

## Monitoring of pollen rain in moss polsters and mats in view of their suitability as controls for determining the air-borne component of pollen spectra in herbivore faeces<sup>1</sup>

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### Abstract

Pollen has been extracted from six bryophyte and two lichen taxa, sampled from three habitats: upland heath, lowland bog and mixed woodland, in both west and east Scotland. The highest number of pollen taxa was recorded in both *Sphagnum* and *Thuidium*; the lowest numbers of pollen taxa were recorded in two of the mosses and both lichens. For pollen rain control purposes in herbivore faecal studies, woodland species of bryophytes are not suitable due to the sheltering effects from rain provided by the overhead canopy. Open habitats such as moorland heath and bog provide polsters/mats which normally trap pollen rain more effectively for control purposes. The aim of this study was twofold: to observe the effectiveness of selected polsters and lichens as traps for pollen rain and to establish eventually, whether or not such vegetative traps could be used as controls in pollen spectra analyses of herbivore faeces for the determination of nutritional regime and habitat. From a comparison with recent studies in north west Spain of three taxa in common with Scottish samples, *Polytrichum* demonstrated a consistently higher number of pollen taxa trapped. *Thuidium* and *Cladonia* all yielded between one and a half and three times the number of pollen taxa as in the same three bryophyte/lichen taxa sampled in Scotland. Investigation relating the pollen rain trapped in polsters to that in faecal material are continuing, and will be reported in due course.

**Keywords:** Pollen rain; Moss polsters; Herbivore faeces

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### 1. Introduction

Studies on pollen rain involving bryophyte, polsters and mats have been undertaken for a number of reasons: Studies of contemporary vegetation on a regional basis have been undertaken in Canada (Patzger et al., 1956), USA (Benninghoff, 1960) and of recent past vegetation in the UK (Caulton and Fiskin, 1993). Contemporary pollen rain studies have been used for assessment of over/under representation in the interpretation of fossil pollen deposits/pollen diagrams (Carroll, 1943; Tinsley and Smith, 1974; Spieksma et al., 1994) and in relation to forest composition (Hansen, 1949). Ecological studies of moss polsters as a microhabitat in which pollen rain is a component have been reported (Corbet

and Lan, 1974; Kinchin, 1987) as well as moss polsters/mats and lichens as traps for pollen rain in different habitats (Moe, 1983; Caulton and Gibson, 1989; Ferreño and Rodriguez, 1990).

### 2. Materials and methods

Six sites were sampled, three in the west of Scotland (Isle of Arran) and three in the east of Scotland (Midlothian) (Fig. 1; Table 1).

Each sample was consigned to a polythene bag, sealed and labelled as collected. In the laboratory, each moss/lichen was rinsed in 250 ml distilled water, the bulk of the thalli removed and squeezed to remove remaining liquid. The resultant suspension was passed through an Endecott sieve (180- $\mu$  mesh) prior to centrifugation at 2000 rev./min for 10 min. Subsequent treatment followed standard acetolysis procedure (Fae-

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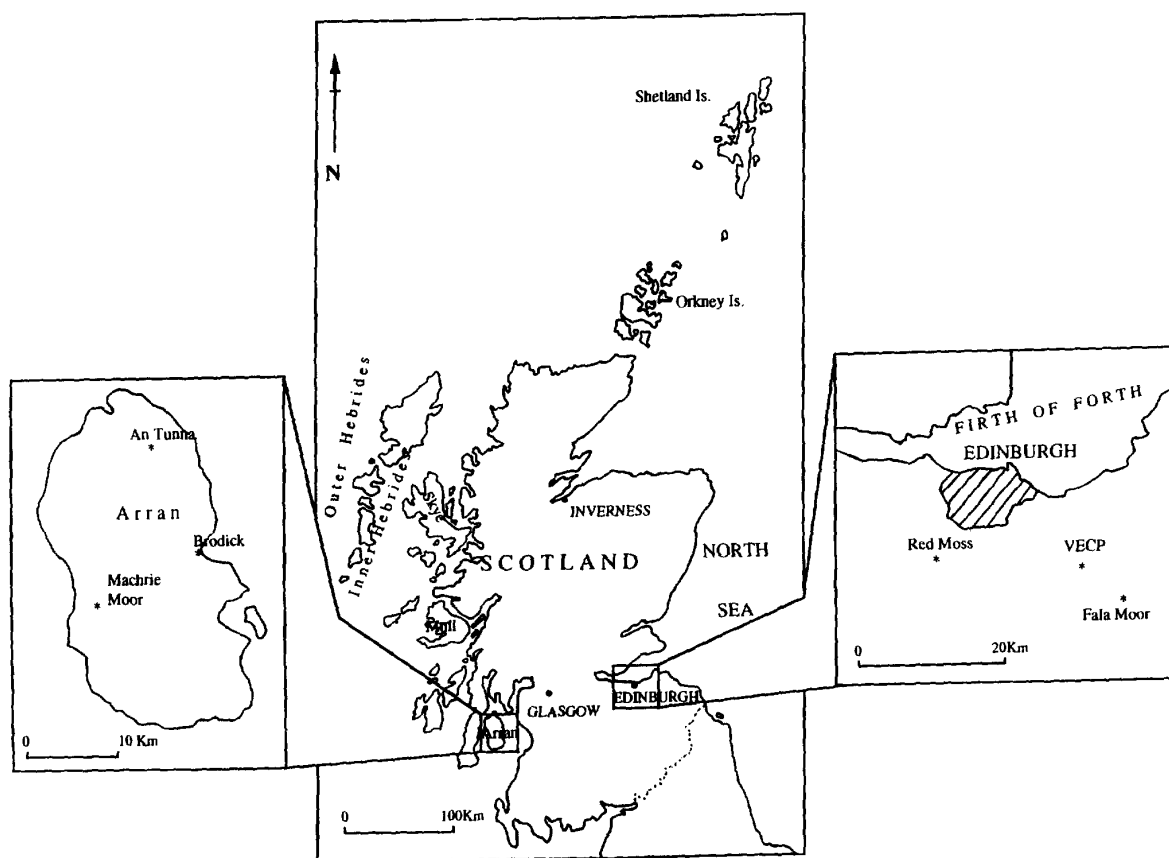


