MOOR HOUSE

13th Annual Report, 1972

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THE NATURE CONSERVANCY

MOOR HOUSE

1972

13th Annual Progress Report

M. Rawes

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I. GENERAL

The Report covers the period 1 October, 1971 to 30 September, 1972.

It is 20 years since Moor House became a Field Station and National Nature Reserve. It was bought from the Appleby Castle Estate on 12 November, 1951 and declared a Reserve on 19 May, 1952. Since this time there have been many developments and the fortunes of the Station have waxed and waned according to interest and factors outside local control. More than 200 scientific papers have now been published, adding considerably to ecological knowledge. It is an undisputed fact that the biological data now held are, for a moorland area, second to none. It is therefore all the more regretable that a Report prepared in 1968 never saw the light of day. It brought together research findings and discussed developments over the first 15 years. The original report envisaged accounts of botany, zoology, microbiology, climate local history, soils, geology, and management. Some of these articles will be produced as Moor House Occasional Papers, a Station series started this year. The object of the Occasional Paper series is to produce accounts, on a range of topics, aimed at a wider public than catered for by scientific journals. The first paper discusses the influence of agricultural practice on the ecology of Pennine moorland whilst an account of grouse studies on the Reserve is in draft. Those who feel they have something to contribute are invited to submit articles for consideration.

Staff

In April, the Hodgson family left Moor House for Somerset, where Tom is now Warden of the Bridgwater Bay Nature Reserve. Tom and Mary came to Moor House in November, 1951. They were the Conservancy's first employees. Many of the facilities now accepted as normal owe their origin to Tom's efforts; for example the improvements to the road, at one time responsible for the breaking of a number of car sumps, are largely due to him, whilst his assistance, particularly in times of adversity, will long be remembered. Mary, after undertaking domestic duties in the hostel, followed Mrs. Steele as housekeeper, a post she held until 1970.

Tom Hodgson has been succeeded by J.P. Houlton as Warden. He and his family took up residence in the cottage in April. P. Holms was appointed Estate Worker in November, 1971, and J. Rose once again carried out duties as part-time warden on the west side of the Reserve, where he supervised the ski-ing during the winter months. E. Phillips took over these duties at the latter part of the season. Sheila Carrick, who before joining the F.B.A. had been a member of the Moor House I.B.P. staff, resigned on her marriage in August.

Students

The work of the Station has been assisted during the summer by four students, Mark Watson from Sheffield University, and Hilary Middleton, David Tattersfield and Dave Paget from Leeds. Paul Taylor continued his I.B.P. study of the Red Grouse whilst employed in Teesdale. Stephen Kirby, funded by his University, Nottingham, undertook a short study of sheep behaviour. The F.B.A. team had assistance from Nigel Reader (Liverpool Polytechnic) and Nicky Robinson (Leicester University).

Among the higher degree students Roger Wotton (Durham) spent much of the latter part of the summer on the Station, whilst from the same University Tusi Butterfield returned in her final year for the emergence of Tipula subnodicornis and Michael Ashmore (Leeds) started investigations into the growth of Calluna.

Visitors

Visits from overseas scientists have been made by Mr. Rowland Clement (Audubon Society of New York), Dr. N.G. Kaule (Munich University), Dr. I.G. Stone (Botany School, Melbourne University), P. Widden (Calgary University), and Peter Williams (Lincoln College, New Zealand). Among others there have been visits by Professor N. Tinbergen (Oxford), Alan Eddy (British Museum), Dr. J. Smart (Cambridge) and Mr. D. Jackson (Game Conservancy). Parties from Durham, London and Newcastle Universities have used the Reserve for teaching purposes and talks by the staff have been given to them. The Warden has conducted other parties, such as the Arnside Natural History Society, and a number of smaller groups of visitors.

The hostel was opened after Easter and the number using it has been up by 50% on last year. Altogether it has been a satisfactory year and the end of the I.B.P. has not resulted in the drop in interest which might have been expected. Nevertheless, it is hoped that the forthcoming changes in organisation of the Nature Conservancy will not affect research use of Moor House and raise once more its future into question; every effort will be made to continue to provide facilities, which must be unique, for ecologists and others to pursue studies of upland habitats. In this connection it may not be out of place to reiterate the management objectives of Moor House. They are: to protect and enhance the scientific interest and conservation value of the Reserve; to use the experience gained in the Reserve as a demonstration, and for advice, on the conservation of similar areas faced with similar management and land-use problems; to undertake and/or foster the necessary survey, monitoring and research to determine optimum management prescriptions in similar potential land-use situations and to facilitate the use of the Reserve for studies relevant to upland ecology, provided they do not obstruct conservation objectives; to permit and encourage educational use of the Reserve and allow recreational use so far as conservation requirements allow in both cases.

Commons Registration

There are three Commons, Milburn, Knock, and part of Dufton, within the boundaries of Moor House. The ownership and certain rights, such as grazing, on these commons have been registered by the Conservancy under the Commons Registration Act of 1965. The final day for objections to be lodged to any registration entry was 31 July 1972. Copies of the relevant parts of the Register are now held by the Nature Conservancy's Land Agents. Registration is but a preliminary stage to possible alteration in the law concerning Common Land.

Developments

Over the western part of the Reserve the mineral rights are not held by the Conservancy and an application to work the barytes in the Silver Band Mine area was granted by the Westmorland County Council on 14 January, 1972. It is expected that operations will start shortly and attention will be paid to possible pollution of Middle Tongue Beck and damage to affected habitats. Meanwhile the Northern Cavern and Mining Research Society have continued their exploration and mapping of old lead mines on the Reserve.

Management

Heather burning of 12 acres in the Green Burn area took place on 23-24 March. The Meadow was mown in July and a hay crop of better quality than usual was harvested, most of it without being rained upon, but yield was lower than usual. Estate work has been largely routine and no major undertaking has been started this year.

Warden's Reports

Quarterly reports on Reserve activities and aspects of the natural history are made by the Warden and copies of these reports are held in the Reserve Record.

II. SCIENTIFIC - Moor House Staff

A. General

Whereas the primary function of the resident staff has hitherto been to monitor changes in the wildlife and the soils of the Reserve and to follow changes after management treatments such as alterations in grazing pressure, burning regimes and draining, it has now become equally important to put the research findings of Moor House into a wider context by extending study beyond the Reserve. Recent surveys have served this purpose as well as providing conservation information of direct value. For instance, the survey of the River Caldew, and of parts of Cumberland for the preparation of a conservation map for the County Structure Plan, have both had an additional use; they provided data on which part of the Conservancy's statement at a Public Inquiry in Penrith on the route of the A66 Trunk road to Workington was based.

This year the Conservancy's North Region has undertaken the provision of the conservation aspects of a North Pennine Study organised by the North Riding Planning Authority. Moor House staff have contributed to this. Also, surveys of a 150 mile square area of North-East Westmorland, from Cross Fell to Mallerstang, have been started and outside research workers have been encouraged to investigate this interesting area within which Moor House lies. It is an extensive tract of high ground, containing a good variety of sites of considerable conservation interest. Improving road communications, change in village populations with the increase in demand for second homes, the build up of recreational and leisure pursuits, all suggest that this relatively undisturbed area will not remain unaffected much longer. By the end of this year broad survey maps of the vegetation and soil will have been completed, using air photographs and ground survey. The work on the vegetation has been done by Mark Watson (Sheffield) supervised by Mr. T. Dargie and Mr. J.L. van Genderen, of the Sheffield Geography Department, whilst Dr. M. Hornung has drawn a soil map. To assist in this work of photo-interpretation a stereoscope was loaned by the Montane Grassland Habitat Team, Bangor. Additionally a number of people have contributed information of the area. Dr. J. Richards (Newcastle) and party searched 16 1Km squares on the higher fells and were successful in finding some interesting plants; Mrs. Christine Mallett (University College, London) has examined the effects of different agricultural managements on the vegetation and soils of in bye and fell land on the western escarpment. Meanwhile Moor House staff are collecting climatological information and listing local plant and animal records. Thus the first objective of this study, to survey and map the area, has got a good start and consideration can be given to the other objectives: the assessment of conservation value and the causes of the present condition, the measurement or prediction of the impact of all relevant changes of management, and finally the production of conservation management plans.

Monitoring of botanical change on sites throughout the Reserve has continued. Examination of the most heavily used ski-run on Great Dun Fell has revealed little direct damage to the vegetation, but as in the previous winter the amount of ski-ing was relatively small due to lack of snow and higher than normal temperatures. Records are kept of the number of skiers and their distribution throughout the ski-ing area.

The present situation concerning the Grouse (see P. Taylor's report) is one of extreme interest and it is imperative that we should continue to study what has for the past two years been a higher than normal population. Two mild winters and ample heather are responsible for the successful breeding of these birds.

Continued efforts have been made to add to the plant and animal species records on the Reserve. P. Houlton has identified fungi not previously recorded. He will be developing a study of tree/fungi relationships which may be of value to further tree planting and helpful in explaining tree failures in some of the past plantings. In the course of a mycological survey he will concentrate on host/fungus relationships.

B. Climatology - Project 1/06 (R.B. Marsh)

The weather summary for 1971 is to be found in the appendices.

The year covered by this report started off by being mild throughout the winter, with the earth thermometer at 30 cm, being above average for the first seven months until April, after which it has been below average.

Rainfall has been below average for the third year running; at 1586 mm it was 791 mm lower than last year. The driest month was September with 30.4 mm which is the lowest rainfall for any month since records began at Moor House in 1953.

The number of days of ground frost recorded was up by 27, only December, April and May had fewer days than average, but there were 23 days more of ground frost recorded between the beginning of June and end of September.

The Spring, April to June, was sunless and wet. Sunshine was below average by 0.96; 1.88 and 1.11 hours per day for each month respectively, whilst over a third (540 mm) of the year's rainfall fell in these three months.

C. Studies on the interaction between sheep and vegetation - Project 1/01 (M. Rawes, R. Williams, R.B. Marsh and L. Teasdale)

Changes in vegetational composition are followed in a number of ways; by air and ground photography, by drawing scaled charts, and, most commonly, by botanical analysis of representative sites that vary in size from the isolated 1 m^2 quadrat to a 0.2 ha site gridded into sampling units. The point quadrat and cover abundance estimation methods are mainly used to follow changes in the following regimes:-

1) The existing free range sheep grazing system,
2) The absence of sheep grazing, and
3) Modified grazing, burning, and draining treatments.

The vegetation types being studied are the Agrosto-Festuceta, Festuceta, a Nardetum, Juncetum squarrosi, varying blanket bog types and a calcareous flush.

1) Some effects of the present sheep grazing regime.

Whilst the number of sheep grazing the three commons of Dufton, Knock and Milburn has remained in total much the same over the past ten years there have recently been management changes, which, if continued, may have some effect on the vegetation. One change is the increase in the number of half-bred (grey faced) lambs on the fell. This has come about with the growing popularity of the Border Leicester, in place of the Wensleydale and Teeswater tup, as a crossing breed for the Swaledale ewe. The Border Leicester cross produces a more hardy lamb and it is thus tempting to graze these on the fell rather than keep them on in bye land, but they are larger than the pure bred Swaledale lamb and require food of a better quality. The other change has been in the increase in the Rough Fell breed, a sheep more adapted to grassland conditions and more "domesticated" than the Swaledale. These changes will have to be recorded also and in view of them it was opportune that an interest in sheep behaviour should have been renewed by a short study by Stephen Kirby on home range and diurnal pattern during the summer. A number of sheep were tagged and after a period of observation their territories were mapped. Records of diurnal pattern included time spent by ewes grazing (14 hours), ruminating (3 hours) and resting (sleeping) (7 hours).

Repeat measurements were made of a series of m^2 vegetation chart quadrats to record cover of selected species, such as Juncus squarrosus and Nardus in Agrosto-Festuceta. In general, the evidence is that Juncus varied markedly over a five year period but that there has been an increase in Nardus. The study is insufficiently precise or of great enough coverage to do more than suggest change. Re-examination of the permanent point quadrat areas, such as those on Knock Fell and Hard Hill, where the two species are components of the grazed sward, are necessary.

2) Some effects of removing the grazing factor

No botanical field work has been done in existing exclosures except Green Hole where D. Tattersfield repeated the Braun Blanquet quadrats set out in 1958. The following shows the order of change that has occurred in an exclosure, erected in 1954, having a variety of aspects, soils and vegetatio with a number of different species of tree planted. Tree canopy is variable, only Pine and Rowan having much influence on the vegetation. The other species have mainly died.

Festuca grassland planted with Birch, Scots Pine and Rowan

Deschampsia flexuosa increased in all cases, but Festuca ovina was still common except under Pine where it has been eliminated. Agrostis species have increased, especially A. tenuis. Juncus squarrosus and Nardus, where originall present, have been eliminated. Galium saxatile has tended to be reduced. Calluna has invaded Rowan sites. The number of moss species has been reduced by half, but Pleurozium schreberi, Hypnum cupressiforme and especially Rhytidiadelphus squarrosus remain and may have increased. Polytrichum commune has increased under Rowan. Liverworts have all been reduced.

Deschampsia flexuosa grassland planted with Birch, Scots Pine and Rowan

There has been little change in the status of Deschampsia flexuosa except under Rowan where it has increased. Festuca has also shown little change. There has been a slight decrease in D. flexuosa under Pine with concommitant slight increase in F. ovina. Galium saxatile has remained stable.

Juncus squarrosus, Nardus stricta, and Vacinnium myrtillus have been eliminated where present. Eriophorum vaginatum has invaded the Pine site in one case and become co-dominant. The number of moss species has been reduced by half except under Pine where the species composition has changed. Otherwise Pleurozium schreberi, Rhytidiadelphus squarrosus and Hypnum cupressiforme have become dominant with Plagiothecium undulatum having replaced Camplylopus flexuosus under Calluna. There has been an almost total reduction of liverworts.

Vegetation under Ash

In a very diverse sward with 20 angiosperms there has been a reduction in the number of species and a large increase in Deschampsia cespitosa and Alchemilla glabra. All other grass species except Poa subcaerulea have been eliminated. Virtually the only bryophyte to survive has been Rhytidiadelphus squarrosus which has increased.

Vegetation under Alder

Two quadrats show a reduction of everything except D. flexuosa and Galium saxatile. All bryophytes are gone except Pleurozium schreberi and Rhytidiadelphus squarrosus. Two streamside quadrats have become dominated by Holcus mollis although here there has been an increase in overall species diversity. There are now no liverworts but the mosses, especially Rhytidiadelphus squarrosus have held on.

