THE NATURE CONSERVANCY

MOOR HOUSE FIELD STATION

Annual Progress Report

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MOOR HOUSE

9 th Annual Progress Report 1967-68

by M. Rawes

This Report covers the period 1 October, 1967 to 30 September 1968.

During the year the administrative arrangements were changed. With effect from 1 August 1968, for a trial period of two years, responsibility for Moor House National Nature Reserve and Field Station has been taken over by the Regional Officer (North Region). New programmes by University and other visiting scientists will, like those of Conservancy staff, require the prior approval of the Regional Officer, rather than the Officer-in-Charge. The Regional Officer will consult with the Head of the Mountain and Moorland Habitat team and the Officer supervising the Moor House I.B.P., before giving permission. The Officer-in-Charge is now a member of the Conservation Branch and is appointed an Assistant Regional Officer. The scientific staff has been reduced by the loss of two permanent posts : Dr. B.P. Springett (S.O.) resigned on 31 December on obtaining an appointment with C.S.I.R.O., Australia, and J.M. Nelson (E.O.) was transferred to Edinburgh on 1 May.

The responsibility of the Moor House-based staff lies primarily in the scientific measurement of change, such as changes in botanical composition, under the existing management and in the absence of sheep grazing. Also, despite a shortage of staff every effort is made to continue to provide a service to other research workers. Assistance has been given with field work, the setting up of experiments, especially where fencing is required, care of recording instruments, provision of climatological and other data and the transportation of personnel and equipment.

Much of the research on the Reserve is now concerned with the I.B.P. ecosystem project, co-ordinated by Dr. O.W. Heal, who provides a general report on the state of the programme. The brief accounts that follow include those from I.B.P., the Nature Conservancy staff, University and other sources, all being grouped under the same subject headings.

A Station Report to cover the first 15 years (1952-67) is being written and will be published in 1969. The Report will include a number of review articles dealing with findings in the main research lines.

International Biological Programme - Moor House Project (O.W. Heal)

In July 1968 the I.B.P. completed the first year of the five year main study period. It was hoped that the programme would be well co-ordinated by now, with the aims and methods clearly defined. However although individual countries have programmes that are clearly specified, there has been relatively little international co-ordination. Moor House is fortunate to have developed strong links with the Tundra group and we have been involved in international meetings at Moor House (November, 1967) and Ustaoset, Norway, (September, 1968).

As a result of these meetings the main programme, which can be achieved by 1972, has been agreed by at least four countries - Norway (Hardangervidda), Finland (Kevo), U.S.A. (site to be specified) and U.K. (Moor House). Russia has tundra sites and it is hoped that these will be involved. Canada has been invited to participate and the Bi-Polar Botanical Project (Greenland and South Georgia run by Birmingham University) should provide a link with Arctic and Antarctic studies.

The level of study which can be carried out on all sites covers net primary production and the transfer of carbon and energy to herbivores and to standing dead to litter and soil. In addition, energy and carbon transfer to soil fauna, carnivores and microflora, and also nutrient circulation, will be covered in some sites allowing further comparisons. The participants have agreed to use systems analysis, particularly the compartment model approach, to compare results from various sites. These meetings have also helped individual workers to discuss methods and ensure greater comparability of data. Reports of the Ustaoset meeting can be obtained from Dr. O.W. Heal.

The need to develop methods of synthesis and comparison is now widely recognised in I.B.P. The Moor House project with about twelve individual projects plus a large amount of past and present data will require considerable effort and full participation by all concerned to produce an integrated final result. We must develop stronger links between individual projects, particularly between the main disciplines of botany, zoology and microbiology.

During 1967-68 we were fortunate to receive funding for three projects. Dr. Valerie Standen (Durham University) has been able to develop the work on Enchytraeidae carried out by Dr. J.A. Springett before she went to Australia. Dr. J.C. Coulson (Durham University) has received funds to continue studies on Tipulidae and Dr. J.B. Whittaker (Lancaster University) has been awarded a grant to work on Psyllid populations and their effect on Calluna. Although there was some difficulty with the grant to Dr. A.J. Holding (Edinburgh University), we hope this will be overcome.

At a practical level, the techniques for recording radiation have been unsatisfactory during the year. The Kent recorder is now being replaced by a battery operated Lintronic integrated counter, and we hope that this will prove suitable. A Grant 30 point temperature recorder was installed on Sike Hill in April and satisfactory results have been obtained for most of the summer for air and soil profiles on blanket bog under Calluna-Eriophorum and Juncus squarrosus (Appendix IV). The results are available to all involved in Moor House research

A general report on the present state of Moor House I.B.P. has been prepared (Merlewood Research and Development Paper No. 2) and can be obtained from O.W. Heal, The Nature Conservancy, Merlewood Research Station, Grange-over-Sands, Lancashire.

A. SCIENTIFIC RESEARCH

I. Climatology (J.M. Nelson and R.B. Marsh)

The Moor House Climatological Station has been in operation since 1952 and is officially recognised as Meteorological Office Station No. 7188. It provides daily records which are published by the Meteorological Office each month.

The Station has the following instruments :- thermometers to measure maximum, minimum, dry and wet temperatures in a Stevenson screen, which also holds a bi-metallic thermograph and hair hydrogram; a standard rain guage and a Dines tilting syphon continuous rain recorder; a sunshine recorder and a Kipps Solarimeter; a vane to show wind direction and a Dines pressure tube anemograph to continuously record wind speed and direction.

A summary of the recordings for 1967 is given in Appendix II.

II. Vegetation

(a) Measurements of changes occurring under sheep grazing and in its absence (M. Rawes and M.W. Read)

The effects of sheep grazing in the uplands are of conservation and land-use interest. The object of a number of studies, most of which have been under investigation since 1956, is to show how sward composition and production are related to management. Swards representative of the more widespread vegetation types have been selected. Grazing effects and information on climax vegetation will also be given by excluding sheep from fenced areas on each site.

The main method of following change has been by point quadrats at permanent positions, and by measuring standing crop and herbage production. Quadrats laid out in 1955 have been examined twice and are due for repeat analysis in 1969.

During the current year, resources have been insufficient to make any measurements, but observations indicated that the rate and kind of botanical change in most exclosures continues as before. The grassland exclosures, Agrostis-Festuca on limestone, Festuca on sandstone and Juncus squarrosus and Nardus on peaty-gleys continue to show a marked difference from the grazed swards. Species diversity continues to decline and local dominance by Deschampsia flexuosa is obvious in several exclosures. No definite botanical change in blanket bog exclosures is clear except in Eriophorum swards at 730 m O.D. where in one case plant cover, mainly Eriophorum angustifolium and E. vaginatum but also Narthecium ossifragum, has increased considerably.

The colonisation and build-up of soil on the enclosed limestone pavement by Rough Sike continues. A Salix seedling is present in one permanent quadrat.

Many exclosures on the Reserve show interests besides those for which they were designed and much information of conservation and biological interest will be given by these areas in the years to come.

(b) The establishment of natural grassland communities (M. Rawes)

It is unlikely that the type of vegetation developing within exclosures will be similar to that which occurred before sheep grazing was commonplace. Therefore certain arctic-alpine and montane species not now present on the Reserve, but thought to be likely constituents of a fern or tall-herb ungrazed community, were planted, mainly in 1956. The survival and performance of these introductions are followed annually and a number of measurements are carried out on some species. At present the most successful species appear to be Polygonum viviparum, Hypericum pulchrum, Saussurea alpina, Thalictrum alpinum, Potentilla crantzii and Salix spp., whereas Cerastium alpinum, Dryas octopetala, Sibbaldia procumbens and Juniperus communis have failed, although the number of plants and habitats chosen has been limited.

Most of the recording, which includes leaf measurement of Alchemilla alpina, in 1968 was by Miss Teasdale.