Fig. 1. Map showing location of sampling sites.

gri and Iversen, 1966). To the final precipitate, 1 ml phenolysed glycerine was added, thoroughly stirred and one drop of basic fuchsin added. The suspension was transferred to a 2-ml analyser cup, sealed, and placed in an outer screw cap specimen tube, which was then labelled. When appropriate, 50  $\mu$ l of the stained suspension was withdrawn and pipetted on to a slide. Three slides were prepared for each sample and covered with a 22  $\times$  40 mm cover slip, sealed with clear nail varnish and labelled.

Pollen identification and counts were made along three lengthwise transects on each slide using  $\times$  40 and  $\times$  100 magnifications of a Leitz 'Biomed' microscope. For pollen identification, reference was made to Hyde and Adams (1958) and Moore et al. (1991). The moss and lichen samples were identified by reference to Watson (1981), Phillips (1980) and Kershaw and Alvin (1963).

Meteorological data were obtained from *The Scotsman* newspaper, or were supplied by the Meteorological Office weather stations at Abbotsinch, Glasgow (western sites) and Turnhouse, Edinburgh (eastern sites). Maximum temperatures ( $^{\circ}$ C) and rainfall (mm) on the 5

days prior to field sampling were obtained (Tables 2 and 3). Pollen data were calculated on a percentage basis for each of the six habitats sampled (Figs. 2–7).

Sampling sites are shown in Fig. 1. Samples collected in the west were all from the Isle of Arran, which lies between the Mull of Kintyre and the Scottish mainland. Machrie Moor on the west side of the island is low lying and of significant archaeological interest with its bronze age stone circles. An Tunna is part of the mountain massif, which characterises the northern half of the island. The sampling site was on the summit's gently sloping plateau, covered with dark oily peat underlying heather. Considerable haggling (to 1–2 m depth) occurs on the southern end of the plateau. Brodick on the eastern side of the island is the main town, to the north east of which is situated Brodick Castle, with extensive landscaped gardens, lawns and woodlands.

Samples collected in the east were all in Midlothian. Red Moss at Balerno is a Site of Special Scientific Interest (SSSI), consisting of a dome-shaped peat moor with dense heather cover. Pockets of wet bog occupied by *Sphagnum* spp. occur frequently. On the drier ex-

Table 1  
Sampling sites

| Geographical location | Site | Ht. a.s.l. (m) | Nat. Grid Reference | Date of collection | Moss or lichen | Habitat             |
|-----------------------|------|----------------|---------------------|--------------------|----------------|---------------------|
| West of Scotland      | AT   | 305            | NS 977471           | 07/05/94           | M              | Montane peat 'moss' |
|                       | MM   | 20             | NS 912323           | 08/05/94           | M              | Lowland peat 'moss' |
|                       | BC   | 80             | NS 012382           | 09/05/94           | M              | Mixed woodland      |
| East of Scotland      | VECP | 150            | NT 378638           | 01/08/93           | M              | Lowland peat 'moss' |
|                       | FM   | 250            | NT 595419           | 04/08/93           | M and L        | Mixed woodland      |
|                       | RM   | 260            | NT 165637           | 06/08/93           | M and L        | Upland heather moor |

The term 'moss' is frequently used in northern Britain to denote an upland habitat — heather overlying peat.

