DR. K. TAYLOR

THE NATURE CONSERVANCY

MOOR HOUSE FIELD STATION

Annual Progress Report

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With the Compliments of

M. Rowell

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"The work of the Nature Conservancy falls into three main parts. The first is the selection and establishment of National Nature Reserves, the notification of Sites of Special Scientific Interest, and an assessment of the importance of the countryside generally for conservation of nature and natural features. The second is research on the ecology of wild plants and animals in Great Britain, specially aimed at elucidating the factors which control the pattern of vegetation and fauna throughout the country and thus to provide a scientific basis for management. Since a large part of Britain, especially in the uplands is still inhabited by natural or semi-natural communities of wild-life, this research has a very wide application. The third is to provide advice on the conservation and management of wild-life, and in a wider context, on problems in terrestrial ecology."

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MOOR HOUSE

11th Annual Progress Report

M. Rawes

I. GENERAL

The Report covers the period 1 October, 1969 - 30 September, 1970, the last year of a two-year trial during which the Regional Officer (North) has been responsible for the Field Station and Reserve. These arrangements have now become permanent. It will therefore continue to be necessary for the approval of the Regional Officer to be obtained before projects are undertaken, and every effort will be made to encourage use of the facilities and to assist research workers to develop new projects. Details of the facilities available can be supplied and applications to undertake research are invited.

During the year the research impetus has been maintained, but as the International Biological Programme at Moor House has passed the half-way stage, it is particularly important to ensure that the fundamental findings of both this project, the study of the blanket bog ecosystem, as well as those of 19 years of ecological work on the Reserve, are fully used. It is hoped that further research will be developed utilising these data.

Staff research has suffered from a shortage of personnel (M.W. Read resigned last year), but emphasis has been placed on recording some of the botanical changes that have taken place in a number of swards on which exclosures have been erected in the past 16 years. There have been some changes in the list of projects. The study in variation in limestone grassland (Project 1/05, M.W. Read) and that on the bedload of streams (Project 6/05, B.M. Amir) have been finished. As no further information is available reports of Project 3/02 (Chemical changes during plant decomposition), Project 5/01 (Water movement in peat) and Project 5/02 (Hydrology of Trout Beck) are not included.

During the year a project register was compiled and this will be brought up to date annually. Copies are available from the Officer-in-Charge.

In the past, publications, the Reserve Record volumes, and local knowledge have been relied upon to provide information on previous research, but the amount of data is now so great that there is a danger of much past work being neglected. Thus data gathered, including such ancilliary items as photographs and, equally important for the management of the Reserve, the use of different sites, should be recorded, possibly using a method such as the Optical Coincidence System. The cost of such a method, however, is too great at present, thus a card system with references

based on a grid overlying the soil map (G.A.L. Johnson with amendments by M. Hornung) of the Reserve will be used to record data for each site.

The year has been one with an unprecedented number of public engagements. Because of this heavy programme of visits and lectures it was decided not to have an Open Day. In May, the Hill-land Use and Ecology Discussion Group held a two day meeting, the first day at Moor House and the second in Teesdale. Staff were involved in the organisation of this meeting and participated in it. Later in the summer, visits were paid by, among others, the British Association (Botany and Zoology sections), the Institute of Biology (N.E. Branch), the N.A.A.S. and Agricultural Trades Technical Representatives (Cumberland) and a Land Use Co-ordination Meeting. The Biology Department of Leicester University held a week's course (see p. 32) at the Field Station and day visits were made by the Conservation (M.Sc.) Course and the Botany Department from University College London, by the Agricultural Botany Department of Aberystwyth, and the Zoology Department and Ecology Course from Durham. School parties have been shown round and talks given in Alston, Knock and Penrith.

Mr. R. Williams was appointed to the vacant A.E.O. post in July. Mr. D. Craig, Estate Worker, resigned in April and Mr. P. Elliott was appointed in his place. During the winter Mr. J. Rose was appointed temporary part-time Warden to supervise ski-ing on Great Dun Fell. Insufficient money was available to employ domestic help during the summer, and, for the same reason, the hostel is to be closed during the coming winter months (October-March).

Moor House staff have continued to provide assistance with research and give data to a wide variety of people. Charts on recording instruments have been changed regularly for the Northumbrian River Authority, the Freshwater Biological Association and the Geography Department of Durham University. Instruments have been loaned to the Zoology Department of Durham University and colour slides have been borrowed by a number of people for lecture purposes.

