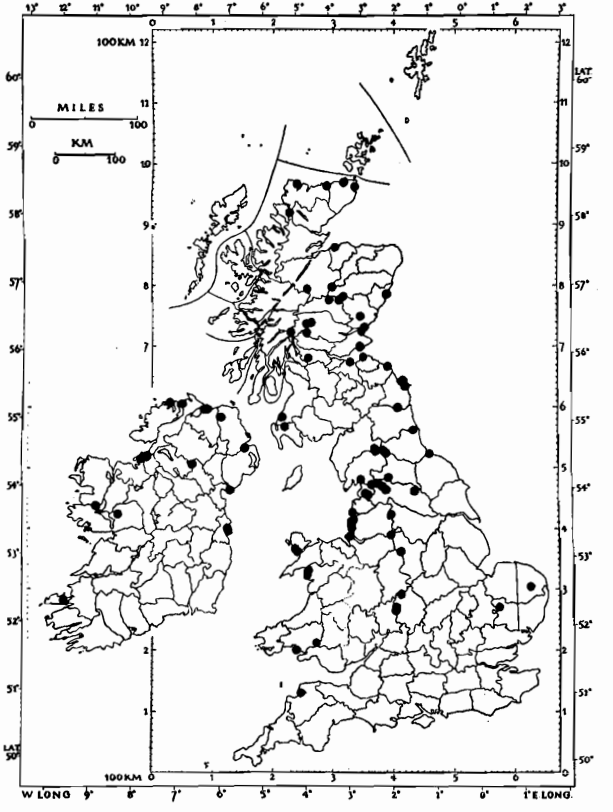

FIG. 10.
The distribution of *Amblyodon dealbatus* in the British Isles. (Recorded also from v.c. 87 (S.Perth), and 94 (Banff).)

post-glacial deposits in Britain. Its remains occur in quantity with those of *Paludella squarrosa* in an interesting layer of peat, of early Atlantic age, in the Tarn Moss near Spiggot Hill. At the present day it survives in rather small quantities in the damp fields on the northern fringes of the North Fen and elsewhere. *Paludella* grows commonly with *Camptothecium nitens* in Scandinavia; but in this country it survived into recent times in only a few localities, and it is probably now extinct in Britain.

It is not easy to distinguish distributions determined by subtle ecological preferences at the present day from those shaped by limitation in the past: in fact any actual distribution is the result of the interaction of the two. Probably some of these striking disjunct distributions largely reflect early post-glacial fragmentation of once more continuous areas: *Rhytidium rugosum* (which has been found in fruit only twice) may be an example of this kind. Others may reflect chiefly present-day ecological preferences of the species concerned: this may be true of *Amblyodon dealbatus*, which is an annual plant and thus fruits freely every year.

(6) *Acid rocks*

Calcareous habitats have been dealt with first, and dealt with at some length, because they dominate both the landscape and the nature of the flora round Malham Tarn. A good many common calcifuge species occur in acid grassland and moorland on leached soils over limestone, and there are also more extensive and characteristic habitats for calcifuge species.

The most important of the acid rocks in the district is the Millstone Grit, which caps the higher summits—Ingleborough, Pen-y-Ghent, Fountains Fell, and the other hills to the north and east—and also covers wide stretches of country south of the Craven faults. Much of its outcrop is occupied by poor grassland and blanket bog. The crags and screes bear a rather poor flora, in which *Dicranum scoparium*, *Polytrichum* spp., *Rhacomitrium* spp., *Barbilophozia floerkii*, and *Mylia taylori* are conspicuous. This is the main habitat of *Andreaea rupestris* and *A. rothii* in Craven; both are rather scarce, though *A. rothii* is the more frequent. Though the Grit is inherently a poor rock, the poverty of the flora must be at least partly due to pollution. Springs on the Grit caps of the hills and on acid drift lower down are marked by carpets of *Philonotis fontana*, *Drepanocladus exannulatus*, and locally *Dicranella squarrosa*, along with *Callitriche* and *Chrysosplenium oppositifolium*.

The woods on the Grit near Bolton Abbey possess quite a good acid woodland flora, of rather surprisingly Atlantic character. *Dicranum majus*, *D. fuscescens*, and *Hookeria lucens* are frequent. The rock outcrops bear some interesting species, including *Bazzania trilobata*, *Barbilophozia attenuata*, *Harpanthus scutatus*, *Orthodontium lineare*, and the rare native *O. gracile*.