Table 2  
Weather data for west of Scotland (Abbotsinch)

| Machrie Moor<br>Samples collected: 8/5/93 |                |               | An Tunna<br>Samples collected: 7/5/93 |                |               |
|-------------------------------------------|----------------|---------------|---------------------------------------|----------------|---------------|
| Date                                      | Max. temp (°C) | Rainfall (mm) | Date                                  | Max. temp (°C) | Rainfall (mm) |
| 3/5/94                                    | 15             | 0.3           | 2/5/94                                | 17             | 0.0           |
| 4/5/94                                    | 15             | 1.6           | 3/5/94                                | 15             | 0.3           |
| 5/5/94                                    | 11             | 0.4           | 4/5/94                                | 15             | 1.9           |
| 6/5/94                                    | 13             | 2.4           | 5/5/94                                | 11             | 1.8           |
| 7/5/94                                    | 13             | 0.7           | 6/5/94                                | 13             | 6.4           |
| $\bar{X}$                                 | 13.4           | 2.3           | $\bar{X}$                             | 14.2           | 2.1           |

| Broddick Castle<br>Samples collected: 9/5/93 |                |               | Samples collected: 7/5/93 |                |               |
|----------------------------------------------|----------------|---------------|---------------------------|----------------|---------------|
| Date                                         | Max. temp (°C) | Rainfall (mm) | Date                      | Max. temp (°C) | Rainfall (mm) |
| 4/5/94                                       | 15             | 1.9           | 2/5/94                    | 17             | 0.0           |
| 5/5/94                                       | 11             | 1.8           | 3/5/94                    | 15             | 0.3           |
| 6/5/94                                       | 13             | 6.4           | 4/5/94                    | 15             | 1.9           |
| 7/5/94                                       | 13             | 1.0           | 5/5/94                    | 11             | 1.8           |
| 8/5/94                                       | 15             | T             | 6/5/94                    | 13.4           | 1.9           |
| $\bar{X}$                                    | 13.4           | 1.9           | $\bar{X}$                 | 14.2           | 2.1           |

posed heather, *Cladonia* occurs in clumps. On the southern margin of the moss the high water table supports luscious growth of *Polytrichum* spp.

### 3. Results

Pollen spectra from five samples of moss polsters collected on Machrie Moor are shown in Fig. 2. Poaceae, *Myrica* and Ericaceae were the dominant taxa. Of the three pollen spectra from polsters collected on An Tunna (Fig. 3) Ericaceae dominated. In the five moss and single lichen polsters sampled on Red Moss (Fig. 4), Poaceae, *Myrica* and Ericaceae were again dominant, with the addition of *Betula*. The two polsters and lichen sampled from Fala Moor (Fig. 5) produced a greater diversity of taxa dominated by Poaceae and Ericaceae. The two woodland samples of *Thuidium* also produced a diverse assemblage of pollen taxa (Figs. 6 and 7).

Tables 1 and 4–7 give details of the sampling sites, mosses and lichens sampled, and pollen taxa recorded per substrate sample and habitat. Machrie Moor and Red Moss produced the highest number of pollen taxa — 16 and 12 respectively. The remaining four sites produced a smaller range of pollen taxa, 6–8 of the 21 pollen taxa recorded in this study with six occurring only once and at very low percentages.

Maximum temperatures (°C) and rainfall (mm) for each of the 5 days preceding sampling in each of western (May) and eastern (August) habitats are shown in Tables 2 and 3, respectively. Rainfall in the three western sites never exceeded 6.4 mm and then only on 1 day. The daily mean of the 5-day period was a third or less than this. The maximum temperatures for each site were fairly constant and typical for the time of year, averaging between 13 and 14°C. Maximum temperatures in eastern habitats were typically higher ranging between 17.6 and 19.0°C. The lowest mean was recorded at the Vogrie Estate Country Park woodland habitat. Rainfall in the east was minimal throughout

Table 3  
Weather data for east of Scotland (Turnhouse)

| Fala Moor<br>Samples collected: 4/8/93 |                |               | Red Moss<br>Samples collected: 6/8/93 |                |               |
|----------------------------------------|----------------|---------------|---------------------------------------|----------------|---------------|
| Date                                   | Max. temp (°C) | Rainfall (mm) | Date                                  | Max. temp (°C) | Rainfall (mm) |
| 30/7/93                                | 21             | 0.9           | 1/8/93                                | 17             | 1.0           |
| 31/7/93                                | 18             | T             | 2/8/93                                | 19             | 0.0           |
| 1/8/93                                 | 17             | 1.0           | 3/8/93                                | 20             | T             |
| 2/8/93                                 | 19             | 0.0           | 4/8/93                                | 18             | 1.0           |
| 3/8/93                                 | 20             | T             | 5/8/93                                | 20             | T             |
| $\bar{X}$                              | 19             | 0.4           | $\bar{X}$                             | 18.5           | 0.3           |

| Vogrie Estate Country Park<br>Samples collected: 1/8/93 |                |               | Samples collected: 12/8/93 |                |               |
|---------------------------------------------------------|----------------|---------------|----------------------------|----------------|---------------|
| Date                                                    | Max. temp (°C) | Rainfall (mm) | Date                       | Max. temp (°C) | Rainfall (mm) |
| 27/7/93                                                 | 17             | T             | 7/8/93                     | 17             | 0.2           |
| 28/7/93                                                 | 17             | 0.3           | 8/8/93                     | 19             | T             |
| 29/7/93                                                 | 19             | 0.2           | 9/8/93                     | 16             | T             |
| 30/7/93                                                 | 19             | 0.0           | 10/8/93                    | 19             | 4.1           |
| 31/7/93                                                 | 18             | T             | 11/8/93                    | 17             | T             |
| $\bar{X}$                                               | 18             | 0.1           | $\bar{X}$                  | 17.6           | 0.9           |

the 5-day period prior to sampling. Generally, the western half of Scotland has a wetter and warmer climate than the eastern half for most of the year.