(c) Tree growth and nutrition (A.H.F. Brown, Merlewood)

Of the various forms of land use and management techniques for upland areas, it is considered that the re-establishment of tree cover, in certain areas at least, will play an increasingly important part. Although timber production may not be an economic proposition on many of these sites, woodlands will create diversity in the habitat, increase its amenity value and stabilising eroding areas.

Although remnants of trees in the peat suggest that they once grew at an elevation of 787 m or more on the Reserve, an assessment of the present situation suggests that 590 - 623 m might be more realistic present-day figures for a tree-line.

However, a knowledge of the extent to which tree growth is currently limited by soil and climate is wanted; the means of overcoming these limitations are basic to any move to introduce trees into these inhospitable and largely treeless areas.

Methods

(1) Species trials

Small scale trials of different species planted both on peat and mineral soils have been established and extended at intervals since 1954. Problems of inadequate nutrition, especially on the blanket peat, soon became apparent and studies into the nutrition of pines on peat were begun.

(2) Nutrition

A small-scale experiment on the correction of potassium deficiencies in Scots Pine at Green Hole was started in 1961 and is continuing.

A larger experiment on fertilising Pinus contorta at Bog End was started in 1962. Nitrogen, phosphorus and potassium fertilisers, singly or in combinations were applied as 12 different treatments (with fourfold replication), soon after planting. Annual assessments have been made of height increment, needle-weight and foliar concentrations of the main plant nutrients. The latter determinations help to assess the rate at which nutrients are released from peat and fertilisers; duration of the effects of various fertilisers; and will also permit a study of

the interactions expected between the quantities taken up of the different plant nutrients.

Results.

(1) Species trials

Of the species tried only Pinus spp. showed any potential on the peat. Initially, several hardwoods, notably birch (Betula spp.) rowan (Sorbus aucuparia) and Swedish Whitebeam (Sorbus intermedia) appeared to be promising for the mineral soil sites. However, during the last few years the rowan and birch have become increasingly moribund, and during the past year more have died. The more recently tried Sorbus intermedia also appears to be unable to do more than coppice afresh each year from the base of the stem. On the other hand several conifers will grow on these soils.

(2) Nutrition

Results from fertilising potassium deficient Scots Pine have not been assessed.

In the P. contorta experiment, data from the control (unfertilised) plots show that height increments increase up to 1965, subsequently falling. The foliar concentrations of nitrogen, phosphorus and potassium also show an initial rise for the first few years. These results support the view that the preparatory ploughing stimulates active mineralization of the nutrients in the peat.

Nitrogen:

Although the total nitrogen content of the Bog End peat is at the lower end of the range usually associated with acid peats, and in spite of the severe climate, nitrogen mineralisation was apparently adequate, judging from tree foliar concentrations. Foliar nitrogen in the control plots rose to 1.5% and although this has since fallen to 1.3%, this range of values is not particularly low for Pinus contorta. Adding nitrogen fertilisers, either singly or in combination with another macro-nutrient element, has reduced height growth. There is no apparent interaction between nitrogen and either phosphorus or potassium.

These results with nitrogenous fertilisers are in contrast with the position in some (but not all) other peat areas where nitrogen additions have been beneficial: this underlines our lack of knowledge of the factors which influence nitrogen mineralisation in peat.

Phosphorus:

Phosphate applications proved beneficial, as is usual on peats. The addition of ground mineral phosphate, alone, however, is associated with the lowest foliar potassium concentrations of any treatment (0.28% compared with 0.36% in the controls). The benefit of the phosphorous applications where added singly, is falling off with time.

Potassium.

Potassium additions have also increased height growth. In contrast to results with phosphorus fertilisers, the effect was slight initially, but has become increasingly marked with time, even though foliar levels of potassium have fallen each year since 1963 in all treatments, with or without added potassium.

Greatest height growth is associated with treatments that combine phosphorus and potassium, which have become increasingly superior to phosphorus alone. It is apparent that Moor House is a site where both phosphorus and potassium additions are needed. The rapid fall in foliar potassium levels also suggests that further doses of potassic fertilisers will become necessary.

A fuller assessment of the Bog End experiment was recently presented at the Symposium on Peatland Forestry held in Edinburgh (8-11 September 1968).

(d) Plant nutrition studies on peat (A.J.P. Gore, Merlewood)

Factors limiting plant growth on peat

Results so far, suggest that Molinia commenced growth (shoot expansion) at about the same time at both sea-level and at 560 m. but the shoots at the higher altitude were much smaller at this starting time.

Productivity of blanket bog vegetation

In this experiment, five different regimes of clipping, from annual through to quinquennial, have been imposed on blanket bog vegetation since the experiment was started in 1958. Two cycles of five yearly clippings were completed this year. This approach is intended to simulate some of the purely extractive effects of burning and grazing on moorland vegetation. There are no ash or faecal returns to the soil under this experiment and it is therefore possible to assess the extreme effects of graded stresses on fertility as measured by yield of dry matter of the plants i.e. those species best adapted to the treatments, and of their nutrient content.

Main emphasis has been on the mineral nutrient budget, with consideration of rainwater input (Gore 1968) and turnover. Turnover can be regarded as the annual fractional loss rates from the living biomass of the different plants and from their dead remains. Fractional loss rates from the peat have also been considered (Gore and Olson 1967). Compartment modelling, of the type described in that paper using a computer, is providing a useful means of simulating nutrient cycles. The dynamic models obtained will be subjected to different "cropping regimes" so that the behaviour expected from the models can be compared with the results obtained from the field experiment. At present the facilities of the Atlas Computer Laboratory, Chilton are being used in this work.

(e) Reclamation of eroded peat areas (A.J.P. Gore, Merlewood)

The experiments at Moor House and Manchester reported in the 1965-66 report have been successful. It is possible and practicable to establish grasses on eroded peat. However, following a meeting in March between Waterworks Officers and Officers from the Institute of Hydrology, the Freshwater Biological Association and the Nature Conservancy it was decided that it was not economically feasible to undertake large scale reclamation work of eroded peat in Longdendale.

The main considerations for this decision were as follows:-

1. An original reason for considering peat reclamation in Longdendale was to reduce the suspended solid content of the water intended for domestic consumption. Firstly, however, the flocculating plant at Arnfield (Manchester Corporation Waterworks) is working at rather below its most efficient level because the suspended solids in the water are fairly low already, and secondly only a proportion of the suspended solids are derived from peat. Consequently, any reduction of solids which resulted from peat reclamation would still necessitate flocculation but mean that the process would have to be conducted even less efficiently that at present.

In short, therefore, reclamation would tend to defeat this aspects its own object.

2. A second reason for reclamation was to reduce the silting of the reservoirs and thereby reduce the rate of loss of storage capacity. The build-up of sediment has been estimated as a result of my original report to the Corporation in 1960. It is probably not greater than 1" per year. A rough calculation shows that this represents a loss of capacity about 11% over the 120 years of the reservoirs' existence, which is equivalent to a 3% loss of yield or 1 million gallons per day in 32.5 million gallons per day. From consideration

of the nature of peat erosion in the Pennines (e.g. Bower, 1962 "The Cause of Erosion in Blanket Peat Bogs - A review of evidence in the light of recent work in the Pennines" Bower, M.M. 1962. The Scottish Geographical Magazine 78, 33-43), the rate of loss of capacity is unlikely to increase and therefore there seems little reason to pursue recolonisation of the eroded peat areas of the catchment for the purpose of reducing silting.

While peat reclamation work may have some value in conservation and agricultural terms it is considered unnecessary to pursue further active research on this topic unless new evidence on colloidal material and silting rates makes it necessary in the future.

(f) A Study of Variation in Limestone Grassland (M.W. Read - MSc. study)

The study aims to generate ideas about the floristic variation of limestone grassland on the Moor House National Nature Reserve.

Soil properties will be examined next year in an attempt to relate soil and plant variation.

