# THE FERN GAZETTE

## VOLUME 12  PART 1  1979

### CONTENTS

#### MAIN ARTICLES

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Killarney Fern, <em>Trichomanes speciosum</em>, in Wales</td>
<td>1</td>
</tr>
<tr>
<td>Preliminary investigation of two south-west England populations of the <em>Asplenium adiantum-nigrum</em> aggregate and the addition of <em>A. cuneifolium</em> to the English flora</td>
<td>5</td>
</tr>
<tr>
<td>An ecological survey of the ferns of the Burren, Co. Clare, Eire</td>
<td>9</td>
</tr>
<tr>
<td>The association between pteridophytes and arthropods</td>
<td>29</td>
</tr>
<tr>
<td>The Philippine <em>Platycerium grande</em></td>
<td>47</td>
</tr>
<tr>
<td>A further chromosome count for <em>Christensenia</em> (Marattiales)</td>
<td>51</td>
</tr>
<tr>
<td>Peltate scales in <em>Saccoloma</em></td>
<td>53</td>
</tr>
</tbody>
</table>

#### SHORT NOTES

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A new name for a European <em>Dryopteris</em></td>
<td>56</td>
</tr>
<tr>
<td><em>Dryopteris</em> hybrids: a correction</td>
<td>56</td>
</tr>
<tr>
<td><em>Equisetum variegatum</em> new to Turkey</td>
<td>56</td>
</tr>
<tr>
<td><em>Equisetum x trachyodon</em> in western Scotland</td>
<td>57</td>
</tr>
<tr>
<td><em>Equisetum x trachyodon</em> in Cheshire, new to the English flora</td>
<td>59</td>
</tr>
<tr>
<td>A second British record for <em>Equisetum x font-queri</em> and its addition to the English flora</td>
<td>61</td>
</tr>
<tr>
<td>Observations on light response in <em>Marsilea crenata</em></td>
<td>62</td>
</tr>
</tbody>
</table>

#### REVIEWS

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The eightieth birthday of R.E. Holttum</td>
<td>28</td>
</tr>
<tr>
<td>Spores of Indian ferns</td>
<td>46</td>
</tr>
<tr>
<td>Ferns of the Ottawa district</td>
<td>46</td>
</tr>
<tr>
<td>Ferns of Florida — an illustrated manual and identification guide</td>
<td>46</td>
</tr>
<tr>
<td>Evolutionary patterns and processes in ferns</td>
<td>50</td>
</tr>
</tbody>
</table>

(THE FERN GAZETTE Volume 11 Part 6 was published 15th January 1979)
THE KILLARNEY FERN, TRICHOMANES SPECIOSUM, IN WALES

R.H. ROBERTS
51 Belmont Road, Bangor, Gwynedd.

ABSTRACT
The history of botanical knowledge of the Killarney Fern (Trichomanes speciosum Willd.) in Wales is discussed.

The first record of the Killarney Fern (Trichomanes speciosum Willd.) in Wales appeared in 1863 when A.M. Gibson drew attention to a note in a Norwich newspaper that the fern had been found in North Wales by J.F. Rowbotham of Manchester (Gibson, 1863).

Rowbotham also reported his discovery to Thomas Moore and his description of the habitat is worth repeating. "I found it", he wrote, "in a large hole formed by fallen rocks alongside a cascade of water; and admission to this hole, which is about five feet high by four feet wide, is obstructed after a depth of about three feet by this Fern falling from the rocks at the top and growing out of the sides in the form of a beautiful curtain, down which the water is constantly trickling" (Moore, 1863). He also added that the fronds were remarkably fine and abundant. The frond he sent to Moore had an overall length of nearly eighteen inches and was seven inches across at the widest part. A second frond in Rowbotham's possession had a total length of about twenty-two inches. Moore does not disclose the locality beyond stating that it was in a part of the Snowdon range.

The following year James Backhouse Jnr. sent specimens of this fern to the Botanical Society of Edinburgh. In the covering letter he stated that they had been found by him and his father, in 1863, "in a truly wild state, in Carnarvonshire," where, he added, the plant was remarkably luxuriant (Backhouse, 1864). His specimens both at Edinburgh and the British Museum (Natural History) are equal to the finest Irish specimens and it is probable that they were from the same locality as Rowbotham’s, although Backhouse did not refer to Rowbotham's discovery either then or subsequently.

Five years later Backhouse found the Killarney fern in Merioneth, v.-c. 48. His specimen in the British Museum is vaguely localised “Mountains of Merionethshire” and dated 1869. Rather uncharacteristically, this find was not published by Backhouse, but in his next letter to the Botanical Society of Edinburgh, in 1875, he announced that he had “collected Trichomanes radicans in a new station in North Wales in 1873” (Backhouse, 1876). Again he gives no locality — not even the name of the county — but it is probable that this was also in Merioneth, for Backhouse is stated to have seen the Killarney Fern in two widely separated localities in the county in 1874: one near Harlech and the other on Cader Idris, and it was flourishing at both of them twenty years later (Percival, 1894). It is almost certain that it was at one of these localities (near Harlech) that Backhouse showed the Killarney Fern to D.A. Jones, the well-known bryologist, who lived in Harlech (Jones, 1898), and to Mrs. Mary Richards of Dolgellau (Benoit & Richards, 1963). Although frequently visited, and no doubt too frequently collected, the fern survived in this site until 1968, but there is now no trace of it left (Dyce, 1975).

These Merioneth localities became known to a number of fern enthusiasts. Specimens were collected from one of them in 1889 and sent to the British Museum by William Robinson, of Weston-super-mare, who claimed to have known the Killarney
Fern there and in "other localities" (all unspecified) for about twenty years (Britten, 1894). D.A. Jones, who knew the county well, gives only two localities for the Killarney Fern in his manuscript 'Flora' and these are the same as those mentioned by Percival (1894). The statement that the Killarney Fern had "been found growing luxuriantly in some abundance in several places extending over several miles in Wales" (Lowe, 1876) seems to be somewhat exaggerated.

In 1887 the Killarney Fern was found independently in Caernarvonshire, v.-c. 49, by J. Lloyd Williams (1887), who was at the time a schoolmaster at the village of Garn Dolbenmaen, near Cricieth. However, he could not be certain that this was not the same locality as that in which the fern had been found previously, because that record had not been localised. Apart from describing the habitat as "a damp hole near the top of a range of mountains" and that it was not on any part of Snowdon, Williams gave no indication of the locality. In his autobiography written many years later he gives a fascinating account of how he found the fern and indicates that the locality was Moel Hebog, near Beddgelert (Williams, 1945). There are, however some curious inconsistencies in Williams's account. According to this the fern was completely removed about a month after he first found it, and even though he made several visits to the site from 1887 until 1893 (when he left the district), he could find no trace of it. Twenty-four years later he visited the place again and was surprised to find the Killarney Fern once more flourishing in its rocky recess. Williams ascribes its recovery to the spores left after the fern itself had been completely removed. However, J.E. Griffith, of Bangor, author of the 'Flora of Anglesey and Carnarvonshire' (1895), gathered a specimen of the Killarney Fern from this locality in 1891 (Hyde, Wade & Harrison, 1969). In his 'Flora', published a few years later, Griffith wrote, "I have seen this fern growing undoubtedly wild, in one place only. This was first found by Mr. J. Ll. Williams. I refrain from giving the locality as it is so rare."

One can only surmise that Williams showed the locality to Griffith, although the latter does not say so. But it seems that he passed through Garn Dolbenmaen, where Williams lived, on his way to Moel Hebog, for he published records of plants which he saw in both these places in August 1891 (Bennett, 1892). It seems that Williams was mistaken when he wrote that the Killarney Fern had been destroyed in his locality before the end of the year 1887. But he was in his late eighties when he wrote this account and perhaps relied too much on his recollection of the events of over fifty years before. However, there is nothing to indicate whether Williams's locality on Moel Hebog was the same as those found by Rowbotham and Backhouse. On the contrary, Rowbotham's description can hardly refer to the Moel Hebog habitat and strongly suggests a different place, possibly one of the two others in which the Killarney Fern was stated to occur in Caernarvonshire.

Professor J. Bretland Farmer (1948) claimed that he had known the Killarney Fern in the Cwm Glas area of Snowdon for over twenty years. Neither this locality nor another, which according to rumour is vaguely localised on the Carneddau, has ever been confirmed. Unfortunately, Farmer did not leave a voucher specimen, but it seems hardly credible that he could have mistaken any other fern for it. Nevertheless his record has remained unconfirmed for fifty years and is now regarded with a good deal of scepticism.

Even when it was first recorded in 1863 there were rumours that the Killarney Fern had been deliberately introduced into Caernarvonshire by a local guide, but Moore (1863) thought that the luxuriant and well-established appearance of the fern found by Rowbotham was not consistent with such a view. Trimen (1871), on the other hand, was of the opinion that there was "reason to suspect an intentional
introduction.” Britten (1879-81) also refers to these rumours, but goes on to make the intriguing statement that the Killarney Fern was already known in two localities in Caernarvonshire about thirty years before its discovery by Rowbotham. The discoverers, he adds, were satisfied that the fern was truly native, but had kept their knowledge to themselves.

Unfortunately there is more direct evidence that some planting did take place. In a tribute to the recently deceased Herbert Stansfield, E.H. Hawkins wrote: “I recall that some years ago he spent some time in North Wales, taking with him some plants of the Killarney Fern, which he planted in some wild and congenial places, with the hope that they may be found subsequently by fern hunters. This thoughtfulness was ever typical of him” (Hawkins, 1928). Herbert Stansfield was a nurseryman of the firm of F.W. and H. Stansfield of Sale, near Manchester, who specialised in British ferns and no doubt had access to Irish material of the Killarney Fern.

Stansfield was not the only one who tried to introduce the Killarney Fern into suitable places. Its occurrence in Westmorland (where it was gathered in the Rydal district about 1863), in the Isle of Arran, and in Argyll, were all suspected to be due to deliberate introductions (Moore, 1863), as it was in the only Cornish locality (Davey, 1909). Even in Ireland this fern was planted in many places in Killarney, around Glengarriff and on Valentia Island (Newman, 1844), though the purpose there was to try to preserve the fern from the depredations of collectors, which even then threatened to exterminate it in its original localities.

We shall probably never know where Stansfield made his introductions into North Wales, or indeed whether any of them were successful. His activities were too late to affect the early records, for he was only seven or eight years old in 1863, but they cast a shadow of doubt over all the Welsh localities of the Killarney Fern.

On the other hand Backhouse’s remarkably fine specimens from both Caernarvonshire and Merioneth give the impression of being from old, long-established colonies of the fern — an opinion already expressed by Moore (1863). Rowbotham’s description of the habitat, quoted above, is also very convincing and does not suggest an introduction. This impression is supported, as far as Merioneth is concerned, by William Robinson’s specimen (BM) gathered in 1889, and A.J. Crosfield’s two specimens (BM) gathered in 1902 and 1904, although all these Merioneth gatherings may well be from the same locality, possibly that in the Cader Idris area, now lost, or, if known, wisely kept secret.

The much smaller size of specimens (BM) gathered by T.J. Foggitt from “wet rocks near Harlech, Merioneth, 27 Sept. 1929,” suggests that they are from a different site. The largest of his two fronds is just under four inches long, including the stipe, and just over an inch wide. They are similar in size and shape to D.A. Jones’s specimens (NMW) gathered in 1905 “near Harlech,” and to a frond I was once shown which had been gathered from the well-known Merioneth locality where the fern now seems to be extinct.

There is still a good deal of mystery attached to the Killarney Fern in Wales. Its discovery as recently as 1961 in Cardiganshire, v.-c. 46, by A. Neville Jones was certainly remarkable, for the colony he found is a luxuriant one, and it is difficult to understood why it remained undiscovered for so long in a comparatively well-botanised area. Perhaps, after all, we can only echo the words of Scully (1916) when referring to the Valentia Island records: that the fern is both indigenous and introduced in different localities in Wales.

However, this should not affect our attitude to its conservation. Its disappearance from its only known Merioneth locality within the last ten years is most
regrettable. Already the Caernarvonshire locality, rediscovered by G.M. Hughes in 1967, has become too well known, as indeed has the Cardiganshire one. Fortunately the Killarney Fern is now protected by the *Conservation of Wild Creatures and Wild Plants Act 1975*, but it is also to be hoped that a new attitude will prevail among botanists who visit the sites of this most attractive fern and that they will be content to look at and admire it without removing a single frond.

ACKNOWLEDGEMENTS

I am grateful to Dr. C.N. Page for his assistance in many ways. Thanks are also due to the Keeper of Botany, National Museum of Wales, the Regius Keeper, Royal Botanic Gardens, Edinburgh, the Keeper of Botany, British Museum (Natural History), Mr. J.W. Dyce, Mr. A.C. Jermy and Mr. M. Morris for their help with many of the references.

REFERENCES


PRELIMINARY INVESTIGATION OF TWO SOUTH-WEST ENGLAND POPULATIONS OF THE ASPLENIUM ADIANTUM-NIGRUM AGGREGATE AND THE ADDITION OF A. CUNEIFOLIUM TO THE ENGLISH FLORA

C.N. PAGE & FRANCES M. BENNELL
Royal Botanic Garden, Edinburgh.

ABSTRACT

Examination of the plants of the Asplenium adiantum-nigrum aggregate from south Devon and west Cornwall questions the status of records of A. onopteris, but confirms A. cuneifolium as new to the English flora.

Asplenium onopteris, A. adiantum-nigrum and A. cuneifolium form a trio of inter-related species in the British Isles. All three are morphologically variable. Because A. adiantum-nigrum is an allotetraploid containing the chromosomes of the other two species (Shivas, 1969), its variation may be particularly wide, approaching and perhaps overlapping that of both its parents. Clearly, without the benefit of a chromosome count, there can be difficulty in separating all specimens in areas where more than one may be suspected to be present. The discovery that A. cuneifolium can also exist as a tetraploid species in Britain (Roberts & Stirling, 1974; Sleep et al, 1978) and elsewhere (Deschatres et al, 1978) further complicates the problem of its inter-relationships and taxonomic separation.

The finding of populations of this plant group in the Bovey Tracey area of South Devon during the British Pteridological Society’s field week in the summer of 1978, which appeared to contain plants of clear A. adiantum-nigrum and ones of extremely attenuate form suggesting the presence of A. onopteris stimulated the present investigation to try to distinguish and identify them. The problem was further highlighted by also finding plants in the Lizard area of Cornwall which resembled A. cuneifolium, apparently linking through plants of rather intermediate appearance with plants of A. adiantum-nigrum. The following investigation was initiated to try to resolve the taxonomic problem arising.

Bovey Tracey Population

These plants occurred as widely-scattered specimens on lightly-shaded earth and rock hedgebanks in the neighbourhood of the village of Bovey Tracey in South Devon. They are very common locally in such habitats, but extraordinarily variable in appearance.

Examination showed them to be mostly large-fronded plants. The cutting of the blade of many suggested they were typical A. adiantum-nigrum, but many more showed varying degrees of attenuation, more finely cut and upswept pinna form, through to at least one individual which had such extremely finely cut and attenuate fronds that it appeared very like A. onopteris (Page 11370).

Study of the spores showed, however, a surprising uniformity. No specimens showed any significant degree of spore abortion. Compared with those of typical A. adiantum-nigrum spores were very slightly paler in colour, and showed an overall greater size range, with those of the most A. onopteris-like morphology proving only slightly smaller (31·57 µ) than those of plants of more A. adiantum-nigrum-like morphology (37·60 µ). By contrast, plants of known A. onopteris from Ireland and the Canary Islands, proved to have distinctly smaller spores (25·43 µ) than those of any of the Bovey Tracey plants. The spores thus present a slightly inter-grading picture
FIGURE 1. Histogram of spore size range (µ) in samples of known Asplenium onopteris from Lough Hyne, Co. Cork, Ireland (dotted line — Phillips s.n., E) and La Gomera, Canary Islands (solid line — Page 413, E), showing their relatively small size and similar size range. (Sample size = 50 spores measured from each specimen, mounted in 100% glycerine, and throughout).

FIGURE 2. Histogram of spore size range (µ) in samples of plants from the Bovey Tracey population, to compare those from one of most A. adiantum-nigrum-like morphology (dotted line, Page 11407, E) with those from one with most finely-divided and attenuate frond-form (solid line — Page 11370, E). The larger spore size range of each distinguishes them clearly from those of A. onopteris in fig. 1, but those from the fine fronds seem consistently slightly smaller than neighbouring good A. adiantum-nigrum.

FIGURE 3. Histogram of spore-size (µ) to compare that for plants of A. cuneifolium from the block-scree habitat in the Lizard (solid line — Page 11242, E) with those of a population of known A. adiantum-nigrum from a typical inland west Cornwall lanebank habitat at Stennack (dotted line — Page 11165, E). Those of A. cuneifolium are very slightly smaller, and in this compare favourably with the situation in Scottish material found by Roberts & Stirling (1974), suggesting that the Cornish A. cuneifolium is probably tetraploid.
corresponding with the overall morphology of the plants, but do not suggest, from their size, that *A. onopteris* is present in this south Devon population, at least as this species is recognised in Ireland and the Canary Islands.

**Kynance Population**

This consists of a large population of plants of the *Asplenium adiantum-nigrum* group in the region of Kynance Cove on the west side of the Lizard Peninsula of West Cornwall. The area is of particular interest not only in being one of the most southerly and climatically oceanic points in the British Isles, but also in containing extensive outcrops of ultrabasic serpentine rock. A preliminary collection of fronds from the area was made by C. Ferreira during the winter of 1977-78, and a more extensive investigation of specimens from different adjacent habitats after examination of the Ferreira material made by one of us (C.N.P.) in the summer of 1978.

Plants were examined in three distinct habitats:

(a) in a large, natural, block-scree slope descending steeply from the cliff tops directly into the sea to the west of Kynance Cove

(b) amongst small outcropping rock bluffs amongst the plateau-like downs running back from the tops of Kynance Cliffs to the north of Kynance Cove

(c) in a recent man-made scree amongst disused soapstone quarry workings about one mile north-west of Kynance Cove.

Plants from the whole area gave a strong impression of distinctness from those of inland stations for *A. adiantum-nigrum* in West Cornwall. Very many from habitats (b) and (c) differed from *A. adiantum-nigrum* in having fronds with fan-shaped segments, whilst in habitat (a), the plants appeared totally distinctive from *A. adiantum-nigrum* and to indeed be *A. cuneifolium*.

Examination of frond samples from habitat (a) showed them to differ significantly from *A. adiantum-nigrum* in the following features:

1. Overall fronds much less finely cut, with a broader triangular outline and coarser segments varying from slightly more to much more fan-shaped.

2. Ultimate serration of the frond margins less acute (but rarely actually obtuse).

3. Stipe much shorter, usually less than $\frac{1}{2}$ to $\frac{1}{4}$ the length of the blade, sometimes less.

4. The deep red-brown colouration more restricted to the lower part of the stipe, extending only rarely as high as the lower pinnæ on the underside and rarely as much as half way up the stipe on the upper side, the remainder of the stipe and the whole of the rachis remaining green.

5. The lowermost pinnæ pair much more broadly triangular and held more perpendicularly to the rachis, and not at all swept upwards on the frond.

6. A much stronger tendency for the veins on the frond undersides near to the margins to show as distinct whitish radiating lines (especially in the lowermost pinna pair).