Calluna and Eriophorum under Pine

Calluna has remained dominant in all cases but Empetrum and E. vaginatum have been largely eliminated and Rubus chamaemorus has increased slightly. Mosses have in every case increased in number, especially Rhytidiadelphus squarrosus and Pleurozium schreberi, which with Plagiothecium undulatum and Hypnum cupressiforme are, as in most other quadrats, now the dominant bryophytes. There is still a range of liverwort species but there are fewer lichens.

A new monitoring site

Calcareous flush vegetation is of high scientific and conservation value. Little work has been done on the effects of managing these flushes and steps are now being taken to record botanical change under grazing and exclosure.

'Johnny's Flush' is by Moss Burn. It covers an area of about 400 m^2, and it is fed by a spring that emerges below a limestone outcrop at its head.

Two similar areas of 10m x 6m were chosen for analysis, each being heavily grazed with a few patches of Juncus effusus. The lower plot will be fenced and the change in vegetation recorded under a no-grazing treatment. The higher plot will act as a grazed control.

Each plot is divided into 60m^2 quadrats; 30 of which were chosen at random for analysis. 20 stratified point quadrats are recorded in each m^2, being in two rows of ten pins with 10 cm between each pin and 10 cm between the two rows.

The analysis was carried out in August and September. Preliminary results show a species list of over 40 angiosperms, 5 carices, 4 juncaceae and 3 saxifrages. There are about 25 bryophytes although no lichens were recorded.

3) Effects of management - increased grazing, burning and draining

This work is at present restricted to blanket bog. A trial in which all treatments are being tested with the minimum of grazing and management alternatives has been described in four previous reports. Data are also obtained from 1) the Hard Hill burning experiment, which has two rotations, a 10 year and a 20 year burning regime, with and without sheep grazing, and, 2) the Burnt Hill, draining - grazed and ungrazed - site. These trials are both long-continued and the information they now yield independently can have wider interpretation. Thus, Rawes and Williams gave a paper at Edinburgh (see publication list), using these data, on the possibility of improving the quality rather than quantity of blanket bog as grazing for herbivores of economic value. Two methods were discussed, i) the increase of sheep stocking to convert the vegetation to a predominantly monocotyledonous sward - this used data from the House Hill grazing trials, and ii) the control or complete removal of sheep grazing and reduction or dispensation with burning to increase the shoot production of Calluna for grouse. Heavy grazing was found to increase the amount of green leaf in Eriophorum vaginatum threefold, although Calluna was eliminated apart from seedlings. Light grazing of blanket bog in the absence of burning, resulted in slightly more heather shoots than in the control, but burning markedly affected production, even when grazing was minimal. Thus even 17 years after a burn Calluna shoot weight per unit area was only 58% of the control. The burning of wet blanket bog can have an adverse effect on the bog surface for a long time. This is shown (see Table) by the extent of bare ground and the cover of colonising bryophytes which were greater than under heavy grazing alone.

	Grazing Trial				Burning Trial				
					Short rotation		Long rotation		
Colonisers	Heavy grazing and burning	Heavy grazing	Light grazing	Control	Ungrazed	Grazed	Ungrazed	Grazed	Control
Pohlia nutans	11	5	2	1	35	14	10	5	13
Campylopus flexuosus	7	3	1	2	31	33	8	16	1
Algae	27	21	5	11	3	30	5	26	1
Bare ground	19	11	-	-	8	10	5	9	1
Total	64	40	8	14	77	87	28	56	16

Relative cover values under different treatments

D. The establishment of natural grassland communities - Project 1/02 (M. Rawes & Miss L. Teasdale)

British upland vegetation is widely regarded as floristically impoverished owing to sheep grazing, and, this poverty, is generally true of much of the Pennines. An account of a trial in which grazing has been removed and about 30 plant species of restricted range introduced to Moor House has been published (Rawes & Welch, Biol. Cons., 4) after 15 years of recording. The persistence and performance of these species has been noted each year. Grasses have suppressed many of the herbaceous plants, but in Rough Sike, a limestone gorge, dwarf-shrubs are increasing and there is now a display of colourful flowering plants, several of which have become firmly established. They include Alchemilla alpina, Salix arbuscula, S. reticulata and Saussurea alpina, whilst Draba incana, Polygonum viviparum, Potentilla crantzii and Thalictrum alpinum, which occur naturally, although infrequently in the area, have spread.

These trials are restricted in the species used and the habitats tested, nevertheless it is clear that different vegetation types from those present now, under range grazing conditions, would flourish given the opportunity. For example dwarf Salix scrub is a possible vegetation for the damper habitats above the tree-line; tall herb communities could be created on the more base-rich soils, and, a greater range of dwarf heath shrubs could grow on the acid soils. There is scope for active manipulation of swards should this be required.

E. Grass species trial - Project 1/04 (M. Rawes, T.H. Davies & Miss L. Teasdale)

The agricultural grasses and clovers sown in 1970 and reported upon last year have, where space planted in rows, almost entirely died, except for 20% of the Cocksfoot - Saborto (BC5754). When sown as a sward the Cocksfoot and Red Clover (Sabtoron AA14 and Maris-Leda, tetraploid) have grown well, but the Agrostis (Saboval Br963) is disappointing. Italian Ryegrass (Sabalan, tetraploid, Bb1241), Hybrid Ryegrass (Sabrina, tetraploid, Bb1237) and White Clover (Sabeda) are very sparse. The trial is now discontinued.

III. RESEARCH BY MERLEWOOD STAFF

A. Tree growth and nutrition - Project 3/03 (A.H.F. Brown)

Growth of the more successful species (Pine and Rowan) continues to be satisfactory except at Green Hole, where further die back of Scots Pine has occurred. In some instances this is associated with the presence of the Pine Shoot beetle (Myelophilus piniperda), which typically attacks trees weakened through other causes. Whether the trees at Green Hole are susceptible to attack merely due to the rigours of the site, or whether there has also been weakening from disease has not been determined.

The more vigorous groups of Lodgepole pine at Nether Hearth have been thinned recently, and dead trees from the unthrifty lower-most groups also removed. The Pasture plot has again escaped damage from snow-drifts, and the trees, especially the Pines, continue to grow satisfactorily on the areas of better soils.

The fertiliser trial with Lodgepole Pine at Bog End has been re-sampled for foliar analysis, and leader extensions measured. Both needle colour and growth generally, continues to be satisfactory.

B. Plant ecological studies on peat - Project 3/01 (A.J.P. Gore)

i) Factors limiting plant growth on peat
ii) Productivity of blanket bog vegetation

Work on these two projects has been delayed by needs of other activities. Both are nearing completion although there is still a fair amount of computation to be done on i).

iii) A study of the redox characteristics of wet and dry peat profiles, at Moor House, Deer Dike Moss and Striber's Moss in North Lonsdale.

A manuscript entitled "The redox characteristics of four peat profiles" has been submitted to the Editor of "Soil Biology and Biochemistry".

iv) Erosion reclamation

A series of point quadrat measurements were made on the erosion reclamation experiments set up in 1965 at Moor House and Longdendale in the south Pennines. At Moor House a wide range of species have colonised the eroded peat which was treated with mineral fertilisers. At Longdendale the same seed material and treatment has resulted in pure stands of Deschampsia flexuosa. At both places no colonisation has occurred in the absence of fertilisers, although sheep have been excluded since the start of the experiment.

IV. RESEARCH BY FRESHWATER BIOLOGICAL ASSOCIATION

A. Studies on freshwater fauna - Fish - Project 4/01(a) (D.T. Crisp)

(1) Object: to obtain information on the age, growth, mortality, fecundity stomach contents, biomass, population density and production of fish in some selected streams on the Moor House National Nature Reserve.

(2) Methods:

a) By sampling three times per year from 1967-1972 at marked reaches in Moss Burn (1 station), Nether Hearth Sike (1 station), Trout Beck (1 station), Great Dodgen-Pot Sike (2 stations) and the River Tees at Tees Bridge.

b) By electro-fishing surveys at c.40 stations covering the whole Trout Beck system three times per year, during the period May 1971 - May 1972.

(3) Results:

Some general information from the study has been given in previous reports. A similar study at Cow Green is now being written-up and suggests that annual production of brown trout (Salmo trutta) there is about 5 - 10 g/m^2 (fresh weigh and annual production for the bullhead (Cottus gobio) is about 1.0 g/m^2.

The fieldwork was completed in May 1972 and the results will be processed and prepared for publication during the 1972/73 winter. The station markers hav for the time being, been left in position. The survey could, therefore, be repeated at some future date, should this prove desirable.

B. Studies on freshwater fauna - Invertebrates - Project 4/01(b) (P.D. Armitage)

(1) Object:

To draw up species lists of invertebrates in the main fish-sampling reaches of the Moor House National Nature Reserve and adjoining Cow Green Basin and to obtain estimates of relative abundance.

To follow the colonisation of the Cow Green Reservoir and study the effects of the Reservoir on the Tees below the dam.

(2) Methods:

The streams were generally sampled in May, August, and October using the "kick" method, and the Reservoir was sampled using quantitative methods involving trays with artificial substrata and semi-quantitatively by net sweeps in the littoral zone. Below the dam a pump was used to sample invertebrate drift down the Tees.

(3) Results:

Sampling of the Moor House streams was completed at the end of 1970 and the data are being processed for publication. Over 110 taxa were recorded from the 4 streams, Moss Burn, Nether Hearth Sike, Trout Beck and Great Dodgen Pot Sike. The pre-inundation survey of the Cow Green Basin streams has been written-up and the survey is continuing; over 120 taxa are recorded, 96 of which are at the species level.

The Reservoir fauna has developed quickly and is dominated by Chironomids in the littoral and sub-littoral with both Chironomids and Oligochaetes in the benthic regions at depths of 15-20 m. A large micro-crustacea population has developed in the Reservoir and this has completely dominated the invertebrate drift, in the Tees, particularly during the summer, large numbers of Copepods and Cladocera being found 4 km downstream of the dam.

V. RESEARCH BY UNIVERSITIES

A. Studies in the life-history of Tipula subnodicornis - Project 6/06
(Mrs. T. Butterfield & J.C. Coulson, University of Durham)

Most of 1972 has been spent in laboratory studies on the effect of temperature and light on stages in the life history of Tipula subnodicornis. Under constant temperature conditions, when the number of days spent in the stage in consideration (y) was plotted against $1/t^{\circ}C$, t being the temperature between 5° and 20° at which the stage is kept, the following relationships were obtained:

a) the length of time for eggs to hatch, $y = 336.2 \frac{1}{t^{\circ}C} - 7.7$ ($r = +0.99$, $p<0.001$);

b) the time taken during pupation, $y = 230 \frac{1}{t^{\circ}C} - 3.4$ ($r = +0.979$, $p<0.001$);

c) the time taken before pupation in the spring, $y = 250 \frac{1}{t^{\circ}C} + 0.28$ ($r = +0.999$, $p<0.05$).

In the field the mean emergence date at a site has been shown to correlate closely with the spring temperatures at the site. At different altitudes of Dun Fell and at Moor House, if y is the mean emergence date at each site, expressed as the number of days after the mean emergence date at the earliest site (day 1), and x is the temperature sum, in days above $0^{\circ}C$, between27.1.70 and 13.5.70; $y = 0.041 x + 16.86$ ($r = -0.92$, $p<0.001$).

Larval growth rates under different temperature requirements have been studied to elucidate the problem of the small difference in mean emergence dates (8 days) at sites separated by 1000 feet in altitude. It was found that larvae reared within the mean field temperature ($7 - 15^{\circ}C$) completed their growth by autumn. If in December they were exposed to spring field temperatures ($10^{\circ}C$) and long day length (L:D, 18:6) they pupated in about a month (mean number of days from beginning of experiment 31.3 ± 1.6). At the same temperature but on a short day (L:D, 6:18) twice the time (mean number of days from beginning of experiment 72.6 ± 2.4) was required. It is suggested that in the field the onset of cold weather slows down development in the Autumn and if a warm spell intervenes the short day length will inhibit the advance towards pupation. It remains to be seen whether pupation can occur at winter temperatures on short day lengths.

B. Studies on black-flies (Simuliidae) breeding in bog streams in Upper Teesdale - Project 6/15 (R.S. Wotton & L. Davies, Durham University)

As a result of last year's work it was decided to concentrate on one Moor House stream : Moss Burn; and one of the Upper Teesdale streams : Fell Dike Sike. Studies were designed to determine the seasonal cycles, populations and mortality of blackflies existing as larvae and pupae in the two streams.

Methods

Two methods have been used which will give quantitative and qualitative information.

A vegetation sampler was made in which Juncus stems, clamped at their bases, were anchored to the stream beds by means of pegs. The surface area of all stems was calculated from length and diameter measurements by applying the results to the formula $2\pi rh$. The numbers of larvae and pupae per unit vegetation can then be found at one point to give a reflection of actual fluctuations in one stream.

In the second method, Fell Dike Sike was divided into two sections and Moss Burn into four with a view to assessing variation between sections. It was based on the removal trapping technique described by Southwood (Ecological Methods (1966) London : Methuen p.181). Three collections were made, each of 15 minutes duration, using the same sampling effort. Collection was always from upstream to downstream, the end of the first 15 minute length being marked by a peg. Subsequent collections were confined to the stretch thus marked. Analysis of results was set out in "Ecological Methods" pp. 183-186.

Results

Extensive larval material from the Juncus samples has not yet been examined.

The following are population estimates for the lower part of Fell Dike Sike and Moss Burn so far analysed.