#### 4. Discussion

Of the samples collected from open habitats, *Sphagnum* yielded 12 identified taxa. The water-logged habitat and morphology of the Sphagnales renders them excellent pollen rain traps. The number of identified taxa recorded from *Acrocladium*, *Polytrichum*, *Mnium* and *Pleurozium*, all from open habitats, ranged respectively in decreasing order: 9, 7, 6 and 5. The two lichens sampled, *Peltigera* and *Cladonia*, yielded 6 and 5 taxa respectively, similar to those of *Mnium* and *Pleurozium*. The two samples of *Thuidium* from the closed woodland habitat revealed a phenological range of pollen taxa which contrasted strikingly with those of the samples collected from open habitats. The woodland samples contained a spectrum of pollen taxa which are 'on the wind' throughout the year from February to August: *Corylus*, *Alnus*, *Betula*, *Ulmus* and *Pinus* extending successively from February to May; the remaining taxa recorded collectively were from inflorescences, shedding pollen during June, July and August, in Scotland. Thus there appears to be a cumulative effect in *Thuidium*, a common woodland species, which suggests the existence of a shelter-

ing effect from rainfall of progressive leaf canopy development from late Spring (April) onwards. Those mosses and lichens sampled from open habitats lack the sheltering effect of canopy and are exposed to direct forceful rain wash which washes pollen down, so that pollen taxa present at the time of sampling reflects the pollen rain during the period immediately preceding, and currently, the time of sampling. In the case of the west of Scotland, sampling occurred in May whilst in the east of Scotland, sampling was in August (Table 1), each reflecting to some extent the current pollen rain. *Sphagnum*, like *Thuidium*, tends to accumulate pollen as the year progresses, which, unlike *Thuidium*, is due to the water-logging effect from the persistence of a high water table in the habitat. Only where *Sphagnum* polsters are raised well above the water table does rainfall have a washing down effect on the pollen trapped, but this situation is not typical for this moss.

In the samples analysed, those from open habitats yielded a significantly higher number of taxa (21) than those from sheltered woodland habitats (12) (Table 7). There was no significant difference between the number of pollen taxa observed in samples collected in open habitats in the west and those in the east (15 and 16, respectively). Likewise, no significant difference was observed between the number of taxa recorded in samples of *Thuidium* collected in sheltered habitats in the west and those in the east (6 and 7,