The Yoredale shales and grits and the Silurian outcrop are largely covered by drift, and in fact their most important ecological effect is probably to be sought in their contribution to the drift. Here and there Silurian rocks are exposed, especially above Stainforth in Ribblesdale. Perhaps their chief bryological peculiarity is the frequency of the small acrocarpous moss *Leptodontium flexifolium*. The Ordovician and Ingletonian (probably Pre-Cambrian) rocks

at Ingleton are bryologically more interesting, because large parts of the Ingleton Glens are cut into them. They bear some areas of well-developed acid woodland; the luxuriant growth of bryophytes (e.g. *Hyocomium flagellare*, *Scapania undulata*, *Heterocladium heteropterum*, *Amphidium mougeotii*) on the dripping slate sides of the glens, and the *Rhacomitrium* spp., *Campylopus atrovirens*, and *Bryum alpinum* on the more open rock faces, remind the bryologist of the much more extensive exposures of acid rocks in the Lake District, not many miles to the north-west.

(7) *Blanket bog*

Blanket bog on deep peat is one of the most characteristic vegetation types of the higher parts of the Pennines. Given a sufficiently heavy rainfall (Pearsall (1950, p. 153) puts the lower limit in the Pennines at about 55 in. a year), *Sphagnum* bog can maintain itself on any flat or gently sloping surface, and the resulting layer of peat covers the landscape like a blanket. Blanket bog is for the most part ombrogenous like raised bog, and has a generally similar flora, though the bog round Malham has suffered badly from burning and grazing. The most important Sphagna are generally *S. nemoreum** and *S. papillosum*, sometimes with *S. recurvum* in flushes and hollows. The blanket peat round Malham Tarn is seldom more than six or eight feet deep: much greater thicknesses are found in the Peak District and in the bogs surrounding upper Teesdale. But, as almost everywhere in the Pennines, the blanket is eroding extensively to produce dissected masses of peat haggs. In places the peat has

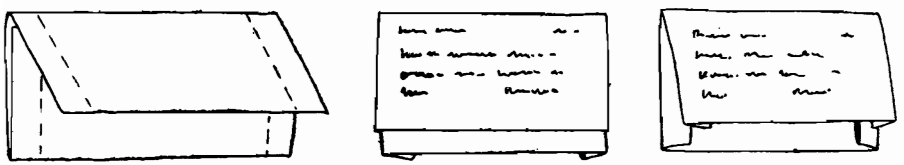

FIG. 11.
Folding two patterns of moss packets.

been stripped off exposing the Grit or drift underneath. *Campylopus flexuosus* and *Drepanocladus fluitans* are often common in this moribund blanket bog where erosion is not too active, the former on bare peat or Grit debris and the latter in shallow pools and seepages. Various causes have been suggested for erosion, including cutting and burning of the bog, industrial pollution, and climatic change. It may be that a phase of erosion is part of a natural cycle of blanket bog development (Pearsall, 1956), and that this has simply been triggered off over a wide area by outside factors.

The foregoing pages give only a brief outline of some of the most striking features of the Malham bryophyte flora: perhaps their most serious omission is any indication of how much still remains to be found out about the mosses

* *S. nemoreum* and *S. rubellum* are closely related: their taxonomy and habitat preferences need further study.

and liverworts round the Tarn. Several local taxonomic problems have been mentioned already. There is a fascinating field for study in the detailed distribution of bryophytes in many habitats, for instance the limestone cliffs and pavements, the streams, the mires, or the fen carr. Much work is needed on the factors limiting the distributions of bryophytes. For instance, can the distributions of the northern and southern species at Malham be related to the temperature, insolation, or humidity of their habitats, or to other factors? Which chemical factors determine the distributions of the bog and fen species? Some problems of this kind have been hinted at on p. 78. Systematic study of single species or of bryophyte communities would both be rewarding; and there are many more general problems of bryophyte ecology for which Malham Tarn provides abundant material.

ACKNOWLEDGEMENTS

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With a few minor exceptions nomenclature of bryophytes in this paper follows Jones (1958) and Richards and Wallace (1950). The most important difference is in the *Plagiothecium denticulatum-P. silvaticum* group (Greene, 1957), which is now generally considered to consist of about eight closely related species, in place of the two variable and rather unsatisfactory species recognized by Dixon and the *Annotated List. Plagiothecium succulentum* is by far the commonest member of the group around Malham Tarn.

APPENDIX

A. Collecting.

The bryologist is fortunate in that his plants can be collected at any time of year, and that mosses and liverworts are exceptionally easily and satisfactorily preserved. Ideally, specimens should be collected into newspaper packets, on which habitat details can be written in the field (pages of the *Radio Times* make excellent packets); old envelopes will serve as long as they do not get wet. Small tins or plastic bags are valuable for collecting from waterfalls and bogs, and in wet weather. A vasculum may be useful for holding packets and bags, but as a receptacle for a miscellaneous accumulation of loose bryophytes it should be scrupulously avoided.