Sampling has been confined to the non-alluvial Agrosto-Festuceta defined and mapped by Eddy, Welch and Rawes. Allocation of sites was by restricted randomisation according to altitude. Within site sampling was systematic and has involved marking with stakes and canes. The quadrat size used is 0.5 m^2, and the number chosen at each site is proportional to the square root of the site's area. Angiosperm presence is listed.

The sampling scheme is as follows:-

	Strata	Sites	Size of sampling (sq. m.) areas	No. of quadrats
A	1500' West side of ridge	1. North side of Knock Ore Gill	In excess of 50,000 sub-sampling adopted	40(2x20)
		2. South side of Knock Ore Gill		40(2x20)
B	1500'-2000' West	1. Brown Snout	100,000 sub-sampled	60(3x20)
		2. Knock Ore Gill near hush on north slope	3,300	46
C	2000'- 2500' West	1. Middle Tongue Beck	4,900	56
		2. Silverband Mine near track	c. 1700	32
D	2500' Central ridge	1. Small grassland to the south-east of Knock Fell exclosure	2,025	36
E	2000'- 2500' East	1. Hard Hill north facing slope	c. 1900	36
		2. Moss Burn	1200	
F	2000' East	1. Rough Sike	4,400	53
		2. Green Hole	450	18
	Total 6	11	-	445

However, the general sampling scheme has broken down in two respects. It was found impractical for the large grasslands, A1, A2 and B1, and subsampling was necessary. This involved randomisation of quadrat clusters 20 in each.

Stratum D had a small area of grassland and so comparison with other strata may be difficult.

The initial description of quadrats involves recording angiosperms present. It is hoped to summarise the data using multivariate techniques.

Further sampling of vegetation and site attributes will be dependent on results obtained from the descriptive data.

Field experience confirms the notion of species groupings. Altitudinal differentiation seems apparent, although the interaction of other factors may obscure it. Quantitative measures of soil and vegetation attributes may be essential in this.

The most interesting altitudinal difference so far noted is the abundance of Minuartia verna in the Knock Fell grassland contrasted with its scarcity in closed swards at lower altitudes.

(g) Chemical changes during plant decomposition (S.E. Allen, Merlewood)

Regular sampling of litter has continued. It is expected that the final collections will be made during 1968-1969. It should then be possible to complete the chemical analyses of the material at different stages of decomposition.

(h) Long-term investigation on effects of burning (M. Rawes)

This investigation aimed to assess the botanical effect of short- and long-rotation burning regimes both in the presence and absence of sheep grazing. Plots on blanket bog were first burnt in 1954. Each treatment was replicated four times and botanical analyses were done in 1961 and 1965. Measurements of standing crop were made in some plots in 1965, 1966 and 1967 and in 1967 studies of Calluna performance were made e.g. the number of flowers per unit area. Dr. Taylor has followed the effects of the treatments on Rubus chamaemorus performance for the last two years.

The short-rotation plots were burnt again in 1965 and both long- and short-rotation plots will be burnt in the next few years.

(i) Sheep grazing studies (M. Rawes and M. W. Read)

A logical development of earlier research on the effects of sheep grazing is to test hypotheses of successional change related to different intensities of animal pressure. The object of this project is to see if increased grazing of blanket bog will induce a seral change, culminating in the dominance of Juncus squarrosus.

The following studies planned in conjunction with I.A. Nicholson and started with the assistance of R.B. Marsh and Miss Teasdale, have begun:-

1) An experiment to determine the reaction of blanket bog to increased grazing.

2) Small scale clipping studies to examine the effect of competition on the establishment of Juncus squarrosus.

3) A survey to obtain evidence concerning the succesional hypothesis.

In 1) the treatments are :- Light grazing, heavy grazing, burning and draining. Each plot is 0.04 ha and is grazed by 4 sheep for short periods: the heavily grazed for periods of up to 10 days and the lightly grazed for 1 day, both 5-6 times a year.

Preliminary botanical analyses and observations of grazing preference and effect have been made. The heavily grazed plots are markedly different after three grazing periods, during which all angiosperms except Empetrum nigrum have been severely grazed. Rubus chamaemorus in mid-summer proved to be palatable. The bog has developed a distinct relief of hummocks and well grazed and trodden hollows. Live weight losses by sheep during the time spent in the heavily grazed plots have averaged 3.5 Kg and in one case reached 10 Kg, a quarter of the animal's live weight.

The clipping studies are on the two blanket bog sites, where Juncus squarrosus already occurs and where it is absent. Treatments include cutting, treading and seeding.

The survey involves making a number of similar measurements at several blanket bog and Juncus squarrosus sites and assessing relationships.

(j) Grass species trial (M. Rawes and T.H. Davies (N.A.A.S.))

Agriculturally and ecologically there is a need to know more about the performance of grasses on poorer soils and under extreme climatic conditions. Grasses have in the past been bred primarily for lowland conditions and this seed has been used, often with poor results, for upland re-seeding.

The Regional National Agricultural Advisory Grassland Officer (T. Davies) was therefore interested in testing a number of species and strains under Moor House conditions. In September 1967, grasses raised from pure seed supplied by the National Institute of Agricultural Botany and the Welsh Plant Breeding Station were planted. There were ten different species and forty varieties, including several indigenous Moor House grasses. The best survival rate has been by Phleum pratense (S.48 and S.50), Poa pratensis (Commercial) and Festuca rubra (Ello), whilst Dactylis glomerata (S.345, S.143 and Trifolium) and Holcus lanatus have been totally unsuccessful and the Moor House Agrostis tenuis failed to germinate. The grasses to flower first were Poa pratensis (Newport), Poa pratensis (Commercial) and Lolium perenne (S.24) and most tillers, 65 per plant have been given by Lolium perenne (Petra) although Festuca ovina (Novina) and Lolium perenne (S.23) have produced many tillers. On balance, the fine fescues appear at present to show the most promise. The recording has been by Miss Teasdale.

The plot will be maintained for a further year after which the most successful species may be tested in block trials.

(k) Primary Production of blanket bog (I.B.P. - G.I. Forrest)

The standing crop increment throughout the year was measured by sampling ten 0.5 m^2 quadrats at each of 20 harvests, selected from a gridded area on Sike Hill on a stratified random system. The aboveground vegetation was cut at bog level, while from each quadrat two peat cores were taken with a 100 cm^2 corer. An estimate of the Sphagnum species, cover, and vigour in each quadrat was made. The aboveground vegetation was separated into different components, and from the cores the roots of all species except Eriophorum were sorted manually. Dry weights were measured after oven-drying for 12 hours at 80°C. Powdered samples of all components were sent three times in the year for nutrient analysis and calorific value determination. Measurement of Calluna litter fall has been started, using a large number of 10 cm^2 shallow "peat" dishes staked down on the bog surface at 1 m intervals along the transects, the line of each transect being shifted after each monthly collection.

A botanical analysis of the vegetation using stratified point quadrats, has been completed.

A separate study on Eriophorum vaginatum has also been initiated: whole tussocks were sampled at intervals outside the gridded area, and the three main tussock strata (aboveground, shoot bases, and roots) were subdivided into a number of different components, both living and dead, the relative proportions and the absolute weights and numbers of which were followed throughout the season in an attempt to estimate turnover-rates and production.

A high variability was encountered in the figures for successive standing crops, so that generally the standard errors of the means were great enough to eclipse production figures; however, by pooling the data for groups of two successive harvests, smoother curves were obtained. Approximate figures are given, which refer to the period Jan. - July.

Calluna : production of green shoots was 100 g/m^2; total living production was estimated by inspection of the standing crop curve to be approximately 150 g/m^2. From correlations between the basal diameter and age of Calluna stems, and between age and dry weight of green shoots and of wood, knowing the distribution of basal diameter size-classes within the community, it has been possible to estimate independently the annual shoot production as 100 g/m^2 and the current year's wood production as 50 g/m^2, thus confirming the figures obtained from the standing crop increment. Production of standing dead was approximately 100 g/m^2, while the rate of litter fall over three months was 120 g/m^2, giving total aboveground Calluna production as 370 g/m^2.