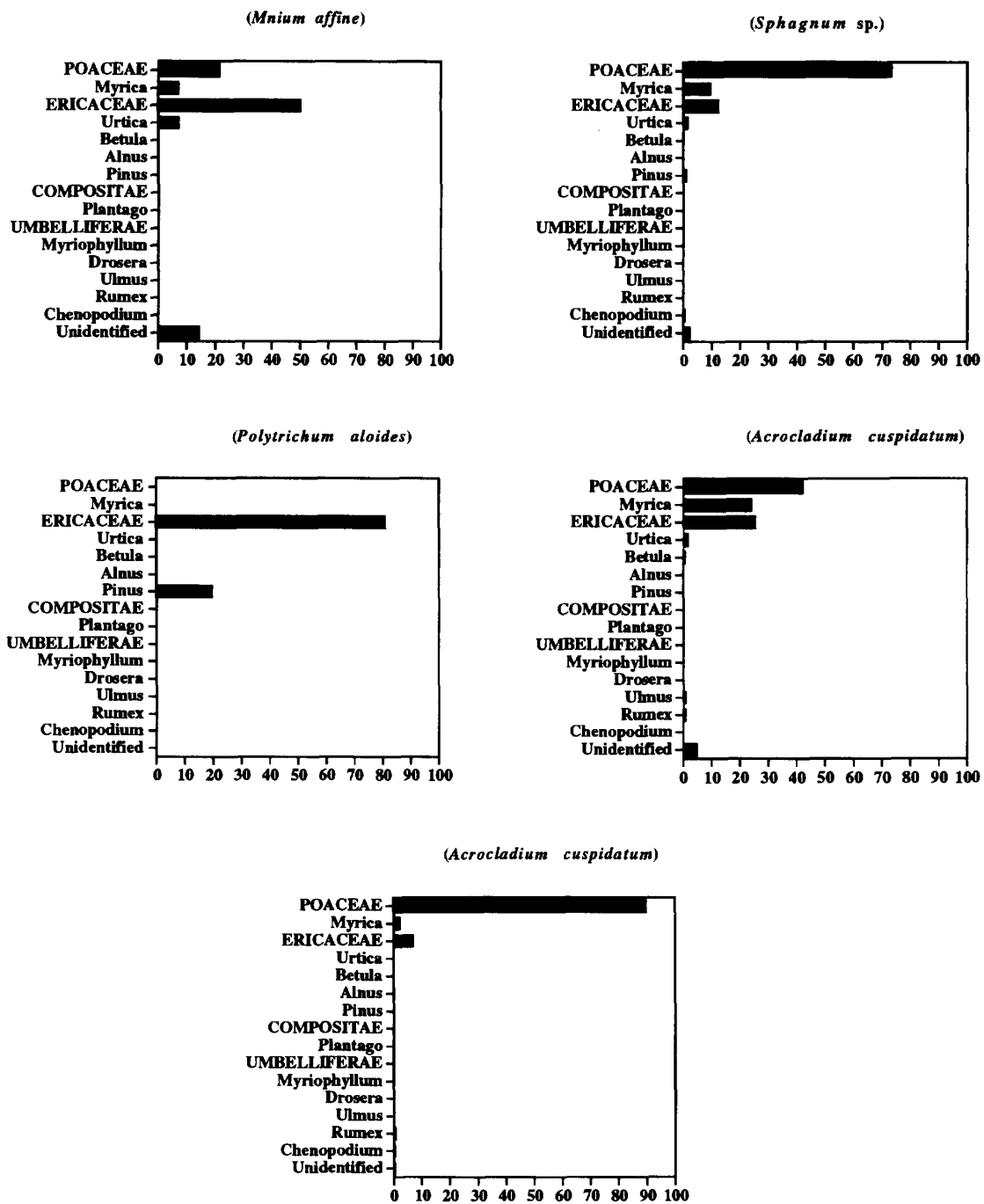


Fig. 2. Machrie Moor (MM) (west of Scotland) pollen spectra.

respectively). Poaceae and *Pinus* were the only taxa recorded in all six habitats sampled. Six taxa were recorded as only occurring in one habitat sampled: *Filipendula*, *Galium*, Papilionaceae, *Plantago*, *Rumex* and *Taxus*.

Similar studies undertaken in Spain (Ferreño and Rodríguez, 1990) make an interesting comparison with respect to *Polytrichum*, *Thuidium* and *Cladonia*. Twenty-three pollen taxa were recorded for *Polytrichum* in Spain, whereas only eight taxa were recorded in

Scotland. *Thuidium* yielded 21 taxa in Spain and 15 in Scotland. Thirteen pollen taxa were recorded trapped in the thallus of *Cladonia* in Spain, but only five in Scotland. Almost three times as many pollen

taxa were recorded by Ferreño and Rodríguez (1990) from *Polytrichum* and *Cladonia*, and one and a half times as many from *Thuidium*. Whilst no meteorological data pertaining to site or time of the Spanish sampling were given, it is reasonable to infer that the significant differences between the number of pollen taxa retained by *Polytrichum* and *Cladonia* are a function of difference in rainfall regimes experienced in Spain and Scotland (Tables 6 and 7). Samples of *Thuidium* from both Spain and Scotland were derived from woodland habitats and the sheltering effect of canopy is possibly a feature in common.

The problem of correlating the pollen rain in moss polsters adjacent to herbivore faecal sampling sites, with the pollen rain component in and on faecal pellets, lies in extrapolating the number of pollen grains per gram of fresh moss sampled to the number of pollen grains per gram of faecal material. Experiments along these lines are continuing and it is hoped to establish a reliable pollen rain monitoring system for comparison using moss polsters from open habitats as controls. Ongoing studies of this aspect indicate, however, that this technique may not be as reliable as at first thought, due to the varying and fluctuating effects of microclimatic factors on bryophyte polsters and their ability to retain pollen rain consistently to enable regular sampling to be effective controls.

## 5. Conclusions

Monitoring pollen spectra in the Bryophyte and Lichen taxa sampled in this study was found to be of value when sampled at regular intervals to reflect current air-borne pollen components and both local and regional vegetation.

This study has indicated that sampling polsters from 'open' sites (e.g. moorland) as opposed to 'closed' sites (e.g. woodland) is to be preferred for reliable results from pollen rain analysis.

Ongoing studies indicate that pollen rain analysis from moss polsters/mats may be difficult to use directly as controls in the assessment of the pollen rain component of the pollen spectra in herbivore.