Plants from scattered rock outcrops (habitat 'b') on the top of the Lizard Downs proved much more variable in morphology, although many of them were stunted by varying degrees of exposure. Nevertheless, some approached *A. cuneifolium* in their morphology, whilst others appeared more close to *A. adiantum-nigrum*, with others apparently linking between these extremes. Examination of spores, however, showed none to be wholly abortive, as far as could be judged by light microscope examination, although many contained a proportion (estimated at up to 10%) which were sufficiently mis-shapen to regard as probably abortive.
Plants from the disused soapstone quarry (habitat ‘c’) proved equally confusing. The habitat was a man-made rough loose boulder slope. *Asplenium* plants were present mainly in sheltered pockets between the boulders, and consequently were rather larger than those on the tops of the downs. They were, however, of equally variable appearance, a few seeming more like *A. adiantum-nigrum*, but most more clearly *A. cuneifolium*, but linked by apparent morphological intermediates. As with those on the Downs, spores appeared mostly good but with up to about 10% mis-shapen ones in many of the plants. One well grown individual which in morphology showed a particularly intermediate appearance, probably had a higher number of abortive spores than this.

The morphology of the fronds in all of the serpentine rock habitats of the Lizard thus suggests that these are all far from typical populations of *A. adiantum-nigrum*, and that each of these habitats (‘a’–‘c’) thus contains at least some plants of *A. cuneifolium*, thus adding this species as new to the English flora. These *A. cuneifolium* plants match very closely indeed with those from the Scottish serpentine localities, and provide further evidence in support of the view (A. McG Stirling, personal communication) that these British plants are morphologically distinctive from at least those of central Europe. The close similarity of the spore size to that of the Scottish ones, suggests that these Cornwall plants are likely to prove tetraploid (although this needs cytological confirmation).

In these Lizard habitats, *A. cuneifolium* appears to be the dominant fern in the natural block scree slope, from where it spreads on to the outcropping boulders of the Downs and into the man-made serpentine scree of the soapstone quarry.

Some questions remain about the identity of the plants of most *A. adiantum-nigrum*-like morphology in the latter two habitats, but the lack of obvious hybrids (at least as indicated through lack of total spore abortion) and the complete range of forms intermediate in overall morphology, suggests too that these are probably extreme forms of *A. cuneifolium*, underlining the possibility that these can approach *A. adiantum-nigrum* very closely indeed.

**ACKNOWLEDGEMENTS**

It is a pleasure to acknowledge the guidance and stimulating discussion in the field of Messrs. J.W. Dyce and M.H. Rickard in south Devon and Miss Rosaline Murphy and Major E.W.M. Magor in West Cornwall.

**REFERENCES**


AN ECOLOGICAL SURVEY OF THE FERNS OF THE BURREN, CO. CLARE, EIRE

A. WILLMOT
Derby Lonsdale College of Higher Education, Derby.

ABSTRACT
A systematic list of the ferns of the Burren (area includes parts of Co. Clare and South East Galway v.c. H9 and H15) is given based mainly on records made in 1978 by the author. This includes notes on the distribution, abundance and habitats of the taxa. The list includes 35 species and 5 hybrids as recently recorded. The records for Polypodium x mantoniae and Dryopteris x tavellii are first county records for Co. Clare. The distribution of the commoner 24 species is shown by maps. Species lists are given for the more interesting or characteristic fern habitats. The phytogeographical affinity of the flora is discussed on a European basis and is shown to be basically southern with a lesser western (atlantic) affinity.

INTRODUCTION
The Burren is the most impressive area of karst scenery in the British Isles. It is situated in the middle of the western coast of Eire, on the southern side of Galway Bay. The bed-rock over most of the area is Carboniferous Limestone, which has been stripped bare of soil by past glaciations. From a distance the general aspect of the area therefore is of a bare, grey, uninviting rock but closer examination reveals that this area is botanically one of the most interesting and beautiful of western Europe.

FIGURE 1. The area referred to as the Burren, showing the four topographic regions. The dashed line in the north east corner separates Co. Clare (v.c. H9) to the south west from South East Galway (v.c. H15) to the north east.
Historically the name Burren, which means great rock, referred to the Barony of Burren. The Barony occupied the north of Co. Clare roughly down to a line from Carron through Kilfenora and Lisdoonvarna to Poulsallagh. Botanically the name has a wider sense and includes surrounding areas. It is used here for a large area of northern County Clare (v.-c. H9) and a smaller, adjacent area of South East Galway (v.-c. H15). This is an area approximately 28km. north/south and 40km. east/west (fig. 1). This is slightly less than the area of Ivimey-Cook & Proctor (1966a) in their paper on the plant communities of the Burren, as it excludes a small area to the east around Gort. A bibliography of the area is given in Malloch (1976).

Geologically the area consists of pure Carboniferous Limestone with only a few bands of chert and shale, overlain in the south-east corner by shales and sandstones of the same age. There is little glacial drift and that which there is bears a close relationship to the composition of the rocks it overlies (Finch 1971). Sweeting (1955) describes the topography of the area, which consists of four distinct regions in County Clare (fig. 1). Three of these form a block of high ground to the west of the fourth lower-lying region (Finch 1971). The three upland regions are the Burren Hills, the Sandstone-shale Uplands and the Recently Glaciated Shale Lands, the fourth region is the Burren Lowlands.

The Burren Hills occupy the north-west of the area. They are an elevated block (300m) of horizontally-bedded limestone, dissected by two, broad, dry valleys running south from Ballyvaghan and Bealclugga. To the east it forms a bold escarpment to the Burren Lowlands from Abbey Hill to Killinaboy and to the south it merges into the Sandstone-shale Uplands. There is a great deal of bare limestone, with soil in the valleys and depressions known locally as dolines. The hill sides are steep, showing the vertical edges of the limestone strata, with flat areas of limestone pavement between. The water table is well below the surface except for the deeper dolines. The only permanent river is the Cahir, which rises north-east of Slieve Elva and runs north-west to the sea at Fanore. The river only exists because the floor of its valley is choked with boulder clay.

The Sandstone-shale Uplands form an elevated block, which drops in altitude from that of the Burren Hills in the north to around 100m in the south. The sub-soil is covered in poorly-drained, acid soils and peat, and there is abundant surface drainage by means of small streams.

The division between the Sandstone-shale Uplands and the Recently Glaciated Shale Lands is not as dramatic as that between the former and the Burren Hills. There is merely a gradual decrease in altitude and an increase in recent glacial deposits. There are ice-deepened valleys in the shale with ridges of sandstone between. The soils are wet and acid.

The Burren Lowlands consists of a low-lying (30–60m) plateau of horizontally bedded Carboniferous Limestone. There is more glacial drift than on the Burren Hills but there are still extensive areas of limestone pavement. However, the water table is only just below the surface and there is a chain of large permanent lakes from Corrofin north-east to Boston. The very similar low-lying area of limestone to the south and west of Kinvarra, in South East Galway, is included here in this region, although it lacks the large Lakes of the Burren Lowlands. This is referred to as the Ardrahan Limestones in Praeger (1934).

The climate of the whole area is highly oceanic like other western areas of the British Isles, though details for aspects other than rainfall are sparse (Finch, 1971; Ivimey-Cook & Proctor 1966a). Rainfall is high in the upland regions, in the range 1250–1500mm but less in the lowlands, around 1125mm. The precipitation-to-evaporation ratio is well in favour of precipitation, which means that most soils, even
shallow soils over limestone (Grime, 1963) are leached and, in areas where the sub-soil is non-calcareous, podzolised. Where drainage is impeded, there are extensive areas of gleyed soils.

The great botanical interest of the area lies in its high floristic diversity due to a mixture of phyto-geographical elements which is unique in western Europe. This is described in Lousley (1950), Praeger (1934) and Webb (1962). Plants which in Europe have a southern distribution, e.g. *Adiantum capillus-veneris*, grow alongside plants of a northern distribution and with yet others of Mediterranean, continental and arctic-alpine distributions. Another remarkable feature is the growth of the arctic-alpine plants at sea-level, which at these latitudes normally grow on mountain tops.

**FIGURE 2.** Hazel scrub in Glen of Clab showing *Polystichum setiferum* also present was *Pteridium aquilinum*, *Athyrium filix-femina*, *Dryopteris filix-mas* and *D. austriaca*.

A general survey of the vegetation of the area is given in Ivimey-Cook & Proctor (1966a); and, more particularly, of fissures in the limestone in Dickinson et al. (1964); of salt-marshes, fens and woodlands in Ivimey-Cook & Proctor (1966b); and of temporarily flooded depressions in the limestone in Praeger (1932). Woodlands are scarce in the area. Semi-natural woodlands of *Fraxinus excelsior* occur on some of the steeper slopes of the Burren Hills. There are small, ornamental plantations throughout the area and recent conifer plantations on the shales around Lisdoonvarna. *Corylus avellana* scrub is abundant on the limestone hills and lowlands (fig. 2) and there are scattered hedges of *Crataegus monogyna* on the shale regions. Tall herb communities are common throughout the area, as are grasslands of an acidic nature on the shales and of a calcareous nature on the limestone. These range from semi-natural communities to small areas of improved grassland on the best soils. These communities merge into marsh and fen communities, especially around the lakes in the Burren.

*Nomenclature follows Clapham et al. (1962) for angiosperms and Jermy et al. (1978) for pteridophytes.*
Lowlands. Blanket bogs with small areas of heath are common on the shales and gritstones, with some raised bogs around the lakes in the Burren Lowlands. Sandstone or shale outcrops are occasional in their areas, and outcrops of limestone and limestone pavement (fig. 3) dominate large tracts of their areas. Stone walls are common in the area, generally of stone local to the region. These are usually drystone walls but occasionally, and more often in the shale and sandstone areas, there is soil between the stones. Mortared walls of all stone types also occur throughout the area.

FIGURE 3. Limestone pavement with grykes near the lighthouse Black Head, the habitat of Adiantum capillus-veneris, Asplenium scolopendrium and A. marinum.

METHODS

Field records on the distribution maps (figs. 4–7) refer to records made by the author in August 1978. These were gathered on the basis that two to three examples of each relevant habitat were visited, in each of the 10 km. grid squares of the Irish national grid in the area. A relevant habitat was defined as a major habitat type, that occurred commonly in the topographical region in which the grid square was situated. These major habitat types are outlined in the previous section. At each site visit a subjective estimate of the abundance of each fern present was made, for each habitat type in which it occurred (see under Habitat Lists for explanation of abbreviations used). No attempt was made to record where habitats contained no ferns. There is a bias in the records to sites near roads, due to the time available to study the area, but it is impossible to assess the strength or significance of this.

A search was made of the major works that give fern records for the Burren: Corry (1880), Foot (1860), Ivimey-Cook & Proctor (1966a), More (1898), Praeger (1901, 1909 & 1934) and Scannel & Synnott (1972). Where these give significant extensions to the geographical or ecological ranges of species, above that recorded here, details are given in the systematic list. Records given in Ivimey-Cook & Proctor (1966a) are plotted on the distribution maps (figs. 4–7) as they are given on a 1 km. grid square basis.
SYSTEMATIC LIST OF TAXA

Each taxon recorded in the field for the study area is given, with notes on (a) its distribution, abundance and habitats as recorded in the survey and (b) significant extensions to these from the literature. Taxa, recorded in the literature but not this survey, are given a (b) type entry. Reference to abundance in habitats in (a) refers only to abundance in examples of the habitat where the species occurred; no account is taken of how often a species was present in the particular type of habitat. Grid references prefixed with *circa* are my interpretations of localities originally given without a reference.

3.1 *Huperzia selago*
(b) Recorded for summit of Gleninagh Mountain (c.M/17.09) and Slieve Elva (c.M/15.04) records communicated by D.A. Webb (Pers. comm. 1978) and in Jermy *et al.* (1978) for M/1.0, M/1.1 and R/0.8. The card for the M/1.0 record in Jermy *et al.* (1978) gives the habitat as blanket bog.

5.1 *Selaginella selaginoides* (fig. 4)
(a) Scattered in small amounts in damp, calcareous, herbaceous communities in flushes around coast near Black Head and lakes in the Burren Lowlands.
(b) Recorded in Jermy *et al.* (1978) for M/2.1 and R/2.9.

7.1 x 2 *Equisetum x trachyodon*
(b) Recorded in Jermy *et al.* (1978) for R/3.9 and in Praeger (1901) near the outlet stream to Lough Inchcronan (c.R/38.86). These are specimens in BM for the outlet stream to Lough Inchcronan dated 1925 and for the east shore of Lough Bunney (c. R/38.97) dated 1966.

7.2 *E. variegatum*
(a) Widely distributed but very local in the Burren Hills and Lowlands. Rare to locally abundant in tall, damp, herbaceous vegetation dominated by monocotyledons, associated with flowing water or loughs. Specimens from Carran (R/28.99) and Lough Bunny (R/38.97) determined as probably var. *majus* Syme by C.N. Page. Also recorded Cahir River (M/15.08).
(b) Recorded in Jermy *et al.* (1978) for M/1.2 & M/3.1.

7.3 *E. fluviatile* (fig. 4)
(a) Widespread but local in the Burren Lowlands and shale regions. In the Burren Lowlands, it is locally frequent to occasional as an emergent along the edges of loughs, and frequent to occasional in marshes fringing them. Occasional to frequent in damp, tall grass and marshy patches in fields in the Burren Lowlands and shale regions. Recorded once growing in old peat workings on blanket bog, Slievebeg (R/16.89).
(b) Recorded in Jermy *et al.* (1978) for M/1.0, M/1.1, % M/2.0 in the Burren Hills and R/0.9.

7.4 *E. arvense* (fig. 4)
(a) Widespread throughout the Burren but usually only occasional to frequent, and it is less common in the limestone regions. Occurs usually in tall, often damp, grass and rarely in woods.
(b) Recorded in Jermy *et al.* (1978) for M/1.1, M/3.0 and R/3.8.

7.4 x 3 *E. x litorale*
(a) Recorded as occasional in tall grass at northern end of Lough Bunny (R/38.97); and frequent on Cahir River (M/15.08) in tall, marshy grass by river and amongst stones in bed of river.
(b) Recorded in Jermy *et al.* (1978) for M/1.1.

7.6 *E. sylvaticum*
(a) Restricted to the shale regions away from the coast but only very local even there. Occasional in damp, tall herbaceous vegetation and locally frequent in the recent, conifer plantation of Cragan West Wood (M/18.01). Recorded for R/13.90 and R/15.97.
(b) Recorded in Jermy *et al.* (1978) for R/1.8.
7.7 *E. palustre* (fig. 4)
(a) Widespread but local in the shale regions away from the coast, although where it occurs it is occasional to frequent. Seen only once growing in a limestone region (M/15.08) and there on boulder clay. Habitats were mostly damp, tall grass and occurred once in old, peat workings on blanket bog, Slievebeg (R/16.89).
(b) Ivimey-Cook & Proctor (1966a) record it frequently in the Burren Lowlands and Jermy *et al.* (1978) for the same region in R/3.8.

7.8 *E. telmateia* (fig. 4)
(a) Widespread but local in the shale regions, and occasional to frequent where it grows. It is very local in the Burren Hills on limestone, and in at least one of its two localities there, it grows on boulder clay (M/15.08). It usually occurs in tall grass and is especially abundant along roads round Lisdoonvarna.
(b) Recorded in Jermy *et al.* (1978) for R/0.9, and in the Burren Lowlands for R/3.9.

8.1 *Botrychium lunaria*
(b) Recorded in Jermy *et al.* (1978) solely for the coastal squares M/1.0, M/1.1, M/2.1 & R/0.9. Older records give inland records for pasture near Lisdoonvarna (Corry 1880) and pasture near Inichcroran Lough c. R/38.86 (specimen in Herb BM dated 1905). Original cards for records in Jermy *et al.* (1978) for M/1.0, M/2.1 & R/0.9 give grassland as habitat.

9.1 *Ophioglossum vulgatum* (fig. 4)
(a) Widespread but local throughout the region on acidic and basic sub-soils, in tall grass, where it is rare in abundance.
(b) Recorded in Jermy *et al.* (1978) for M/1.0, M/1.1, M/2.1, R/0.8, R/0.9, R/2.9 & R/3.9 Ivimey-Cook & Proctor (1966a) recorded it for damper, tall grass (R/17.93) and *Corylus avellana* scrub (R/26.93). Recorded in Praeger (1909) for *Plantago* sward near the sea.

10.1 *Osmunda regalis* (fig. 5)
(a) Widely distributed but local on the shale regions and Burren Lowlands. It is occasional to frequent in areas of blanket bog and heath on the shale and at the edge of raised bogs around lakes in the Burren Lowlands.
(b) Recorded in Jermy *et al.* (1978) for M/1.0, R/0.8, R/1.8, and R/3.9.

13.1 *Adiantum capillus-veneris* (fig. 5)
(a) Widespread but local in the Burren Hills near the coast. It is occasional in grykes and damp crevices in the limestone.
(b) Recorded for a wider area of the Burren Hills and Lowlands in Jermy *et al.* (1978): M/2.1, M/3.0, M/3.1, R/1.9 and R/2.9; and Praeger (1901) records it for two areas of crags north of Corofin (c. R/28.89). The present records and those in Jermy *et al.* (1978) when viewed on a 10 km. basis indicate a distribution throughout the limestone areas. However, when these, along with the older records in Foot (1860) and More (1898), are viewed on a 1 km. basis there is a tendency for a coastal distribution.

14.2 *Hymenophyllum wilsonii*
(b) Recorded in Jermy *et al.* (1978) for M/2.0 and M/3.0, habitats on original record cards are "under moss-covered boulder" and "tree trunk" respectively. D.A. Webb (Pers. Comm. 1978) records the species as an epiphyte on a tree trunk and as growing on a sandstone erratic in Fraxinus excelsior woodland come *Corylus avellana* scrub in the Poulavallian doline (c. M/28.02).

16. 1–3 *Polypodium vulgare* agg. (fig. 5)
(a) Widespread and common throughout the area on walls where it is occasional to frequent. Widespread but less common on outcrops of limestone and shale, where it is occasional in abundance. It is also widespread, but much less common, as an epiphyte on *Corylus avellana* in C. avellana scrub, on *Acer pseudoplatanus* trees and rarely on *Alnus glutinosa* trees and *Crataegus monogyna* bushes. It is locally frequent on moss-covered rocks on the floor of C. avellana scrub on limestone, and on the floor of woods on limestone and shale. It was also recorded once, as occasional, on the banks of hedges in the shale regions (R/09.91). All segregated records below have been determined by J.M. Mullin of the British Museum (Nat. Hist). As only a few of the
FIGURE 5. The distribution of the following in the Burren, circles Willmot 1978 and triangles Liviney-Cook & Proctor (1966a): a, Osmunda regalis; b, Adiantum capillus-veneris; c, Polypodium vulgare agg.; d, Pteridium aquilinum; e, Asplenium scolopendrium and f, A. adiantum-nigrum.
records for the *P. vulgare* aggregate were critically determined, it is not possible to be completely confident of the differences in the ecologies of the species as recorded here. However, the preference of *P. interjectum* and *P. australis* for lime-rich substrates and the avoidance of such by *P. vulgare* support findings elsewhere Benoit (1966) and Jermy *et al.* (1978).

16.1 *P. vulgare*
(a) Widespread in the shale regions. Recorded as frequent on shale walls near Ballybreen (R/15.92 & 15.93) and occasional as an epiphyte on base of tree in mixed, deciduous woodland near Lisdoonvarna (R/12.98).
(b) Recorded by Jermy *et al.* (1978) for R/2.8 and there is an herbarium specimen in BM for a wall (most probably limestone) near sea at Blackhead (M/1.1) dated 1962.

16.2 *P. interjectum*
(a) Widespread throughout the area. Occasional to frequent on limestone walls both mortared and drystone (R/05.96, 18.93, 18.94, 23.93 & 26.89). Rare as an epiphyte on an *Acer pseudoplatanus* tree (R/14.94) and a *Corylie avellana* bush in hazel scrub (M/29.02). Occasional on a hedge bank near Moymore House (R/09.91).
(b) Recorded by Jermy *et al.* (1978) for M/1.1, M/2.1 & M/3.0.

16.2 x 1 *P. x mantoniae*
(a) Recorded once for a mortared limestone wall at Ennistimon (R/13.90) as occasional. First county record for Co. Clare.