Moss Burn

Date	Total (± S.E. at 95% confidence limits)	Approximate % by species of large larvae			
		S. latipes	S. brevi-caule	S. monti-cola	S. nitidi-frons
20.6.72	55 ± 32	-	-	-	-
28.6.72	450 ± 8	-	-	-	-
30.6.72	1129 ±130	46	46	8	0
5.7.72	304 ± 37*	-	-	-	-
11.7.72	680 ±104	68	0	24	8
19.7.72 P	625 ± 30	54	5	31	10
26.7.72 P	650 ± 67	11	4	74	11
2.8.72	1680 ±218	82	12	6	0
15.8.72 P	329 ± 29	81	11	4	4
29.8.72 P	231 ± 64	62	7	21	10

Fell Dike Sike

Date	Total (± S.E. at 95% confidence limits)	Approximate % by species of large larvae			
		S. latipes	S. brevi-caule	S. monti-cola	S. nitidi-frons
13.6.72	0 124 ± 3	-	-	-	-
16.6.72	195 ± 8	-	-	-	-
19.6.72	0 244 ± 8	-	-	-	-
26.6.72	497 ± 79	43	39	18	0
29.6.72	0(1384 ± ?)	-	-	-	-
3.7.72	P 350 ± 18*	53	47	0	0
7.7.72	782 ± 52	38	58	0	4
12.7.72	580 ± 36	45	50	0	5
17.7.72	1035 ± 16	77	23	0	0
21.7.72	775 ± 17	92	8	0	0
27.7.72	766 ± 24	76	24	0	0
16.8.72	1998 ± 95	42	39	11	8
30.8.72	P 1709 ±116	53	13	21	13
3.9.72	0 P1884 ± 65	26	13	31	31

0 = egg masses found
* = low numbers after a spate
( ) = artificially high estimate because of the very large numbers of 1st instars in the second removal sample thus making prediction difficult
P = dates on which pupae occurred in samples

Peaks in larval numbers were found at the end of June and at the beginning of August in Moss Burn with a rapid build-up in numbers to the first peak and a similar decline after the second. Pupation occurred at the end of July and also at the end of August. Reference to large larvae shows that all four common species : S. latipes; S. brevicaule, S. monticola; and S. nitidifrons were pupating at these times. S. monticola and S. nitidifrons would seem to be confined to these periods of pupation whereas S. latipes is present as large larvae throughout, but with S. brevicaule tending to pupate before S. monticola and S. nitidifrons.

In Fell Dike Sike the build-up in numbers was very much slower but again two peaks show at the end of June and also at the end of August with an additional peak in the middle of July. In the late August peak, S. monticola and S. nitidifrons are beginning to pupate the former also being found as large larvae at the end of June and the latter at the beginning of July. As in Moss Burn numbers of S. latipes are present as large larvae throughout the summer, while S. brevicaule is found in larger numbers than in Moss Burn. Pupation of S. brevicaule in early July is later than that of S. latipes and similarly for that in late July - early August.

From both streams it can be seen that the total numbers drop off from a peak much more slowly than the build-up which is rapid. This decline is due to mortality and pupation together with the effect of flow changes - whereas recruitment of first instar larvae into the population produces very sudden increases in numbers.

To determine the age structure of the whole population over a short period the first tubes collected from Fell Dike Sike on 17.7.72 and 21.7.72 and from Moss Burn on 19.7.72 and 26.7.72 were divided into four size classes. These were not determined accurately by measurement but could be used in a chi-square test for heterogeneity. The divisions made were : very small : small : medium and large larvae and the chi-square values obtained from the test, assuming

homogeneity were as follows. For Fell Dike Sike $x^2 = 40.4$ and for Moss Burn $x^2 = 25.0$, giving in both cases a probability $p<0.001$. Thus, for both streams the numbers found on the second sampling date were distributed very differently within the size groups.

If the figures are converted to percentages it is possible to make a direct comparison between sampling dates and see where the differences arise.

Fell Dike Sike	% very small	% small	% medium	% large
17.7.72	30	39	27	4
21.7.72	15	46	27	12
Moss Burn				
19.7.72	34	26	15	25
26.7.72	16	43	28	13

Between the sampling dates above the weather was settled with no spates which drastically reduce numbers of larvae (see early July above).

In both streams there is a marked pattern of growth between sampling occasions with pupation occurring in Moss Burn. With recruitment of very small larvae occurring in mid- and late- July one would expect a rapid build-up of numbers at this time. This clearly occurred in Fell Dike Sike to a peak on 17.7.72, where the numbers started to decline probably due to mortality and migration. In Moss Burn, the very small larvae have mostly grown through to larger instars by 26.7.72 but the overall population numbers remained very similar. Moss Burn is subject to much greater fluctuations in water-level and it could be that, with very little water flowing, the numbers found were limited by the amount of available suitable habitat. Thus, in the mid-July batch the peak reached on 11.7.72 may have been artificially low. The detailed picture of these events will emerge after further analysis.

Where vegetation collections were made it is hoped to make production estimates of dry weight larvae per unit dry weight of vegetation. This should provide an interesting comparison to data obtained by the Freshwater Biological Association on production of blackfly larvae in a lowland chalk stream.

C. Studies on Molophilus ater Meigen (Diptera: Tipulidae) - Project 6/16 (G.R.J. Smith & J.C. Coulson, Durham University)

The population studies on Molophilus ater have been continued, and the 1971-72 season has been particularly interesting as populations on all the Juncus squarrosus sites have suffered a sharp decline. The adult populations on the sites have previously been fairly constant (some have been studied since 1964) and are usually in the range 800 - 3,000 per sq. metre. This year the highest recorded density on 7 sites was 443 and others had populations as low as 32 per sq. metre. The one Blanket Bog site (Bog End) studied showed a population similar to previous years.

Mortality on the Juncus sites has not been attributable to any single factor, but has operated at different stages at different sites. Egg, first and second instar, mortality has been high and this may be due to an exceptional dry July recorded in 1971, dessication is known to be a major cause of mortality in these early stages. Mortality at the pupation-emergence stage has also acted at an exceptional level on one site there is evidence of almost complete failure to pupate and larvae still surviving in the fourth instar well after the normal emergence date.

Fecundity has also been reduced and the high rainfall during the emergence period this year is thought to have reduced activity and mating, where populations were already low. Preliminary surveys of the new generation show little trend to recovery and virtual extinction of the population on some sites.

In addition to the population study some respirometry and calorimetry has been carried out and it is hoped to produce an energy budget and production details in the near future.

A study of Molophilus ater emergence relative to photoperiod has shown that short day-length inhibits pupation but a temperature threshold of 5 - 6°C is also operating.

Studies on the distribution of Molophilus on blanket bog show that the site studied for the last six years carried a population (mean number of adults 1965-72, 198 per sq. metre) rather higher than is general. An investigation of larval distribution relative to microhabitat has shown the Eriophorum vaginatum litter areas to support a higher population (535 ± 104) than the Sphagnum (197 ± 52) and Calluna (198 ± 52) litters over the period November 1971 to April 1972.

D. A study on feeding methods of Crane Flies - Project 6/17 (S. Renner, & J.C. Coulson, Durham University)

A study was made of the distribution of the larvae Tipula pagana and Tipula gimmerthali on several flushes in the Moor House area. The latter species was present in almost all base-rich flushes, whilst the former species occurred only in a proportion of these. In addition, T. pagana is found in mineral grassland soils, a habitat which is never occupied by T. gimmerthali.

Studies were made on the feeding of these two species and T. paludosa. The three species showed a high inefficiency of digesting their normal plant food. On average only 40 percent of the content was damaged, the remainder passing through the gut intact. Most of the damage is apparently caused by the mandibles, and there is little suggestion of any further damage to the cell walls during passage through the gut.

E. Studies on Cercopidae - Project 6/03 (J.B. Whittaker, Lancaster University)

No field work has been done at Moor House this year.

F. Studies on the photosynthesis and assimilate distribution of Calluna vulgaris - Project 6/18 (M. Ashmore & Professor H. Woolhouse, Leeds University)

This work is based on the work of John Grace on the physiology of Calluna growth at Moor House described in previous reports: in particular, it is hoped to improve our knowledge of the storage and distribution of assimilates in the plant.

At the end of this growing season, measurements of photosynthesis were made on Sike Hill, in order to evaluate how valid Grace's model of photosynthesis, which was based solely on laboratory measurements, is in the field. The technique used involves the measurements of the amount of $^{14}CO_2$ taken up by the plant from an air stream containing $^{14}CO2$ and $^{12}CO_2$ in a known proportion. The apparatus, which was developed by Dr. L. Incoll at Leeds, was used with a series of leaf chambers especially designed for use with Calluna shoots. The enclosed shoot was exposed to an air stream containing $^{14}CO_2$ for 1½ minutes and then immediately

placed in a vial containing 1 ml of "Soluene", a tissue solubilizer. The amount of $^{14}CO_2$ taken up by the shoot could then readily be determined by adding a suitable scintillant to the dissolved tissue, and counting the resultant solution in a scintillation counter.

In order to obtain a more detailed knowledge of the pattern of distribution and storage of assimilate in Calluna vulgaris throughout the year at Moor House, samples of Calluna shoots have been taken at regular intervals from Sike Hill. The amount of the various sugars and sugar derivatives present in the ethanolic extract of these samples is then determined by the use of gas chromatography. Attention has been particularly directed at the soluble sugars since they were shown by Grace to be the major form in which assimilate is stored by Calluna vulgaris in this environment. A record of the micro-temperature on Sike Hill over the period of sampling has been obtained using the Grant temperature recorder, together with the probes set up there by O.W. Heal; Grace's work suggests that changes in assimilate levels in Calluna are correlated to a considerable extent with temperature changes.

It is hoped to summarise the results obtained from the work described above in the next annual report.

G. Biosystematic studies of Alopecurus alpinus - Project 6/20
(G.M. Fearn, Sheffield Polytechnic)

A survey of the bryophyte flushes on Little Dun Fell and Great Dun Fell was made. On Little Dun Fell Alopecurus alpinus is found in flushes characterise by an abundance of bryophytes, particularly Philonotis calcarea and a species of Drepanocladus. Monocotyledons are common. On Great Dun Fell Campylium stellatum was the most abundant bryophyte. Species of high constancy in these flushes are Carex nigra, Triglochin palustris, Cardamine pratense, Montia fontana Saxifraga stellaris, and Philonotis calcarea.

The approximate population size of A. alpinus in the flushes visited was estimated by counting the number of tillers and inflorescences. These are listed below. It was noted that many inflorescences had been bitten off, possibly by horses as hoof marks were seen nearby in the soft ground.

	Little Dun Fell Site 1	Little Dun Fell Site 2	Great Dun Fe
Tiller No.	100	100	20
Inflorescence No.	8	4	2
Inflorescence height cm	7.5	7.5	13
Remarks	Awnless	Awnless	Awnless

Tillers collected in the field have been rooted and potted up for morphological studies and breeding experiments. Root tips are being excised, pretreated and fixed for cytological studies. It is hoped that it will be possible to carry out a breeding programme next spring. The object of this programme will be to test the hypothesis (Fearn 1971) that individual population may consist of single plants which have spread clonally and which are unable to reproduce sexually because of self sterility.

H. The ecology of certain species of heavy metal indicator plants - Project 6/21 (R.F. Smith & Professor M.M.Cole, Bedford College, London)

A national pattern of the distribution of Minuartia verna and Thlaspi alpestre is being built up in relation to the composition of the mine dump material. Sites in Upper Teesdale seemed to be completely artificial, the debris having been brought from below the peat cover by mining operations. A search is being made for sites where natural rock outcrops occur associated with mine workings.

I. Quarternary investigation of Valley Bog, Moor House - Project 6/14 (J. Turner & K. Chambers, Durham University)

The object of the investigation was to obtain radiocarbon dates for the major pollen assemblage zone boundaries on the valley bog pollen diagram published by Johnson & Dunham (1963).

Methods: a second pollen diagram was prepared from samples of peat which could be dated and once the relevant horizons had been identified on this second diagram the peat from these levels was sent to the Scottish Research Reactor Centre at East Kilbride for dating by Dr. D.D. Harkness.

Results: the second pollen diagram from the site is shown in Fig. 1, 2 and 3. The results of the radiocarbon determinations are shown in Fig 1. They show when the major changes in the vegetation of the region actually occurred.

Mr. Chambers will include these results in his thesis entitled "The vegetational history of Teesdale", to be submitted to the University of Durham this autumn for a Ph.D. degree.

They will also be published as part of a paper on the vegetational history of the Tees valley at a later date.

J. Ecological and land use Survey of an area of the North Pennines - Project 6/19 (Mrs C. Mallett, University College, London)

The Upper Eden Valley in north-east Westmorland forms a distinctive geographical unit in terms of physical structure, history and present economy. The fertile valley floor is renowned as being one of the most productive dairy farming regions in lowland Britain and yet within a few miles of the river bed can be found poor rough grazings of the upland fells above about 1500', whose sward can barely support one sheep per acre. Thus the "two Britains" described by Professor Pearsall, the one an orderly, productive, lowland agricultural landscape and the other a land of mountains and moorlands, "its need forgotten and its possibilities almost unknown" are brought into close juxtaposition, especially on the eastern side of the valley where the proximity of the western Pennine scarp to the valley floor serves to emphasise the contrast between marginal upland and fertile lowland. This part of the valley affords a near perfect location for a comparative study of differing physical, biological, and economic systems within the natural unit of a single drainage basin and the survey concentrated on assembling this type of information. Agriculture being the main land use received most attention and it was concluded that the fellside farm, restricted to livestock farming by climate and soils, was economically vulnerable and dependent on subsidy support.