Eriophorum vaginatum : net aerial production about 20 g/m^2. Net production of green leaves was 47 g/m^2, and approximately 25 g/m^2 of brown leaf was converted from standing dead to fallen dead. Inflorescence production was 1.5 g/m^2, i.e. 3% of leaf production. The ratio of production to peak standing crop (productivity index), 0.63, was much higher than that of Calluna (0.41).

Empetrum nigrum : total production approx. 20 g/m^2 (shoots 6 g/m^2, stems 14 g/m^2.

Rubus chamaemorus : production 2 g/m^2; mean peak shoot density was 27 shoots per m^2.

Vaccinium myrtillus : production less than 0.5 g/m^2; very sporadic.

Listera cordata : production 0.3 g/m^2.

Total aboveground production of higher plants was thus approx. 440 g/m^2. The standing crop of roots sampled, mostly Calluna, with some Empetrum and a little Rubus was around 700 g/m^2, giving a root/shoot ratio for Calluna and Empetrum of about 0.8 to 1.0.

Visitors

(1) Production of Sphagnum (I.B.P. - R.S. Clymo and E.J.F. Reddaway, Botany Department, Westfield College)

Measurements are in progress to determine Sphagnum productivity on the Reserve, and, on Burnt Hill, to investigate the relative distribution of the Sphagnum species (rubellum, papillosum, recurvum, and cuspidatum) and their growth. An attempt is being made to find out if differences in growth and decay rates can be explained as responses to differences in temperature and wetness in their usual habitats and in reciprocal transplant experiments.

Methods for determination of Sphagnum growth are described elsewhere (Clymo - submitted to Journal of Ecology). The Burnt Hill site is equipped with a 20 point Grant recorder. Records include, in addition to soil and air temperature profiles, surface temperatures in carpets of S. rubellum and papillosum and S. cuspidatum in a pool. Radiation, rainfall, the water level in a pool and the water status of the surface of the Sphagnum are also recorded. Gas fluxes from the peat are routinely analysed for carbon dioxide and methane.

Values already obtained for Sphagnum production on the Reserve are as follows:-

Species	Habitat	Production in $g/dm^{-2}yr^{-1}$
S. rubellum	Hummock	2.4
S. papillosum	Lawn	3.3
S. recurvum	Lawn	4.8
S. cuspidatum	Pool	6.0

Results for the current year's growth, at the time of writing, are still being processed. Instrument teething troubles and sheep damage have interrupted the continuity of the habitat data. However, some features of the Hummock - Lawn - Pool type of Sphagnum habitat have become apparent. It appears that the pools are often warmer than the lawn or hummock habitats, e.g.:-

Time	Pool	Lawn	Hummock	(°C)
13.00 hrs 1 May	14.0	13.0	11.5	
14.00 "	15.5	14.5	12.5	
15.00 "	16.0	14.0	13.0	
16.00 "	13.3	11.0	11.0	
17.00 "	11.0	9.0	9.0	

Similarly at night the temperature in the pool has been up to 2°C higher than in the lawn or hummock.

Differences can also be observed between aspects of the same hummock:-

Time	S.W.	N.	N.W.	Top
13.00 hrs. 1 May	13.5	11.0	10.5	11.5
14.00 "	15.8	12.0	12.3	12.5
15.00 "	18.5	11.0	12.0	13.0
16.00 "	13.3	9.0	10.0	11.0
17.00 "	10.0	7.5	8.3	9.0

1 May was partially overcast but differences of this type are found on both bright and completely overcast days.

Losses of carbon from the peat have been observed to be as high as 4 mg. dm.$^{-2}$day^{-1} as carbon dioxide and 1 mg. dm.$^{-2}$day^{-1}as methane. Improved collection methods may show up habitat and seasonal differences in these fluxes.

We should be interested to co-operate with others in the transcription of our chart data, possibly in return for some processing facilities.

(m) An experimental evaluation of the influence of climate on the growth of moorland plants (H. Woolhouse and J. Grace, Botany Department, Sheffield University.)

The object of this study is to measure CO_2 exchange as a function of selected environmental variables, using a laboratory system in which environmental variables may be controlled at will. Knowing values for these variables from field measurements, CO_2 exchange, and hence growth, is computed under field conditions. Comparisons with actual values will be obtained by direct measurement. If agreement is good the effect of imposing other climatic conditions on the ecosystem will be predicted.

In a series of short-term experiments on samples of Calluna vulgaris and Sphagnum rubellum, CO_2 exchange was measured as a function of temperature, light intensity and time of season. At optimum conditions, photosynthesis in Calluna proceeded at a rate of up to 145 micrograms of CO_2 per gm dry wt of leaf per min, and in Sphagnum 20 micrograms of CO_2 per gm dry wt of heads per min.

Preliminary measurements have been made on a laboratory model designed to investigate light climate within and below Calluna canopy.

(n) Autecology of Rubus chamaemorus (K. Taylor, Botany Department, University College, London.

This is a preliminary experiment to assess the performance of Rubus chamaemorus in relation to sheep grazing and burning of Calluneto-Eriophoretum on Hard Hill.

Samples (1 m^2) of the above-ground parts of R. chamaemorus were taken at random in the Hard Hill burning/grazing experiments in earlyJuly; 10 samples per treatment in Block A only. Shoot densities per m^2 and number of fruits per treatment (30 m^2).

In the laboratory, plant samples were sorted into a) leaves and b) petioles plus stem. Discs were punched from a random heap of leaves using a sharp cork borer, and complete discs were used for determining total leaf area for each sample. The discs were oven dried at 80°C and weighed. The regression of leaf area on leaf dry weight was linear ($Y = -0.0237 + 0.0067X$). The remainder of the samples were oven-dried at 80°C and weighed. Each sample was ground to pass 0.05 mm sieve and subjected to chemical analysis.

A selection of the results from Block A is presented in the following table:-

Means of 10 determinations	Total oven-dry wt. g/m^2	Total leaf area cm^2/m^2	%oven-dry weight of leaves %N	%K	%P	%Ca	Shoot density m^2
Fenced							
Short rotation burn	29.48	539.48	2.78	1.85	0.2	0.55	217
Not burned since 1954	8.96	-	3.03	1.59	0.18	0.52	65
Unfenced							
Short rotation burn	2.75	50.32	-	-	-	-	69
Not burned since 1954	1.61	-	2.67	1.59	0.26	0.42	21

There are differences in standing crop under each treatment. The concentration of mineral nutrients in the leaves was similar in all treatments, but the absolute amounts reflecting the differences in total dry matter were greatest in the fenced short rotation burn and least in the unfenced and unburned treatment.

(o) The distribution of Hordeum murinum L. in Britain. (A.W. Davison, Botany Department, Newcastle-upon-Tyne University)

Hordeum murinum is an annual grass of ruderal habitats. In Britain and most of Europe it is restricted to lowland areas and areas with a rainfall less than about 900 mm per annum.

The experiment is designed to investigate the reactions of the species to low temperature, high rainfall and competition in order to determine the factors restricting its distribution. Moor House is one of several sites.

Large polythene pots full of a garden loam were sown on site with seeds of Hordeum. In addition, some of the pots were sown with a mixture of Poa annua, Matricana matricoides, Polygonum aviculare and Plantago major. A survey of Hordeum stands has shown that these species are some of its commonest associates.

In order to differentiate between the effects of the autumn and winter climate as opposed to the spring and summer climate some of the pots will be transferred from Moor House to Newcastle and vice-versa in March or April.

Similar groups of pots were set out at Allenheads (altitude 366 m, rainfall c. 1290 mm per annum) and Newcastle (altitude c. 46 m, rainfall c. 640 mm per annum) on the same day.

Establishment, flowering and seed set will be examined over the next year.