16.3 *P. australis*
(a) Scattered throughout the area. Occasional to frequent on mortared and drystone limestone walls (M/10.00, M/17.10 and R/25.92); and rare on grykes at Burrin (M/28.11) and on moss-covered boulders in hazel scrub at Dromore Woods (R/34.86).
(b) Recorded by Jermy *et al.* (1978) for M/3.0 with habitat given as “limestone karst” on original card, and R/3.9.

17.1 *Pteridium aquilinum* (fig. 5)
(a) Common throughout both the limestone, and sandstone and shale regions. It is occasional to frequent in tall, acidic grassland; widespread and frequent in abundance in short grassland over limestone; and occasional to frequent in *Corylie avellana* scrub and scrub in general. It is locally abundant in acidic, tall grass and herb communities in a few places. It is also rare to frequent in grykes in the limestone pavements.

18.1 *Thelypteris thelypteroides*
(a) Recorded once as locally abundant in marsh next to Lough Inchicronan (R/39.87) where it was recorded by Praeger (1901).
(b) Jermy *et al.* (1978) also give M/2.0. There are old records for Ballycullinan Lough (c. R/28.86) in Praeger (1901) and a specimen in herb. BM for marsh in Inchiquin Lough dated 1905 (c. R/26.89).

20.1 *T. limbosperma*
(b) Jermy *et al.* (1978) give M/1.1 and an old record for R/1.9.

21.1 *Asplenium scolopendrium* (fig. 5)
(a) Widespread and common throughout the area in both areas of limestone and of sandstone and shale, more abundantly in damper and shadfd habitats. It is rare to frequent on walls and outcrops of all rock types; occasional in grykes in the limestone; rare to occasional on the floor of *Corylie avellana* scrub and woods; and occasional on hedge banks in shale regions.

21.2 *A. adiantum-nigrum* (fig. 5)
(a) Widespread but local in the limestone regions and very local in the sandstone and shale regions. Rare on outcrops of limestone and shale.
(b) Recorded over a wide range of both the limestone and shale regions in Jermy *et al.* (1978): M/1.0, M/1.1, M/2.1, R/1.9, R/3.8 and R/3.9. Ivimey-Cook and Proctor (1966a) record it for limestone pavement at Carran (R/28.99).

21.5 *A. billotii*
(b) Recorded in Jermy *et al.* (1978) for M/1.0.
FIGURE 6. The distribution of the following in the Burren, circles Willmot 1978 and triangles Ivimey-Cook & Proctor (1966a): a, Asplenium marinum; b, A. trichomanes agg.; c, A. ruta-muraria; d, A. ceterach; e, Athyrium filix-femina and f, Cystopteris fragilis.
21.6 *A. marinum* (fig. 6)
(a) Widespread but local along the coast particularly the western coast. Occasional on walls and outcrops of both limestone and shale and frequent in grykes in the limestone (fig. 3).
(b) Recorded in Jermy *et al.* (1978) for M/1.0 and in Praeger (1901) for Ballyvaghan (c. M/22.08).

21.7 *A. trichomanes* agg. (fig. 6)
(a) Widespread and common throughout the area. Occasional to frequent on limestone outcrops; and on walls of limestone and of shale. Rare in grykes in the limestone. Recorded once, as rare, in *Corylus avellana* scrub.
(b) Ivimey-Cook & Proctor (1966a) record it more commonly in *C. avellana* scrub.

All specimens collected would appear to be referable to subsp. *quadrivalens*, which is the common subspecies on lime-rich substrates, but no specimens were critically determined.

21.9 *A. ruta-muraria* (fig. 6)
(a) Widespread and common throughout the area. Frequent to occasional on outcrops of limestone; and on walls of limestone or shale. Recorded once as occasional in grykes in limestone.
(b) Ivimey-Cook & Proctor (1966a) record it more commonly in grykes.

21.11 *A. ceterach* (fig. 6)
(a) Widespread and common throughout the area except near the coast between Liscannor and Black Head. Widespread and occasional to rare on outcrops of limestone. Widespread and frequent to rare on walls of limestone, but much more local on shale walls.
(b) Ivimey-Cook & Proctor (1966a) record it more commonly in grykes, and Jermy *et al.* (1978) record it for R/0.9.

22.1 *Athyrium filix-femina* (fig. 6)
(a) Widespread and common in the shale regions, but less widespread and less frequently encountered in the limestone regions. Frequent to occasional in damp, tall grass in the shale regions. Occasional in hedges; in *Corylus avellana* scrub on limestone; and in woods throughout the area.
(b) Jermy *et al.* (1978) record it for M/1.1, R/0.8 and R/2.9.
Plants with red rachises and with green rachises occur in the area.

23.1 *Gymnocarpium dryopteris*
(b) Praeger (1901) records this species on outcrop by road between Roadford and Cliffs of Moher.

24.1 *Cystopteris fragilis* (fig. 6)
(a) Widespread but local throughout the Burren Hills and the Sandstone-shale Uplands. Rare to occasional on damp outcrops of shale and limestone. One favoured situation in this type of habitat is around swallow-holes on the edge of the limestone, where streams passing off the shales go underground. Only occurs on limestone walls at their base amongst other vegetation. Recorded once in grykes as occasional.
(b) Jermy *et al.* (1978) record it for a wider range: M/2.1, M/3.0, M/3.1, R/0.8, R/1.8, & R/3.9. Prof. Webb considers it rarer in the Burren Lowlands than elsewhere in the area (D.A. Webb Pers. Comm. 1978).

26.2 *Polystichum aculeatum* (fig. 7)
(a) Widespread but local throughout the Burren Hills and very local in the shale regions. Rare to occasional on limestone outcrops, in grykes and tall grass. Occasional in *Corylus avellana* scrub; and rare in shale hedgebanks.
(b) Recorded for the Burren Lowlands and for a wider range of the Burren Hills in Jermy *et al.* (1978) M/3.0 and R/3.9. Much less common and abundant than *P. setiferum*.

26.2 x 3 *P. x bicknelli*
(a) Recorded once as rare on rock outcrops in quarry by road north east of Cross Bridge (R/25.91).
(b) Recorded for R/2.9 in Jermy *et al.* (1978), with habitat given as walls of old mineshaft on original card.
FIGURE 7. The distribution of the following in the Burren, circles Willmot 1978 and triangles Ivimey-Cook & Proctor (1966a): a, Polystichum aculeatum; b, P. setiferum; c, Dryopteris filix-mas; d, D. pseudomas; e, D. austriaca and f, Blechnum spicant.
26.3 *P. setiferum* (fig. 7)
(a) Widespread but rather local throughout the area. Occasional to frequent in woods. Rare to occasional in *Corylus avellana* scrub on limestone, though sometimes locally abundant in the latter habitat (fig. 2). Occasional in hedges in a few places in the shale regions. Rare on walls and rare to occasional in tall grass.
(b) Jermy *et al.* (1978) give records for M/1.1, M/2.1, & M/3.1.

27.2 *Dryopteris filix-mas* (fig. 7)
(a) Widespread and common throughout the area but never in large amounts. Occasional in deciduous woods and *Corylus avellana* scrub on limestone. Rare to frequent in tall herb and grass communities. Occasional on limestone walls. Occasional to rare, on limestone outcrops and walls.

27.2 x 3 *D. x tawellii*
(a) Recorded once as rare, with parents, in tall grass by roadside near Ennistimon (R/13.90). First county record for Co. Clare.

27.3 *D. pseudomas* (fig. 7)
(a) Widespread but rather local throughout the area. Occasional in woods and *Corylus avellana* scrub on limestone. Rare in grykes. Occasional in damp, tall grass communities in shale regions.
(b) Recorded for M/3.0 in Jermy *et al.* (1978).

27.5 *D. aemula*
(a) Widespread but very rare throughout the area. Recorded three times: frequent in mixed deciduous wood Lisdoonvarna (R/15.97); occasional in *Corylus avellana* scrub Poulavallan (M/29.02); and rare in damp, tall, herbaceous vegetation Slievebeg (R/16.89).

27.9 *D. austriaca* (fig. 7)
(a) Widespread and common in the shale regions, while less widespread and rare in the limestone regions. Rare to occasional in mixed deciduous woods; occasional but much less common in *Corylus avellana* scrub on limestone and rare to occasional in damp, tall grass and blanket bog in the shale regions.
(b) Recorded more commonly in *C. avellana* scrub on limestone by Ivimey-Cook & Proctor (1966a).

28.1 *Blechnum spicant* (fig. 7)
(a) Rare but widespread in the shale regions and recorded once for the Burren Hills, as rare in *Corylus avellana* scrub. Occasional to frequent in heath and short, acid, grass communities in the shale regions. Occasional in woods on shale and very local but frequent where it does occur on shale outcrops.
(b) Recorded over a wider part of the western and central portions of the area in Jermy *et al.* (1978): M/0.0, M/1.1, R/0.8, R/2.8 & R/2.9.

**HABITAT LISTS**

Species lists are given for some of the more interesting and/or characteristic fern habitats of the Burren. As in the systematic list, abundance only refers to abundance in examples of the habitat in which the species in question occurred. The abbreviations 'D', 'A', 'F', 'O', & 'R' stand for Dominant, Abundant, Frequent, Occasional and Rare respectively and '( )' means exceptionally. 'L' stands for locally. How often the species occurred in the habitat is given as a percentage frequency, rounded to the nearest ten percent.

**Woodland**

No examples of woodlands consisting of "an open tree layer over-topping the hazel (scrub)" were examined (Ivimey-Cook & Proctor, 1966a). However, as these merge into hazel scrub, its species list can be taken as a good approximation for this habitat. The list here refers to mixed deciduous woodlands of an obviously planted nature, and to eight examples of the vegetation.
The paucity of the flora for deciduous woods on limestone probably reflects the planted nature of the woodlands and lack of damp areas.

Hazel Scrub

This is one of the most characteristic types of vegetation in the Burren (fig. 2). It is species-rich and has a typical, woodland-ground flora. Although often restricted to more-sheltered situations and often wind-cut in more exposed areas, it is considered that hazel scrub could cover much more of the Burren (Ivimey-Cook & Proctor, 1966a), presumably if grazing pressure was reduced. Pollen analysis (Watts, unpubl.), however, indicates that it is not the climax vegetation at least in the east of the area. The list refers to eleven examples of the vegetation.

<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance</th>
<th>Occurrence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polypodium vulgare agg.</td>
<td>R</td>
<td>10</td>
</tr>
<tr>
<td>Pteridium aquilinum</td>
<td>O - F</td>
<td>80</td>
</tr>
<tr>
<td>Asplenium scolopendrium</td>
<td>R - O</td>
<td>70</td>
</tr>
<tr>
<td>A. adiantum-nigrum</td>
<td>R</td>
<td>10</td>
</tr>
<tr>
<td>A. trichomanes agg.</td>
<td>R</td>
<td>10</td>
</tr>
<tr>
<td>Athyrium filix-femina</td>
<td>O - (LF)</td>
<td>30</td>
</tr>
<tr>
<td>Polystichum aculeatum</td>
<td>O</td>
<td>10</td>
</tr>
<tr>
<td>P. setiferum</td>
<td>R - O(LA)</td>
<td>80</td>
</tr>
<tr>
<td>Dryopteris filix-mas</td>
<td>R - F</td>
<td>90</td>
</tr>
<tr>
<td>D. pseudomas</td>
<td>O</td>
<td>30</td>
</tr>
<tr>
<td>D. aemula</td>
<td>O</td>
<td>10</td>
</tr>
<tr>
<td>D. austriaca</td>
<td>O</td>
<td>30</td>
</tr>
<tr>
<td>Blechnum spicant</td>
<td>R</td>
<td>10</td>
</tr>
</tbody>
</table>

Allowing that my samples are much larger than those of Ivimey-Cook and Proctor (1966a), there is a close similarity between their values and mine for the occurrence of ferns in hazel scrub. The only large differences are that they record Asplenium trichomanes agg. and Dryopteris austriaca more commonly. Assuming these are real differences, there are no obvious explanations. Generally the flora has a woodland aspect apart from Asplenium adiantum-nigrum and A. trichomanes agg. These are rock crevice plants and grow on limestone outcrops in the scrub.

Grykes

Grykes (fig. 3), which are vertical fissures in limestone pavement, have long held a special fascination for botanists in the Burren (Dickinson et al., 1964; Heslop-Harrison, 1960), probably because they contain a rich flora, in stark contrast to the bare
pavement around them. They do not constitute a single habitat, as pointed out by Ivimey-Cook & Proctor (1966a), but a mixture of several distinct types, including gryke floors and rock crevices. Nevertheless grykes are considered a single habitat here, as this was considered sufficient for the survey. The list refers to fourteen examples of the vegetation.

<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance</th>
<th>Occurrence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adiantum capillus-veneris (M)</td>
<td>O</td>
<td>10</td>
</tr>
<tr>
<td>Polypodium vulgare agg.</td>
<td>R</td>
<td>20</td>
</tr>
<tr>
<td>Pteridium aquilinum</td>
<td>R – F</td>
<td>60</td>
</tr>
<tr>
<td>Asplenium scolopendrium</td>
<td>O</td>
<td>90</td>
</tr>
<tr>
<td>A. marinum (M)</td>
<td>F</td>
<td>20</td>
</tr>
<tr>
<td>A. trichomanes agg. (R)</td>
<td>R</td>
<td>20</td>
</tr>
<tr>
<td>A. ruta-muraria (R)</td>
<td>O</td>
<td>10</td>
</tr>
<tr>
<td>Cystopteris fragilis (R)</td>
<td>O</td>
<td>10</td>
</tr>
<tr>
<td>Polystichum aculeatum</td>
<td>O – R</td>
<td>20</td>
</tr>
<tr>
<td>P. setiferum</td>
<td>R</td>
<td>10</td>
</tr>
<tr>
<td>Dryopteris filix-mas (W)</td>
<td>O – R</td>
<td>20</td>
</tr>
<tr>
<td>D. pseudomas (W)</td>
<td>R</td>
<td>10</td>
</tr>
</tbody>
</table>

(W) = Woodland-floor elements
(R) = Rock-crevice elements and
(M) = Maritime element

The flora illustrates the multiple habitat nature of grykes, containing as it does woodland-floor and rock-crevice elements. The presence of the former is explained by the micro-climate of the gryke floors being like that of woodland floors in the vicinity (Dickinson et al., 1964). A third element is the two species that only occur commonly in grykes near the sea, however, these species occur separately. Ivimey-Cook & Proctor (1966a: Table XL) give a species list with higher frequencies of the rock-crevice element and also include Asplenium ceterach. This is probably because their list refers to limestone pavement in general and not just grykes. However, Webb (1962) also records the Asplenium spp. as common on the pavement.

Limestone outcrops

The list refers to natural outcrops and not man-made ones. However, this does not mean that it describes or even resembles the flora of outcrops before the advent of agriculture. No doubt originally outcrops would have been generally more shaded and have harboured a different flora at least in quantitative terms. This is the only commonly-occurring terrestrial habitat apart from walls, which are artificial rock outcrops, where ferns are the dominant element in the vegetation. The list refers to twenty-eight examples of the vegetation.

The two maritime-element species only occurred in crevices near the sea. They occurred separately with practically no other vascular plants. Ivimey-Cook & Proctor (1966a) note similar differences between crevices near and away from the sea. Asplenium scolopendrium and Cystopteris fragilis occurred more commonly in damper areas. This list only differs significantly from the Ivimey-Cook & Proctor (1966a) list by the greater frequency of A. scolopendrium. This may be due to the fact that A. scolopendrium prefers damper habitats and thus more often grows at the base of outcrops. I may have been more likely to record it as on the outcrop in such situations than Ivimey-Cook & Proctor.
Limestone walls

This is the most striking habitat for ferns because it is so common, especially near roads, and because ferns constitute a large part of its vascular flora. The distribution maps of *Asplenium trichomanes* agg, *A. ruta-muraria* and *A. ceterach* for my records show the pattern of major roads in the south of the area. The list refers to twenty-five examples of the vegetation on drystone walls and to twenty-two examples on mortared walls.

<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance</th>
<th>Occurrence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Adiantum capillus-veneris</em> (M)</td>
<td>R</td>
<td>10</td>
</tr>
<tr>
<td><em>Polypodium vulgare</em> agg.</td>
<td>O</td>
<td>20</td>
</tr>
<tr>
<td><em>Asplenium scolopendrium</em></td>
<td>O</td>
<td>60</td>
</tr>
<tr>
<td><em>A. adiantum-nigrum</em></td>
<td>R</td>
<td>10</td>
</tr>
<tr>
<td><em>A. marinum</em> (M)</td>
<td>O</td>
<td>10</td>
</tr>
<tr>
<td><em>A. trichomanes</em> agg.</td>
<td>O – F</td>
<td>70</td>
</tr>
<tr>
<td><em>A. ruta-muraria</em></td>
<td>O – F</td>
<td>60</td>
</tr>
<tr>
<td><em>A. ceterach</em></td>
<td>R – O</td>
<td>50</td>
</tr>
<tr>
<td><em>Cystopteris fragilis</em></td>
<td>R – O</td>
<td>20</td>
</tr>
<tr>
<td><em>Polystichum aculeatum</em></td>
<td>R – O</td>
<td>10</td>
</tr>
<tr>
<td><em>P. setiferum</em></td>
<td>R</td>
<td>10</td>
</tr>
<tr>
<td><em>Dryopteris filix-mas</em></td>
<td>R – O</td>
<td>20</td>
</tr>
<tr>
<td><em>D. pseudomas</em></td>
<td>O</td>
<td>10</td>
</tr>
</tbody>
</table>

(M) = Maritime element

*Cystopteris fragilis* and *Dryopteris filix-mas* only occurred at the base of drystone walls, undoubtedly due to the preference of these species for damper habitats. The overall similarity of the floras of limestone walls and outcrops is obvious but there are important differences. Walls in the area often have soil cappings but outcrops rarely do and in at least one area *Polypodium vulgare* agg. shows a preference on limestone, for areas of thin soil (Willmot, 1977). The major differences in occurrence of species between drystone and mortared walls may be due to differences in size of crevices. Mortared walls have a predominance of smaller, presumably drier, crevices, whereas drystone walls have larger, presumably damper, ones. It is possible then that *Asplenium ruta-muraria* and *A. ceterach*, which amongst the outcrop-ferns occur in the driest situations, are commoner on mortared walls because they grow in the smaller, drier crevices. On the other hand *A. scolopendrium* may occur more commonly on the drystone walls because it prefers damper crevices.
Shale walls

These are less numerous than limestone walls. The list refers to eight examples of the vegetation of drystone walls and to nine examples of that on mortared walls.

<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance</th>
<th>Occurrence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Drystone</td>
<td>Mortared</td>
</tr>
<tr>
<td>Polypodium vulgare agg.</td>
<td>O – F</td>
<td>O</td>
</tr>
<tr>
<td>Asplenium scolopendrium</td>
<td>F</td>
<td>R</td>
</tr>
<tr>
<td>A. marinum</td>
<td>–</td>
<td>O</td>
</tr>
<tr>
<td>A. trichomanes agg.</td>
<td>R</td>
<td>O – F</td>
</tr>
<tr>
<td>A. ruta-muraria</td>
<td>O – F</td>
<td>O – F</td>
</tr>
<tr>
<td>A. ceterach</td>
<td>O</td>
<td>O – F</td>
</tr>
<tr>
<td>Athyrium filix-femina</td>
<td>O</td>
<td>F</td>
</tr>
<tr>
<td>Cystopteris fragilis</td>
<td>–</td>
<td>F</td>
</tr>
<tr>
<td>Polystichum setiferum</td>
<td>–</td>
<td>A</td>
</tr>
<tr>
<td>Dryopteris austriaca</td>
<td>O</td>
<td>–</td>
</tr>
</tbody>
</table>

The difference in abundance and occurrence between the two types of wall for *A. scolopendrium*, *A. ruta-muraria* and *A. ceterach* mirror the differences for these species between the two types of limestone wall. This is presumably for the same reason. In terms of occurrence the mortared, shale walls are more like limestone walls than the drystone, shale walls. This is possibly due to the mortar increasing the base status of the otherwise acid soil that collects in the crevices of the shale walls. The hypothesis that the soil in shale walls is acid if mortar is not present, is supported by the appearance of a calcifuge element on shale walls e.g. *Dryopteris austriaca* and *Athyrium filix-femina*.