The threats to the area have been outlined. The challenge which faces us is the production of a landuse plan, based on sound ecological principles, which integrates all the conflicting demands on the land and can serve as a guide-line to future development. The completion of such a plan would require a long period of intensive study with information inputs from several specialist

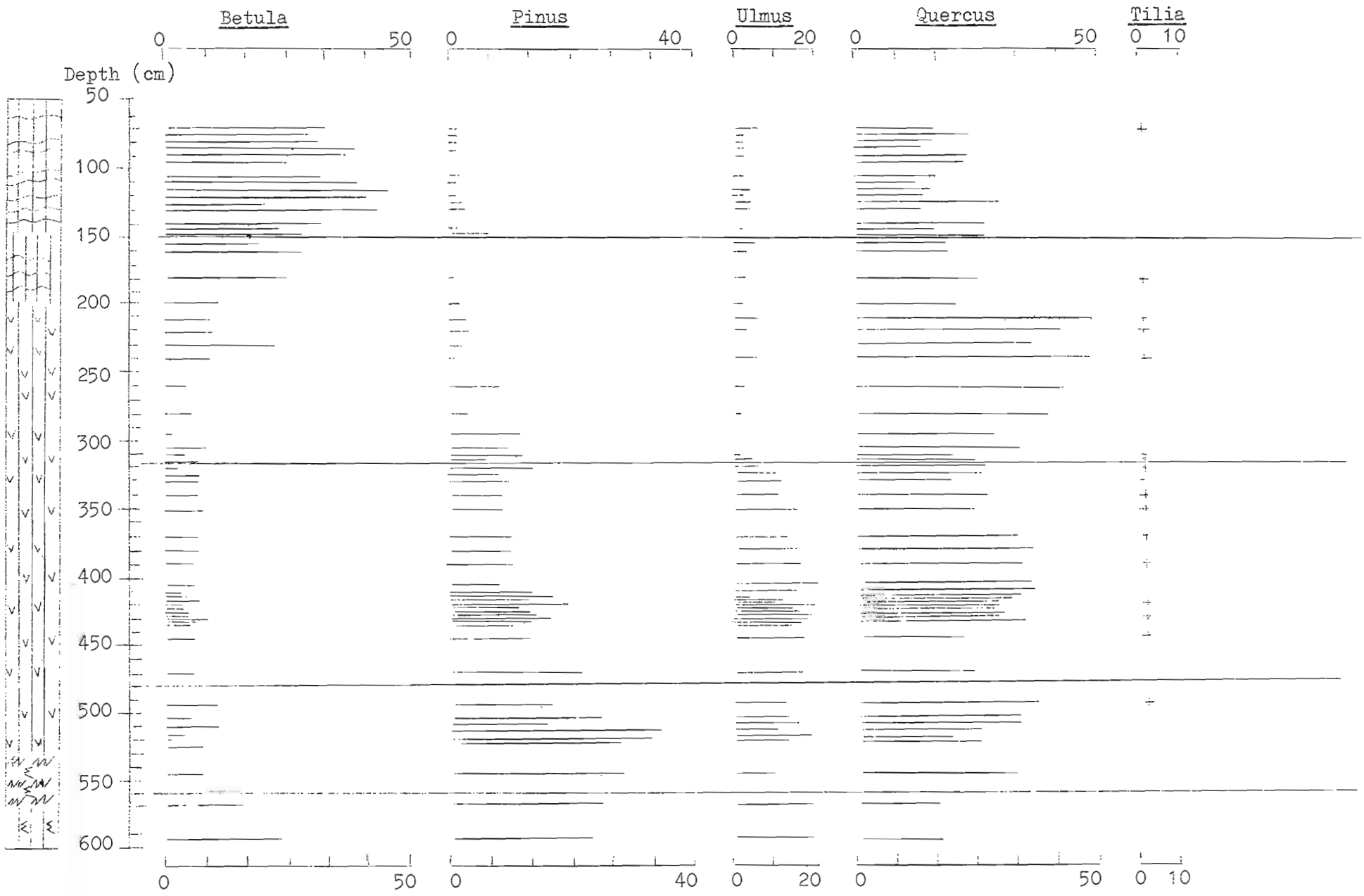
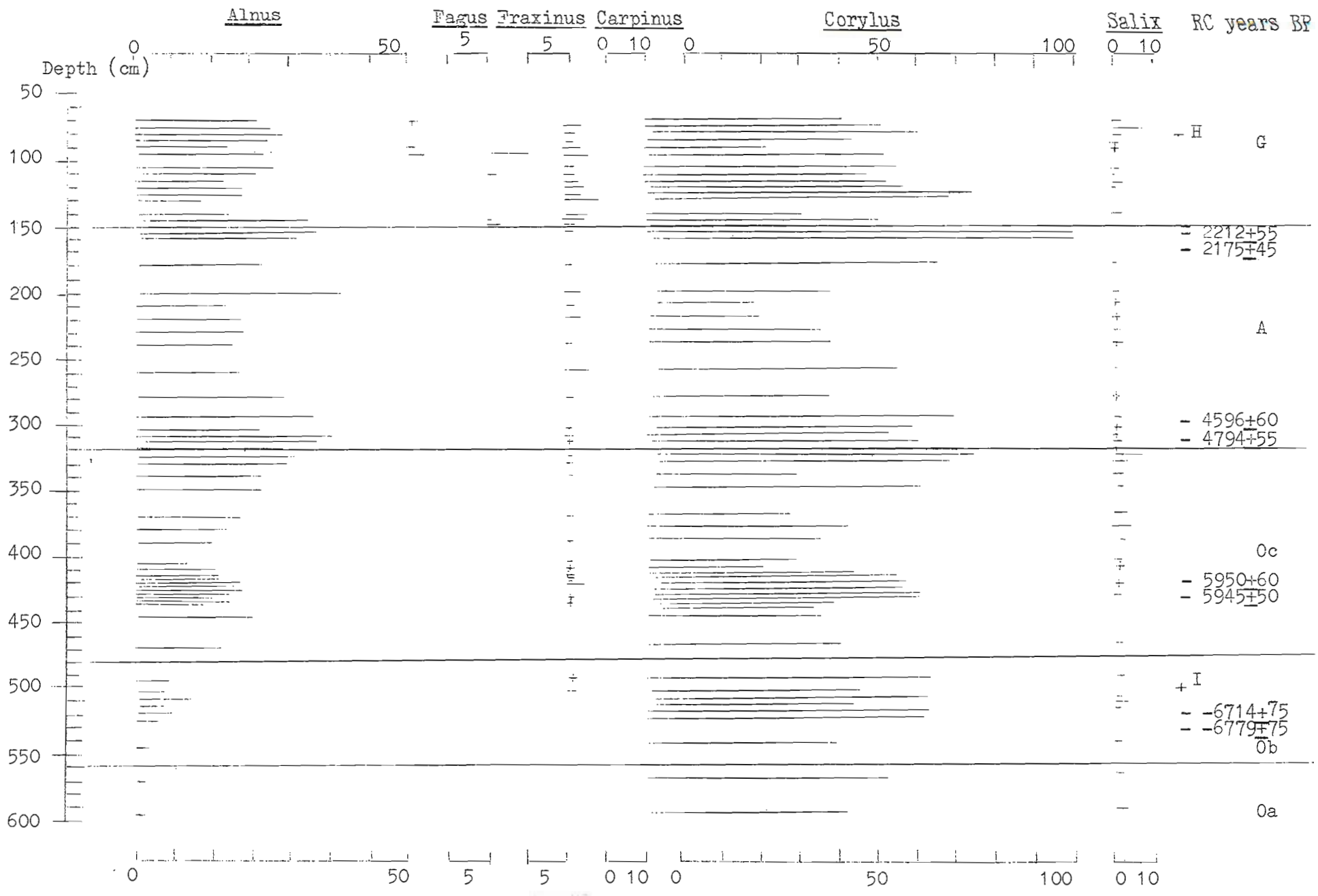


Fig. 1. Valley Bog - Percentage total tree pollen


Alnus
Fagus
Fraxinus
Carpinus
Corylus
Salix
RC years BP
Depth (cm)
0
50
5
5
0 10
0
50
100
0 10
50
100
150
200
250
300
350
400
450
500
550
600
H
G
2212±55
2175±45
A
4596±60
4794±55
Oc
5950±60
5945±50
I
-6714±75
-6779±75
Ob
Oa