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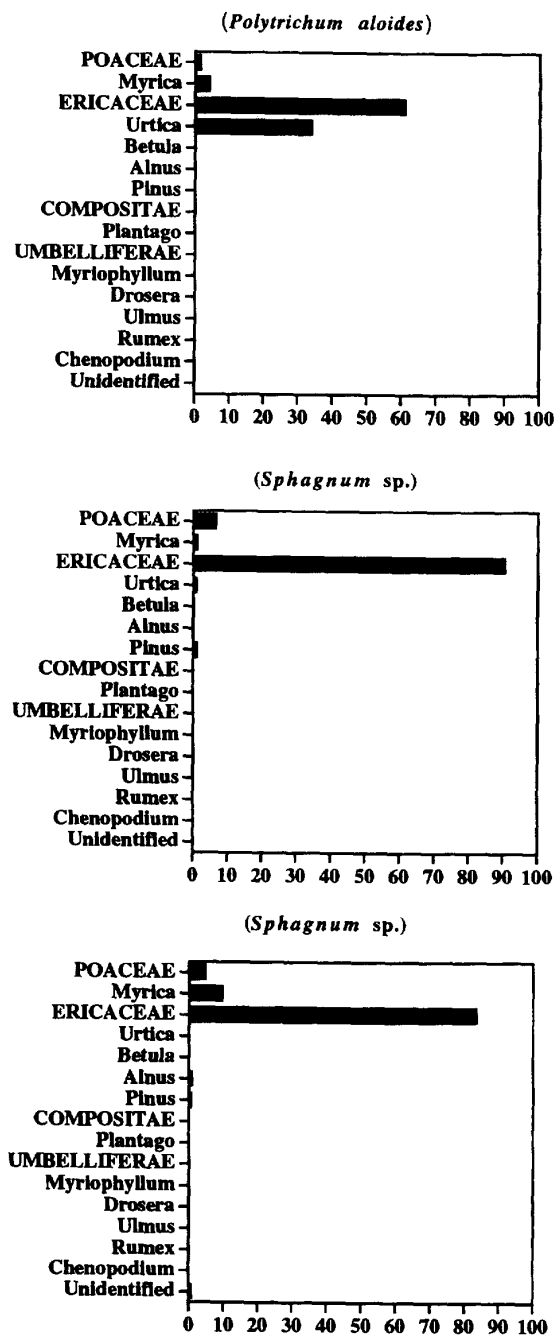


Fig. 3. An Tunna (AT) (west of Scotland) pollen spectra.