**SUMMARY OF FLORA**

Thirty-five species are recorded from the area, which is 60% of the native fern flora recently recorded for Ireland (Jermy et al. 1978). An idea of the richness of the flora of the area can be obtained from Jalas & Suominen (1972). They record only seven out of forty-eight 50 km squares with more species than the square containing this study area. Note that the study area is about half the area of one of their squares. Also five hybrids out of nine recently recorded for Ireland were found. Two, of these, *Polypodium x mantoniae* and *Dryopteris x tavelii* are first county records and a third *Polystichum x bicknelli* a second county record for Co. Clare. The record for *D. x tavelii* is only the second for Ireland, though the hybrid is doubtless under-recorded there.

The most valuable contribution of the fern flora of the area to that of the British Isles is the abundance of *Adiantum capillus-veneris*. This has nine of its thirty-three recent localities (Jermy et al. 1978) in the area. Efforts should therefore be made to conserve the best of these localities. Two species, *Asplenium viride* and *Dryopteris carthusiana*, which are widespread elsewhere in Ireland in habitats that occur in this area are absent from the study area. The ease of recognition of the species and the extent to which the area has been studied suggest that these are probably genuine absences. However, they should be looked for in the area.

The ferns illustrate the well-known commingling of northern and southern elements in the flora (Praeger, 1934). Examples of northern species are *Huperzia selago* and *Selaginella selaginoides* and of southern species *Adiantum capillus-veneris* and *Polypodium australe*. There is, however, a complete absence of any arctic-alpine element although there is one in the flowering plant flora (Praeger 1934). A more
detailed analysis of the phytogeographical affinities of the flora is given below and in Table 1. This is based on the European distribution of species as recorded in Jalas & Suominen (1972) and Jermy et al. (1978). The figures for the British Isles refer to recently-recorded, native species of the British Isles excluding the Channel Isles. Minor elements are excluded, as are a few species whose distribution is intermediate between the classes given or is indeterminate. On the same basis there are eleven widespread species in Europe which all occur in the Burren; seven arctic-alpine species none of which occur; and seven northern, montane species two of which occur.

TABLE 1: THE PHYTOGEOGRAPHICAL AFFINITIES OF THE FERN FLORA OF THE BURREN

<table>
<thead>
<tr>
<th></th>
<th>Atlantic Isles</th>
<th>Sub-atlantic Isles</th>
<th>Continental Isles</th>
<th>Total Isles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burren</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Southern</td>
<td>2</td>
<td>6</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Widespread</td>
<td>6</td>
<td>8</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>18</td>
<td>7</td>
<td>35</td>
</tr>
</tbody>
</table>

Overall Table 1 shows the atlantic/sub-atlantic and southern affinities of the flora. Most striking is the presence of all species of southern, atlantic and southern, sub-atlantic affinity in Europe which are in the British fern flora. This is particularly so since the area is so far north relative to the definition of southern Europe in Tutin et al. (1964). This is probably due to the relatively mild climate of the area for a region 53°N, which is caused by the warming effect in winter of air masses moving over the area from the Atlantic. This southern nature to the flora is not so marked in the bryophyte flora of the area. Ratcliffe (1968) records 18 out of his 25 northern atlantic bryophytes in Mid-West Ireland, and 16 out of his 27 southern atlantic. Note, however, that Ratcliffe's Mid-West area is much larger than the Burren. The relatively high representation of atlantic/sub-atlantic species and low representation of continental species is to be expected in an area on the western seaboard of Europe. Although the relatively higher over-representation of sub-atlantic compared to atlantic species is worthy of comment. This may be due to the fact that although the Burren is on the western seaboard of Europe and thus has a damp, oceanic climate, this is partially ameliorated by the exposed and/or free-draining nature of many of the habitats in the area.

Birks (1976) gives a more detailed analysis of the phytogeography of European pteridophytes, dividing them into twenty-one floristic elements, that is groups of species with similar distributions. Examination of the placing of the thirty-five species from the Burren amongst Birks' groups confirms the southern and western (atlantic) affinities of the flora and lack of northern, eastern and alpine elements. However, the character of the flora that emerges from this examination is rather more southern and less western than the previous analysis (Table 1) suggested. This is probably a truer picture of the affinities of the flora as Birks' methods were more objective.

One ecological problem in the area has not been discussed: the occurrence of species in more acidic habitats than those in which they usually occur. The best example is Pteridium aquilinum, a calcifuge which occurs commonly in short calcareous grassland over limestone pavement. Webb (1962) records it in such habitats more especially in the east of the area. In such grassland it is usually stunted (Webb
1962) being about 40 cm. high and it does not grow in dense masses but as separate fronds. It is tempting to suggest this anomalous occurrence is due to leaching of the top layers of the soil caused by the high rainfall of the area. However, Grime (1963) demonstrates that some calcifuges occur in calcareous soils in the area without surface leaching. Jermy et al. (1978) suggest an alternative hypothesis that there might be a calcicolous ecotype involved, similar to the diploid cytotype on limestone in Spain. As no calcicolous ecotypes have been found in calcifuge species growing on calcareous soils (Grime 1963), the ecotype explanation appears unlikely. As a number of calcifuge flowering plants occur in similar habitats in the area (Grime 1963 & Webb 1962), a more general explanation appears probable. However, Grime (1963) has analysed the ecologies of a number of calcifuge species growing on calcareous substrata in various sites in the British Isles and could find no general explanation.

Amongst the other species growing in more calcareous habitats than usual, Oreopteris limbosperma & Blechnum spicant have each been recorded once in a locality which suggests that they were growing in a habitat similar to P. aquilinum. I have recorded O. limbosperma once growing in soil over Carboniferous Limestone in Derbyshire. Dryopteris pseudomas is recorded in Clapham et al. (1962) as usually on acid soils but is recorded here as growing once on a limestone outcrop, once in a gryke and once amongst limestone blocks. Willmot (1977) records the species as growing rarely on Carboniferous Limestone in Derbyshire.

ACKNOWLEDGEMENTS

My thanks are due to Prof. D.A. Webb of Dublin Univ. for pointing out some of the more interesting pteridological sites and problems of the area. My thanks are due to the following authorities for determining critical material in the genera indicated: A.C. Jermy and J.M. Mullin of the British Museum (Nat. Hist.), Polypodium and Dryopteris; C.N. Page of the Royal Botanic Garden, Edinburgh, Equisetum; and A. Sleep of Leeds University, Polystichum. I also wish to thank F.H. Perring of the Biological Records Centre, Monk's Wood for information on habitats of records in Jermy et al. (1978).

REFERENCES


FOOT, F.J. 1860. On the Ferns of West Clare, being a list of those growing west of a line drawn north and south through the town of Tulla. Nat. Hist. Rev. 7 : 36–40.


REVIEW


This birthday issue for Richard Eric Holttum contains introductory biographical accounts and 22 papers of which 13 are about ferns. Descriptive taxonomical papers including B.J. Hoshizaki on Platycerium (13–15); G.J. de Joncheere on Humata (45–58); K. Iwatsuki on Meringium (63–74); M.G. Price on Dryopteris (239–250) and A.C. Jermy & T.G. Walker on Botrychium. Three papers describe spore morphology: E. Soepadmo & E.E. Khoo on Malayan Dennstaedtiaceae (85–95); F.S. Liew, on Oleandraceae (101–110) and K.U. Kramer on 'Synaptoспоры: a hypothesis' (79–83) in which the author elaborates an interesting theory in which spore ornamentation is said to hold spores together thus allowing two prothalli to establish themselves, and thus help cross fertilization. A very interesting account and discussion by Herb and Florence Wagner (251–267) on fertile-sterile leaf dimorphism is stimulating and that by D.W. Lee (21–29) on iridescence in Selaginella is similarly so. Two floristic papers: A.G. Piggott, the ferns of Gunong Ulu Kali (31–43) and a larger paper on the limestone hill flora of Malaya I, by S.C. Chin (165–219) make interesting reading. The latter gives notes and a key to 97 species of ferns in 43 genera. Last, a paper listing all Holttum’s new taxa and name changes in ferns to July 1975 by J.A. Crabbe (221–238) which lists over 700 items abstracted from 420 papers and shows the productivity of this Grand Old Man of Pteridology, whom this journal seeks to honour.

A.C. JERMY
THE ASSOCIATIONS BETWEEN PTERIDOPHYTES AND ARTHROPODS

URI GERSON
The Hebrew University of Jerusalem, Faculty of Agriculture, Rehovot, Israel.

ABSTRACT
Insects belonging to 12 orders, as well as mites, millipedes, woodlice and tardigrades have been collected from Pteridophyta. Primitive and modern, as well as general and specialist arthropods feed on pteridophytes. Insects and mites may cause slight to severe damage, all plant parts being susceptible. Several arthropods are pests of commercial Pteridophyta, their control being difficult due to the plants' sensitivity to pesticides. Efforts are currently underway to employ insects for the biological control of bracken and water ferns. Although Pteridophyta are believed to be relatively resistant to arthropods, the evidence is inconclusive; pteridophyte phytoecdysones do not appear to inhibit insect feeders. Other secondary compounds of pteridophytes, like prunasin, may have a more important role in protecting bracken from herbivores. Several chemicals capable of adversely affecting insects have been extracted from Pteridophyta. The litter of pteridophytes provides a humid habitat for various parasitic arthropods, like the sheep tick. Ants often abound on pteridophytes (especially in the tropics) and may help in protecting these plants while nesting therein. These and other associations are discussed. It is tentatively suggested that there might be a difference in the spectrum of arthropods attacking ancient as compared to modern Pteridophyta. The Osmundales, which, in contrast to other ancient pteridophytes, contain large amounts of phytoecdysones, are more similar to modern Pteridophyta in regard to their arthropod associates. The need for further comparative studies is advocated, with special emphasis on the tropics.

INTRODUCTION
This is the fourth and final installment in a series of review papers intended to explore the relationships between arthropods and the lower green plants. These reviews, while not intended to be comprehensive, are meant to draw attention to some hitherto-neglected areas of arthropod-plant inter-relationships. Former parts dealt with mosses, lichens and algae, respectively (Gerson, 1969; 1973; 1974-76).

The associations between arthropods and pteridophytes have been of some recent interest to entomologists. The continuing weed problem of bracken (Pteridium aquilinum) in some parts of the world (Braid, 1959), and the relatively new problem of Salvinia as a nuisance in Asian and African waterways (Anders and Bennett, 1975) are being tackled by a biological control approach. Some Pteridophyta, of ornamental interest, are grown commercially; their pests have become of economic importance.

Finally, the discovery of insect moulting hormones in many pteridophytes has brought forth a series of biochemical studies and some speculations concerning the role of these and other compounds in regard to insects. Balick, Furth and Cooper-Driver (1978) compiled a fairly comprehensive list of about 420 insects and mites believed to be herbivorous on pteridophytes. The presence of primitive as well as advanced insects among these arthropods suggested to Balick et al. (1978) the possibility of co-evolution of arthropods and pteridophytes, both before and after the radiation of angiosperms. The main interest of Balick et al. (1978) concerned arthropod feeding on Pteridophyta. This will be the first association to be discussed.
ARTHROPODS FEEDING ON PTERIDOPHYTA

Diverse arthropods, mainly insects and mites, feed on pteridophytes wherever these grow. The insects include representatives of several orders (Table 1). Among the sucking insects, the Hemiptera are dominant. Some examples are the mirid bugs Bryocoris pteridis and Monalocoris filicis, which feed mainly on sporangia (Southwood and Leston, 1959). The whiteflies Aleurotulus nephrolepidis and Filicaleyrodes williamsi (Mound, 1966), the mealybugs Nesopedronia cibotii (Beardsley, 1971) and Spillococcus filicola (Hussey, Read and Hesling, 1969) and the aphids Idiopterus nephrolepidis and Sitobion ptericolens (Robinson, 1966) all settle on and suck from the fronds. Among the Thysanoptera (thrips), the fern thrips, Leucothrips nigripennis and the gall-making Pteridothrips pteridica will serve as examples. Many fly (Diptera) larvae are found on pteridophytes, the Anthomyiid genus Chirosia being restricted to them. Other representatives are the gall midges Dasineura filicina and D. pteridica, which form galls on bracken fronds, the Agromyziid Phytoliriomyza pteridii which mines in bracken (Spencer, 1973) and the Drosophilid Drosophila notha induces multiple galls on bracken in New Guinea (Kirk, 1977). Several beetles (Coleoptera) feed on pteridophytes. These include the notorious fern weevil, Syagrius fulvitarsis and its relatives (Marshall, 1922), the pteridophyte-specific Megacolabus (May, 1973), some Chrysomelids (Kirk, 1977) and Poecilips pteridophytae, a Scolytid from New Guinea (Gray, 1970). Many caterpillars of butterflies and moths (Lepidoptera) were collected from Pteridophyta. The Pyralid Samea multiplicalis was tried for the biological control of Salvinia in Africa (Bennett, 1972). The leatherleaf fern borer, Undulambia polythicalis (Pyraustidae) is a pest of Rumohra adiantiformis in Florida (Short, Driggers, Kuitert and Roberts, 1971) as is the Florida fern caterpillar, Callopistria floridensis, a Noctuid (Pirone, 1970). Theichobia verhuellella induces galls on several pteridophytes (Hering, 1937). The Hymenoptera have many pteridophyte-feeders among members of the Selandriinae, including the Equisetum-associated Loderus and Dolerus (Benson, 1962), Blasticotoma filiceti and many Strongylogaster spp. (Smith, 1969). Mites reported from Pteridophyta comprise the gall-making Eriophyids

| APTERYGOTA | 14. Isoptera (Termites) |
| 1. Thysanura (Bristle-tails) | 15. Zoraptera |
| 2. Diplura | 16. Psocoptera* (Booklice) |
| 3. Protura | 17. Mallophaga (Biting Lice) |
| 4. Collembola* (Spring-tails) | 18. Siphunculata (Sucking Lice) |
| 5. Thysanoptera* (Thrips) |

| PTERYGOTA | 19. Hemiptera* (Bugs) |
| 1. Ephemeroptera (Mayflies) | 20. Thysanoptera* (Thrips) |
| 2. Odonata* (Dragonflies) | 21. Neuroptera (Lacewings) |
| 3. Plecoptera (Stoneflies) | 22. Coleoptera* (Beetles) |
| 4. Grylloblattoidea | 23. Strepsiptera (Stylopids) |
| 5. Orthoptera* (Grasshoppers and Crickets) | 24. Mecoptera* (Scorpion Flies) |
| 6. Phasmatodea | 25. Siphonaptera (Fleas) |
| 7. Dermaptera (Earwigs) | 26. Diptera* (Flies) |
| 8. Embioptera | 27. Lepidoptera* (Butterflies and Moths) |
| 9. Dictyoptera* (Cockroaches and Mantids) | 28. Trichoptera (Caddis Flies) |

TABLE 1: THE ORDERS OF INSECTS (BASED ON RICHARDS AND DAVIES, 1977). ORDERS WITH WHICH ARTHROPODS ARE KNOWN TO BE ASSOCIATED ARE MARKED BY AN ASTERISK.
**Phytoptus pteridis** (Lawton, 1976) and **Nothopoda pauropus** (Anthony, 1974), the fern mite *Hemitarsornemus tepidariorum* (Cameron, 1925) and several Tenuipalpids, among them *Tenuipalpus lygodii* (DeLeon, 1966). A detailed list of insects and mites reported from Pteridophyta was compiled by Balick et al. (1978).

Few other arthropods are known from pteridophytes. Hussey et al. (1969) reported that the woodlouse *Porcellio laevis* damages *Adiantum* roots in greenhouses. Kühnelt (1976) cited observations on the Diplopods *Taueriulus* and *Pteridoiulus*, both said to live in pteridophyte rhizomes. Unspecified millipedes (Diplopoda) and sowbugs and pillbugs (Isopoda, woodlice) were reported to feed on the tender new growth of pteridophytes (Hoshizaki, 1975). Horning, Schuster and Grigarick ((1978) collected Tardigrades from Pteridophyta in New Zealand.

Feeding may be on any part of the plants. Roots, rhizomes, stems, fronds and spores are eaten. Members of pteridophyte-feeding genera may utilise different parts of the same plants. Thus *Chirosia parvicornis* mines in bracken frond-tips, *C. crassiseta* mines the stem, and *C. albitarsis* mines in both the stem and leaf stems (Lawton, 1976). Most feeding insects (Coleoptera, Hymenoptera, Lepidoptera) have chewing mouth parts; many of them in fact skeletonise fern fronds (Beer, 1955; Swezey, 1921). Others, such as aphids, whiteflies and scale insects, suck out the contents of pteridophyte tissues. Feeding aphids induced circular, chlorotic areas on pteridophyte fronds, chlorosis extending along the midrib (Severin and Tompkins, 1950). As damage extended to newly developing fronds, it was concluded that the causative agent had a systemic nature. There was no evidence that plant viruses were involved (but see below).

Pteridophyte feeders comprise species confined to one plant alone (monophagous), others which feed on several species of Pteridophyta but on no other plants (oligophagous) and arthropods which attack pteridophytes as well as higher plants (polyphagous). A special, minor group are some aphids which alternate between Pteridophyta and other angiosperm host plants. Examples are *Shinjia pteridifoliae*, alternating between bracken (*Pteridium*) and *Viburnum* (Miyazaki, 1968) and *Aulacorthum pterinigrum*, on *Pteris* and *Vaccinium* (Richards, 1972).

Gall makers are usually monophagous. Several arthropods induce galls on pteridophytes, mites being said to cause more than half of the known galls (Mani, 1964). This author, however, included only mites and Diptera among arthropod gall makers (Mani, 1964; fig. 126), ignoring Hemiptera (Beardsley, 1971), Coleoptera and Thysanoptera (Docters van Leeuwen, 1938), as well as Hymenoptera and Lepidoptera (Buhr, 1964-65). The Pteridophyta appear to have fewer arthropod-incuded galls than other large plant groups (Mani, 1964). Several quite specific insects were found during projects aimed at the biological control of pteridophyte weeds (Bennett, 1966; Wieczorek, 1973). Such specificity is of paramount importance in these projects, the insects therefore undergoing vigorous starvation tests. In other cases, the reported specificity may reflect only lack of knowledge, as most pteridophyte feeders appear to be oligophagous. Feeding on several pteridophyte species has been reported in mites (Beer, 1954; DeLeon, 1966). Thysanoptera (Hussey et al., 1969), Hemiptera (Mound, 1966; Gosh, 1974; McKenzie, 1967; Southwood and Leston, 1959), Diptera (Wieczorek, 1973), Coleoptera (Kirk, 1977; Swezey, 1921), Lepidoptera (Swezey, 1921; Hering, 1937) and Hymenoptera (Benson, 1962; Smith, 1969).
Many of the polyphagous insects which feed on Pteridophyta are pests of agricultural crops (Table 2). While listing these species, it became evident that two superfamilies of plant-feeding Hemiptera, namely the Aphidoidea (aphids) and Coccoidea (scale insects) show a marked difference in specificity to pteridophytes. Among aphids, specificity is the rule, only very few species feeding on other plants also. Pteridophyte-associated scale insects, on the other hand, are by and large not restricted to these plants (see also Eastop, 1973). Even the fern scale, *Pinnaspis aspidistrae*, has many angiosperm host plants (Dekle, 1976).