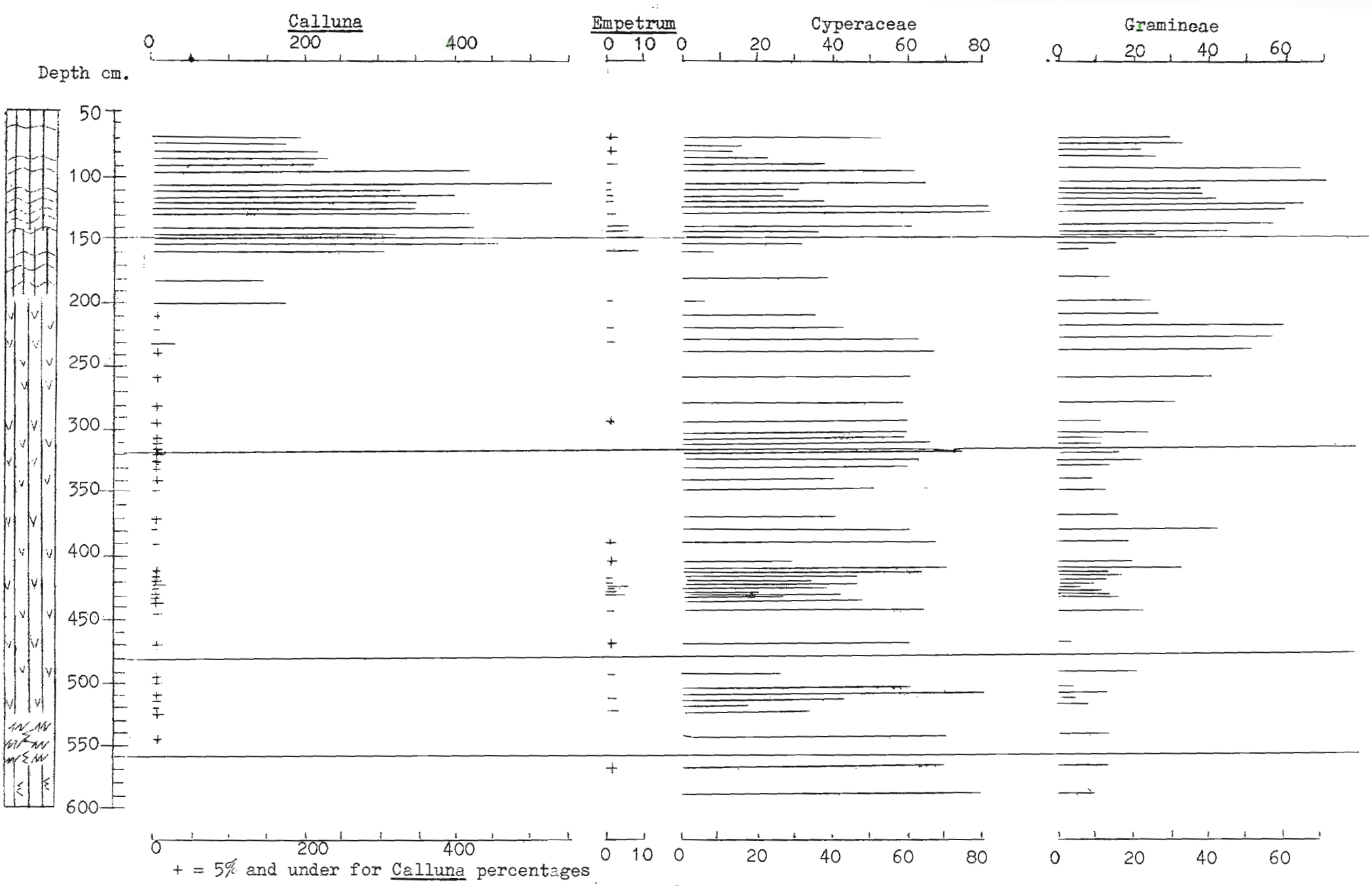


Fig 2. Valley Bog - Percentage total tree pollen

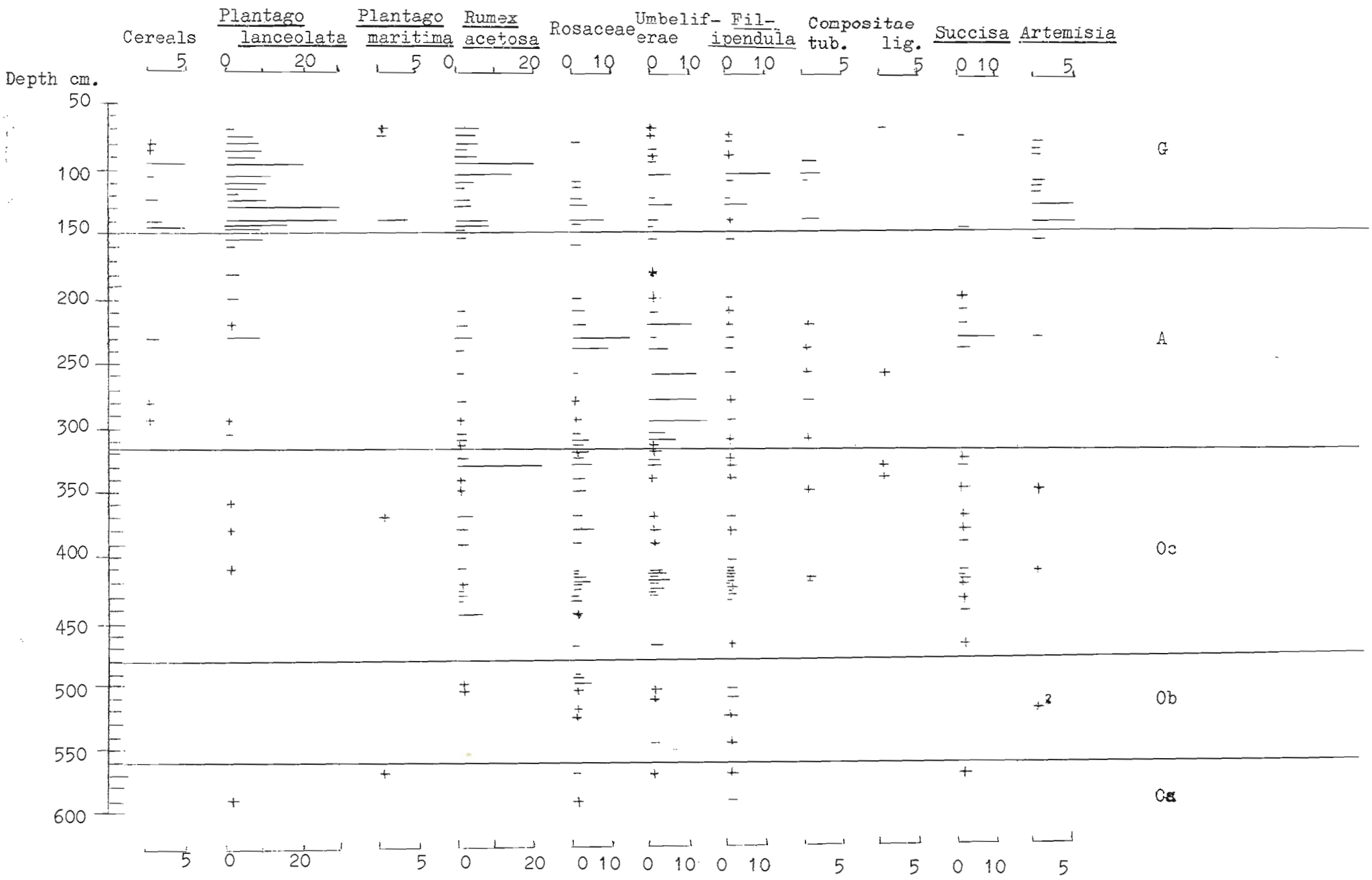


Fig 2. cont. Valley Bog - Percentage total tree pollen

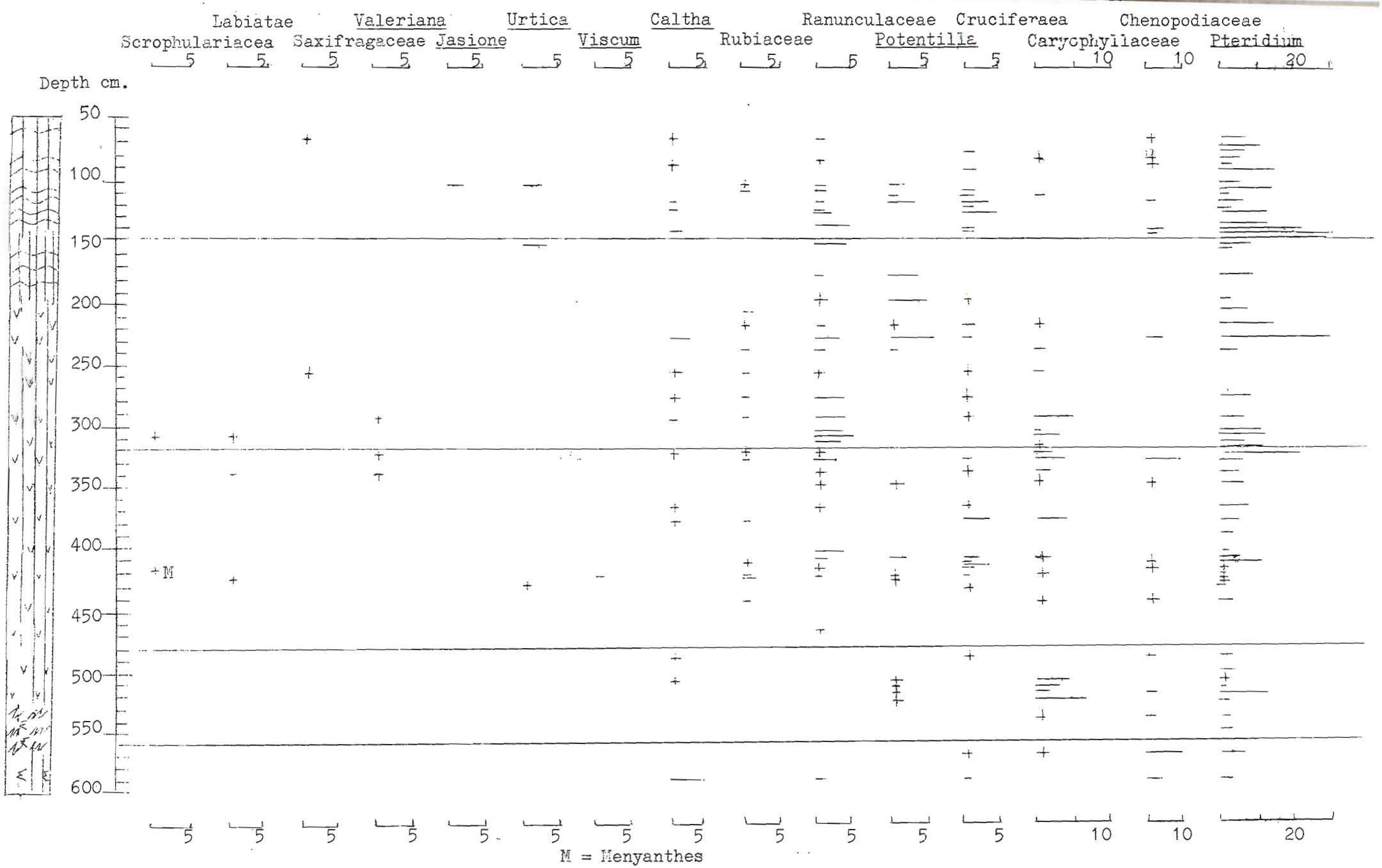


Fig 3. Valley Bog - Percentage total tree pollen

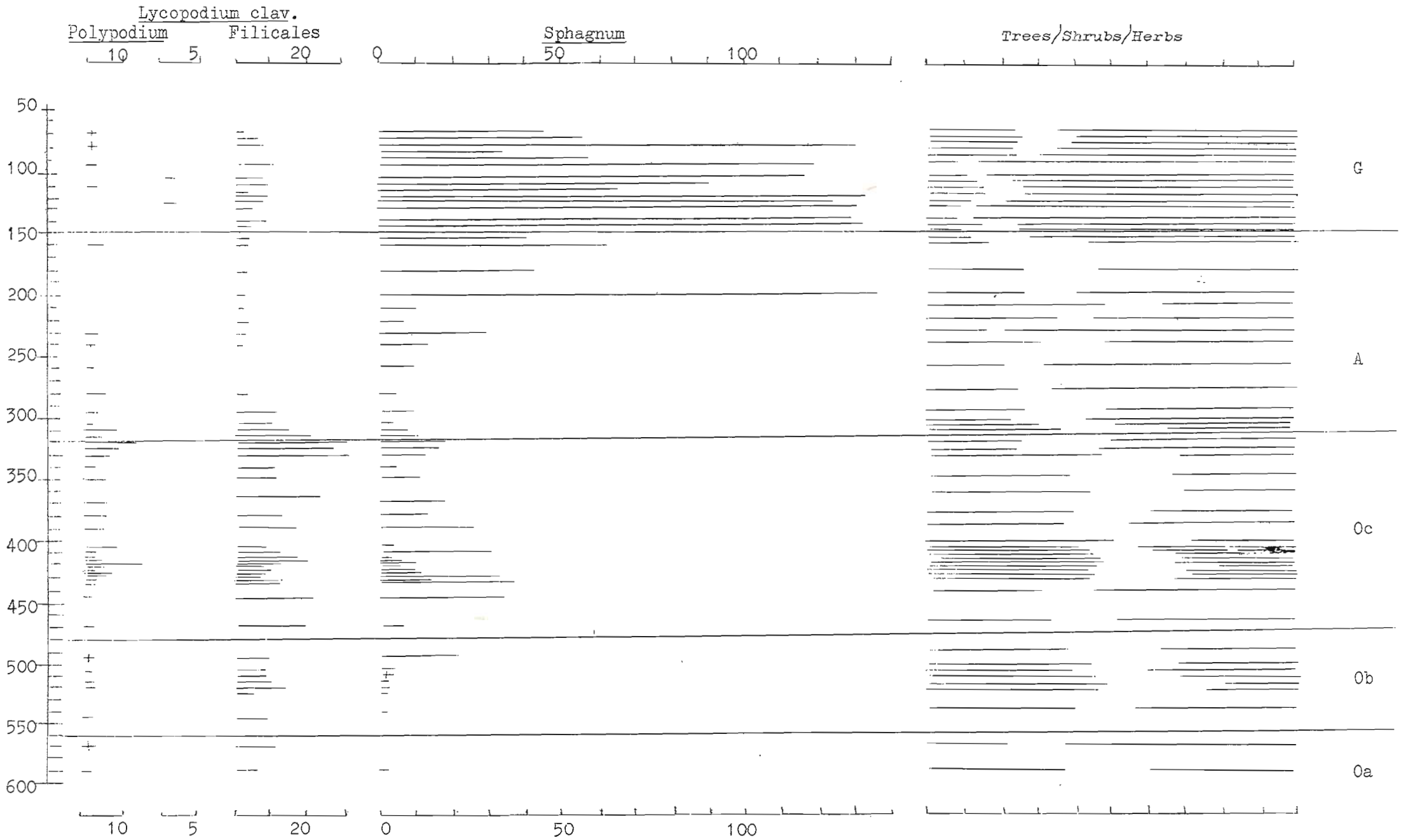


Fig 3. cont. Valley Bog - Percentage total tree pollen

fields, and is far beyond the scope of this project, which attempts rather to provide a general ecological and landuse survey on which future work could be based. It is hoped that the project will provide a useful input to the North Pennine Conservation Project being currently undertaken by the Nature Conservancy North Regional Staff at Moor House Field Station, and also serve as a meaningful background to the 1973 Conservation Course Group project.

K. Studies of periglacial phenomena - Project 6/10 (L. Tufnell, Huddersfield Polytechnic)

For the seventh consecutive year data were obtained on the movement of 5 ploughing blocks situated above 680 m on the Reserve. It was found that in general displacements for the period July 1971 - August 1972 exceeded those of the previous 12 months.

A study has been made of the distribution, size, morphology and vegetation of hummocky micro-relief at two contrasting sites on the Reserve. The first of these is near the summit of Great Dun Fell (GR: 709322); the other lies above the junction of the roads from the Silverband mine and the Great Dun Fell radio station (GR: 716309). An article will shortly be submitted for publication to "Biuletyn Peryglacjalny" under the title "Hummocky micro-relief in the Moor House area of the northern Pennines, England".

Work on elucidating the nature of block fields and screes has continued with the examination of further sites in the upper Knock Ore Gill valley and on Knock Pike.

Investigations have begun into the characteristics of stone stripes (both active and fossil) and gelifluction terraces.

VI. INTERNATIONAL BIOLOGICAL PROGRAMME

Field work at Moor House is now complete and there are only six reports concerned with individual project details. The general report on the programme is longer than usual. It incorporates a number of short reports received from individuals, and outlines the plans for synthesis papers to be presented at the meeting on IBP Terrestrial Ecosystem Studies at Liverpool University, 11-13 April 1973. This meeting is sponsored jointly by the British Ecological Society and the Royal Society.

A. General Report (O.W. Heal, Merlewood)

Ecosystem Studies

Burnt Hill

Clymo and Reddaway (1971) presented a dry matter balance for the Sphagnum dominated Burnt Hill site. Sphagnum net production in pools, lawns and hummocks was estimated to be 4.4, 3.4 and 1.8 g $dm^{-2}yr^{-1}$ respectively. When combined with estimates of the areas of these habitats, and with production data for other species, net production was estimated at 2.98 ± 1.03 t $ha^{-1}yr^{-1}$. Sphagnum comprised about 65% of this. Estimated losses of gaseous carbon (CO_2 and CH_4) and of carbon in solution in stream run-off, were used to calculate a preliminary dry matter balance for the three habitats (Table 1). This indicated that up to 70% of net production accumulates as peat.

Table 1 Preliminary balance of dry matter on Burnt Hill. Gas loss is calculated as $(CH_2O)_n$. Solution loss has been assumed to be equal in all three habitats. Net production in pools assumes $\frac{2}{3}$ cover by S. cuspidatum. Units are g dry matter $dm^{-2}yr^{-1}$.

Habitat	Pool	Lawn	Hummock	
Net production	3.46	3.82	2.39	± 1.07
Loss as gas	1.50	0.89	1.29	± 0.60
Loss in solution	0.21	0.21	0.21	± 0.59
	1.71	1.10	1.40	
Net gain	1.8	2.7	1.0	± 1.35

The data on production and decay obtained in this study are being used to check the values predicted by a simulation model which uses the bulk density at known depths as its data. Age of any horizon is produced as a by-product.

Cs^{147} dating of the surface layers of the profile and measurements of peat density at different depths provide field checks on the accuracy of the model predictions. This model was presented by R.S. Clymo at a BES Production and Energetics Group Meeting in September, 1972.

Other bog sites

On the other IBP blanket bog sites at Moor House, primary production is dominated by Calluna and Eriophorum vaginatum, with Sphagnum a less important component. In the synthesis of results from these sites, one of the aims of the modelling project of Helen E. Jones and A.J.P. Gore is to investigate ways in which data from discrete projects can be combined,

summarised and tested against other information and current ideas. Because of the slow rate of turnover of organic matter on the blanket bog and the low utilisation of plant material by grazing animals, the primary production and decomposition data are of prime importance to this study.

Results from two of the IBP sites, Sike Hill (dry) and Green Burn are being studied in detail to determine whether the data on production and decomposition are sufficiently accurate to predict peat accumulation at the two sites.

The blanket bog vegetation is not in a seral state, therefore measurements of the annual production of the individual major species and their components can be extrapolated to the long term. Production data from G.I. Forrest on above-ground and below-ground parts of Calluna and Eriophorum, plus Sphagnum are being used.

Data from the litter bag experiments (O.W. Heal and P.M. Latter) are used to calculate decay rates for the major species components. Some extrapolations have been made for those components for which long-term weight losses are not available. The exponential weight losses calculated for the litter bag components, are modified by a decrease in the rate with increasing depth. This decrease is calculated from the change in tensile strength of cotton strips from 0-20 cm in the profile. The decrease in rate with depth emphasises the importance to peat accumulation of the below-ground parts, particularly the root distribution.

It is important to be able to date the profile, since it is essential to know how long the litter will be acted on at each rate before passing down into the next layer. Possible methods of doing this are being studied. The model must be based on information derived independently of the test information. While this standard will be followed as strictly as possible, it is fairly evident that some vital information is so poorly known e.g. below-ground decomposition rates, that the best that can be hoped for from a model at this stage is some statement as to the degree of precision required for the various measurements assuming that other measurements are held constant or may only vary within certain prescribed limits.

A third development in the ecosystem study was that a series of vegetation and peat samples were taken by R.A.H. Smith from the 8 IBP bog sites, plus a Juncetum squarrosi on podsol and Agrosto-Festucetum on a brown earth. Analyses of mineral elements will provide further basic data on nutrient distribution in these sites.

In addition R.A.H. Smith prepared a draft of a paper which draws together most of the data now available for a complete IBP site description. This includes geology, soils, climate, vegetation, fauna, microflora and land use. Data on the grassland sites are included for comparison. This document is intended to be a source of information for the final synthesis and for future use, and will be circulated as a Moor House Occasional Paper. It is proposed that a shortened version may be included in the publication of the Moor House results.

Primary Production

In addition to the studies on Sphagnum production (Clymo and Reddaway 1971) a detailed study of Rubus chamaemorus has been published (Marks and Taylor 1972). The latter shows that the supply of inorganic elements is not limiting the performance of the plant on the Moor House blanket peat and the

increased production after burning may result from modification of the microclimate close to the ground. The experimental approach adopted in this study, and in that of J. Grace, has provided a valuable insight into the factors controlling production which was not available from the description studies.

The results of the field cropping by G.I. Forrest, to define between site and between year variation, are being prepared for publication by G.I. Forrest and R.A.H. Smith. The main conclusion from this work is that in the three years of investigation there was little variation, either between sites or between years, in the total production of blanket bog vegetation. The mean figure for total production of seven sites, including representatives of Calluneto-Eriophoretum, Trichophoro-Eriophoretum and Eriophoretum derived from burning, was 660 $\pm$ 55 g^{-2} $year^{-1}$. However, in the Calluneto-Eriophoretum and Trichophoro-Eriophoretum there was a trend, although not significant, of decreasing production with increasing wetness. The high production of the wettest sites at Cottage Hill, is largely a result of the presence of the high yielding Eriophorum angustifolium and Trichophorum cespitosum but it may also result from the influence of burning in 1960.