III. Fauna

(a) Invertebrates of an area of Moorland (J.M. Nelson)

The work reported in previous years, 1963-1967, has been concluded and it is hoped to have a paper ready for submission to the Transactions of the Society for British Entomology before the end of the year.

A reference collection of insects has been built up at Moor House with the assistance of Miss S. Carrick. It contains examples of practically all the species referred to in the above paper and should prove useful to future workers.

Visitors

(b) Studies on Cercopidae (J.B. Whittaker, Lancaster University)

Changes in density of two populations of Neophilaenus lineatus (L) at Moor House have been studied since 1961 and the two populations showed parallel changes in every year up to 1967. In that year one of the populations was experimentally reduced to less than one half of its former density.

In 1968 the density at the two sites differed significantly at the start of the season as a result of the 1967 experiment. They were 18 m^2 at the experimental site and 66 m^2 at the control. Subsequent nymphal survival on the two areas was comparable (44% and 42% respectively), but adult survival has so far been significantly higher at the site with the reduced density (64% compared with 36%). One further series of samples will be taken in September to check this preliminary finding.

(c) Studies on freshwater fauna (D.T. Crisp, R.H.K. Mann, and J.C. McCormack (F.B.A.))

The population dynamics and production of freshwater fish is being studied in the Trout Beck system. Some additional sampling is being done in the River Tees and in Great Dodgen Pot Sike. This work is part of a larger survey centred on the site of the Cow Green reservoir. The main aim is to study the effect of the reservoir upon the distribution and population dynamics of fish in the basin of the reservoir and in the River Tees downstream of Cauldron Snout. The results of our studies on fish population at Moor House will be used for comparison with the results from Cow Green and the whole project will probably last for about ten years.

A number of regular sampling places have been marked out and in May, July and October the number and size distribution of the fish in each sampling reach were determined by electro-fishing. In addition, the aquatic invertebrate fauna is sampled.

During 1967 and early 1968, material was collected for construction of tables for weight for length, age for length and fecundity for trout and bull-heads. Some information on the density and age composition of the fish populations was also obtained. During 1968 the collection of census data has continued and some general surveys of fish distribution over the whole Moor House Reserve have been made. Tentative estimates suggest that within the Trout Beck system the annual production is likely to be much less. A thermograph has been set up to record the water temperature in the River Tees a little downstream of Tees Bridge. This instrument is at present being serviced by members of the Moor House staff.

(d) Ecological studies on some moorland Carabidae (Coleoptera) (K. Houston, Zoology Department, Durham University)

The life history of most species of Carabidae found at Moor House and the surrounding areas has been elucidated. The life histories fall into two main groups according to the type of vegetation on which they live. The vegetation types can be divided into "wet" habitats e.g. blanket bog, and "non wet" habitats, e.g. alluvial grasslands. The former are poorly drained and are usually waterlogged except in the

summer, whereas the latter are well drained but in the summer may become very dry.

Of the 31 species whose life history is known, 15 have larvae which occur in the spring and summer and have overwintering adults and are found on the "wet" habitats.

Of the remaining species, 13 are found mainly on the 'hon-wet" habitats. Their larvae are found in the colder months and overwinter normally as third instars. The adults may also overwinter.

There are few exceptions but these appear to have larvae which are either well adapted to resist either drowning and/or dessication. However, there is one species, Patrobus assimilis Chaud., which is found in most habitats. It is a montane species and shows interesting environmental adaptions in that it can have both summer and over-wintering larvae. It has been intensively studied in the laboratory and it has been found that its life history is regulated by both temperature and photoperiod.

Experiments are in progress with other species and preliminary results suggest that the photoperiod is the main factor governing the synchronisation of their life histories.

Work on the role of frogs and shrews as moorland predators is nearing completion. Frogs do not appear to be as important predators of carabids as shrews.

(e) Studies on Tipulidae (I.B.P. - J.C. Coulson and J.C. Horobin, Zoology Department, Durham University.)

Detailed ecological studies are being made on selected species of Tipulidae together with more general observations on the other Tipulidae of Moor House.

Over the past two years population and other data for the brevi-pulp crane fly Molophilus ater, have been obtained from six different altitude sites on Great Dun Fell and from four different vegetation sites on the eastern side of the Reserve. During the last half of the study, temperature data have been obtained from these and other sites using the inversion of sucrose as a temperature integrator.

Other investigations have been carried out during the adult emergence periods of Tipula subnodicornis, T. paludosa, and T. pagana, and as a result detailed study is to begin on the latter. It is frequent on limestone and alluvial grasslands, emerging during late September and early October.

Material collected now is being dried and weighed in preparation for the determination of calorific values later in the year and construction of energy budgets.

After the adult emergence period there are of the order of 100,000 eggs/m^2 in the ground at the most dense sites and over the larval life cycle this value reduces to 4,000/m^2, prior to emergence. The classic pattern of high mortality in the egg and early instars accounts for most of this drop.

There is a difference of about 20 days in the dates of 50% adult emergence between the earliest site at 427 m and the latest at 823 m on Dun Fell. There is evidence to suggest that mean adult weight decreases with increasing altitude.

The duration of the middle 66% of the emergence decreases from 9 days at the lowest site to 3 days at the highest.

An intensive culturing programme is planned for early 1969 to test several hypotheses on the behaviour of Molophilus populations under different climatic conditions.

(f) Studies on Enchytraeidae (I.B.P. - V. Standen, Zoology Department, Durham University)

This study is a development of J. Springett's work. It is concentrated on Cognettia sphagnetorum, the dominant enchytraeid, on a mixed moorland site at Bog End, Moor House. The objects of the study are to find the annual production of C. sphagnetorum, which reproduces asexually by fragmenting, and to estimate energy losses due to respiration by enchytraeid populations.

Calculations of annual production will be based on the existing population studies on Moor House enchytraeids. In addition, fortnightly samples have been taken from the site since 26 April, 1968, and these will be continued until spring 1969. The material from the samples is being used to estimate the birth rate and rate of increase of the population and hence the death rate and annual production which will be expressed as dry weight.

Field data are supplemented by laboratory cultures which give growth rate, the size at which worms fragment, fragmentation rate, and the rate of regeneration of new parts.

Preliminary analysis of the data shows that the birth rate expressed as a ratio of whole worms to fragments decreased from 2.2 : 1 in April, to 3.6 : 1 in August.

The rate of fragmentation has not yet been separated from death rate of adults but the average size of head fragments is 22 segments and of tails, 24 segments. The distribution of size groups of adults shows that numbers decrease after 40 segments achieved, in all samples.

Population size is at present expressed as the total number of segments in the samples. The total fell from 14000 in April, to 7000 in May, and then rose steadily to 18000 until early August when it dropped back to 11000.

The death rate of fragments (tails) has been calculated taking into account the laboratory estimate of the rate of regeneration. It is 20% until the beginning of July when it rises to 50% - 60% - 70% in successive samples by 9 August.

Worms cultured in extracted peat give a growth rate of 0.10 segs/day at 5°C, 0.15 segs/day at 10°C and 0.18 segs/day at 15°C. The rate of fragmentation for worms with over 40 segments is 17% in 35 days, and for those with less than 40 segments, it is 12% in 35 days.

Fragments obtained by cutting large worms in half regenerate new heads and tails in cultures. At 10°C tails complete regeneration of the head in 40 days, and heads complete tails in 27 days. At 5°C the tail fragments are complete after 50 days.

IV. Hydrology

(a) The Northumbrian River Authority have installed a telephonically connected interrogable rain guage in the Climatological Station enclosure. Records of daily run-off from the Trout Beck catchment (1140 ha) are available and a summary is given in Appendix III.

(b) Water movement in peat, a tritium investigation (D.B. Smith, U.K.A.E.A.)

The movement of tritium from one of the 5 points at which tritium was injected in blanket peat in October 1966 was examined by taking core samples at 39 sites on a grid pattern downslope from the injection in July 1968.