Primitive arthropods are believed to be more closely associated with Pteridophyta than recent ones. Cooper-Driver (1978) has suggested that the more ancient insect orders (except the Orthoptera) are better represented among pteridophyte feeders than would be expected. This was taken to indicate a prolonged association between pteridophytes and these insect orders. Gall makers in particular are said to have been recruited from the older arthropod groups. Mani (1964) who considered the mites to be "undoubtedly" the oldest group of cecidooza (gall-forming animals), stated that they are responsible for more than half of all known pteridophyte galls. He further wrote that of the Thysanoptera (thrips), only the more general (and thus presumably older) Terebrantia induce pteridophyte galls. The millipedes (Diplopoda) *Taueriulus* and *Pteridoiulus* live in pteridophyte rhizomes; Kühnelt (1976) finds this interesting in view of "the great geological age of ferns and diplopods". Members of the sub-family Selantriinae (Hymenoptera: Tenthridinidae) are regarded as the most generalised in the family, and the genus *Hemitaxonus* as especially primitive (Smith, 1969). Members of this genus feed on Pteridophyta. On the other hand, *Heptamelus*, a related but highly advanced genus, also lives on these plants (Smith, 1969).

As the latter case shows, pteridophytes have also become hosts to arthropods in more recent geological periods. For instance, Docters van Leeuwen (1938) notes that despite the reported antiquity of the Pteridophyta, relatively few galls occur on their older members, most galls being found on what are nowadays called "Polypodiceeous" ferns (Lovis, 1977). Feeding of the Scolytid beetle *Poecilips pteridophytae* on bracken in New Guinea was believed by Gray (1970) to be of recent origin, due to the highly specialised feeding and the relatively recent geological origin of New Guinea. Occurrence of the endemic Hawaiian mealybug *Nesopedronia* on introduced pteridophytes is probably also quite recent (Beardsley, 1971). Hering (1951) concluded that several Dipterous leaf miners have only recently transferred to the Pteridophyta.

A special form of feeding is on the "nectaries" or on sap exudates. Darwin (1877) noted that the secretion of bracken nectaries is attractive to ants. Bees, Elaterid beetles, numerous flies as well as ants were reported by Meikle (1937) to visit these nectaries. Adult sawflies, whose larvae feed on bracken, drink sap exuding from wounded fronds (Beer, 1955). Little is known concerning pteridophyte litter breakdown in the soil through arthropod activity. C. Overgaard Nielsen (in Elton, 1966) reported that the polyphagous millipede *Glomeris marginata* is an important consumer of bracken litter in Denmark. Harding and Stuttard (1974), reporting on former work, found large numbers of the Oribatid mite *Platynothrus peltifer* and the springtail *Onychiurus procampatus* in bracken litter. These authors concluded that ... "much remains to be investigated concerning the role of microarthropods in the decomposition of litter of pteridophytes and other cryptogams".
ARTHROPODS AS PESTS OF PTERIDOPHYTA

Several pteridophytes (Asplenium bulbiferum, Rumohra adiantiformis and others) are commercially cultivated; arthropods which damage them are plant pests which require control measures. The fern mite, Hemitarsonemus tepidariorum, lives in the innermost recesses of unopened frond and pinnae, and feeds there. Damage is manifested as minute brown depressions, leaf deformations and stunted and asymmetric growth, resulting in dwarfed, weak plants (Cameron, 1930). The fern aphid, Idiopterus nephrolepidis, is another destructive pest of glasshouse pteridophytes. Infested fronds curl and turn black (Hussey et al., 1969). The leatherleaf fern borer, Undulambia polystichalis, has recently become a major pest of Rumohra adiantiformis in Florida (Short et al., 1971) requiring weekly control measures. Several non-insect arthropods, like Isopoda (sowbugs and pillbugs) and Diplopoda (millipedes) feed on the tender new growth of commercial pteridophytes (Hoshizaki, 1975). Other pteridophyte pests are polyphagous insects which damage many agricultural plants. Some representative, non-specific pteridophyte pests are listed in Table 2.

Many of these pests must be controlled by chemicals, a problem aggravated by pteridophyte sensitivity to certain insecticides. Pirone (1970), for instance, advocated using only pesticides of plant origin (like pyrethrum or nicotine), and warned against organophosphorus compounds. Fluffy ruffle fern, Nephrolepis exaltata, was very sensitive to acaricides like Omite and Plictran, Acarol causing leaf deformations and burns (Short and McConnell, 1973). The chemical control of pteridophyte pests thus poses some special problems.

The fern weevil, Syagrius fulvitarsis, invaded the Hawaiian Islands and became a destructive pest of the large Sadleria cyatheoides there in 1919. Pemberton (1948) discovered that the weevil originated from Australia and found an efficient natural enemy (the Hymenopterous Braconid Ischiogonus syagrii) in New South Wales. This parasite was introduced to Hawaii and controlled the pest there. Pemberton collected several other pteridophyte-infesting weevils, belonging to the genera Syagrius and Neosyagrius; these were described by Marshall (1922). The fern weevil also invaded England and Ireland, infesting many Pteridophyta in the Dublin Botanical Gardens (Lloyd, 1944). One way of controlling weevils, as narrated by Lloyd (1944), was by placing infested plants into water, the beetles then floating to the surface. Dozens of weevils and their larvae were thus found to infest single pteridophyte plants.

BIOLOGICAL CONTROL OF PTERIDOPHYTA

The tables are turned when pteridophytes become weeds and insects are brought in to control them by feeding on them. The prime example of a pteridophyte weed is bracken, which has long been an agricultural pest in various parts of the world (Rymer, 1976). Salvinia, on the other hand, has only become a nuisance in tropical and sub-tropical waterways in more recent times (Bennett, 1966). While chemical and agrotechnical measures were being taken, biological control by insects was not neglected. The resultant surveys (Bennett, 1966; Kirk, 1977; Simmonds, 1967; Wieczorek, 1973) have materially contributed to general knowledge concerning pteridophyte arthropods. Of the ten phytophagous insects found on Salvinia by Bennett (1966), three, namely the Pyralid Samea multiplicalis, the weevil Cyrtobagous singularis and the Orthopteran Paulinia acuminata, were considered most promising. They were subsequently released at various sites in Central Africa, and P. acuminata became established there (Anders and Bennett, 1975).
TABLE 2: SOME POLYPHAGOUS PESTS WHICH ALSO FEED ON CULTIVATED PTERIDOPHYTA.

<table>
<thead>
<tr>
<th>Insect Order</th>
<th>Species</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thysanoptera</td>
<td><em>Heliothrips haemorrhoidalis</em></td>
<td>Schneider, 1966</td>
</tr>
<tr>
<td></td>
<td><em>Thrips tabaci</em></td>
<td>Pirone, 1970</td>
</tr>
<tr>
<td>Hemiptera</td>
<td><em>Trialeurodes vaporariorum</em></td>
<td>Schneider, 1966</td>
</tr>
<tr>
<td></td>
<td><em>Coccus hesperidum</em></td>
<td>Pirone, 1970</td>
</tr>
<tr>
<td></td>
<td><em>Planococcus citri</em></td>
<td>Hussey et al., 1969</td>
</tr>
<tr>
<td></td>
<td><em>Chrysomphalus aonidum</em></td>
<td>Dekle, 1976</td>
</tr>
<tr>
<td>Orthoptera</td>
<td><em>Tachycines asynamorus</em></td>
<td>Schneider, 1966</td>
</tr>
<tr>
<td>Coleoptera</td>
<td><em>Otiorrhynchus sulcatus</em></td>
<td>Schneider, 1966</td>
</tr>
<tr>
<td>Lepidoptera</td>
<td><em>Argyrotaenia citrina</em></td>
<td>Pirone, 1970</td>
</tr>
</tbody>
</table>

Other cases of insect injury to bracken include reduced germination due to spore feeding by deep soil springtails (Collembola) (Conway, 1953), and conspicuous injury to isolated stands by sawflies (Beer, 1955). Balick et al. (1978) reported that arthropod damage to wild pteridophytes in tropical Mexico may affect the reproductive capacity of these plants. Invertebrates thus have the potential to affect pteridophyte survival in the field.

PTERIDOPHYTE RESISTANCE TO ARTHROPODS

Notwithstanding all cases of arthropod feeding on Pteridophyta, a concept of intrinsic pteridophyte resistance to insects and mites has found its way into the literature. This concept was formulated in the following quotation: “In spite of the similarity of their foliage to that of the flowering plants, ferns do not commonly serve as food plants for insects. They are, in fact, strikingly immune from insect pests of all sorts. This is hardly what might be expected from the long presence of this group of plants, their enormous development in the past, and their persistence at the present time in quite considerable abundance. Why they should be so sparingly selected as food plants does not seem to have been adequately explained” (Brues, 1920). Although this generalization was already challenged by Swezey (1921), Brues later (1946) reinforced it. This concept was supported by studies in plant galls (Docters van Leeuwen, 1938; Mani, 1964), by Elton’s (1966) observations on bracken arthropods and more recently by Cooper-Driver (1978).

Apparent pteridophyte resistance to grazers was subjected to experimental studies. Soo Hoo and Fraenkel (1964) incorporated *Nephrolepis exaltata* frond extracts into a diet for the polyphagous moth *Prodenia (=Spodoptera) eridania*, and reported that this extract contained a water-soluble feeding deterrent. Soon afterwards (Kaplanis, Thompson, Robbins and Bryce, 1967; Takemoto, Ogawa, Nishimoto, Arihara and Bue, 1967) it became known that many Pteridophyta contain ecdysones (insect molting hormones). These were believed to play a role in pteridophyte defence against herbivorous arthropods (Slama, 1969). Carlisle and Ellis (1968), however, reported that a diet of air-dried bracken fronds did not interfere with the molting cycle of the desert locust, *Schistocerca gregaria*. Furthermore, there were indications that these insects do not take up ecdysones from the food into their blood. Hikino, Ohizumi, and Takemoto (1975) reviewed and studied the effect of ingested
phytoecdysones on insects. They concluded that the absorption of these compounds by insects is slow and limited, their excretion rapid, and absorbed ecdysterone is rapidly catabolised into compounds with little or no moulting hormone activity. Jones and Fjrn (1978) showed that amounts of phytoecdysteroids obtained from bracken were considerably below levels which affected several phytophagous insects belonging to three different orders. These authors believed that ecdysteroids might still act as nontoxic feeding deterrents. Hendrix (1977) offered dried bracken-leaf meal to larvae of the polyphagous moth *Trichoplusia ni* and reported some inhibition of feeding, which was not, however, considered to be due to phytoecdysones.

The effect of prunasin, a cyanogenic glycoside present in bracken, on herbivorous insects was studied by Cooper-Driver and Swain (1976). In the south of England bracken was found to be polymorphic in regard to this glycoside, as well as to its hydrolase. Although 96% of individual plants of most populations contained prunasin and its hydrolase (and were thus cyanogenic), there were a few populations in which most individual plants were acyanogenic. Bracken disks from the various populations were offered to *Schistocerca gregaria*. Those originating from cyanogenic plants were hardly touched by the locusts, whereas the others, even though they contained the cyanogenic glycoside itself, were eaten to a large extent. The authors concluded that the production of hydrocyanic acid from prunasin probably has a positive role in protecting bracken against herbivores. In a later study (Cooper-driver, Finch, Swain and Bernays, 1977) they showed that when bracken was periodically collected and offered to the locusts, there were two peaks in inhibition, during late May and in late August. The first period coincided with a maximum of cyanogenesis, the second with a peak in tannin production. The importance of these feeding deterrents for general feeders like locusts was thus demonstrated.

The level of several possible feeding deterrents produced by bracken during its growth cycle was studied by Lawton (1976). He did not exclude any bracken component, including phytoecdysones, from inhibiting arthropod herbivores. As noted, there is no clear evidence that such hormones actually protect ferns, but their occurrence in pteridophytes provides an unexpected link between these two groups. Lists of phytoecdysone-containing Pteridophyta were presented by Hikino, Okuyama, Sin and Takemoto (1973) and by Russell and Fenemore (1971).

As recent studies on pteridophyte-associated arthropods show, these plants actually have a considerable number of herbivores. Lawton (1976) compared the bracken fauna to that of other English plants and showed that the *Pteridium*-supported fauna is not an improvised one. (See also Lawton and Schroder (1977) in regard to *Dryopteris villarii*). Further studies will likely provide similar results in regard to other Pteridophyta. Although, as noted, pteridophytes are supposed to deter the feeding of arthropods, Milne (1968) obtained complete development of several springtail species which were given bracken spores as their only nutrient. Balick *et al.* (1978) reported that insects appeared to prefer pteridophytes over angiosperms as a food source in tropical Mexico.

Another kind of defence mechanism was called the "set a thief to catch a thief" principle (Lawton, 1976). Ants which visit pteridophyte nectaries may repel other insects, coming for that or other purposes. Little is known about this mechanism at present, but Bentley (1977) believes that most plants gain some protection from herbivore damage by the ants which visit their nectaries.
TABLE 3: TOXICITY OF SOME PTERIDOPHYTE EXTRACTS TO THREE SPECIES OF INSECTS.

(A: Effect of injecting pteridophyte extracts into American cockroaches, *Periplaneta americana*; 1 = 100% paralysis at 1 day, without recovery; 2 = 100% paralysis at 2 days, without recovery; 3 = 50% mortality at 3 days; 4 = less than 50% mortality at 3 days. B and C: Effect of immersion of German cockroaches, *Blatella germanica*, and milkweed bugs, *Oncopeltus fasciatus*, respectively, into aqueous fern extracts for one minute; N = less than 20% average mortality in 4 days). (From Table 1 in Heal et al., 1950).

<table>
<thead>
<tr>
<th>Pteridophyte</th>
<th>Part of Plant</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Adiantum</em> sp.</td>
<td>Entire</td>
<td>3</td>
<td>N</td>
<td>-</td>
</tr>
<tr>
<td><em>Anemia mexicana</em></td>
<td>Entire</td>
<td>2</td>
<td>N</td>
<td>-</td>
</tr>
<tr>
<td><em>Cheilanthes microphyllus</em></td>
<td>Entire</td>
<td>3</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>Dryopteris filix-mas</em></td>
<td>Leaves</td>
<td>3</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>D. marginalis</em></td>
<td>Rootstocks</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Equisetum arvense</em></td>
<td>Entire (fresh)</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>E. arvense</em></td>
<td>Entire (dry)</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>E. bogotense</em></td>
<td>Entire</td>
<td>3</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>E. hyemale var. californicum</em></td>
<td>Stems</td>
<td>4</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>E. robustum</em></td>
<td>Stems</td>
<td>3</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>Isoetes dodges</em></td>
<td>Entire</td>
<td>2</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>Lycopodium clavatum</em></td>
<td>Entire</td>
<td>4</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>L. complanatum var. flabelliforme</em></td>
<td>Fronds</td>
<td>4</td>
<td>N</td>
<td>-</td>
</tr>
<tr>
<td><em>Marsilea vestita</em></td>
<td>Entire</td>
<td>1</td>
<td>N</td>
<td>-</td>
</tr>
<tr>
<td><em>Notholaena sinuata</em></td>
<td>Entire</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Osmunda claytoniana</em></td>
<td>Rhizomes</td>
<td>3</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>Pellaea ornithopus</em></td>
<td>Entire</td>
<td>4</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>Polypodium angustifolium</em></td>
<td>Entire</td>
<td>2</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>P. nervifolium</em></td>
<td>Entire</td>
<td>2</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>Polypodium</em> sp.</td>
<td>Rhizomes</td>
<td>4</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>Pteridium aquilinum</em></td>
<td>Leaves</td>
<td>2</td>
<td>N</td>
<td>-</td>
</tr>
<tr>
<td><em>P. aquilinum</em></td>
<td>Stems</td>
<td>3</td>
<td>N</td>
<td>-</td>
</tr>
<tr>
<td><em>P. caudatum</em></td>
<td>Leaves</td>
<td>3</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>P. caudatum</em></td>
<td>Stalks</td>
<td>4</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td><em>Selaginella myosurus</em></td>
<td>Entire</td>
<td>2</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

ANTI-ARTHROPOD SUBSTANCES FROM PTERIDOPHYTA

Heal, Rogers, Wallace and Starnes (1950) assayed extracts from many plants for insecticidal properties. Some of their results, in regard to pteridophyte extracts, are presented in Table 3. It is noteworthy that bracken was not among the most toxic. In a further set of tests, extracts of fewer Pteridophyta were assayed against more insect species. Extracts of *Lycopodium annotinum*, *L. clavatum*, *L. complanatum var. flabelliforme* and *L. quadrangulare*, as well as *Anemia mexicana*, *Dryopteris marginalis* and *Marsilea vestita* were used. Of several household pests, only the black carpet beetle, *Attagus piceus*, was consistently affected. Woollen fabric impregnated with extracts of all *Lycopodium* spp., *Anemia mexicana*, and *Dryopteris marginalis* reduced feeding injury of this pest by 90% or more. Filicin, a drug originating from *Dryopteris*, gave 90% kill of the aphid *Aphis rumicis* (Hartzell and Wilcoxon, 1941). Additional information on the insecticidal activity of *Dryopteris* and other Polypodiaceae was provided by Jacobson (1958). Seaward (1976) suggested that bracken layers placed in Roman dwellings at Vindolanda (north England) produced an insecticidal exudate which adversely affected stable flies. A liquid from boiled bracken fronds was reported to be very effective against rose aphids (Long and Fenton, 1938). Botanists at a European meeting were seen by Rymer (1976) to burn bracken in order to repel nuisance midges. Rhizomes of *Pellaea involuta* (crushed in milk) are being applied by
Southern Sotho (Africa) tribesmen to counteract spider bites. They also use a decoction from rhizomes of *Polystichum pungens* as an enema for horse bots (Watt and Breyer-Brandwijk, 1962).

**ARTHROPOD-TRANSMITTED VIRUSES IN PTERIDOPHYTA**

Feeding by sucking insects (especially Hemiptera) is often accompanied by transmission of plant viruses. Eastop (1977, appendix 1-11-2) maintains that no aphid-transmitted viruses occur in the Pteridophyta. Nienhaus, Mack and Schinzer (1974), however, suggested that a viral disease of *Polypodium vulgare* and *Dryopteris filix-mas* may be vectored by aphids. They inoculated the angiosperm test plant, *Nicotiana glutinosa*, with this virus. Aphids (*Myzus persicae*, a vector of many plant viruses) were allowed to feed on *N. glutinosa* for one minute, and then placed onto healthy test plants. These *N. glutinosa* later showed symptoms of the same fern virus. The disease may therefore be transmitted by aphids.

**PTERIDOPHYTES AND THEIR LITTER AS SHELTER FOR ARTHROPODS**

Old or dying pteridophytes are inhabited by various non-specific insects in Hawaii (Swezey, 1921). Many beetles, belonging to the families Nitidulidae, Staphylinidae and Curculionidae were reported from insect-damaged pteridophytes by Gray (1970, 1972), none of these beetles apparently feeding on Pteridophyta. Roaches deposit and live in older tuber ferns (Gómez, 1974; Yapp, 1902); the latter author also found a centipede in that habitat. Bracken litter maintains a considerable dampness, allowing arthropods to flourish there (Elton, 1966). Though none of these arthropods appear to be specific to bracken, their numbers may exceed those found in oak litter (Elton, 1966). Certain members of the bracken litter, like the pill millipede, *Glomeris marginata*, are important consumers of bracken litter (Elton, 1966). Frankland (1966), in her study of bracken breakdown in the soil, noted some mites and Collembola in decaying petioles, but found no evidence that they were actually feeding on bracken. She considered them to be mycophagous, and even to aid in fungal dispersal. Bracken litter arthropods may occur on the plant above ground; the mite *Chamobates* is one example (Lawton, 1976).