By far the most satisfactory way to keep a collection of mosses and liverworts is simply to dry them and keep them in paper packets. The mosses in their temporary newspaper packets should be allowed to dry out thoroughly as soon as possible; if kept damp for any length of time they may become mouldy. They can be dried under *light* pressure in a plant press, which often improves the appearance of the specimens and makes them take up less space, but this is not essential. To examine a specimen later it can be soaked out in water, when most species

regain their fresh condition in a minute or two; a trace of detergent in the water speeds the process, because it helps to wet the waxy cuticles.

A fairly firm paper should be used for the final packets. If these are all made of one standard size they can be kept conveniently in shoe boxes or card-index drawers (small plants can be put in a small packet of thin paper or cellophane inside the larger packet); or, if preferred, they can be stuck to herbarium sheets. A sheet of quarto (10 in. × 8 in.) paper, folded as shown in Fig. 11, gives a convenient packet roughly the size of a postcard. Labelling deserves due care. The information on the packet should include the name of the species, whether it is fruiting or shows perianths or male or female shoots, the substratum and other details of the habitat, locality (preferably with National Grid reference), date, collector, and determiner. Full notes on the habitat are often very valuable.

B. Species lists

The following lists are intended to indicate the kind of bryophyte flora to be found in a number of habitats in the Malham Tarn district. They are probably fairly complete for the small areas which were listed, but are far from exhaustive for the habitats as a whole. The frequency symbols refer to the areas examined (a=abundant, f=frequent, o=occasional, r=rare).

(i) LIMESTONE WOODLAND. Colt Park Wood (c. SD/775773). Ash, with some birch, on limestone pavement. c. 50 sq. m. A habitat which owes its richness in bryophytes, in part at least, to the great diversity of micro-habitat. The calcifuge species are growing on small patches of leached soil or humus on the clints, and on tree bases. No frequencies have been given for the species growing on the trunks and bases of the few trees in the sample.

Acrocladium cuspidatum	f	Isothecium myurum	r
Barbula cylindrica	o	Mnium cuspidatum	o
B. recurvirostris	f	M. hornum	r
Brachythecium glareosum	r	M. marginatum	r
B. populeum	r	M. punctatum	f
B. rutabulum	f	M. undulatum	f
Bryum capillare	f	Plagiothecium silvaticum	o
Camptothecium sericeum	r	P. succulentum	f
Campylopus fragilis	(trees)	P. undulatum	r
Climacium dendroides	o	Polytrichum formosum	r
Ctenidium molluscum	a	Rhytidiadelphus squarrosus	o
Dicranum majus	r	Seligeria doniana	o
D. scoparium	o	Tetraphis pellucida	(trees)
Ditrichum flexicaule	r	Thamnium alopecurum	a
Encalypta streptocarpa	r	Thuidium delicatulum	a
Eurhynchium confertum	o	T. tamariscinum	f
E. murale	o	Tortella tortuosa	a
E. striatum	f		
Fissidens cristatus	f	Diplophyllum albicans	(trees)
F. pusillus	f	Lejeunea cavifolia	r
Grimmia apocarpa	a	Lophocolea bidentata	f
Hylocomium brevirostre	r	Lophozia ventricosa	(trees)
H. splendens	r	Metzgeria pubescens	o
Hypnum cupressiforme	(trees)	Plagiochila asplenioides	f
H. cupressiforme var. lacunosum	a	P. asplenioides var. major	o
Isopterygium depressum	r	Scapania aspera	f
Isothecium myosuroides	(trees)		

(ii) LIMESTONE GRASSLAND. Two small samples, probably both showing some surface leaching.

(a) West of Great Close Hill (SD/899670). 1 sq. m. *Festuca ovina, Sesleria varia, Sieglingia decumbens, Helictotrichon pratense* etc.

Acrocladium cuspidatum	r	Rhacomitrium lanuginosum	r
Dicranum scoparium	o	Weissia sp.	r
Fissidens cristatus	r		
Hypnum cupressiforme	r	Plagiochila asplenioides	r

(b) Bastow Wood, Grassington (SD/990656) 1 sq. m. *Festuca ovina, Sesleria varia, Carex flacca,* etc.