Approximately 40 millicuries of tritium had originally been injected 25 cm below the peat surface. Sampling showed that high concentrations still existed within a metre of the injection point (where more detailed sampling is now to be undertaken), but there was then a rapid reduction of tritium further downslope with a maximum of 7 metres. The mean movement was approximately 1 metre downslope in 21 months.

An estimate of the amounts of tritium located was about 30% but further samples at the injection point may increase this considerably. The vertical spread was over the total depth of the peat (about 70 cms) and certainly extended into the underlying clay, which is likely to have a permeability of the same order as the peat. This penetration into the clay is technically interesting and will be investigated further.

(c) Thermal characteristics and related low-flow hydrology of upland catchments (K. Smith, Geography Department, Durham University)

This is a two year project financed by the N.E.R.C. and designed to commence in October 1968. The main emphasis is in Teesdale, where the establishment of river water and air temperature recorders at existing flow gauging stations operated by the Northumbrian River Authority will permit an investigation into the influence of various climatic and hydrologic factors on the thermal regime of the Tees.

In the Moor House Nature Reserve, air and water temperatures will be continuously measured at the Trout Beck guaging station, and a small experimental catchment is being established on Netherhearth Sike, where air and water temperatures will also be measured.

A special emphasis will be placed on the effect of low winter temperatures on the run-off from these two high-level catchments and the frequency of low flows resulting from freezing effects. The results from this area will be compared with those from another small catchment at a similar elevation in upper Weardale.

(d) The bedload of streams - its origin, characteristics and movement with specieal reference to two catchments in the Northern Pennines. (P. Beaumont & B.M. Amir, Geography Department, Durham University)

The aim of the study is to discover the range of particle sizes in stream bedloads, the lithologies of the sediment, and to establish if a change in grain size is observable in a downstream direction. As a control, random samples of bank material within the catchments will be analysed to show the changes occurring in this material under the influence of stream action. Trays are also being sunk into the beds of the streams so that a quantitative measure of the amount of material in movement can be made.

V. Microbiology

(a) Decomposition of plant remains (O.W. Heal & P.M. Latter, Merlewood)

To show the decomposition of the main components of the vegetation samples of Calluna and Eriophorum were laid down on Bog Hill in September, 1966. Enough material is available to continue annual sampling for up to 10 years with measurements of dry weight loss and respiration.

The low rates of decomposition recorded for Calluna and Eriophorum, and previously for Juncus and Sphagnum may result from the resistant nature of the organic matter or from environmental condition. To find if high rates of decomposition can be achieved with less resistant material, samples of dead leaves of Rubus chamaemorus were laid down in nylon nets in September 1967 by J. Grue.

The results to date (means of 10 samples) are shown below:-

	% dry weight loss		Respiration mμ/O2/g/hr at 10°C	
	1 yr	2 yr	1 yr	2 yr
Calluna stems	7.9	16.1	11.1	-
Calluna shoots	14.7	29.3	32.7	-
Eriophorum leaves	26.2	37.3	49.8	-
Rubus leaves	38.1	-	-	-

Rubus leaves from burned and unburned plots have been placed on the experimental burning plots on Hard Hill to examine the influence of burning on rates of decomposition. Preliminary results here have shown no marked trends.

(b) Fauna - microflora relationships (J.A. Springett & P.M. Latter, Merlewood)

The results of the laboratory and field experiments, which indicated that fungi but not bacteria were eaten by enchytraeidae are being prepared for publication. Further laboratory experiments are necessary e.g. to test if dead organic matter is digested, but for these bacteria free worms are necessary. The sterilisation is being attempted using combinations of antibiotics.

Visitors

(c) Methods of studying the cycling of selected ions during the decomposition of vegetation at Moor House (I.B.P. - A.J. Holding and N. Martin, General Microbiology Department, Edinburgh University).

The object is to show the influence of microbial activity on the release and immobilisation of inorganic ions in peat.

a) Pure culture studies

In addition to Bacillus spp., data are now available on some of the biochemical and physiological characteristics of the Gram-negative aerobic and facultatively anaerobic bacteria. The organisms do not appear to possess any unusual characteristics in comparison with arable soil bacteria.

b) Respiration studies

Using the PO_2 monitor, data confirm that added Ca^{++} and K^{+} ions produce a greater respiration rate in peat than added SO_4, NO_3 or

$PO_4^{=}$ ions or unamended peat. With added Ca^{++} ions an uptake of 32.4 µl O_2 per hour per ml peat macerate compares with 12.0 µl in the unamended control series. Peat macerate held under static conditions prior to placing in the monitor produces a respiration rate three times greater than in previously shaken cultures. Lower concentration of oxygen in the unshaken flasks may be the reason for for this result.

c) Continuous percolation studies

Dilute solutions of single salts are passed through a column (2.5 x 25 cms) of peat-sand (15:85) misture at a rate of approximately 1.5 ml per hour. So far, $CaCl_2$ solution giving up to a 10 fold increase in bacterial populations has produced a larger response than $NaNO_3$, NaCl, KCl, or NaH_2PO_4. The expected changes in the composition of the bacterial flora shows the preferential development of pseudomonads.

The table shows the results of the release and immobilization of certain major nutrients during the percolation of distilled water in comparison to the results obtained with $CaCl_2$ solution.

Ion	Amount in fresh peat	Inorganic ions A Released	Inorganic ions B Released/Fixed	% A Released/Fixed	% B Released/Fixed	Amount in bacterial cells	Amount in column (non bacterial)
K	0.9*	0.16	0.14	18	16	0.33**	0.43
Mg	0.25	0.02	0.2	10	80	0.05	NIL???
P	1.3	0.1	0.006	7	0.5	0.55	0.76
N	11.6	0.16	0.48	1.4	4	3.3	8.3
Ca	2.3 + 8.0 added as $CaCl_2$	0.03	2.7 5.3	1		0.1	7.5

* All figures mg/g dry peat
** Total direct count 5.5×10^{10} cells/g dry peat
A = Distilled H_2O column
B = Difference between $CaCl_2$ solution and distilled H_2O columns.

d) Field Experiments

1. The microflora has been investigated at 3, 6 and 9 weeks after the addition to the dark-brown horizon of $NaNO_3$[1], NaCl, NaH_2PO_4, $CaCl_2$ and KCl solutions. All the solutions promoted an increase in the number of bacteria; the $CaCl_2$, $NaNO_3$, and NaH_2PO_4 producing the greatest response.

2. Bacteria in the rhizosphere of Eriophorum have also been investigated. Even at a depth of 40 cms the population is mainly made up of aerobic and facultatively anaerobic Gram-negative bacteria; only a few obligately anaerobic bacteria occurring. The occurrence of the facultative anaerobes is of particular interest since they do not normally occur as a predominant group in soils.

3. Attempts to obtain obligately psychrophilic bacteria from peat have failed. It is concluded that the incubation temperature of 22° - 25°C being used for these studies are not too high to prevent the growth of the numerically important bacteria.

(d) Study of anaerobic and facultative micro-organisms in peat soil. (I.B.P. - V.G. Collins and B.T. d'Sylva, Freshwater Biological Association.)

The main objectives of the present studies are to enumerate, isolate, identify and examine the biochemical activities of the facultative and anaerobic bacteria present in peat soil from the I.B.P. site at Moor House.

Pure culture studies

240 pure cultures of bacteria already isolated from a 47 cm long peat core were tested for their response to growth assessed visually at various temperatures on Tryptone Soya Agar (T.S.A.). All the isolates grew well at 25°C, 20°C, and 16°C : 99.2% of the cultures tested grew at 12°C; 98% were able to grow at 7-8°C; 83.3% grew at 5°C and 41.2% grew at 0-2°C; There was no difference in the growth of cultures from different zones over range 12°-25°C. The isolates from the "Litter" zone grew better at low temperatures than did the isolates from the lower zones.

The isolates were examined for their ability to ferment dextrose and lactose on Kligler's Double Sugar Iron Agar. 59.3% were dextrose fermenters; 30% were lactose fermenters. The rest of the isolates either had a partial action on lactose or no action on both sugars.