The bracken litter fauna may have some value as prey for small vertebrates, like the bank vole, which uses bracken as cover (Elton, 1966). Other small vertebrates also shelter there, and their parasites and inquilines possibly find the litter suitable for host finding and resting. An example is the sheep tick, *Ixodes ricinus*, which completes its life cycle in the humid bracken litter (Nicholson and Patterson, 1976).

**ANTS AND PTERIDOPHYTA**

Ants are often associated with pteridophytes. At least two species visit bracken nectaries, where they suck up the abundant secretion and possibly also gnaw shallow excavations (Darwin, 1877). In the tropics many ants nest fortuitously in pteridophytes (Yapp, 1902), but many more constant associations have also been reported. *Camponotus* sp., for instance, regularly visits the Neotropical potato fern, *Solanopteris brunei*, although it was never observed to breed there (Gómez, 1974). At a more advanced level, the ants consistently nest within a certain pteridophyte species; this relationship is regarded as symbiotic. *Azteca* sp. regularly built its nest on and in touch with the potato fern (Gómez, 1974). The tubers served queen ants to start new colonies, and were also used as brooding chambers, in which eggs were deposited and larvae tended by worker ants.
Two Malaysian "myrmecophilous" Pteridophyta and their ant associates were reported by Yapp (1902). *Polypodium (=Lecanopteris) car nosa* was associated with the ant *Crematogaster yappi*, and *Polypodium (=Lecanopteris) sinuosum* with *Technomyrmex albipes*. Ants entered both plants through openings excavated in large-celled, thin-walled tissue (with apparent water-storing functions), which, upon breaking down, gives rise to the galleries that run throughout the plant. These and other Malaysian *Lecanopteris* and their ant associates were also discussed by Holttum (1954). *Lecanopteris* was recently revised by Jeremy and Walker (1975), who provided additional data on the accompanying ants, like a *Camponotus* sp. on *L. spinosa*. Daniels (1974) briefly referred to *Iridomyrmex cordatus*, an ant living in the rhizome galleries of *Drynaria quer cifolia* in Australia. Advantages accruing to ants from this relationship are shelter, moisture and carbohydrates present in the plants' "ripe" parenchymatous cells (Gómez, 1974). Pteridophyta appear to have evolved towards mutualism with ants, as suggested by various anatomical modifications; thin-walled points of entry, ready-made galleries and carbohydrate-containing tissues. *Solanopt eris brunei* produces an aldehyde-like substance which attracts the ant *Azteca* and may serve as an allelophone, restricting these ants to the plant. What the pteridophytes gain from this association is not clear. Darwin (1877) rejected the possibility of defence against herbivores, a possibility which Lawton (1976) termed the "set a thief to catch a thief" principle. Such protection is usually ruled out in regard to tropical ant ferns (Gómez, 1974; Jeremy and Walker, 1975; but see Bentley, 1977 for a divergent view). Other postulated advantages include imported minerals and nitrogen from ants' excreta (Holttum, 1954), and CO₂ provided by actively respiring ants in the green rhizomes of *Lecanopteris spinosa* (Jeremy and Walker, 1975).

Janzen (1974) conducted a comparative study of the relationships between several epiphytes (including *Phymatodes (=Lecanopteris) sinuosum*) and their associated ant, *Iridomyrmex myrmecodiae*. He thought that ants may prefer epiphytes for nesting as they provide relatively dry cavities of long duration (in the tropics). He also pointed out that epiphyte-ant associations often occur when epiphytes develop on slow-growing vegetation with an insufficient supply of nutrients. Without the ants, which supply their remnants as well as CO₂, the epiphytes, including Pteridophyta, may not have been able to survive in low productivity habitats. One such association appears to have implications for a Lepidopteron herbivore, the Lycaneid *Hypochrysops theon medocu s*, whose larvae feed on *Drynaria quercifolia*. Ovipositing Lycaneid females alight on the undersurface of the fronds and walk about. Eggs are laid only if ants are encountered; otherwise females search other fronds. Larvae feed within rhizome galleries, where they coexist with the attendant ant, *Iridomyrmex cordatus*, which apparently never molests the larvae (Daniels, 1974). This appears to be another case of Lycaneid-ant symbiosis, a little understood series of associations (Owen, 1971).

**EPIZOIC SYMBIOSIS**

A different form of pteridophyte-arthropod mutualism was reported by Gressitt (1969) within the context of "epizooic symbiosis". This involves weevils which support extensive plant growths on their backs. The beetles — mostly belonging to the subgenus *Symbiopholus* in the genus *Gymnop holus* — are structurally modified to accommodate the plants growing on them. These modifications include dorsal depressions surrounded by ridges, as well as various adapted setae and scales. A sticky secretion, which may promote propagule germination and subsequent growth, is also produced. Most plants found were fungi, algae, lichens and mosses; but a specimen of
Gymnopholus (Symbiopholus) lichenifer had an unidentified pteridophyte gametophyte growing on it. The association was believed to be mutualistic; the weevils providing a favourable environment for the plants, the latter serving as protective covering for the beetles (Gressitt, Samuelson and Vitt, 1968).

DISPERSAL AND AN ETYMOLOGICAL ASSOCIATION
Some herbivores of Pteridophyta, especially those which attain pest status, were probably inadvertently brought to various parts of the world with their host plants by humans. The aforementioned fern weevil, of Australian origin, is one example. Arthropod dispersal of pteridophytes appears to be of minor importance. Ants were seen to carry spores on their bodies, thus transferring them from tree to tree. Such spore transport was considered by Holttum (1954) to be “hardly necessary” as wind dispersal of spores was very effective. Thompson (1977) observed that Apirocalus, a New Guinean weevil, sometimes has pteridophyte sporangia attached to it, although the beetles were never collected on cryptogamic plants. Many spore feeders possibly void some viable spores away from the feeding site and thus disseminate them.

Finally, on a whimsical note, it might be mentioned that the scientific name for pteridophytes, and the names of the insect subclasses (as well as many orders) (Table 1) have a common root, the Greek word Pteron, a wing. Thus the names Pteridophyta, Apterygota, Pterygota, Diptera, Lepidoptera etc., have all originated from the same word.

DISCUSSION
The most interesting current problem in regard to pteridophyte-associated arthropods is the extent to which the plants’ defences deter or inhibit insect feeders. The opinions of Brues (1920, 1946), Elton (1966) and more recently Cooper-Driver (1978), were that Pteridophyta have far less than their share of herbivores. The discovery of phytoecdysones in pteridophytes (Kaplanis et al., 1967), as well as other feeding deterrents (Lawton, 1976; Cooper-driver, 1978) tended to support the hypothesis that Pteridophyta are highly resistant to insect attack (Hendrix 1977; Slama, 1969). However, other, contradictory data were concurrently becoming available. The search for natural enemies of bracken and water pteridophytes disclosed that these plants were actually being attacked by a large and diverse arthropod fauna (Bennett, 1966; Kirk, 1977; Simmonds, 1967; Wieczorek, 1973). An analysis of the structure of an arthropod community on bracken (Lawton, 1976) showed that the size of this fauna fits well within the range of comparative angiosperm-associated faunas. Working in tropical Mexico, Balick et al. (1978) reported that pteridophytes were apparently preferred over angiosperms as food for insects.

On theoretical grounds, there is no reason why the pteridophyte fauna should be depauperated. Strong, McCoy and Rey (1977, and former papers) strongly argue that host-plant range is the most important factor determining the species-richness of its herbivores. Age of a host within a given region was considered to be of minor importance. Smith (1972) concluded that the number of endemic pteridophyte genera is less than half that of the flowering plants and that pteridophyte genera and species, on the whole, are more widely distributed than angiosperms. Upon applying the concept stated by Strong et al., (1977) to Pteridophyta, it becomes reasonable to expect that these plants may actually have as many, or more, arthropods associated with them as the angiosperms. As to the role of pteridophyte chemical defences, the secondary substances, there is no doubt that they confer some protection upon the Pteridophyta (Cooper-Driver et al., 1977). However, this by itself does not mean that
TABLE 4: SOME ANCIENT PTERIDOPHYTA AND THE SPECIFICITY OF THEIR HERBIVORES.
(Monophagous: feeding only on one genus; oligophagous: feeding on ancient as well as modern ferns; polyphagous: feeding on ferns and on flowering plants).

<table>
<thead>
<tr>
<th>Pteridophyte</th>
<th>Arthropod taxon</th>
<th>Monophagous</th>
<th>Oligophagous</th>
<th>Polyphagous</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equisetum</td>
<td>Dolerini (Hymenoptera: Tenthredinidae)</td>
<td>+</td>
<td>+</td>
<td></td>
<td>Benson, 1962</td>
</tr>
<tr>
<td></td>
<td>Liriomyza spp. (Diptera: Agromyzidae)</td>
<td>+</td>
<td></td>
<td></td>
<td>Spencer, 1972</td>
</tr>
<tr>
<td></td>
<td>Sitobion equiseti (Hemiptera: Aphidoidea)</td>
<td>+</td>
<td></td>
<td></td>
<td>Ossiannilsson, 1964</td>
</tr>
<tr>
<td></td>
<td>Aphis aquiseticola (Hemiptera: Aphidoidea)</td>
<td>+</td>
<td></td>
<td></td>
<td>Ossiannilsson, 1964</td>
</tr>
<tr>
<td>Selaginella</td>
<td>Phenacoccus solani (Hemiptera: Pseudococcidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>McKenzie, 1967</td>
</tr>
<tr>
<td></td>
<td>Cecidomyiidae (Diptera)</td>
<td></td>
<td></td>
<td>+</td>
<td>Docters van Leeuwen, 1938</td>
</tr>
<tr>
<td></td>
<td>Euptychia westwoodi (Lepidoptera: Nymphalidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Singer, Ehrlich &amp; Gilbert, 1971</td>
</tr>
<tr>
<td></td>
<td>Boreus reductus (Mecoptera: Boreidae)</td>
<td></td>
<td></td>
<td>+</td>
<td>Penny, 1977</td>
</tr>
<tr>
<td>Dicranopteris</td>
<td>Nesopedronia spp. (Hemiptera: Pseudococcidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Beardsley, 1971</td>
</tr>
<tr>
<td>Lygodium</td>
<td>Saissetia coffeae (Hemiptera: Coccidae)</td>
<td></td>
<td></td>
<td>+</td>
<td>Hussey, Read &amp; Hesling, 1969</td>
</tr>
<tr>
<td></td>
<td>Tenuipalpus lygodii (Acari: Tenuipalpidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>DeLeon, 1966</td>
</tr>
<tr>
<td>Marattia</td>
<td>Agromyza sp. (Diptera: Agromyzidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Swezey, 1921</td>
</tr>
<tr>
<td>Osmunda</td>
<td>Micromyzus osmundae (Hemiptera: Aphididae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Miyazaki, 1968</td>
</tr>
<tr>
<td></td>
<td>Utamphorophora flicis (Hemiptera: Aphididae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Miyazaki, 1968</td>
</tr>
<tr>
<td></td>
<td>Chiroia hystricina (Diptera: Anthomyiidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Hering, 1937</td>
</tr>
<tr>
<td></td>
<td>Phytoliriomyza hilarella (Diptera: Agromyzidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Hering, 1951</td>
</tr>
<tr>
<td></td>
<td>Hemitaxonus dubitatus (Hymenoptera: Tenthredinidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Smith, 1966</td>
</tr>
<tr>
<td></td>
<td>Hemitaxonus albidoptictus (Hymenoptera: Tenthredinidae)</td>
<td></td>
<td></td>
<td>+</td>
<td>Smith, 1969</td>
</tr>
<tr>
<td></td>
<td>Strongyllogaster osmundae (Hymenoptera: Tenthredinidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Okutani, 1967</td>
</tr>
<tr>
<td></td>
<td>Strongyllogaster secundus (Hymenoptera: Tenthredinidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Okutani, 1967</td>
</tr>
<tr>
<td></td>
<td>Euplexia lucipara (Lepidoptera: Noctuidae)</td>
<td></td>
<td></td>
<td>+</td>
<td>Heslop-Harrison, 1944</td>
</tr>
<tr>
<td></td>
<td>Polia assimiles (Lepidoptera: Noctuidae)</td>
<td></td>
<td></td>
<td>+</td>
<td>Godfrey, 1972</td>
</tr>
<tr>
<td>Todea</td>
<td>Syagrius intrudens (Coleoptera: Curculionidae)</td>
<td></td>
<td>+</td>
<td></td>
<td>Lloyd, 1944</td>
</tr>
</tbody>
</table>
the protection afforded to pteridophytes is much more efficient than that given to angiosperms. The latter are extremely diverse from the chemical point of view, and lumping all flowering plants together in order to compare them with pteridophytes, in regard to number of associated arthropods (Brues, 1920), is not convincing. What may be needed is a comparative study on one or two angiosperm groups with similar numbers of species, distribution and apparency (sensu Feeny, 1976). Plant chemistry alone possibly makes little difference to the total number of insect species which eventually evolve to exploit a given plant (Lawton, in press); or, as stated by Levin (1976), "no defence is sacrosanct". The considerable insect and mite guilds which live on bracken and Salvinia suggest that arthropods have indeed evolved mechanisms to circumvent the plants' protective chemicals. Other often ignored factors in host-plant selection are temperatures and specific habitats (especially in the tropics), as shown by Eastop (1973) in regard to aphids, and the non-chemical (i.e., plant architecture, abundance, seasonality) components of apparency. There is no cause to exclude the Pteridophyta from such considerations.

And yet, some of the available literature tentatively suggests that a distinction could perhaps be made between the ancient Pteridophyta (including Selaginella and Equisetum) and the modern ones. Although records of ancient pteridophyte-associated arthropods are meagre, the pattern of these associations appears to differ from those of modern Pteridophyta.

A difference between the number of animal-induced galls formed on ancient and modern Pteridophyta was noted by Docters van Leeuwen (1938). A listing of arthropods currently known to feed on and live on ancient pteridophytes suggests that most insects and mites which feed on them are either monophagous (restricted to one pteridophyte species or genus), or else polyphagous (subsisting on Pteridophyta as well as flowering plants). Aside from two exceptions (see below), ancient Pteridophyta are only very rarely attacked by arthropods which also feed on modern pteridophytes (Table 4).

The exceptions are Osmunda and Todea, both members of the order Osmundales. They are attacked by aphids, sawflies, leaf-mining fly maggots and a weevil (Table 4), all of which also occur on one or more modern Pteridophyta. In so far as further collections confirm these observations, it could be argued that from the herbivore point of view, Osmunda and Todea are more similar to modern pteridophytes than to the ancient ones. According to current ecological concepts, the similarity is probably biochemical in nature. Hikino et al. (1973), while assaying Japanese Pteridophyta for phytoecdysones, found no activity in most ancient pteridophytes. These included Equisetaceae, Lycopodiaceae, Selaginellaceae, Ophioglossaceae, Marattiaceae, Schizaceae and Hymenophyllaceae. Only in Hicriopteris glauca (Gleicheniaceae) and in six members of Osmunda (Osmundales) were phytoecdysones found. The related Todea also showed insect moultin hormone activity (Russell and Fenemore, 1971). Nothing is known about arthropods of H. glauca, so it will not be further discussed. The Osmundales remain as almost the only group of ancient Pteridophyta with high phytoecdysone activity, and the only group which has herbivores in common with modern pteridophytes. It is tempting to postulate that these phenomena are related.

As already noted, available experimental data do not confirm that phytoecdysones act as feeding deterrents in Pteridophyta. This does not imply that they did not affect herbivores in the past; the phytoecdysones may have played an important role in the co-evolution of Pteridophyta and their associated herbivores, but have now become a "redundant defence mechanism" (Jones and Firn, 1978). The associations between arthropods and the ancient Osmundales may well have initiated
later co-evolutionary processes with modern pteridophytes. A relatively advanced state of Osmundales-arthropod co-evolution is also suggested by the disproportionately high number of insects found on the few extant species of Osmundales, as pointed out by G. Cooper-Driver (in lit.).

The comparative studies of Lawton (1976) and Kirk (1977) on bracken arthropods in England and Papua New Guinea, respectively, emphasize the differences in these faunas between temperate and tropical regions. Britten (1881), and Cooper-Driver (1978), among others, noted dissimilarities in the extent of pteridophyte susceptibility to insect attack between temperate and tropical regions, but quantitative data are scarce. And yet over 90% of all extant Pteridophyta grow in the tropics (Manton, 1973) and evolution in tropical regions operates in fundamentally different ways than in temperate zones (Dobzhansky, 1950). Tropical Pteridophyta doubtless carry a multitude of unstudied arthropods (Balick et al., 1978); relevant studies thus promise to enrich and modify our concepts about pteridophyte-arthropod associations.

ACKNOWLEDGEMENTS

The work invested in the preparation of this review was undertaken during a sabbatical at the School of Environmental Science at the University of Bradford. It is a pleasure to thank my host there, Dr. Mark R.D. Seaward, as well as Professor M.J. Delany, for their generous hospitality.

Professor I. Manton, The University of Leeds, Professor G. Cooper-Driver, Boston University, and Dr. J.H. Lawton, University of York, commented on the manuscript and made some literature sources available to me. Dr. V.E. Eastop, of the British Museum (Natural History) supplied records of fern-associated aphids, and A.C. Jermy, of the same institute, offered helpful advice. To all of them I wish to extend my sincere thanks.

REFERENCES


GRAY, B. 1972. Observations on *Poecilops cardamoni* (Schaufuss), the second species of Scolytidae to be found in bracken fern *Col. Entomol. TS. Arg.* 93: 229–237.


REMEMBERED


Dr. Devi starts her book with a brief preview of the history and recent studies on spore morphology and then describes systematically the spores of over 720 fern species in 134 genera. In describing techniques she rightly points out the dangers of only looking at external features with the S.E.M. There follows (pp. 99–122) a comparative analysis of the spore morphology, family by family, following B.K. Nayar's treatment. Both description and discussion is illustrated by 172 light micrographs of varying quality, which are printed on the kind of paper we have come to expect in Indian publications. This is not Santha Devi's fault, however, and she must be congratulated for carrying out the considerable amount of work that is needed to produce such a book. She is making a major contribution to fern palynology, for, although it is not apparent from the title of this book, more than half of the spores investigated were obtained from outside India. In fact when one reads Appendix I, which gives the source of spores, a large proportion of them are from cultivated botanical garden material of unknown provenance and some, one might think, of dubious name.

A.C. JERMY


This is a little fern flora of 48 km (30 miles) radius of the centre of Ottawa — some 2,800 sq. miles; 18 genera, 36 species and one hybrid (Dryopteris x boothii (Tuckerm.) Underw.) are described and dotmaps and photographs (of pressed specimens, but very informative) are given.

After the earlier edition, published in 1956 it was thought that little would be added except a few dots on the distribution maps. Nevertheless five new species were found for the area: Asplenium platyneuron, Pellaea atropurpurea, P. glabella, Woodsia obtusa and W. oregana. In the text, ecological notes are good and references are given to further reports.

A.C. JERMY


This is an extremely attractive little book with 117, mostly full page, illustrations (mainly photographs). Many of the species described and illustrated are familiar to British horticulturists and to those interested in ferns. From a botanical point of view, the number of genera (53) is wide and gives a good insight into ferns generally. I thoroughly recommend it whilst it is still available.

A.C. JERMY
THE PHILIPPINE PLATYCERIUM GRANDE

E. HENNIPMAN, G.J. DE JONCHEERE
Rijksherbarium, Leiden, Netherlands
and M.G. PRICE
University of Michigan, Ann Arbor, U.S.A.

ABSTRACT
For the first time Platycerium grande (Fée) Presl, a rare, giant staghorn fern from the Philippines, is fully described, based upon cultivated material.