The average production figures and estimated total areas for each blanket bog type are shown in Table 2. The total production of 1215 ha. blanket bog within the Reserve, (excluding high level Eriophoretum and recolonising or eroding peat complexes) was estimated as 7.65×10^6 Kg $year^{-1}$ which is equivelent to a mean figure of 630 $gm^{-2}year^{-1}$.

Table 2 Total production of each blanket bog vegetation type within the Reserve.

Vegetation Type	Area in Reserve-ha. (Eddy, Welch and Rawes, 1969)	Mean total production (above and below ground) $gm^{-2}yr^{-1}$	Total production Kg yr^{-1}
Calluneto-Eriophoretum	1169	625 $\pm$ 49	7.31×10^6
Burnt areas	31	824 $\pm$ 83	0.26×10^6
Trichophoro-Eriophoretum	15	531	0.08×10^6
			7.65×10^6

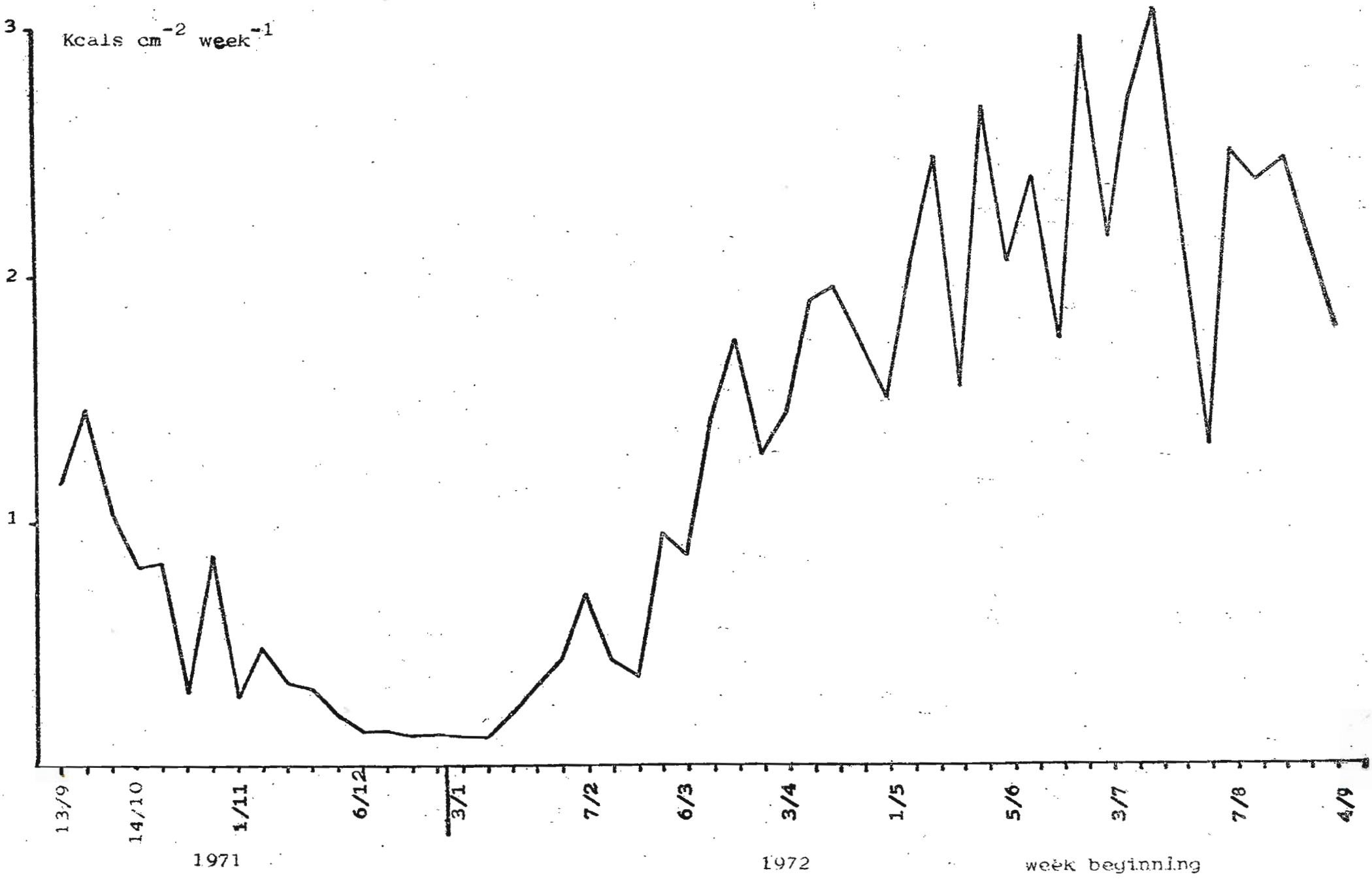
Other studies

Reports on fauna, microflora and decomposition are given later. In addition, the main population and production results on psyllids (I.D. Hodkinson) and enchytraeids (V. Standen) are in press with J. Anim. Ecol.

Abiotic

A full year's data on solar radiation have not been obtained (Fig 1) from the Kipp head and Lintronic integrating counter. This replaced the previous Lintronic assembley in September 1971, after a long history of technical problems. Recording will continue indefinitely to supply the Meteorological Office, and data can be obtained from A.D. Bailey (Merlewood).

Fig. 1 Solar radiation input, weekly totals



Arrangements for the completion of the IBP project

At the B.E.S./Royal Society Meeting in Liverpool, one day (April 12th) will be devoted to the Moor House results. Individual projects will not be discussed in detail, but papers will summarise and combine the main results and present additional analysis and interpretation.

The following people have accepted responsibility for co-ordinating the presentation of the main subjects:- primary production - R.A.H. Smith; fauna - J.C. Coulson and J.B. Whittaker; microbiology and decomposition - A.J. Holding and V.G. Collins; ecosystem - O.W. Heal.

The papers prepared for the meeting will be used as drafts for publication in the Ecological Studies Series of Springer Verlag. The results from Moor House studies plus those from the main Grassland site (Snowdon) and the supporting studies will be published in a single volume.

Space will be available at the meeting for demonstrations of methods or results of individual projects. Anyone wishing to provide a demonstration should contact O.W. Heal.

International activities

The large commitment of Moor House to the International Tundra programme has continued. The aims of the programme are to compare results from about 30 polar, alpine and moorland sites, and to define the range of production and the biotic and abiotic factors influencing this.

A.J.P. Gore and H.E. Jones have continued work on the international comparisons of primary production. Following the Tundra Primary Production meeting at Glenamoy in March 1971 an attempt was made to meet some of the criticisms of the compartment model presented at that meeting. A paper (Jones and Gore, 1972) was read at the IVth International Tundra meeting held in Leningrad, November, 1971. This paper outlined a relationship between models in which field data only are used in a curve fitting procedure to estimate transfer coefficients between recognisable compartments and models depending on the use of explicit relations between radiation and temperature and photosynthesis. Although the models of the latter type have much to recommend them, especially in their well developed form, at present they have a less general application to data from investigations at several sites and therefore have less comparative value. The Moor House data on Eriophorum vaginatum, collected by G.I. Forrest, were used in this example.

Helen Jones attended a meeting of the Ecosystem Group at San Diego, U.S.A. to discuss further model developments and it is planned to present a final paper at Abisko in 1974 utilising as much of the available international data as possible to estimate primary production and turnover in at least three IBP Tundra sites. In the work of international comparisons the help of Father J.J. Moore (Eire) is gratefully acknowledged.

Fauna comparisons have only reached preliminary stages, but J.B. Whittaker is involved in their development, and Moor House data were submitted to an inter-biome meeting held in Louvain, Belgium during July 1972.

A.J. Holding and O.W. Heal attended a decomposition group meeting in Abisko, Sweden, at which a number of papers were presented for discussion. The results indicate that there is a large variation in decay rates of different litters within a site, but decay rates at Moor House are slower than those on the blanket bog site at Glenamoy, Ireland, and similar to those in the bog site at Abisko in northern Sweden. The lowest rates, under extreme polar conditions at Signy Island in the Antarctic, are an order of magnitude lower

than those at Moor House. A wide range of microbiological and decomposition data, from nine countries, have been submitted to a data bank for use in international synthesis activities. The main bank is held at the U.S. Tundra Biome Centre, University Alaska, with a subsidiary bank at Merlewood.

A combined Grassland-Tundra-Workshop, attended by O.W. Heal, was held at Fort Collins, Colorado in August 1972. Data from about 30 sites, including Moor House, were submitted to initiate inter-biome synthesis and some preliminary analyses were carried out. These will not be published, but will be used as a basis for further activities.

The Royal Society has awarded a £10,000 grant to assist in international Tundra synthesis. A Research Assistant, D.D. French, is now based at Merlewood where Dr. P. Widden (Canada) spent three months developing a Tundra site classification and comparing fungal data from the various sites. Dr. T.V. Callaghan (York University) has started a one year Fellowship to compare production of individual plant species and life forms. He has already visited the intensive study sites in Finland, Norway, Sweden, Ireland, Canada and U.S.A. and will spend some time at Moor House.

Forthcoming meetings of Tundra group

April 1973 - Abiotic, Primary Production and Ecosystem Groups, Dublin.
August 1973 - Microbiology, Decomposition and Invertebrate Groups, Fairbanks, Alaska.
April 1974 - Tundra Biome Final Meeting, Abisko, Sweden.

Copies of the Proceedings of the previous Tundra meetings at Kevo (1970) and Leningrad (1971) can be obtained from O.W. Heal (£1.00 and £1.50 respectively). The Leningrad Proceedings contains 30 papers with results of a wide range of research on the five major Tundra sites in Russia.

B. Studies on Red Grouse - Project 2/17 (P. Taylor)

Following the high breeding success of the red grouse (Lagopus lagopus scoticus) in 1971, funds were made available to continue monitoring the grouse population at three sites, Bog End, the Drive and Burnt Hill. The following parameters were measured, as in 1971: Numbers of adults; numbers of nests and the position of nest sites; clutch size; hatching success; mortality of chicks; and breeding success.

The number of adults was estimated from the number of nests found on each site and gave an average population density in May of 1.85 birds/ha. Bog End had the highest population density at 2.35 birds/ha and Burnt Hill the lowest with 1.48 birds/ha. Clutch size ranged from four to fifteen eggs. The average for the three sites was 8.02 eggs/clutch, Burnt Hill having the highest average with 9.46 eggs/clutch. Almost 95% of the eggs were hatched from the clutches which were incubated successfully and of the eggs which failed to hatch 60% were fertile. Observations on chick mortality were limited to birds found dead at or around the nest. This was 7.5% of the eggs hatched and much of the mortality can be attributed to high rainfall during the peak hatching period. Breeding success was estimated from counts in July/August over the three sites and from other areas of the Reserve. The young/old ratio averaged 2/1 ranging from 1/1 to 3.3/1.

A summary of these results is given below together with comparable data for 1971.

		1971	1972
Av. clutch size		8.2 ± 0.67 (95% C.L.)	8.02 ± 0.62 (95% C.L.)
Av. hatching success		93.3%	94.1%
Density of adults		1.14 birds/ha	1.85 birds/ha
Eggs failed to hatch			
	fertile	80% (4)	60% (12)
	infertile	20% (1)	40% (8)
Nests failed	deserted	5	3
	robbed	3	5
	predated	2	1
Chick mortality on nest		1.9% (5)	7.5% (26)
Breeding success		3.3 young/1 old	2 young/1 old

The results did not show the expected decline from the 1971 peak population. The population density of adults increased by over 50% probably partly because of the second successive mild winter (1971-72). It is estimated that these adults removed between 2.3 and 4.6% of the green shoot production of Calluna in 1972.

The average clutch size was slightly lower than for 1971, 8.02 compared to 8.2, but taking sites individually it was noticeable that the Drive, with the greatest increase in population density (81%), was the only site with a lower average clutch size than in 1971. Burnt Hill with the lowest density of adult grouse had the highest average clutch size (9.46) and the highest hatching success (95.3%).

Comparison of population size and breeding success shows that in 1971 the density of 1.14 adults/ha and a breeding success of 3.3 young/old birds gave a density of 3.76 grouse/ha in August 1971 while in 1972 a higher population but lower success gave 3.70 grouse/ha.

The results are obviously too limited to draw any conclusions but the comparison of population data on the three sites in two years raises a number of questions concerning the maximum densities on an unshot moor in good years, and on possible density dependent control of the population. The need for continuation of the study is emphasised but no IBP funds are available.

C. The influence of soil fauna on the decomposition of blanket bog litters - 2/18 (Mrs. V. Standen, Durham University)

The objectives of this research are:

1. to measure growth and production of Cognettia sphagnetorum in the field and compare it with estimates made previously based on samples of the standing crop.

2. to show the influence of different population densities of C. sphagnetorum and the tipulid M. ater on the rate of decomposition of different types of litter and on the rates of respiration of decomposing litter.

Weighed quantities of litter of different types were put into nylon mesh bags (apature 45 microns), known numbers of C. sphagnetorum or M. ater or both together were put into the bags before they were returned to the field. The bags were retrieved after 3 months and brought into the laboratory at 10°C. Microbial activity was then measured as the rate of uptake of oxygen of the undisturbed litter using a Dixon respirometer. The bags were then opened and the litter removed. The animals were recovered by extraction by a water funnel using a small quantity of cold water and the litter was then dried and weighed. The animals were also weighed. The contribution to oxygen uptake by animals in the respirometer is known from previous studies on their rate of respiration using a Cartesian Diver.

The experiment was carried out first in June-September 1971. It was repeated in November-April 1972 and June-September 1972 with modifications as to the number and conditions of animals used and the addition of laboratory replicates (controls) at 10°C.

Some of the results of the first two experiments are given in Tables 1 and Tables 2 as mean ± S.E. The results of the third experiment are still being analysed.

Microbial activity

The results given are of the respiration of microflora and experimental animals combined. The amount due to respiration by C. sphagnetorum in the sample may be up to 0.1 µl/h. Thus the results of the analysis of the final estimates of microbial activity may be different to those given here. Tables 1c and 2c show that there is no significant increase in the rate of respiration of the treated samples over the control for any of the litters, but that the rate of respiration of the different litter types is different in the control group but not in any of the treatment groups. Respiration at 10°C of the winter experiment was only slightly lower than the comparable summer experiment.

Carbon dioxide production on the site has been measured by a conductimetric method.

Loss in dry weight by litter

The loss in dry weight of litter expressed as a percentage of the initial dry weight is shown in Table 1a and 2a. The loss is greater in summer than in winter as is well known and these experiments also confirm previous ones in that the weight loss between litter types is significantly different in all cases. However, a significant difference in weight loss caused by treatment was found only in the summer experiment with Eriophorum litter. Loss in dry weight as loss of carbon will be compared with its loss due to respiration when temperature data become available.