The oxygen tolerance of the cultures was determined in 0.9% T.S.A. deep stabs at 25°C. 93.1% of the cultures tested were microaerophilic; 7.9% were aerobic - capable of growing only at the surface of the stabs.

Cellulose decomposing organisms

Samples were taken from four distinct zones of a peat core. Undiluted peat and serial dilutions of peat were inoculated into liquid media - Callvibro medium and Cellulose-Strip Peptone medium. Isolations were done on agar plates of the same media and also on Skerman's Cellulose Mineral Salts Agar at 20°C. Approximately 40 isolates were obtained. 57.5% were from the 0-3 cm zone ('Litter'); 12.5% were from the 3.6 zone ('Fermentation'), and 17.5% and 12.5% from the 6-18 cm ('Green') and 18-24 cm ('Rust') zones respectively.

Sulphate reducing organisms

A peat core examined for sulphate-reducers at 1 cm intervals down to 6 cm and then at 2 cm intervals down to 42 cm. Using the serial dilution technique, inoculations were made into Starkey's Medium B and incubated anaerobically at 30°C. A few cultures have been obtained from the "Green" zone. The experiment is in progress.

Further work involves the study of lignin- and chitin-decomposing bacteria, denitrifiers and nitrogen-fixers from peat.

VI. Projects

The list of research projects is changed as follows:-

Hydrology

In Progress - Thermal characteristics and related low-flow hydrology catchments (K. Smith).

In Progress - The bedload of streams - its origin characteristics and movement with special reference to two catchments in the northern Pennines (B. Amir & P. Beaumont).

Zoology

Terminated - Secondary production on blanket bog (B.P. Springett)

Terminated - Grouse studies (B.P. Springett)

Terminated - Faunal survey of Knock Fell exclosure (B.P. Springett).

Completed - Invertebrate study (J.M. Nelson)

Completed - Vertical migration of Enchytraeidae (J. Brittain, B.P. Springett, and J.A. Springett)

Terminated - Sheep production (M. Rawes)

Completed - Studies on Enchytraeidae (J.A. Springett)

In Progress - Studies on Enchytraeidae (V. Standen)

Botany

In Progress - Sheep grazing experiments (M. Rawes & M.W. Read)

In Progress - Grass species trial (M. Rawes & T. Davies)

In Progress - Primary production of blanket bog (G.I. Forrest)

In Progress - Production of Sphagnum (R.S. Clymo & E.J.F. Reddaway).

In Progress - An experimental evaluation of the influence of climate on the growth of moorland plants (J. Grace)

In Progress - The distribution of Hordeum murinun in Britain (A.W. Davison)

Soils

Completed - Soil physiology on Knock Fell (P.T.A. Howard)

Microbiology

Completed - Fungi and bacteria associated with moorland soils (P.M. Latter and O.W. Heal)

VII. Publications

COLLINGE, V.K. & JAMIESON, D.G. 1968. The spatial distribution of storm rainfall. J. Hydrol., 6, 45-57.

GORE, A.J.P. & OLSON, J.S. 1967. Preliminary models for accumulation of organic matter in an Eriophorum/Calluna ecosystem. Aquila, Ser. Botanica., 6, 297-313.

GORE, A.J.P. 1968. The supply of six elements by rain to an upland peat area. J. Ecol., 56, 483-496.

PARKER, J.R. 1968. Alpine and polar spiders new to Britain. Fld. Nat., 13, 5-7.

RAWES, M. 1968. Sheep as an ecological factor. Chimaera, Journal of the Biological Society, Sheffield University. Spring 1968, 7-10.

SPRINGETT, B.P. 1968. Aspects of the relationship between burying beetles, Necrophorus spp. and the mite, Poecilochirus necrophori vitz. J. Anim. Ecol., 37, 417-424.

WELCH, D. 1968. Sheep grazing in northern England : some ecological considerations. Hill-land symposium of European Grassland Federation.

WHITTAKER, J.B. 1968. Estimation of production in grassland froghoppers and leafhoppers (Homoptera-Insecta). Secondary Productivity of Terrestrial Ecosystems, 779-789.

WHITTAKER, J.B. 1968. Polymorphism of Philaerus spumarius (L) (Homoptera, Cercopidae) in England. J. Anim. Ecol., 37, 99-111.

Appendix I

Staff List

Officer-in-Charge

M. Rawes (Senior Experimental Officer)

Scientific Staff

Dr. G.I. Forrest (Scientific Officer, I.B.P.)

M.W. Read (Assistant Experimental Officer)

R.B. Marsh (Scientific Assistant)

Miss S. Carrick (Scientific Assistant, I.B.P.)

Miss L. Teasdale (Scientific Assistant and Secretarial Assistant)

Warden

T.L. Hodgson

Estate Worker

D.W. Craig

Housekeeper

Mrs. M. Hodgson

Domestic (part-time)

Mrs J. Ryding.

Meteorological Summary for Moor House 1967 (Met. Office Station No. 7188)
c. 558 m O.D. (Main instrument site) Lat. 54° 41' N., Long. 2° 23' W. National Grid Ref. NY/757328

		JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
Mean Maximum Temperature	°C	2.6	2.7	4.0	6.9	8.3	14.6	14.8	14.7	12.4	8.1	5.5	1.9	8.0
Mean Minimum Temperature	°C	-1.7	-1.0	-0.2	0.1	2.1	5.1	7.8	7.8	6.1	3.6	-0.8	-2.2	2.2
½ (Max. + Min.) Temperature	°C	0.5	0.9	1.9	3.5	5.2	9.9	11.3	11.3	9.3	5.9	2.3	-0.1	5.1
Highest Maximum Temperature	°C	7.8	8.3	10.6	17.2	13.9	20.0	21.1	20.6	16.1	12.8	11.1	10.6	21.1
Lowest Minimum Temperature	°C	-12.2	-8.3	-6.1	-9.4	-6.7	-2.2	1.1	3.3	-0.6	-2.8	-5.6	-10.0	-12.2
Lowest Maximum Temperature	°C	-2.8	-1.7	0.6	1.7	3.3	11.1	10.0	10.0	8.9	2.8	1.1	-5.0	-5.0
Highest Minimum Temperature	°C	5.0	5.6	3.9	5.0	6.7	9.4	11.7	11.7	10.6	8.3	2.8	5.0	11.7
Lowest Grass Min. Temperature	°C	-12.8	-12.2	-7.8	-8.9	-9.4	-5.6	-1.1	0.0	-3.9	-3.9	-11.1	-13.9	-13.9
Av. Earth Temp. at 1 foot 0900 GMT	°C	1.8	2.1	2.4	3.4	5.8	10.2	11.6	11.9	10.3	7.4	3.6	2.0	6.0
Av. Vap. Press. at 0900 GMT mbs	°C	6.2	6.4	6.7	7.2	8.3	10.2	11.8	12.3	11.0	8.9	6.7	6.3	8.5
Av. Rel. Hum. at 0900 GMT	%	95.5	95.1	93.9	90.2	90.1	77.2	85.9	88.3	91.1	93.3	91.6	94.1	90.5
Av. Dew Point at 0900 GMT	°C	-0.3	0.1	0.7	1.9	3.9	7.3	9.1	9.7	8.2	4.8	0.8	-0.4	3.8
Av. Cloud amount at 0900 GMT.,	oktas	7.0	7.1	6.6	7.1	7.3	5.7	6.8	6.8	7.1	7.1	5.9	6.8	6.8
Rainfall,	inches	6.14	10.34	8.68	4.02	8.74	2.90	6.89	8.51	8.10	14.76	7.26	7.75	94.09
Greatest Daily Rainfall,	inches	1.01	1.76	1.08	.84	.75	.52	.97	1.88	1.42	1.78	2.57	1.95	2.57
Av. Rate of Rainfall,	inches/hour	-	-	-	-	(.078)	-064	.092	.101	.098	-	-	-	-
Number of Rain Days		25	23	27	23	29	15	22	22	20	28	21	21	276
Number of wet days		17	18	25	17	28	12	19	18	17	26	20	17	234
Days with Snow or Sleet falling		11	10	9	10	5	0	0	0	0	3	9	12	69
Days with Snow lying 0900 GMT		16	17	14	8	1	0	0	0	0	2	7	9	74
Days with Hail		1	2	2	1	2	1	0	2	1	2	0	0	14
Days when Thunder heard		0	1	0	0	1	1	2	5	1	1	0	0	12
Days with Fog at 0900 GMT		7	5	3	4	5	1	1	2	1	4	5	6	44
Days with Air Frost		21	20	18	14	6	2	0	0	1	3	15	19	119
Days with Ground Frost		26	22	19	22	10	9	3	0	5	7	23	23	169
Days with Gale (anemograph record)		1	6	16	5	0	2	1	0	4	6	3	5	49
Total sunshine hours		39.5	38.7	79.7	98.1	104.1	185.7	130.7	131.5	80.8	61.3	64.3	43.0	1057.4
Total snow fallen,	Inches	17	28	13	5	2	0	0	0	0	2	13	12	92
Greatest Depth Snow lying,	Inches	6	9	3	2	2	0	0	0	0	2	10	4	10
Average wind speed,	knots	15.4	20.0	25.1	16.3	13.4	11.4	13.3	10.6	12.2	19.1	13.1	17.3	15.6
Potential Evaporation,	Inches	-	-	-	2.5	1.5	3.1	2.1	2.1	1.5	-	-	-	-
Potential Water Deficit,	Inches	-	-	-	0.4	0.0	1.3	0.3	0.6	0.5	-	-	-	-
Potential Water Surplus,	Inches	-	-	-	1.9	7.2	1.1	5.1	7.0	7.1	-	-	-	-