INTRODUCTION
The two first-mentioned authors remarked in an earlier publication (De Joncheere & Hennipman, 1970) on the confusion existing with regard to the application of the name Platycerium grande (Fée) Presl. Although typified by a Cuming collection from the Philippines, it became commonly attached to a well-known and extensively cultivated Australian staghorn fern. As that element proved to be different from the Philippine type, the Australian taxon had to be given a new name, viz. Platycerium superbum Jonch. & Hennipm. Both these species were regarded as closely related to P. wandae of New Guinea, and also to the newly described P. holttumii Jonch. & Hennipm. of Thailand and Indo-China.

A difficulty encountered when reaching these conclusions was the surprising scarcity of authentic P. grande collections from the Philippines, and the poor quality of the few specimens present in large herbaria. Only one complete fertile leaf of P. grande (the type; BM) was traced.

Although the taxonomy of the giant staghorn ferns is primarily based upon differences in shape and size of the foliage leaves, other features of interest such as the rhizome scales, and the shape of the nest leaves are also important and were unknown for P. grande. They could therefore not be taken into consideration earlier.

Although our classification was accepted by others, e.g. Hoshizaki (1972), others expressed doubts.

We long tried unsuccessfully to obtain a complete living or dried specimen of true P. grande. Obviously this species is very local. Quite accidentally, young specimens of P. grande said to have been collected from the wild in Davao, were traced in 1975 at a local nursery in Cebu, southern Philippines. One of these plants was sent to Leiden and another to Kew. The specimen at Leiden was placed in the tropical greenhouse of the Leiden Botanical Garden, and reached maturity in the summer of 1977.

The cultivated material thus available makes it possible now to complete the description of P. grande proper, and to discuss its systematic position within the group of the giant staghorn ferns.

THE CULTIVATED MATERIAL OF PLATYCERIUM GRANDE (FÉE) PRESL

Rhizome short, but massive, the apex densely covered by scales which are basally attached, 4–7 times as long as wide, 13–18 by 2–4 mm, stiff-herbaceous, light brown with the central and basal part somewhat darker coloured, margin with a c. 0.5 mm wide fringe of uniseriate (always?) unbranched multicellular hairs, apex acute. Nest leaves upright, forming huge basket, sessile,
FIGURE 1. *Platycerium grande* plant in cultivation showing the upper side of the bipartite fertile frond.

FIGURE 2. The same specimen, showing the lower side of the fertile frond, with the two conspicuous soral patches.
obliquely reniform, 80–90 by 150–180 cm, greyish green, soft-coriaceous, recurved and withered when old; basal part appressed, auriculate, semi-circular (radius c. 45 cm), nearly completely encircling the growing point and with a conspicuous, thin, projecting frill up to 8 cm long around the petiole base of the foliage leaves; the lateral margins entire, wavy; upper part lobed, lobes spreading, 3–5 times dichotomously divided, 15–25 cm wide at the base, 40–50 cm long, sinuses narrow, ultimate segments rather coarse with blunt tips. veins anastomosing with prominent veins running in pairs to the lobes, otherwise dichotomously forked up to the ultimate segments. Fertile leaves produced in pairs, c. 120 by 150 cm, fleshy-coriaceous, greyish green, stalk to 4 cm long, woody, striated, in cross-section elliptic, 1.5 by 1.0 cm, gradually widening distally; lamina pendent, symmetrically divided into two equal parts, separated by a long narrow sinus; each part c. 85 by 130 cm and c. 20 cm wide at the cuneate base (20–30 by 40–50 cm) which largely covered by a soral patch measuring c. 15 by 20–30 cm, distally divided into strap-like segments by 3–5 oblique, inwardly directed, dichotomous divisions, the lowest sinuses dilated, ultimate segments up to 25 by 2.5 cm; veins anastomosing with some prominent veins running parallel to the margin. Indument: leaves on both sides thinly covered by a felt of whitish, ± sessile stellate hairs 300–600 μm in diam., with 8–11 slender arms. Sporangia stalked, pyriform, 300–500 μm long, with 18–22 indurated cells; spores bean-shaped, somewhat dented, 55–80 by 35–45 μm, brown, smooth; paraphyses stellate, stalked, 150–200 μm in diam., with 9–11 arms.

Notes. 1. An earlier remark (De Joncheere & Hennipman, l.c.) that the size of this species is smaller than that of its relative P. superbum is incorrect; the size of the specimens in cultivation at Leiden and Kew ± equals that of P. superbum and P. holtttumii.

2. The rhizome scales are similar to those of P. holtttumii being flat (not bullate as in P. superbum), and lacking a so-called midrib (present in P. wandae). Also, the marginal fringe of hairs on the scales is similar to that of P. holtttumii, differing from that of both P. superbum and P. wandae (hairs few-celled).

3. In our cultivated specimens, mature nest leaves of P. grande differ from those of P. holtttumii; being less deeply cut, of a greyer colour, of a softer texture, and with less conspicuous veins. Further, the main veins in the nest leaves of P. grande run up to the ultimate lobes, in P. holtttumii they run up to the penultimate lobes only.

DISCUSSION AND CONCLUSIONS

P. grande is a distinct species easily recognized by the shape of the fertile leaves. Those formed on our cultivated plant are similar in shape to the type specimen at BM, although much larger. This confirms the treatment of P. grande as a separate species. By its fertile leaves P. grande is easily distinguished from its relatives P. holtttumii and P. wandae (fertile leaves with two strongly unequal halves, each with one soral patch), and P. superbum (fertile leaf with one soral patch only).

The rhizome scales of P. grande turned out to be similar to those of P. holtttumii, and different from P. superbum and P. wandae.

The sterile leaves of P. grande show conspicuous differences from those of P. holtttumii.

A discussion on the phylogenetic relations within the genus will be included in a forthcoming paper on the genus Platycerium by Mr. M.C. Roos, a graduate student from Leiden University.

ACKNOWLEDGEMENTS

It is a pleasure to express our gratitude to Mr. A. Mulder, who skilfully handled this beautiful ornamental fern in horticulture. The photographs were made by Mr. B.N. Kieft.

REFERENCES


REVIEW


This substantial paper is a review of up-to-the minute literature presented with a depth of knowledge and critical appraisal that few, if any, pteridologists could surpass. It is divided into six chapters. After an Introduction, Prof. Lovis reminds the reader of a number of trends seen in the fossil record (pp. 232-255). There follows a short introduction to the development of cytological studies in ferns followed by the largest chapter (pp. 258-319): cytology in relation to classification and phylogeny. Lovis accepts a single class (Filicopsida) and includes at subclass level the Psilotales as suggested by Bierhorst (1971); Osmunda and the Eusporangiates are given similar subclass status. Within the Filicidae are nine orders containing 23 families, the Marsileaceae with chromosome numbers 10–20 are placed next to Adiantaceae with a base number 29 or 30, a situation which seems sound. Three families, Hymenophyllopsidaceae, Loxsomaceae and Plagiogyriaceae are regarded as incertae sedis. At the subfamily level those accepted are similar to Crabbe et al (1975) except the ‘aspidiaceous’ group are placed under Dryopteridaceae and the latter authors are rightly criticised for not segregating Onocleoideae. A full list of genera and chromosome numbers is given with levels of ploidy, and number of species both known and counted. The gaps are most interesting and will hopefully lead to further work. Polyploidy in ferns is discussed in relation to systematic and geographical distribution.

The rest of the work (pp. 330–400) is given over to a detailed account of the biosystematics of ferns describing as the basis for such work, genome analysis, species interrelationships in temperate genera: Asplenium, Cystopteris, Dryopteris, Polypodium and Polystichum; and tropical complexes: Adiantum caudatum, Asplenium aethiopicum and Ceratopteris. The role of introgression, breeding systems and apomixis generally is considered in the process of evolution. There are over 500 references and author and subject indices.

This is a work that should be read by all taxonomists, especially pteridologists. Every word is carefully weighed, precise and meaningful, be it criticism or praise, and all points of view are fairly given. The reader is left in no doubt, however, of Professor Lovis’ own assessment.

REFERENCES


A.C. JERMY
A FURTHER CHROMOSOME COUNT FOR
CHRISTENSENIA (MARATTIALES)

T.G. WALKER
Department of Plant Biology, University of Newcastle upon Tyne

ABSTRACT
A chromosome count of n=40 is recorded for a diploid plant of Christensenia from Sarawak. The only previous determination showed a Solomon Islands representative to be tetraploid. The base number of x=40, so characteristic of the Marattiales, is thus confirmed.

INTRODUCTION
Christensenia is a small member of the Marattiales and whilst it shares many of the highly distinctive features of this order, it stands well apart from the other members in its palmately-divided fronds with round synangia scattered on the lower surface and with reticulate venation. In some systems of classification (for review and discussion see Pichi Sermolli, 1959, 1977) these differences have been considered sufficient to justify the erection of a separate family, Christenseniaceae (Kaulfussiaceae).

CYTOLOGY
Christensenia occurs in Assam, Malaysia, through much of Indonesia and the Philippines, with a noteworthy extension of its range to Melanesia reported by Braithwaite (1977). One of the plants from San Cristobal in the Solomon Islands was cytologically investigated by Braithwaite and found to have n=80, 2n=160. From these chromosome counts he concluded that he was dealing with a tetraploid plant based on x=40. This assumed base number is in conformity with the x=40 found in other members of the Marattiales that have been cytologically examined, namely Angiopteris (Manton and Sledge, 1954; Mehra and Singh, 1955; Ninan, 1956; Ghatak, 1962), Danaea (Walker, 1966) and some species of Marattia* (Walker, in Manton, 1959; Walker, 1966).

Whilst a member of the Royal Geographical Society Expedition to Gunong Mulu in Sarawak in the summer of 1978, I collected several plants of Christensenia for cytological fixation. Of these only one proved suitable for the purpose but it gave numerous cells clearly showing 40 pairs of chromosomes at meiosis. One such cell is illustrated in fig. 1. This count of n=40 thus confirms Braithwaite’s deductions as regards both the basic chromosome number of the genus and of the tetraploid nature of his plant in contrast to the diploid status of my Sarawak specimen.

Christensenia has been considered to consist of a small number of species but Copeland (1947) states that these all may better be regarded as forms of the one species C. aesculifolia (Bl.) Maxon. The presence of at least two cytotypes has now been demonstrated but whether or not these are recognizable on morphological grounds requires further sampling.

ECOLOGY AND CULTIVATION
All my specimens were gathered from several localities in lowland alluvial forest in or near the Gunong Mulu National Park in Sarawak and were growing in fairly deep shade in permanently damp or wet alluvial silt at c. 65 m (c. 200 ft) above sea level. Holttum (1954) records that it has been found up to 3000 ft altitude in Malay. Although Schneider (1893) declares that this species (under the name Kaulfussia aesculifolia) is easy to grow in cultivation this has not been my experience. Plants sent in the past to Newcastle have not proved easy to establish and those that survived for a time were preferentially grazed by slugs which attacked and destroyed the growing apices.
FIGURE 1. Meiosis in diploid *Christensenia aesculifolia* (Bl.) Maxon from Sarawak (T13319) showing 40 bivalents, x 1000. Permanent acetocarmine squash preparation.

ACKNOWLEDGEMENTS

My thanks for financial assistance are due to the Research Fund of the University of Newcastle upon Tyne.

REFERENCES


*Footnote. The existence of x=39 in other species of *Marattia* has been confirmed (Ninan, 1956; Brownlie, 1961). This number has doubtlessly been secondarily derived from x=40 (Walker, 1966, 1973).*
PELTATE SCALES IN SACCOLOMA

G.B. NAIR
Institut für Systematische Botanik, Universität Zürich, 8008 Zürich, Switzerland

ABSTRACT
Peltate scales are described in *Saccoloma elegans* Kif.

INTRODUCTION
In ferns, peltate scales are mainly confined to essentially epiphytic groups. According to Alston (1956) “peltate scales seem to be found only in Polypodiaceae, Grammitidaceae and Davalliaceae”. They occur also in terrestrial representatives of essentially epiphytic groups, but to my knowledge their occurrence is entirely terrestrial groups has not been reported before. This account is to report the presence of peltate scales on the rhizome and petiolar base of the terrestrial neotropical fern *Saccoloma elegans* Kif.

The genus *Saccoloma* was established by Kaulfuss in 1820. On account of its pouch-shaped indusia it was usually associated with, or even combined with, *Davallia*, where peltate scales are of regular occurrence.

At present, *Saccoloma* (with its segregate genus *Orthiopteris*) is usually placed near *Dennstaedtia* and its relatives (e.g. Copeland, 1947: 49; Holttum, 1955: 305–306; Tardieu-Blot, 1958: 14; Mickel, 1973), although it seems somewhat distinctive because of its scaly rhizome, the other genera of the *Dennstaedtia* alliance having consistently uniseriate, pluricellular dermal appendages usually called hairs (Nair, 1973). The presence of peltate scales in *Saccoloma* was observed in the course of monographic work now in progress.

MATERIALS AND METHODS
These observations are based on study of the following specimens:


Dermal appendages were carefully removed after flooding the dried specimen with wetting agent for 15-20 minutes, washed, and mounted in lactic acid for observation.

OBSERVATIONS
The growing regions of the rhizome and the young circinate coiled fronds are covered by numerous scales. Hairs, however were found to be completely absent from the rhizome (cf. Copeland 1947: 49) but present on the young frond. Only soft-textured, multicellular, non-glandular hairs (5-12 cells long) have been found in *Saccoloma*. In *Dennstaedtia*, on the other hand, both multi-cellular acicular or multi-cellular glandular and non-glandular hairs have been observed in all the species so far studied (Nair, 1973). In *Saccoloma*, the scales at the apex of the rhizome are densely crowded. The majority are peltate in structure, and these remain intact far from growing region on the parts of the thizome that are buried in the soil.

Among such peltate scales, variously modified other scales of smaller size occur on the growing parts of the thizome ('basifixed scales'). These often show some degree of lateral expansion giving a cordate appearance near to the scale base (fig. 1: d, f &
h). Both types of scales occur abundantly also on the basal parts of the stipe.

Mature peltate scales are 5-12mm long and 3-7mm wide at the broadest region. They are linear-lanceolate to lanceolate in shape. Sometimes the scales are smaller in size and almost circular in outline (fig. 1g). On the older parts they are dark brown in colour and on the younger parts light brown. The proximal end of some peltate scales shows a v-shaped insertion (fig. 1 : a & c), except when well-developed (fig. 1 : e & i). The stalk is dark brown, firm, 0.1-0.2mm long. The persistant scale bases (stalks) later develop into often backwardly pointed, firm, spine-like structures, particularly on the basal half of the stipe. The distance from the base of the point of attachment of the scale may vary considerably. The cells of the scale are uniformly thick in the central portion of the scale and the marginal cells pale and thin. The scale margins often bear lateral appendages of varying length (fig. 1 j). The distal part of the scale is frequently branched, their tips ending in a uniseriate row of cells (fig. 1 k-m). The cells of the marginal appendages are indistinguishable from the rest of the cells. The terminal cells of the branches contain a granular substance of unknown chemical nature.

ACKNOWLEDGEMENTS

I am greatly indebted to Professor K. U. Kramer for his suggestions, criticism and encouragement. I am also grateful to Professor C.D.K. Cook for reading the manuscript and to the Directors of herbaria from whom material was borrowed.

REFERENCES


FIGURE 1. Scales of *Saccoloma elegans*: a & c, peltate scales with incised base; b, peltate scale with an undivided base; d & f, basifixed scales; e & i, the proximal portion of a peltate scale showing point of attachment; g & h, basifixed scales from a circinate coiled frond; j, portion of a peltate scale showing the marginal appendages; k-m, distal portions of peltate scale showing the terminal granular cell and branchings of the scales.
SHORT NOTES

A NEW NAME FOR A EUROPEAN DRYOPTERIS

The name *Dryopteris pseudomas* (Wollaston) Holub et Pouzar is illegitimate, its basionym of 1855 being predated by *Nephrodium affine* Lowe.

A different taxon, "*Dryopteris affinis*" Newman, was never validly published at the specific rank, but only as a variety, so the following new combination is made and replaces the name *Dryopteris pseudomas*:-

*D. affinis* (Lowe) Fraser-Jenkins, comb. nov.


The type from Madeira in Key (K!) represents the atlantic European diploid taxon, common also in western Britain.

C.R. FRASER-JENKINS
British Museum (Natural History) London.

DROPTERIS HYBRIDS: A CORRECTION

Due to the temporary loss of Fraser-Jenkins' original manuscript the name *Dryopteris x sarvelae* was inadvertently misspelt as *Dryopteris x sarvelii* (Fern Gaz. 11(5): 339 (1977), as has been pointed out to us by Mr. Sarvela. The following new country records for *D. x ambroseae* were also omitted: Romania, Austria, Czechoslovakia, Sweden, Norway, North Turkey, West and Central Caucasus (all from collections of Fraser-Jenkins deposited in BM).

C.R. FRASER-JENKINS & A.C. JERMY
British Museum (Natural History), London.

EQUISETUM VARIEGATUM NEW TO TURKEY

The presence of *Equisetum variegatum* Schleich ex Weber & Mohr has recently been confirmed from Turkey from a herbarium specimen (Davis & Coode 38422, E) collected in 1962 in Kastamonu Province, North side of Ilgaz Dag, which had been formerly regarded as *E. ramosissimum* Desf. in Flora of Turkey, vol. 1: 32 (1965). The occurrence of this plant in north central Turkey (N. Anatolia) adds significantly to the range of *E. variegatum*, the nearest other stations to which occur in scattered localities high in the main Caucasus mountains of the USSR. This new Turkish station represents the most southerly known Eurasian outpost from the extensive northern circumboreal range of this species.

This typically high-altitude streamside horsetail occurs at about 1350 m, in an area of *Abies* forest on the northern slope of the highest mountain in this part of Turkey, where mist and rain is frequent. It is of interest that the area also includes a number of other outlying Euro-siberian or circumboreal elements, such as all the Turkish species of *Pyrola, Orthilia secunda* and *Moneses uniflora* (all Ericaceae) (P.H. Davis, personal communication).

C.N. PAGE
Royal Botanic Garden, Edinburgh.
EQUISETUM X TRACHYODON IN WESTERN SCOTLAND

For more than 100 years, *Equisetum x trachyodon* A. Br. (= *E. mackaii* Newm. of older literature, the presumed hybrid between *E. hyemale* L. and *E. variegatum* Schleich. ex Web. & Mohr), has been known in Scotland only as a single station* on the banks of the River Dee in Kincardineshire (VC 91), where it was first reported growing in the mid 19th-century (Brichan, 1842). It occurred in patches along several miles or river bank, with both parents nearby. *E. x trachyodon* is known to have still grown in the Kincardineshire locality in 1935 (Matthews, 1940), and is believed to have persisted into the 1950’s (J.G. Roger, personal communication), although more recent searches (since 1971, by the author and A.C. Jermy) have failed to find it. The correct identity of the Deeside plant is confirmed by herbarium material housed at Edinburgh (E).

It is therefore of interest that in the last few years, no less than three further stations for undoubted *Equisetum x trachyodon* have been confirmed in Scotland. None seems to result from recent spread or formation of the hybrid. All appear to be long-established colonies which have been hitherto unrecognised as hybrids. All three are remote from the previously-known station and all occur in the Hebrides: one on the island of South Harris (VC 110), one on the Isle of Rhum (VC 104) and one in the north of the Isle of Skye (VC 104). Records for all three have been included in the ‘Atlas of British Ferns’ (Jermy et al., 1978), and the purpose of this note is to add some field observations and diagnostic details.

Subsequent to these finds, *E x trachyodon* has been confirmed from a similar habitat in England, and is discussed by Barker (1979) (see below).

The first of the new Scottish finds was that in South Harris, at a site to which my attention had been drawn by Dr. W.A. Clarke of Newcastle University, who had found, some years earlier, a horsetail resembling *E. variegatum*, but about the identity of which some doubts had been expressed at the time. With instructions, I was able to refind the exact locality near Nisabost in the field in June 1972, and established that this horsetail was indeed *E. x trachyodon*.