Change in standing crop of C. sphagnetorum

The animals were examined and their segments counted and the change in standing crop is taken to be the difference between the number of segments added initially and the final number. The results for the first two experiments (Table 1b and 2b) show that standing crop declined where the animals were confined with Sphagnum litter, whereas the standing crop increased with other litter types. In the experiment using 5 C. sphagnetorum their increase in standing crop between litter types is significant in the winter experiment, and greater with Calluna litter. In no case did the treatment lead to any significant difference in the change in standing crop of C. sphagnetorum.

The increase in standing crop of M. ater was found from the final live weight - initial live weight. The death rate was 50%. The animals recovered from Sphagnum litter had not increased in weight while animals recovered from Calluna litter had trebled in weight.

Table 1 June - September 1971

Analysis of Variance (randomised)

a) Percentage dry weight loss from litter.

	d.f.	v.r.	Samples of litter containing 14 C.sphagnetorum	5 C.sphagnetorum	control
Eriophorum	2,9	6.9*	24.9 ± 2.7	17.5 ± 1.2	15.5 ± 1.4
Calluna	2,9	0.9	15.6 ± 2.7	13.8 ± 1.2	12.1 ± 1.3
Sphagnum	2,6	0.1	5.4 ± 2.1	5.2 ± 1.8	3.6 ± 3.0
d.f.			2,9	2,8	2,7
v.r.			15.1**	19.9**	10.3**

b) Change in standing crop of Enchytraeidae. Number of segments.

	d.f.	v.r.	t	14 C.sphagnetorum	5 C.sphagnetorum
Eriophorum	1,6	0.83	0.913	142.5 ± 119.4	327.5 ± 163.6
Calluna	1,6	0.56	0.752	301.5 ± 178.0	500.2 ± 195.4
Sphagnum	1,6	5.05	2.246	-352 ± 101.1	-2 ± 118.6
d.f.				2,9	2,9
v.r.				6.21*	2.46

c) Rate of oxygen consumption µl/g dry weight/h. after 3 hours.

	d.f.	v.r.	14 C.sphagnetorum	5 C.sphagnetorum	control
Eriophorum	2,5	0.62	196 ± 5	131 ± 48	174 ± 37
Calluna	2,9	0.76	75 ± 31	118 ± 29	95 ± 12
Sphagnum	2,4	0.43	248 ± 236	45 ± 45	37 ± 7
d.f.			2,5	2,6	2,7
v.r.			0.34	1.04	7.31*

* $P<.05$
** $P<.01$
v.r. = variance ratio

Table 2 November 1971 - April 1972

a) Percentage dry weight loss from litter

	d.f.	v.r.	Samples of litter containing 5 *C.sphagnetorum*	5 *C.sphagnetorum* and 1 *Molophilus ater*	1 *Molophilus ater*	control
Eriophorum	3,14	0.53	9.8 ± 1.070	8.1 ± 0.939	10.5 ± 1.240	10.4 ± 2.780
Calluna	3,16	0.94	3.9 ± 0.972	2.9 ± 0.156	2.7 ± 0.124	3.6 ± 0.583
Sphagnum	3,16	1.73	1.5 ± 0.595	1.1 ± 0.783	2.7 ± 1.092	0.3 ± 0.300
d.f.			2,11	2,12	2,12	2,11
v.r.			22.30**	26.06**	22.28**	12.60**

b) Change in standing crop of *C.sphagnetorum*. Number of segments initial - final

	d.f.	v.r.	5 *C.sphagnetorum*	5 *C.sphagnetorum* and 1 *Molophilus ater*
Eriophorum	1,4	0.24	103.3 ± 73.1	200 ± 184.7
Calluna	1,4	0.15	146.7 ± 26.7	93 ± 135.3
Sphagnum	1,4	1.45	-66.6 ± 26.7	-13 ± 35.3
d.f.			2,6	2,6
v.r.			5.64*	0.64

c) Rate of oxygen consumption µl/g dry weight/h. after 3 hours.

	d.f.	v.r.	Samples of litter containing 5 *C.sphagnetorum*	5 *C.sphagnetorum* and 1 *Molophilus ater*	1 *Molophilus ater*	control
Eriophorum	3,19	0.96	114 ± 37	63 ± 14	75 ± 17	87 ± 4
Calluna	3,16	0.11	71 ± 14	76 ± 6	78 ± 21	66 ± 20
Sphagnum	3,16	1.16	63 ± 21	60 ± 9	83 ± 16	44 ± 5
d.f.			2,13	2,14	2,12	2,12
v.r.			0.98	0.62	0.05	5.64*

D. Feeding studies on Enchytraeidae - Project 2/06 (Miss P.M. Latter & Mrs G. Howson, Merlewood)

The observations on gut contents, faeces, and microbial content of foods given to Cognettia sphagnetorum have been completed (Annual Report 1970) and together with previous experimental results all data are now being analysed and prepared for publication.

The observations of gut contents of field and experimental worms suggest that older humified material was ingested, when available. The proportion of material showing cellulose cell walls was low except when Eriophorum leaves were the sole food. Sphagnum leaf cells were seldom observed in the gut. In a selection experiment foods were placed between nylon gauze, in six compartments in a petri dish and worms were placed in a central area containing mixed Sphagnum peat. The distribution of worms after eight weeks is shown in Table 1.

All the results confirm that Rubus, Calluna and Eriophorum are the main food materials consumed in the field.

Table 1 The distribution of worms in six foods. For each dish the % of worms is given.

Dish No.	1	2	3	4	5	Mean % All Dishes
Rubus	36	40	52	35	46	42
Calluna	35	16	17	25	27	24
Eriophorum	16	20	8	16	9	14
Eriophorum & fungus	6	8	10	15	12	10
Sphagnum	2	6	13	9	1	7
Cladonia	5	9	0	1	5	4
Total number of worms	63	79	84	89	85	

E. Decomposition of plant remains - Project 2/07 (O.W. Heal & Miss P.M. Latter, Merlewood)

The measurement of the long term weight loss, respiration and chemical changes of litter samples, begun in 1966 and 1967, has been terminated. The data are still being analysed and incorporated into a model of production, decay and accumulation.

Between-year variation has been examined by measurement of dry weight loss of leaves of Rubus chamaemorus placed on Bog Hill in 1967, 1970 and 1971. Observed losses were consistent, the mean percentage weight loss in the respective years being 38.1 $\pm$ 1.6, 38.6 $\pm$ 1.6 and 39.0 $\pm$ 1.8.

Weight loss in 10 replicate samples of 15 litters on the litter surface on Sike Hill was measured in November 1971. Percentage losses after 1 year are given in Table 1. Results for species studied previously were consistent with the earlier data e.g. Rubus. The two unexpected, and unexplained, results were for Sphagnum and E. vaginatum roots neither of which showed detectable weight loss. In another experiment, E. vaginatum roots showed a loss of 8.2 $\pm$ 1.3% on the bog surface, and Clymo (1965 J. Ecol) found a loss of about 10% for Sphagnum acutifolium on Bog Hill.

Examination of variation in decay rate, using Rubus chamaemorus leaves showed significant differences between habitats within Burnt Hill and Sike Hill (Table 2). Positive correlations between weight loss and moisture content at the time of sampling were significant and showed that in the two sites, 32 and 26% of the variation in weight loss could be explained by moisture variation. In another experiment using Rubus leaves in eight different bog sites, results were similarly correlated with moisture. The percentage weight loss after one year ranged from 34.4 ± 2.0 at Bog Hill to 43.4 ± 1.9 on Cottage Hill.

In a further experiment on Sike Hill samples of E. vaginatum roots, Calluna below ground stems and Juncus effusus leaves were placed at 5 cm intervals down the peat profile to 25 cm depth. Weight loss of Calluna and Juncus decreased with depth, but Eriophorum roots showed a small but significant increase in loss rate. The latter result was unexpected and there is no obvious explanation, except for the possibility that the microflora associated with the Eriophorum roots is adapted to activity under the reducing conditions within the peat.

The results from this series of experiments, along with those from studies on decomposition of cotton strips, are being analysed in detail. The results and interpretation given here are preliminary. Some of the data are being used in the model being developed by Helen Jones.

Table 1 Percentage loss in weight for a range of plant remains on Sike Hill. Samples were placed on the litter surface, for one year.

Calluna vulgaris shoots	19.7
" " above-ground stems	7.5
" " below-ground stems	6.6
" " roots	5.0
Eriophorum angustifolium leaves (in nets)	23.5
" " " (in bags)	17.6
E. vaginatum leaves	22.0
" " roots	0.6
Juncus effusus leaves	31.3
Nardus stricta leaves	22.8
Narthecium ossifragum leaves	44.9
Pinus contorta needles	24.5
Rubus chamaemorus leaves	36.1
Sphagnum acutifolium	-1.6
Trichophorum cespitosum leaves	18.2
Standard error of treatment means	± 1.86

Table 2 Percentage loss in weight of Rubus chamaemorus leaves in habitats within sites

Burnt Hill		Sike Hill	
Sphagnum pools	59.2	Sphagnum litter	51.9
" lawns	52.6	Calluna litter	38.1
" hummocks	44.1	Eriophorum litter	33.7

Standard error of treatment means ± 5.1

F. Studies on nitrogen-fixation in peat - Project 2/16
(Miss V.G. Collins & Miss B.T. D'Sylva, F.B.A.)

Investigations have continued to determine the rates of nitrogen fixation and to estimate the numbers of nitrogen-fixing bacteria in peat at Moor House.

The numbers of aerobic and anaerobic "nitrogen fixing" bacteria were estimated by a dilution plate count on Biggins and Postgate's mineral salts medium containing a small amount of combined nitrogen (20 µg/l). Anaerobic conditions were obtained by replacing air with carbon dioxide gas. All incubations were done at 25°C.

The amount of nitrogen fixed was determined by a modified Hardy et al' acetylene reduction technique. Peat samples were flushed with one of three gas mixtures: (Ar), ($Ar + O_2$) or $Ar + O_2 + CO_2$), and then flushed with acetylene gas, sealed and incubated for 1 hour at field temperature. The samples were analysed in a gas chromatograph for the production of ethylene from acetylene.

Sampling was done on five occasions in the year at the Bog End site; the four horizons were studied for between depth variation. Between site and between depth variation were investigated on the Bog End, Sike Hill, Green Burn and two Cottage Hill sites. Unfortunately only one sampling could be carried out at sites other than Bog End.

The characteristics of the peat profiles at the five sites are given in Tables 1a and 1b. The five sites are very similar in pH and moisture content; Cottage Hill B however appears to be slightly less acidic, and Green Burn wetter than the other sites.

The numbers of aerobic and anerobic bacteria are similar and show similar trends at Bog End. Highest numbers tend to occur in the winter and in the upper horizons. The seasonal variation in numbers tends to decrease with depth (Tables 2a, b). The other sites show similar numbers to Bog End and a similar trend of higher numbers in the upper horizons (Table 3a, b). Further analysis of these results is in progress.

The amounts of ethylene produced from acetylene/cm^3/hr are shown in Tables 4a and b. Theoretically the ratio of nitrogen fixed: ethylene produced is 1:3, but various workers have reported ratios of 1:4.5, 1:5.5 and even 1:6. It is not certain which ratio applies to peat soils.

There appears to be no correlation between the numbers of bacteria and the proportions of nitrogen fixed under the three different gaseous conditions. The bacteria growing on the "nitrogen-free" agar plates could be potential nitrogen fixers, but it is not certain whether they are responsible for any nitrogen fixation in the field. Seven of the isolates were tested under laboratory conditions.

The bacteria were grown in a glucose, mineral salt, nitrogen free medium (Norris and Chapman). Cultures which were 48 hours old produced between 0.008 and 0.847 n mols ethylene/10^5 bacteria/hour. This indicates that these bacteria can, under laboratory conditions, produce amounts of ethylene equivalent to those observed in field measurements.

It should be emphasised that analysis of results is still in progress and that all interpretation is tentative.

Table 1a Characteristics of the samples used in N fixation measurements at Bog End, Moor House.

Horizon	Range of depth (cm)	pH dist. water	pH 1M KCL	Moisture Content % wet wt.	Moisture Content % dry wt.
September 1970					
Litter	0- 4	3.88	-	91.45	1264.7
Black brown	2-12	3.50	-	91.56	1099.6
Green Brown	7-22	3.41	-	90.23	959.7
Red brown	22+	3.40	-	89.92	909.9
October 1970					
Litter	0- 9	3.70	3.25	87.98	806.6
Black brown	4-16	3.71	3.20	91.45	1084.2
Green brown	10-27	3.60	3.03	91.21	1044.2
Red brown	27+	3.60	2.98	89.66	869.9
February 1971					
Litter	0-12	3.33	2.90	92.21	1289.1
Black brown	2.5-14	3.20	2.73	91.12	1069.4
Green brown	11-19	3.06	2.58	91.41	1073.4
Red brown	19+	2.93	2.61	89.28	833.5
April 1971					
Litter	0- 9	3.50	3.00	87.97	798.2
Black brown	2-16	3.53	2.85	91.51	1097.9
Green brown	6-23	3.36	2.71	89.43	873.5
Red brown	23+	3.19	2.66	89.50	854.8
June 1971					
Litter	0-10	3.46	2.83	89.56	926.0
Black brown	4-20	3.56	2.85	91.81	1124.0
Green brown	11-28	3.36	2.68	89.36	866.3
Red brown	28+	3.33	2.66	91.00	1026.0

Results are the means of 3 samples

Table 1b Characteristics of the samples used in N fixation measurements at four Moor House sites

Site and sampling date	Horizon	Range of depth (cm)	pH		moisture content	
			dist water	1M KCL	% wet wt.	% dry wt.
Sike Hill September 1971	Litter	0–15	3.30	2.77	91.58	1237.0
	Black brown	2–19	3.26	2.71	90.29	930.0
	Green brown	10–27	3.30	2.67	91.10	1037.5
	Red brown	27+	3.41	2.71	89.89	918.9
Cottage Hill B September 1971	Litter	0– 9	3.73	3.04	93.33	1488.0
	Black brown	6–19	4.06	3.23	91.87	1180.0
	Green brown	14–25	4.28	3.55	92.43	1261.4
	Red brown	25+	4.63	3.87	91.27	1082.8
Cottage Hill A April 1972	Litter	0– 8	3.31	3.21	90.82	1218.6
	Black brown	3–16	3.45	2.83	91.44	1089.8
	Green brown	7–23	3.53	2.81	91.57	1091.0
	Red brown	23+	3.64	2.90	92.09	1180.0
Green Burn April 1972	Litter	0–11	3.47	2.80	90.94	1018.2
	Black brown	1–23	3.50	2.70	94.04	1597.0
	Green brown	12–29	3.53	2.69	94.42	1710.0
	Red brown	29+	3.51	2.73	94.27	1654.0

Results are the means of 3 samples

Table 2a Numbers of aerobic bacteria x 10^5/gm dry wt ± standard error, growing on a "nitrogen-free" medium. Bog End Site. Results are the means of 3 subsamples from each of 3 cores.