Dicranum scoparium	o	Pseudoscleropodium purum	r
Hylocomium splendens	f	Rhytidiadelphus squarrosus	a
Hypnum cupressiforme	o	Thuidium tamariscinum	o
Pleurozium schreberi	o		

(iii) EXPOSED LIMESTONE CLIFF. Vertical Yoredale limestone cliff, facing due west, at c. 1,950 ft. on Pen-y-Ghent (SD/836732). c. 10 sq. m. *Festuca ovina, Sesleria varia, Saxifraga oppositifolia,* etc.

Barbula recurvirostris	o	Mnium marginatum	r
Bryum capillare	o	Neckera complanata	r
Camptothecium sericeum	r	Pseudoleskea catenulata	f
Cirriphyllum crassinervium	r	Tortella tortuosa	f
Ctenidium molluscum	f		
Distichium capillaceum	r	Lejeunea cavifolia	r
Encalypta streptocarpa	r	Plagiochila asplenioides	r
Encalypta cf. ciliata	r	Porella platyphylla	o
Fissidens cristatus	f	Reboulia hemispherica	o
Grimmia apocarpa	f	Scapania aspera	r
Gymnostomum aeruginosum	f		

(iv) SHELTERED LIMESTONE OUTCROP. Side of Penyghent Gill (SD/859734). Low north-west-facing cliff by stream, at c. 1,250 ft., on Great Scar Limestone. c. 10 sq. m.

Amblystegiella sprucei	r	Orthothecium intricatum	f
Barbula recurvirostris	f	Plagiobryum zierii	o
Campylium protensum	o	Plagiopus oederi	f
Ctenidium molluscum	a	Seligeria pusilla	r
Encalypta streptocarpa	o	Tortella tortuosa	f
Fissidens cristatus	f		
Grimmia apocarpa	r	Cololejeunea calcarea	f
Gymnostom aeruginosum	o	Leiocolea muelleri	f
Mnium marginatum	o	Preissia quadrata	o
M. orthorrhynchum	f	Solenostoma triste	f
Neckera crispa	f		

(v) LIMESTONE DRY-STONE WALL. By road west of Tarn House (SD/881671). A rather sheltered wall facing north-west, partly shaded by the plantation behind. c. 20 sq. m.

Barbula cylindrica	o	Grimmia apocarpa	f
B. recurvirostris	o	Hypnum cupressiforme	a
Brachythecium populeum	r	Neckera complanata	f
B. rutabulum	r	N. crispa	a
Bryum capillare	f	Thamnium alopecurum	o
Camptothecium lutescens	f	Tortula ruralis	o
C. sericeum	a		
Cirriphyllum piliferum	r	Barbilophozia barbata	f
Climacium dendroides	r	Cephaloziella sp.	o
Ctenidium molluscum	a	Plagiochila asplenioides	o
Ditrichum flexicaule	f	Porella platyphylla	o
Encalypta streptocarpa	o	Scapania aspera	r
Eurhynchium striatum	r		

(vi) CALCAREOUS STREAM. Boulders in Crooke Gill at c. 1,450 ft. (SD/847730). Just below confluence with tributary stream issuing from Yoredale limestone. c. 10 sq. m.

Brachythecium plumosum	Hygroamblystegium tenax
B. rivulare	Hygrohypnum luridum
Eurhynchium riparioides	Rhacomitrium aciculare
Fontinalis antipyretica	
Grimmia alpicola	Solenostoma cordifolium

(vii) RAISED BOG

(a) An area with a fair amount of *Sphagnum* cover south of Spiggot Hill (SD/887665). Rather wet, but on firm peat; conditions which favour such species as *Gymnocolea inflata* and *Lepidozia setacea*. c. 25 sq. m. *Eriophorum vaginatum*, *E. angustifolium*, *Scirpus cespitosus*, *Calluna*, *Narthecium ossifragum*. Surface water (Jan. 1960): pH 3·7, Ca 2·6 p.p.m., K 0·2 p.p.m., Na 4·8 p.p.m.

Campylopus flexuosus	f	Gymnocolea inflata	o
		Lepidozia setacea	r
Sphagnum papillosum	f	Lophozia ventricosa	a
S. plumulosum	o	Mylia anomala	a
S. rubellum	o	Odontoschisma sphagni	a

(b) Near the centre of the main dome of the Tarn Moss (SD/888668). An area which has probably suffered much burning and grazing in the past, dominated by *Eriophorum vaginatum*. c. 25 sq. m.