* Brackets in this line indicate incomplete record, but for more than half the month.

Appendix II

Meteorological Summary for Great Dun Fell 1967

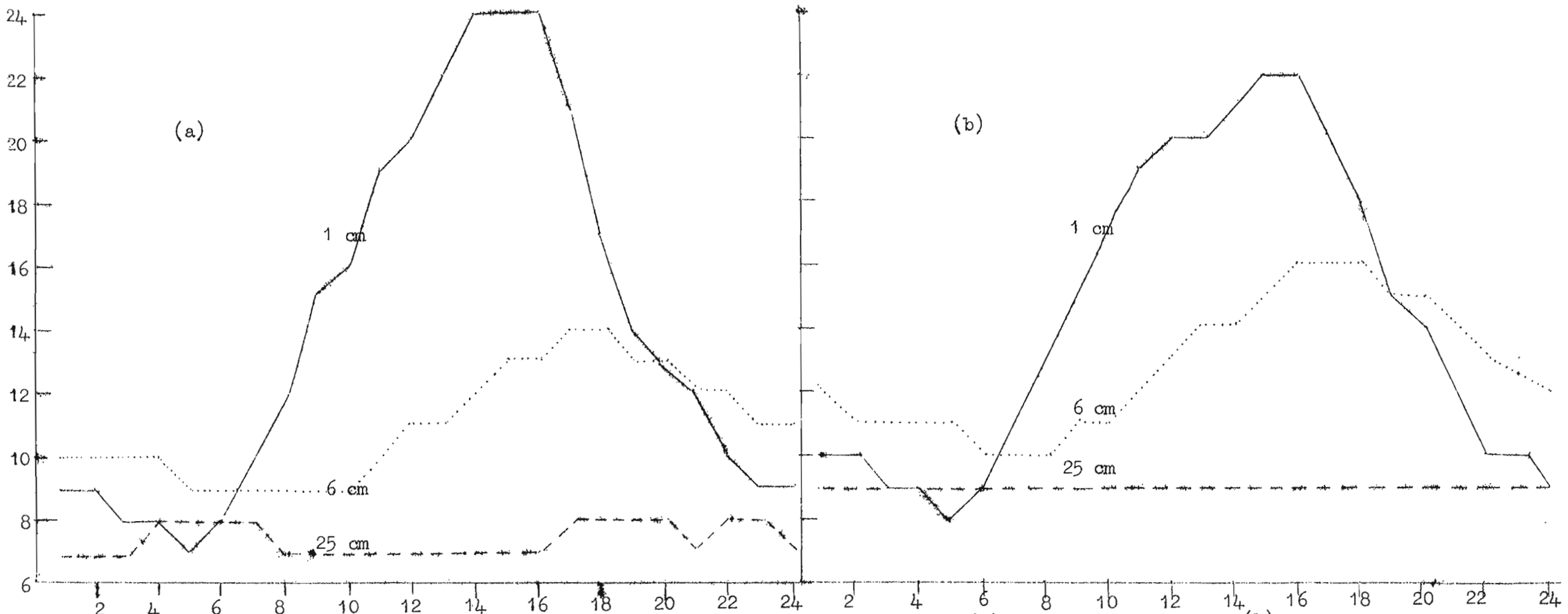
c. 655 m O.D. Lat. 54° 35' N. Long. 02° 28' W. National Grid Reference No. NY/710322

		JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
Mean Maximum Temperature	°C	0.4	0.6	1.3	3.4	5.6	12.2	11.9	11.9	9.7	5.4	3.1	0.5	5.5
Mean Minimum Temperature	°C	-2.3	-1.7	-1.5	-0.7	1.0	5.2	6.5	7.3	5.5	1.9	-0.3	-2.4	1.5
½ (Max. + Min.) Temperature	°C	-0.9	-0.5	-0.1	1.3	3.3	8.7	9.2	9.6	7.6	3.7	1.4	-0.9	3.5
Highest Maximum Temperature	°C	5.8	7.1	7.6	14.6	14.6	18.4	18.2	18.6	13.4	11.5	12.7	8.6	18.6
Lowest Minimum Temperature	°C	-9.4	-6.1	-7.3	-6.6	-5.1	1.4	3.0	3.8	1.2	-4.8	-5.1	-11.1	-11.1
Lowest Maximum Temperature	°C	-5.3	-3.8	-3.2	-4.2	-0.7	7.7	7.2	8.1	6.0	0.0	-3.0	-7.8	-7.8
Highest Minimum Temperature	°C	3.0	3.8	1.7	5.5	5.6	10.7	10.6	11.6	9.2	7.6	3.8	4.8	11.6
No. of days Snow lying 0900 GMT		19	21	16	15	5	0	0	0	0	3	10	16	105
No. of days with Fog at 0900 GMT		27	22	24	20	21	11	20	24	19	28	19	20	255
No. of days with Air Frost		25	24	24	21	8	0	0	0	0	7	21	23	153
No. of days with Gale		6	15	25	14	11	7	3	2	8	18	8	10	127
Average daily sunshine hours		23.3	31.6	32.1	67.3	59.6	157.5	74.3	86.3	58.6	21.9	56.6	37.8	706.9
Average Wind Speed for months, kts		18.4	23.7	29.7	22.7	18.1	15.7	17.9	13.6	16.5	25.0	16.7	20.2	19.9

Trout Beck Flow Data - 1967 (catchment size - 1140 ha)

Cu. Secs. Days	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	22.07	27.55	25.69	18.47	25.85	4.55	16.92	27.49	22.72	46.28	26.76	26.70
Highest Flow	345.0	280.0	142.0	142.0	220.0	34.1	450.0	552.0	430.0	345.0	361.0	371.0
Lowest Flow	1.6	1.0	2.1	1.6	1.7	0.9	1.0	2.0	1.6	6.1	1.2	1.5

Appendix III



Temperature profiles in peat under Calluna-Eriophorum (a) and Juncus squarrosus (b) 1-6-68. Data for 3 and 10 cm are omitted.

Appendix IV