Horizon	September 1970	October 1970	February 1971	April 1971	June 1971
Litter	8.6 ± 4.3	48.0 ± 2.9	153.0 ± 14.0	61.0 ± 5.8	44.0 ± 15.0
Black brown	91.0 ± 11.0	18.0 ± 7.2	150.0 ± 37.8	47.0 ± 14.0	25.0 ± 2.2
Green brown	13.0 ± 4.4	52.0 ± 3.0	60.0 ± 10.0	30.0 ± 11.0	11.0 ± 3.3
Red brown	2.4 ± -	20.0 ± 9.1	42.0 ± 14.0	33.0 ± 3.2	19.0 ± 3.5

Table 2b Numbers of anaerobic bacteria x 10^5/gm dry wt ± standard error growing on a "nitrogen-free" medium. Bog End site. Results are the means of 3 subsamples from each of 3 cores.

Litter	26.0 ± 2.6	68.0 ± 11.5	173.0 ± 27.0	70.0 ± 38.6	39.0 ± 15.0
Black brown	44.0 ± 4.7	24.0 ± 11.3	62.0 ± 16.0	66.0 ± 22.0	17.0 ± 3.2
Green brown	19.0 ± 1.9	116.0 ± 20.0	48.0 ± 13.0	44.0 ± 23.0	15.0 ± 1.5
Red brown	7.2 ± 2.9	25.0 ± 25.0	52.0 ± -	10.0 ± 7.5	10.0 ± 1.5

Table 3a Numbers of aerobic bacteria, x 10^5/gm dry wt. ± standard error, growing on a "nitrogen-free" medium. 4 Moor House sites. Results are the means of 3 subsamples from each of 3 cores.

Horizon	Sike Hill September 1971	Cottage Hill B September 1971	Cottage Hill A April 1972	Green Burn April 1972
Litter	33.0 ± 7.9	471.0 ± 210.0	106.0 ± 25.0	47.0 ± 17.0
Black brown	34.0 ± 8.6	76.0 ± 25.0	78.0 ± 18.0	102.0 ± 29.0
Green brown	15.0 ± 6.2	74.0 ± 15.0	34.0 ± 11.0	62.0 ± 22.0
Red brown	20.0 ± 8.1	22.0 ± 12.0	4.6 ± 3.0	22.0 ± 7.7

Table 3b Numbers of anaerobic bacteria x 10^5/gm dry wt ± standard error, growing on a "nitrogen-free" medium. 4 Moor House sites. Results are the means of 3 subsamples from each of 3 cores.

Litter	15.0 ± 6.0	447.0 ± 190.0	144.0 ± 14.0	81.0 ± 19.0
Black brown	25.0 ± 16.0	78.0 ± 10.0	65.0 ± 20.0	111.0 ± 30.0
Green brown	14.0 ± 4.0	36.0 ± 10.0	27.0 ± 7.4	52.0 ± 19.0
Red brown	13.0 ± 8.7	15.0 ± 11.0	9.9 ± 5.0	19.0 ± 8.0

Table 4a Acetylene Reduction at Bog End. Results are means of 3 subsamples from 3 cores, expressed as n-moles ethylene produced/cm^3/hr. The incubation temperature on both occasions was 11°C.

Horizon	April 1971			June 1971		
	Argon	Argon + Oxygen	Argon + Oxygen + Carbon dioxide	Argon	Argon + Oxygen	Argon + Oxygen + Carbon dioxide
Litter	0.1608	0.1185	0.5640	0.1623	0.0933	0.1239
Black brown	0.4144	1.1990	0.7681	0.0588	0.4634	0.2275
Green brown	0.1818	0.0126	0.9042	0.6380	0.2799	0.0692
Red brown	0.2838	0.0836	0.3377	-	0.1595	-

Table 4b Acetylene reduction at 4 Moor House sites. Results are means of 3 subsamples from 3 cores, expressed as n-moles ethylene produced cm^3/hr.

Horizon	Sike Hill September 1971			Cottage Hill B September 1971			Cottage Hill A April 1971			Green Burn April 1971		
	Al	$Al+O_2$	$Al+O_2+CO_2$	Al	$Al+O_2$	$Al+O_2+CO_2$	Al	$Al+O_2$	$Al+O_2+CO_2$	Al	$Al+O_2$	$Al+O_2+CO_2$
Litter	-	0.0757	0.0346	-	-	0.0609	-	0.0889	0.1194	0.0806	0.0237	0.0052
Black brown	-	-	0.0518	-	-	0.0727	-	-	0.2723	0.0175	0.0171	0.1622
Green brown	-	0.1135	0.1517	-	-	-	-	-	-	-	1.8130	-
Red brown	-	-	-	-	-	-	-	-	-	0.0279	1.1570	-
Incubation temperature (°C)		18			16			15.5			15.5	

VII. APPENDICES

A) Publications

CLYMO, R.S. & REDDAWAY, E.J.F. 1971. Productivity of Sphagnum (Bog-moss) and peat accumulation. Hidrobiologia, 12, 181-192.

HADLEY, M. 1969. The adult biology of the Crane-fly Molophilus ater Meigen. J. Anim. Ecol., 38, 765-790.

HEAL, O.W. 1972. A brief review of progress in the studies at Moor House (U.K.). In: Proc. IVth Int. Meeting on the Biological Productivity of Tundra, Leningrad. (Ed. F.E. Wiegolaski and T. Rosswall), 295-305.

HODKINSON, I.D. 1972. Long range dispersal of certain species of Psyllidae in the northern Pennines. Ent. Mon. Mag., 108, 21-22.

JONES, H.E. & GORE A.J.P. 1972. Descriptive models in comparative ecosystem studies. Proc. IVth Int. Meeting on the Biological Productivity of Tundra, Leningrad. (Ed. F.E. Wiegolaski and T. Rosswall), 35-47.

MARKS, T.C. & TAYLOR, K. 1972. The mineral nutrient status of Rubus chamaemorus L. in relation to burning and sheep grazing. J. appl. Ecol., 9, 501-511.

RAWES, M. & WELCH, D. 1972. Trials to recreate floristically rich vegetation by plant introduction in the northern Pennines, England. Biol. Cons., 4, 135-140.

RAWES, M. & WILLIAMS, R. 1972. Productivity and Utilisation of Calluna and Eriophorum. In: Hill pasture improvement and its economic utilisation. Colloquium, Edinburgh, 1972. Ed. M.J.S. Floate.

TUFNELL, L. 1971. Erosion by snow patches in the north Pennines. Weather, 26, 492-498.

TUFNELL, L. 1972. Ploughing blocks with special reference to north-west England. Biuletyn Peryglacjalny, 21, 237-270.

Ph.D. Thesis

MARTIN, N.J. 1971. Microbial activity in peat with reference to the availability and cycling of inorganic ions. Edinburgh University.

Dissertations

BELL, S.N. 1972. A population study of Collembola on heather moor. (Liverpool Polytechnic).

MALLET, MRS. C. 1972. The Upper Eden Valley - Challenge and Threat. (University College, London).

TAYLOR, M.M. 1970. A study on the species composition, distribution and possible preference for reduced oxygen conditions of fungal isolates from mixed moor (blanket bog). (Liverpool Polytechnic).

Moor House Occasional Papers

RAWES, M. 1971. The influence of agriculture. In: Aspects of the Ecology of the Northern Pennines. No. 1., 15pp.

RAWES, M. 1971. Moor House Publication List. In: Aspects of the Ecology of the Northern Pennines. No. 2., 20 pp.

STAFF LIST

Officer in Charge

M. Rawes (Senior Scientific Officer)

Scientific Staff

R. Williams (Scientific Officer)

R.B. Marsh (Assistant Scientific Officer)

Miss L.M. Teasdale (Secretarial and Assistant Scientific Officer)

Warden

T.L. Hodgson (until April, 1972)

J.P. Houlton (since April, 1972)

Estate Worker

P.J. Holms (since November, 1971)

Housekeeper

Mrs. G.G. Dunn (April - October)

Part-time Warden

J. Rose (December - March)

F.B.A. Staff

Dr. D.T. Crisp (Principal Scientific Officer)

Dr. P. Armitage (Higher Scientific Officer)

Miss S. Carrick (Assistant Scientific Officer)(until August, 1972)

Meteorological Summary for Moor House 1971 (Met. Office Station No. 7188)
c. 558 m O.D. (Main Instrument Site) Lat. 54° 41' N., Long. 2° 23' W. Nat. Grid Ref. NY/758328

		JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
Mean maximum temperature	°C	3.6	3.8	3.6	7.3	11.3	10.8	16.8	14.3	14.1	10.1	4.9	5.7	8.9
Mean minimum temperature	°C	-1.2	-1.4	-1.7	-0.2	2.7	4.1	7.7	8.0	6.3	4.6	-0.6	0.9	2.4
½(max. + min) temperature	°C	1.2	1.2	0.9	3.5	7.0	7.5	12.3	11.1	10.2	7.3	2.1	3.3	5.6
Highest maximum temperature	°C	10.2	8.2	7.0	14.7	15.7	16.3	22.8	18.6	19.8	18.6	11.0	10.3	22.8
Lowest minimum temperature	°C	-12.4	-10.2	-10.5	-5.2	-2.8	-2.8	-0.9	3.3	-3.5	-5.5	-8.4	-3.6	-12.4
Lowest maximum temperature	°C	-1.9	-1.1	-0.6	3.0	7.3	7.6	10.8	7.6	8.8	3.7	-2.8	-0.1	-2.8
Highest minimum temperature	°C	6.4	3.0	4.0	5.5	7.8	8.4	12.1	14.0	10.4	10.7	8.4	5.0	14.0
Lowest grass minimum temperature	°C	-13.6	-13.6	-13.6	-10.8	-8.4	-8.3	-6.6	-1.2	-8.9	-11.0	-12.4	-8.1	-13.6
Average earth temperature at 1 ft. 0900 G.M.T.	°C	2.5	2.2	2.2	4.5	7.6	8.9	12.7	12.0	11.0	8.7	4.9	4.3	6.8
Rainfall	mm	138.8	154.1	127.2	53.6	76.4	129.1	63.7	186.6	41.1	140.2	172.7	61.6	1345.1
Greatest daily rainfall	mm	27.6	50.5	25.7	23.3	11.5	17.7	21.5	32.5	19.6	33.7	35.6	11.5	50.5
No. of rain days		23	14	24	17	17	20	12	23	12	20	22	28	232
No. of wet days		14	11	21	10	16	16	8	17	6	13	16	14	162
Days with snow or sleet falling		7	7	13	7	1	0	0	0	0	1	9	4	49
Days with snow lying 0900 G.M.T.		7	12	13	1	0	0	0	0	0	0	7	4	44
Days with hail		0	0	6	4	0	0	0	0	0	0	1	1	12
Days with snow or ice pellets		0	1	0	2	1	1	0	0	0	0	1	2	8
Days when thunder heard		0	0	0	0	0	0	3	0	0	1	0	0	4
Days with fog at 0900 G.M.T.		9	7	3	4	3	6	2	4	2	3	5	3	51
Days with air frost		15	18	22	17	7	2	1	0	2	3	19	11	117
Days with ground frost		24	20	21	19	16	8	6	2	5	10	21	15	167
Total sunshine hours		21.8	50.0	68.6	122.9	220.0	114.0	227.9	109.3	140.4	82.0	41.0	9.3	1207.2
Av. daily bright sunshine, hours		0.70	1.79	2.21	4.10	7.10	3.80	7.35	3.53	4.68	2.65	1.37	0.30	3.30
Total snow fallen, cm		15	43	44	1	0	0	0	0	0	0	26	9	138
Greatest depth snow lying, cm		28	13	15	1	0	0	0	0	0	0	14	6	28
Average wind speed, knots		14.6	13.2	12.3	10.6	10.7	11.5	8.6	11.1	10.4	17.7	19.6	21.1	13.4
Days with gale (anemograph record)		5	1	0	1	0	0	1	1	1	7	4	14	35

Potential Evaporation Data

Potential evaporation	mm	(17)	(17)	(19)	36	74	(68)	66	36	34	26	20	14	427
Rainfall	mm	139	154	127	53	76	129	64	187	56	140	173	62	1360
Potential water deficit	mm	3	0	0	7	20	8	53	4	20	4	0	0	119
Potential water surplus	mm	125	137	108	24	22	69	51	155	42	118	153	48	1052

Metecrological Summary for Great Dun Fell 1971
c. 655 m O.D. Lat 54° 35' N. Long 02° 28' W. National Grid Ref: No. NY/710322

		JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
Mean maximum temperature	°C	1.2	0.9	0.8	4.8	8.9	8.2	14.1	11.5	11.7	7.8	2.1	2.7	6.2
Mean minimum temperature	°C	-1.6	-2.2	-2.6	-0.5	2.5	3.1	7.9	7.2	6.6	3.9	-0.9	0.7	2.0
½(max + min) temperature	°C	-0.2	-0.7	-0.9	2.1	5.7	5.7	11.0	9.3	9.1	5.9	0.6	1.7	4.1
Highest maximum temperature	°C	9.0	6.8	5.0	12.0	13.4	14.6	20.5	16.5	18.2	16.3	8.7	8.3	20.5
Lowest minimum temperature	°C	-7.8	-7.5	-8.2	-6.6	-1.2	-0.9	2.5	3.5	1.1	-3.8	-7.8	-4.6	-8.2
Days with snow lying		15	11	24	3	0	0	0	0	0	0	12	8	73
Fog at 0900hrs. G.M.T.		23	23	26	15	16	18	13	22	16	21	23	25	241
Days with air frost		26	23	28	21	5	2	0	0	0	3	20	12	140
Wind speed, knots		19.0	-	-	15.0	16.7	18.9	12.2	17.5	14.2	23.0	25.5	29.6	(19.2)
Sunshine hours, daily mean		0.59	1.11	1.56	3.85	5.56	3.20	6.20	2.53	3.99	1.80	0.90	0.05	2.61