Campylopus flexuosus	f	Calypogeia muelleriana	a
Dicranum scoparium	f	Lophozia ventricosa	a
		Mylia anomala	o
Sphagnum rubellum	o	Odontoschisma sphagni	a

(viii) CALCAREOUS FEN. Spiggot Hill fen (SD/886667). A rather unusually rich patch, though very similar areas can be found in various parts of the North Fen. c. 50 sq. m. *Carex* spp., *Eriophorum angustifolium*, *Potentilla palustris* etc. Surface water (Jan. 1960): pH 6·3, Ca 26 p.p.m., K 0·1 p.p.m., Na 6·1 p.p.m. The *Sphagnum* cushions provide a more acid and drier microhabitat.

Acrocladium cuspidatum	a	Sphagnum contortum	r
A. giganteum	o	S. plumulosum	a
A. stramineum	r		
Aulacomnium palustre	o	Calypogeia fissa	r
Campylium stellatum	a	Chiloscyphus pallescens	o
Cinclidium stygium	o	Leiocolea bantriensis	o
Drepanocladus revolvens	a	Riccardia pinguis	f
Fissidens adianthoides	o	Scapania irrigua	r
Mnium pseudopunctatum	a		
Scorpidium scorpioides	o		

(ix) FEN CARR. Wet carr, mainly *Salix cinerea*, close to the north inflow stream (SD/887672). Surface water (Jan. 1960): pH 6·8, Ca 52 p.p.m., K 0·5 p.p.m., Na 3·6 p.p.m.

Acrocladium cordifolium	f	Mnium hornum	a
A. cuspidatum	f	M. punctatum	o
Amblystegium serpens	o	M. undulatum	r
Brachythecium rutabulum	a	Plagiothecium succulentum	o
Climacium dendroides	a	Tetraphis pellucida	o
Dicranoweisia cirrata	o		
Dicranum scoparium	o	Cephalozia bicuspidata	r
Drepanocladus uncinatus	a	Cephaloziella sp.	r
Eurhynchium praelongum	f	Conocephalum conicum	r
Hypnum cupressiforme	a	Lepidozia reptans	o
		Lophocolea cuspidata	f

(x) CALCAREOUS SPRING-FEN. Great Close Mire (SD/9066). A not untypical patch, though with an unusual concentration of the rare species which are thinly scattered over the area. Other parts of the mire vary in the direction of fen, with *Scorpidium scorpioides*, *Drepanocladus revolvens*, and *Acrocladium giganteum*. c. 25 sq. m. This list embraces a diversity of micro-habitats, including drift- and tufa-hummocks and their surrounding runnels. Surface water (Jan. 1960): pH 7·7, Ca 74 p.p.m., K 0·2 p.p.m., Na 3·0 p.p.m.

Acrocladium cuspidatum	f	Philonotis calcarea	o
Amblyodon dealbatus	r		
Bryum pallens	o	Cephaloziella hampeana	r
B.pseudotriquetrum	f	Leiocolea bantriensis	o
Cratoneuron commutatum var. falcatum	a	L. muelleri	o
C. filicinum	o	Moerckia flotowiana	r
Ctenidium molluscum	f	Preissia quadrata	f
Fissidens adianthoides	r	Riccardia pinguis	a
Gymnostomum aeruginosum	f	Solenostoma atrovirens var. sphaerocarpoidea	o
G. curvirostrum	o	S. triste	f
Mnium pseudopunctatum	r		

(xi) ACID WOODLAND. Damp woodland on Ingletonian slates, Twisleton Glen (SD/699737). c.50 sq. m. *Quercus petraea*, *Betula pendula*, *Sorbus aucuparia*.

Campylopus flexuosus	o	Sphagnum quinquefarium	o
Dicranum majus	a		
Hypnum cupressiforme var. ericetorum	r	Barbilophozia attenuata	(trees)
Isopterygium elegans	r	Bazzania trilobata	o
Leucobryum glaucum	o	Calypogeia muelleriana	r
Mnium hornum	o	Cephalozia bicuspidata	r
Plagiothecium undulatum	a	Diplophyllum albicans	f
Pleurozium schreberi	r	Lejeunea ulicina	(trees)
Tetraphis pellucida	f	Lepidozia reptans	a
		Lophozia incisa	r
		Scapania gracilis	o

(xii) BLANKET BOG. Grazed blanket bog on drift south of Pen-y-Ghent (SD/835722). c. 25 sq. m. 1,550 ft. *Eriophorum vaginatum*, *Juncus squarrosus*, etc.

Campylopus flexuosus	o	Sphagnum nemoreum	o
Dicranum scoparium	r	S. recurvum	r
Hypnum cupressiforme var. ericetorum	f	Barbilophozia floerkii	r
Plagiothecium undulatum	f	Lophozia ventricosa	r
Pleurozium schreberi	r	Ptilidium ciliare	o
Pohlia nutans	r		
Polytrichum commune	f		