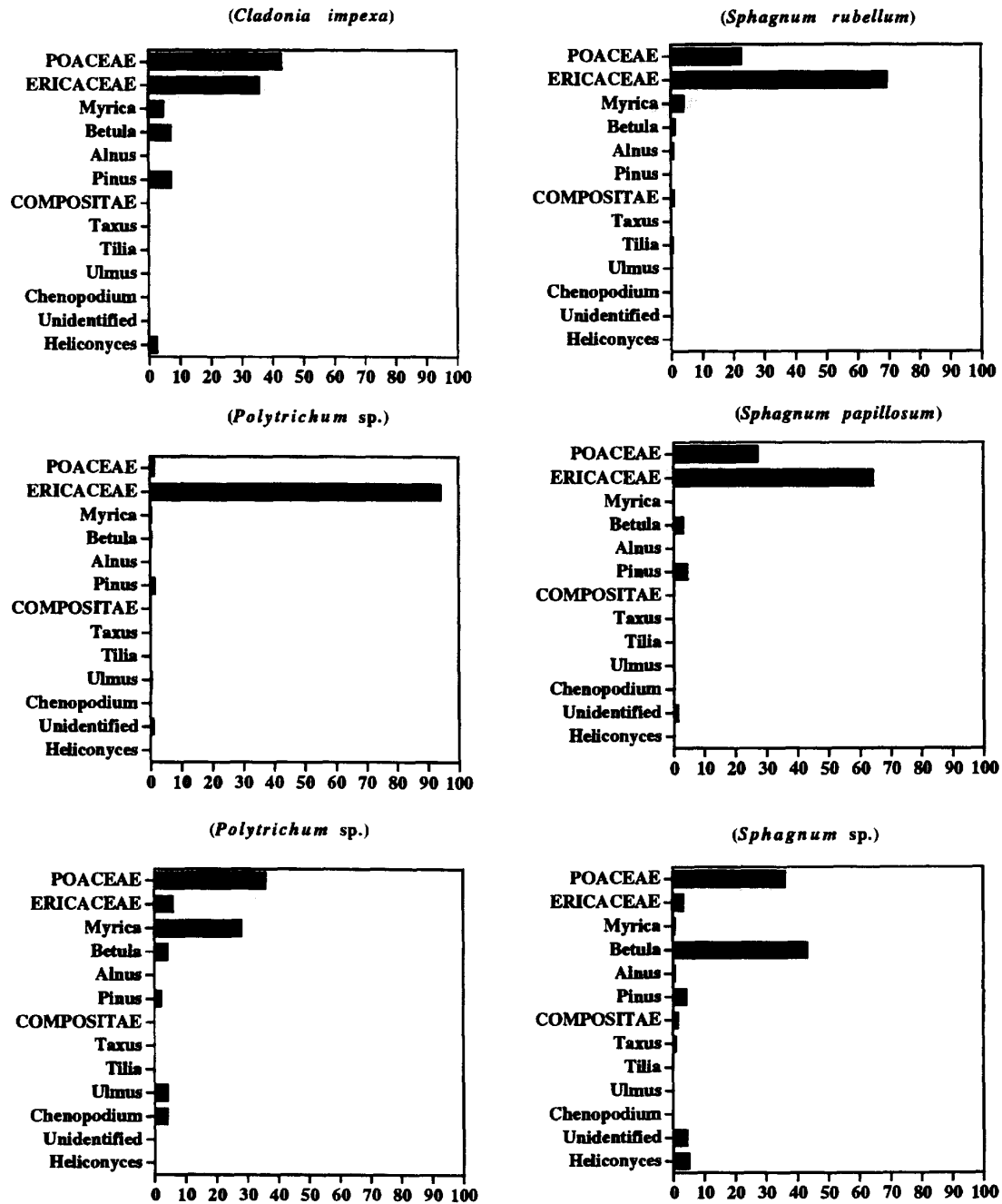


Fig. 4. Red Moss Balerno (RM) (east of Scotland) pollen spectra.

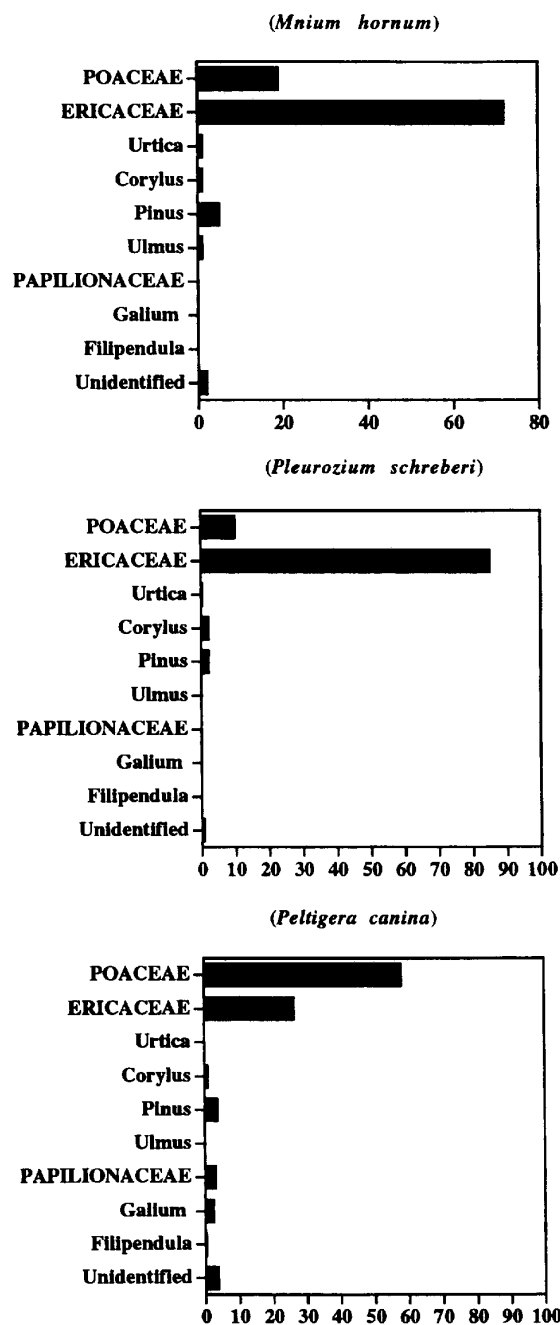


Fig. 5. Fala Moor (FM) (east of Scotland) pollen spectra.

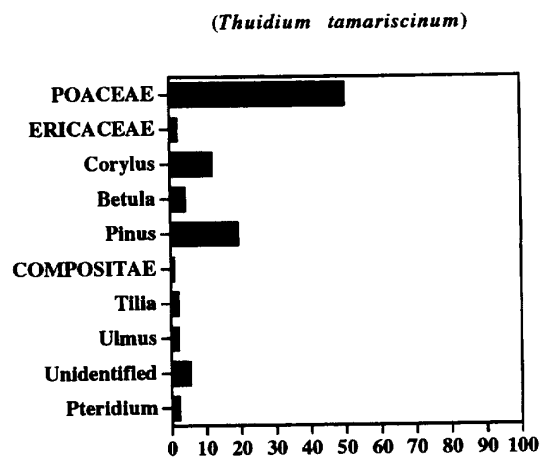


Fig. 6. Brodick Castle (BC) (west of Scotland) pollen spectra.

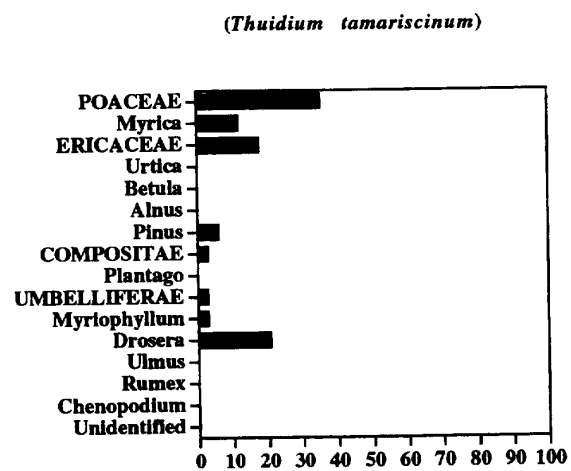


Fig. 7. Vogrie Estate Country Park (VECP) (east of Scotland) pollen spectra.