At this South Harris locality the hybrid forms a colony several square metres in extent. Most shoots of the plant are little larger than those of typical *E. variegatum* in dune-slack habitats, and most are similarly decumbent for much of their length, becoming ascending or erect only towards their tips. These plants could clearly easily be overlooked for a form of *E. variegatum*.

The colony occupies the steep ESE slope of a gradually eroding dune of calcareous shell sand, and the habitat is kept continually moist by percolating fresh water. The site is a maritime one, no more than 2-4 m above normal high-tide level and scarcely 2 m horizontal distance from the sea. Although sheltered from exposure to the west, it is unprotected in order directions, and the hybrid seems likely to receive some salt spray, at least intermittently. The seepage water originates from acidic peaty moorlands, but doubtless becomes calcium-enriched as it percolates through the shell-sand of the dunes before emerging at the site of the hybrid. The slight erosion of the slope by the slowly seeping water keeps the habitat both a moist and a more or less continually open one, colonised only by this horsetail which continually pioneers the site.

*An old Loch Tummel, Perthshire, locality given in the ‘Atlas of British Ferns’ as an open circle (Jermy et al., 1978) remains unconfirmed and doubtful.*
The Isle of Skye station on the river Hinnisdal was discovered in November 1974 by Mrs. C.W. Murray, who sent a specimen to Edinburgh for confirmation. The site is possibly that from which an old record for *E. variegatum* exists, and the shoots of the *E. x trachyodon* are only a little larger than those of robust riverside forms of *E. variegatum* and could easily have been confused with this species, or taken for a small plant of *E. hyemale*.

As with the Harris station, this Skye site is an essentially open one, with the hybrid occurring on two portions of collapsed bank of a small river, about half a mile (c. 1 km) from the sea and 25 ft (c. 8 m) altitude. The hybrid grows at the edge of the river in a basic sandy silt derived from basalt and the site is permanently moist. The habitat is kept open by gradual erosion by river water, which intermittently floods it (C.W. Murray, personal communication).

The Isle of Rum station was first determined in 1975 from a herbarium specimen collected by Dr. C. Ferreira in November 1960, and housed in the herbarium of the Nature Conservancy Council in Edinburgh. The specimen originated in an area of low-lying slack in machair sand at Kilmory dunes in the north of the island, near the mouth of a small river, about 150 m distance from the strand-line of the sea and about 1 m above the spring-tide level. The plant is probably under some influence of saline groundwater at least intermittently, but is also flushed by fresh-water seeping from sandstone slopes above, keeping the habitat more or less permanently moist. The seepage water flows through dunes of shell-sand and thus, as in the Harris station, doubtless becomes considerably calcium-enriched before entering the slack, the shell-sand soil of which also contains a thin organic horizon. Although partially sheltered from the sea by surrounding slightly higher ground, the habitat is nevertheless rather exposed and most shoots of *E. x trachyodon* are nearly prostrate on the sand (C. Ferreira, pers. comm.). A further specimen collected in July 1978 by Dr. C. Ferreira from near this former site, but in *Ammophila* fixed-dune machair, also proved to be *E. x trachyodon*. Here too the plant is reported to be locally frequent and spreads into adjacent moist-slack grassland, associated with *Festuca rubra*, *Bellis perennis*, *Lotus corniculatus* and *Galium verum*. The hybrid thus appears locally widespread and well-established in this habitat.

It is significant that in each of these new Scottish stations, *E. x trachyodon* occurs in open sites where one of both parent species are absent, at least in the immediate vicinity. Near the Harris station, *E. variegatum* is known in a sand-dune slack about 4 km away, but *E. hyemale* remains unknown in the whole of the Outer Hebrides. In Skye, both *E. variegatum* and *E. hyemale* are present on the island, but both are rare, and absent near to the hybrid site. In Rum, both parents are recorded for the island, but only *E. variegatum* grows near the *E. x trachyodon*.

Specimens from the Harris and Rum stations have somewhat smaller shoots (mostly less than 20 cm high and less than 2 mm stem diameter) than those from Skye and Deeside (which reach 20-30 cm in height and up to 3 mm stem diameter), but are otherwise morphologically similar. The size differences probably result in part from the more exposed habitat of the Harris and Rum colonies, as well as their probably involving a smaller dune ecotype of *E. variegatum*, rather than a larger river-side one, in the parentage of the hybrid. The following points of diagnosis may help in location of possible further sites for this hybrid.

As seen at these stations, *E x trachyodon* is best distinguished from its parents by the following characters. The sheaths typically have a much broader black band (occupying most of the upper 1/2 to 2/3 of each sheath), and end in teeth which are long, dark, slender and flexuous and have only a very narrow white margin to their slightly dilated bases. The teeth normally persist either indefinitely on the shoot, or at
least for a time after the shoot has fully expanded (depending on degree of exposure of the habitat), but as they become lost, break along preformed abscission zones at the top of the fused portion of the sheath to leave an irregularly crenate sheath margin. This latter character contrasts strongly with both parents: in *E. variegatum* the teeth are almost always persistent, in *E. hyemale* they are almost always shed during the actual expansion of the shoot (during which process they become torn off to collectively form small pagoda-like caps on the tips of the shoot). The shape of the teeth, the broadness of the black band and the absence of broad white scarios teeth margins thus distinguish most shoots of *E. x trachyodon* even from large specimens of *E. variegatum*, whilst the persistence of the teeth, as well as absence of the ash-grey coloured band around the upper sheath margin, more clearly biangulate internodal ridges and teeth which are clearly 2-ribbed, separate most shoots of *E x trachyodon* even from small specimens of *E. hyemale*. In the hybrid, sheaths are longer in relation to their width than in either parent. Cones, where present, contain only highly misshaped abortive spores, thus confirming its hybrid status.

Herbarium specimens from each of these three localities are deposited at R.B.G., Edinburgh (E).

REFERENCES


BRICHAN, J.B. 1842. Description of *Equisetum hyemale*, Mackaii and *variegatum*, as found on the Banks and in the bed of the River Dee; with additional observations. *Phytologist* 1: 369–377.


C.N. PAGE
Royal Botanic Garden, Edinburgh

**EQUISETUM X TRACHYODON IN CHESHIRE, NEW TO THE ENGLISH FLORA**

Some specimens of *Equisetum*, recently sent to C.N. Page, were determined as the hybrid *Equisetum x trachyodon* A. Br. (*Equisetum hyemale* L. x *Equisetum variegatum* Schleich. ex Web. & Mohr). These specimens came from the Cheshire Conservation Trust's Red Rocks Nature Reserve and the adjoining Royal Liverpool Golf Course at Hoylake, Merseyside, (v.c. 58, Cheshire).

Here, the *E. x trachyodon* grows on the leeward side of a slightly brackish marsh at the base of some 'yellow' sandhills, which are still reached by blown sand from the foreshore. The colony is extensive and abundant in rough grassland at the base of the sandhills, and stretches for 1.3 km south from the Red Rocks. The dominant vegetation of the habitat is a turf of *Festuca rubra* L. and *Ammophila arenaria* (L.) Link. It is the density of the Ammophiletum rubrae community which effectively limits the growth of *E. x trachyodon* at this site. Consequently, it is most vigorous where this community is sparse or where the ground has been recently burnt. In such bare sandy situations associated plants are: *Agrostis stolonifera* L., *Myosotis ramosissima* Rochel., *Galium verum* L., *Rubus caesius* L., *Rose pimpinellifolia* L. and *Taraxacum officinale* agg. (predominately *T. brachyglossum* (Dt.)Dt.).
The morphology of *E. x trachyodon* at Red Rocks varies within the population. In the north of the site there is a form resembling *E. variegatum* (and this is where the only pure *E. variegatum*, in a small quantity, grows at Red Rocks), while in the south it resembles *E. hyemale* more closely. Dr. Page has commented that the Red Rocks *E. x trachyodon* is unusual in that it branches and that these branches, because of their small size, have a morphology close to that of *E. variegatum* (and in isolation could easily be confused with it), although the main stem exhibits the characters of *E. x trachyodon*.

This colony is of particular interest because it is the first station found in England. Elsewhere in Britain, it has a mainly Atlantic distribution, in North and Western Ireland and Western Scotland (Jermy et al., 1978; Page, 1979 — see above). This new site extends the range of the species now to the coast of north-west England. The other notable feature of the colony is that, apparently, only one of its parents, *E. variegatum*, still grows with it.

In both Floras of Cheshire (Newton, 1971; Warren, 1899) *E. variegatum* is recorded from Wallasey on the North Wirral coast and along the Dee estuary to Gayton (which includes the Red Rocks site). It is also recorded in the earlier Liverpool Floras from the North Wirral coast (Hall, 1838; Dickinson, 1851; and Liverpool Naturalists Field Club, 1872.) However, the other parent, *E. hyemale* was first recorded at Red Rocks in 1968 by A. Newton (Newton, 1971). The voucher specimen for this record has not been obtainable and recent intensive searches have failed to find *E. hyemale* at Red Rocks. The only verified record for *E. hyemale* from the Wirral is from, 'sandhills, Heswell Cheshire', collected by Brown in 1871 (LIV), a site 7 km south of Red Rocks, along the River Dee shore. The 19th century Liverpool Floras (Dickinson, 1851; Liverpool Naturalists Field Club, 1872), also record *E. hyemale* from Parkgate and Thurstaston (sites which are also south of Red Rocks along the Dee shore) but neither of these records are supported by herbarium specimens. Recent searches of all these localities, have failed to find *E. hyemale*, but it is possible that it may yet be found in the area.

ACKNOWLEDGEMENTS

I am indebted to Mr. & Mrs. E.F. Greenwood, who first introduced me to the population of *Equisetum* at Red Rocks and for their subsequent help, and to Dr. H.A. McAllister and Dr. C.N. Page for their advice.

REFERENCES


HALL, T.B. 1838. *A Flora of Liverpool.*


MARIAN BARKER
9 South Drive, Irby, Wirral, Merseyside
A SECOND BRITISH RECORD FOR EQUISETUM × FONT-QUERI, AND ITS ADDITION TO THE ENGLISH FLORA

In June 1978, an unfamiliar *Equisetum* was noticed by one of us (R.H.R.) on the site of a disused railway near Evesham, Worcs., v.c. 37. At a first glance it looked like a somewhat slender *E. telmateia* Ehrh., but closer inspection showed that cone-bearing shoots were present at this time of the year. These cone-bearing shoots had numerous whorls of long, green branches and seemed almost identical with the vegetative shoots. No unbranched, fertile stems, such as are characteristic of *E. telmateia*, could be found despite a prolonged search. The plant appeared to answer closely to the description of *E. x font-queri* Rothm., first reported for the British Isles by Page (1973). A representative sample of freshly-gathered material was sent to Edinburgh, where its identification was confirmed (by C.N.P.) as the second British station for *Equisetum × font-queri* Rothm. (*Equisetum palustre* L. × *E. telmateia* Ehrh.), and the first for England (the previously known British station being on the Isle of Skye).

The Worcestershire site on which the hybrid *Equisetum* grows is a disused railway embankment by the River Avon meadows near Evesham. A comparison between the Evesham plants of *E. x font-queri* and those known from Skye, shows the existence of strong overall similarities, yet some interesting differences in detail.

The overall shoot outline of the Evesham plants is very similar to that of the Skye plants and distinctly intermediate between those of *E. palustre* and *E. telmateia*. Thus the outline is slender, and tapers in most specimens to a long terminal branchless portion in the upper 10 cm or so of the shoot (see illustrations in Page 1973) — this is probably the best feature to look-out for in spotting plants of this hybrid. The overall size of the Skye and Evesham plants is similar, both being much larger than *E. palustre* (reaching 60-70 cm in the Evesham plants and about 65 cm in the Skye ones). In both Evesham and Skye material the whorled branches are abundant throughout the middle two-thirds of the shoot, and are quite strongly ascending (inheriting this feature from the *E. palustre* parent). Both have about 8-12 ridges to the main stem. The Evesham plants however differ from the Skye ones in having even more conspicuously white internodes, and longer free teeth to the main stem sheaths, and in these characters the Evesham plants approach the condition found in *E. telmateia* more than do those from Skye. However, the Evesham plants also have less distinctly bi-angulate and more rounded branch internode ridges, and less strongly 2-ribbed teeth to both the main stem and branch sheaths than do the Skye plants, and in these characters the Evesham plants approach nearer to the condition of *E. palustre* than do the Skye ones.

Despite these small morphological differences, there can be little doubt that the Evesham plants, like the Skye ones, are the result of crossing between *E. palustre* and *E. telmateia*. The differences, if not environmentally induced (which cultivation alongside the Skye plants at Edinburgh will determine), might either reflect differences in the relative genetic dominance of the particular characters in the original parents, or might result from the cross having occurred in the other direction, or a combination of both phenomena.

In the Evesham locality, the single colony of the hybrid forms a dense stand for a distance of about 75 metres on both sides of the top of a railway embankment, which is capped by a layer of ballast composed of coarse limestone chippings. As the habitat is entirely man-made, the origin of the hybrid *Equisetum* is problematic. It seems rather unlikely that it could have arisen on this site, for neither of the putative parents occurs anywhere near it at present. The ten-mile section of the old L.M.S. railway from Evesham to Alcester was opened in 1866 (Evesham Journal, July 14,
1866). The remaining section from Alcester to Redditch and Birmingham was opened later. It is most likely that the material used to build the embankment came from the large cutting between the embankment and the station in Evesham (B.G. Cox, pers. comm. 1978). The cutting was made through a ridge of well-drained soil and hence this too seems a most unlikely source of origin for the *Equisetum*.

A more likely explanation is that a piece of rhizome was introduced with the ballast brought in at a later date, as the material making up the embankment became consolidated. This implies that another colony of *E. x font-queri* existed (and perhaps still exists) elsewhere in Worcestershire, or in one of the adjoining counties. The Evesham to Redditch railway was closed in 1963 (Cox 1977: 109), and parts of the disused track to the north of the embankment have been sold. But the embankment itself, which at this point is about 4 metres above the level of the ground on either side, has so far remained undisturbed.

The dense and vigorous stand of the hybrid in the Evesham locality, in a habitat which does not appear particularly favourable to the growth of either *E. palustre* or *E. telmateia*, lends support to the observation already made on the very large colony on the Isle of Skye (Page 1973) that this hybrid is very vigorous and, once established, is capable of considerable vegetative spread even into habitats in which the occurrence of the parents would be unlikely.

Specimens of *E. font-queri* from Evesham have been deposited at BM, E, and P.

REFERENCES


R.H. ROBERTS
51 Belmont Road, Bangor

C.N. PAGE
Royal Botanic Garden, Edinburgh

OBSERVATIONS ON LIGHT RESPONSE IN MARSILEA CRENATA

Ferns, like other plants, are phototropic — their fronds tend to turn towards the direction of greatest illumination. In addition, different species have distinct preferences for particular conditions of light and shade. *Marsilea crenata* Presl is a small aquatic fern which grows in full sunlight, rooting in the mud of rice fields, ponds and irrigation ditches. Where illumination is restricted, at the edge of a rice field or by competing plants, the fronds lean in the direction of maximum light intensity.

During the wet season the rhizome is long-creeping, producing fronds at intervals of 4-6 cm, but during the dry season it is short-creeping, producing small fronds close together. The lamina consists of two close pairs of pinnae arranged in a square at the apex of the stipe. Laminae of submerged plants either float on, or project above, the surface of the water. The following observations have been made in Malaysia.

In the field, under conditions of full illumination, the stipes are either vertical or lean with the flow of the water. The pinnae of projecting mature laminae lie in a horizontal plane during the middle of the day. Early or late in the day the lamina tilts to face towards the sun. When the light intensity decreases towards sunset, or when a heavy storm approaches, the pinnae fold together and the closed lamina assumes a nodding position. At dawn, or when the storm has passed, the lamina re-opens.
The daily variation in water temperature in rice fields can be more than 20°C, but this appears to have little or no effect on the opening and closing of the lamina, except that at temperatures greater than 40°C the stipes tend to wilt and the laminae then close. Both open and closed laminae were observed throughout the range of temperatures from 23° – 39°C.

In order to study the sensitivity of fronds of Marsilea crenata to light intensity and direction of illumination under more controlled conditions, plants were taken from a wet rice field near Rembau in Malaysia and grown in an aquarium tank. The rhizomes were planted at random, their elongating tips facing in all directions. Light intensities were measured with a photographic light meter and converted to foot-candles, using the formula quoted in Hoshizaki (1976):

\[
\text{Foot candles} = \frac{20 (f)^2}{T \cdot S}
\]

where \( f \) = aperture in f stop, \( T \) = shutter speed in seconds, and \( S \) = film speed in ASA units. The position of the tank was changed from time to time and the various responses were recorded.

The following observations were made:

1. During the day the stipes of mature fronds assumed a position pointing in the direction of illumination. The open laminae were at right angles to this, tilted towards the east in the morning and gradually changing their angle through the day until, in the early evening, they tilted towards the west.

2. Towards sunset, when the intensity of illumination decreased to 294 foot-candles, the laminae started to close (fig. 1 a-b). As the light dimmed, first the upper pair of pinnae gradually moved together, their upper surfaces facing. Then the lower pair started to close around them. Movement originated at the point of attachment of each pinna to the stipe apex. Finally, just before it was fully closed, the lamina changed position. Fronds facing both the elongating tips of their rhizomes and the direction of illumination during the day nodded in that direction. Fronds facing away from the elongating tips of their rhizomes either nodded in its direction or took up a vertical position. The process of closing, which took place over a period of 1-1.25 hours, was complete before sunset.

3. At dawn, when the light intensity reached 294 foot-candles, the laminae started to open again. First the lower or outer pair of pinnae moved apart, then the upper or inner pair, followed by tilting of the lamina towards the sun. Opening was complete after 1-1.25 hours on a normal sunny day.

4. As storms approached during the hours of daylight and the light intensity dropped below 294 foot-candles, the lamina closed as at night. The length of time taken depended on the speed of reduction of the light intensity. As soon as the storm passed and illumination increased again, the laminae re-opened. When prolonged heavy rain caused the light intensity to remain low, the laminae stayed closed until the following day. The critical light intensity for this response thus appears to be of the order of 294 foot-candles.

5. Placing the aquarium tank in a dark cupboard overnight delayed the opening of the lamina until such time as it was replaced in sunlight. The period taken for the lamina to open was dependent on the intensity of the sunlight when the tank was replaced. Removal of the tank from darkness to very bright sunlight, about 4500 foot-candles, reduced the time taken to half an hour.

6. Removal of the tank into the dark cupboard during the day also caused the laminae to close. They re-opened when the tank was replaced in sunlight. This effect was repeated several times in one day.
7. The artificial illumination provided by ordinary electric lights was insufficient to cause the laminae to remain open at dusk, but by placing a powerful spot-light close to the tank it was possible to cause the laminae to re-open during the hours of darkness. They closed again when the spot-light was withdrawn.

8. During the observation period, new fronds were produced regularly. Very young fronds started to uncoil facing towards the tip of the rhizome. As elongation took place, the stipes twisted so that the fronds uncoiled facing the direction of illumination.

9. The water level in the tank was raised until several of the open laminae were floating on the surface. At dusk, or when placed in the dark, the smaller floating laminae remained open. Those with larger pinnae managed to overcome the effect of surface tension and close. Sometimes only one, two, or three, of the four pinnae were able to assume the folded position. Thus, where the laminae are not projecting but are floating on the surface of the water, only those fronds with large pinnae are able to overcome the surface tension and close their laminae.

10. Some small plants with short-creeping rhizomes were collected from the dry bank of an irrigation ditch and added to the tank. The small fronds of these dry season plants showed little response to changes in direction of illumination or to changes in light intensity. As the now submerged rhizomes elongated and produced larger fronds, the laminae became sensitive to such changes.

REFERENCE

A.G. PIGGOTT
29, Jalan Dungun, Damansara Heights, Kuala Lumpur 23-05, Malaysia.