Table 4  
Mosses and lichens sampled

| Site                                | Taxon - Substrate                                                                                                                                  |
|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. An Tunna (AT)                    | <i>Polytrichum aloides</i><br>Hedw., <i>Sphagnum</i><br>spp.                                                                                       |
| 2. Machrie Moor (MM)                | <i>Sphagnum</i> sp.,<br><i>Mnium affine</i><br>Bland. ex Funck,<br><i>P. aloides</i> ,<br><i>Acroladium</i><br><i>cuspidatum</i> (Hedw.)<br>Lindb. |
| 3. Brodick Castle (BC)              | <i>Thuidium</i><br><i>tamariscinum</i><br>(Hedw.) B., S. and<br>G.                                                                                 |
| 4. Vogrie Esate Country Park (VECP) | <i>T. tamariscinum</i>                                                                                                                             |
| 5. Fala Moor (FM)                   | <i>Mnium hornum</i><br>Hedw., <i>Pleurozium</i><br><i>schreberi</i> (Brid.)<br>Mitt., <i>Peltigera</i> sp.                                         |
| 6. Red Moss (RM)                    | <i>Sphagnum rubellum</i><br>Wils., <i>S. papillosum</i><br>Lindb., <i>Sphagnum</i><br>sp., <i>Cladonia</i> sp.,<br><i>Polytrichum</i> sp.          |

Table 5  
Number of pollen taxa recorded per moss/lichen taxon

| Moss/lichen        | No. samples | Total No. taxa recorded |
|--------------------|-------------|-------------------------|
| <i>Acrocladium</i> | 2           | 9                       |
| <i>Mnium</i>       | 2           | 8                       |
| <i>Pleurozium</i>  | 1           | 7                       |
| <i>Polytrichum</i> | 4           | 9                       |
| <i>Sphagnum</i>    | 5           | 12                      |
| <i>Thuidium</i>    | 2           | 12                      |
| <i>Cladonia</i>    | 1           | 5                       |
| <i>Peltigera</i>   | 1           | 8                       |

Table 6  
Pollen taxa recorded by habitat

| Habitat            | No. taxa |
|--------------------|----------|
| Woodland (W and E) | 12       |
| Open (W and E)     | 21       |
| Woodland (W)       | 7        |
| Woodland (E)       | 8        |
| Open (W)           | 15       |
| Open (E)           | 16       |

Table 7  
Distribution of pollen taxa among habitats sampled

| Pollen taxa         | Habitat type |    |    |    |          |      | No. habitats recorded |
|---------------------|--------------|----|----|----|----------|------|-----------------------|
|                     | Open         |    |    |    | Woodland |      |                       |
|                     | MM           | AT | RM | FM | BC       | VECP |                       |
| <i>Alnus</i>        | ×            | ×  | ×  |    |          |      | 3                     |
| <i>Betula</i>       | ×            |    | ×  |    |          | ×    | 3                     |
| <i>Corylus</i>      |              |    |    | ×  |          | ×    | 2                     |
| <i>Pinus</i>        | ×            | ×  | ×  | ×  | ×        | ×    | 6                     |
| <i>Taxus</i>        |              |    | ×  |    |          |      | 1                     |
| <i>Tilia</i>        |              |    | ×  |    |          | ×    | 2                     |
| <i>Ulmus</i>        | ×            |    | ×  | ×  |          | ×    | 4                     |
| Ericaceae           | ×            | ×  | ×  |    |          | ×    | 4                     |
| <i>Myrica</i>       | ×            | ×  | ×  | ×  | ×        |      | 5                     |
| <i>Chenopodium</i>  | ×            |    | ×  |    |          |      | 2                     |
| Compositae          |              |    | ×  |    |          | ×    | 4                     |
| <i>Drosera</i>      | ×            |    |    |    | ×        |      | 2                     |
| <i>Filipendula</i>  |              |    |    | ×  |          |      | 1                     |
| <i>Galium</i>       |              |    |    | ×  |          |      | 1                     |
| <i>Myriophyllum</i> | ×            |    |    |    | ×        |      | 2                     |
| Papilionaceae       |              |    |    | ×  |          |      | 1                     |
| <i>Plantago</i>     | ×            |    |    |    |          |      | 1                     |
| Poaceae             | ×            | ×  | ×  | ×  | ×        | ×    | 6                     |
| <i>Rumex</i>        | ×            |    |    |    |          |      | 1                     |
| Umbelliferae        | ×            |    |    |    | ×        |      | 2                     |
| <i>Urtica</i>       | ×            | ×  | ×  |    |          |      | 3                     |

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