II. CLIMATOLOGY - Project 1/06 (R.B. Marsh)

The summary of weather averages for 1969 is given in the appendix. During the year October, 1969 - September, 1970 the recent pattern of late springs was maintained. But winter also started early with 20 days of snow lying in November, 16 more days than average. There were 102 days of snow-lie, more than usual, but rarely of much depth and little drifting occurred. For six months, November until May, the average minimum temperatures were below freezing. However, temperatures rose sharply in May, both this month and June being remarkably warm and dry (157 mm compared with the average of 243 mm of rain). Even so the longest period without rain was only 10 days. After June the climate reverted to normal, with the maximum temperature deviating little more than a degree from average

III. STAFF RESEARCH

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

The main object of these studies is to investigate the effects of change in sheep management on tbe botanical composition of hill vegetation. At present, the following three treatments are being examined.

1. No grazing : Fenced plots from which sheep are excluded have been set up on a number of sward types so that the vegetation of the Reserve is adequately represented.

2. Present free-range grazing regime

3. Modified grazing: Emphasis is placed on increasing the grazing pressure on blanket bog.

Further introductory remarks may be found in last year's Report (see pages 2-4). During the current year the following measurements have been made.

1. No grazing

Change in the floristic composition has been recorded in exclosures at seven sites, all grass or moor rush (Juncus squarrosus) swards. The experimental lay out at each exclosure is basically similar, permanent positions for point quadrat frames put down at set intervals. The frame carries 10 vertically placed pins and the species touching each pin are recorded. There are 100 frame positions (1000 points) at most sites. At half of the frames records were also made of the number of species hit at four different levels (0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm) on the pin. Results are compared with similar measurements on the grazed (control) plots and also with previous records. Preliminary calculations suggest the following:-

KNOCK FELL - originally, under grazing, an Agrosto-Festucetum with patches of Juncetum squarrosi. Enclosed in 1955. Previous analyses in 1956, 1962 and 1966. The changes recorded in 1970 follow the trend, noted in 1962 and 1966, of an increase in cover by gramineous species and a decrease in Juncus squarrosus and in dicotyledons. The change since 1966 is shown in the following table of increase or decrease in cover and the difference between grazed and ungrazed swards in the number of tillers, or plants per unit area.

	Point Quadrat Analysis						Tiller Count
	Increase in cover			Decrease in cover			Decrease in number under enclosure
Significance level	5%	1%	non sig.	5%	1%	non sig.	
Agrostis tenuis		x					15-30%
Deschampsia cespitosa		x					
D. flexuosa	x						
Festuca ovina							80%
Poa subcaerulea					x		
Carex bigelowii					x		
C. caryophyllea					x		
Juncus squarrosus					x		
Luzula multiflora					x		
Achillea millefolium			x				
Galium saxatile							100%
Minuartia verna						x	
Thymus drucei						x	
Trifolium repens							100%
Vaccinium myrtillus						x	100%

LITTLE DUN FELL - A Festucetum enclosed in 1955, analysed in 1955 and 1962. Little change has been recorded since 1962, the most significant being a 5% increase of Carex bigelowii. However, core samples from inside and outside the exclosure showed that large differences existed in the number of tillers per unit area, as at Knock Fell. The ungrazed sward had twice the number of tillers of Deschampsia flexuosa but with Festuca ovina there was half the number.

HARD HILL - A Festucetum enclosed in 1955, analysed in 1955 and 1962. Slight increases in the amount of Vaccinium myrtillus and Carex bigelowii were recorded.

TROUTBECK HEAD - An Eriophoretum enclosed in 1966 when the last botanical examination was made. Eriophorum angustifolium has decreased (1% level) and a non-significant increase in Calluna vulgaris has been recorded.

SILVERBAND - An Eriophoretum also enclosed in 1966. There has been no significant change although Narthecium ossifragum and Empetrum nigrum appear to have increased.

TEES - A Nardetum enclosed in 1967. Both Agrostis spp. and Nardus stricta have decreased, but this has also occurred on the control plots.

TROUTBECK - A Juncetum squarrosi enclosed in 1967. Juncus squarrosus and Eriophorum angustifolium have both decreased (1% level) whilst Festuca ovina has increased (1%) and Eriophorum vaginatum (5%).

In general, the changes recorded by the point quadrat method appear usually to be small, but the data have to be analysed further. The comparison of botanical composition where swards have altered structurally adds to the problems brought about by differences between workers and in season. The significance of changes and the degree of acceptability of experimental errors are being discussed with P. Rothery of the Biometrics Section and also with Dr. A. Davison and T. Bines of the Botany Department, Newcastle University.

2. The present grazing regime

The control plots at each of the above sites were re-examined, their lay-out being very similar to that of the exclosures. There appears to have been an increase (1% level) in Vaccinium myrtillus and Juncus squarrosus and a decrease in Galium saxatile under grazing on Hard Hill. At Trout Beck Head a non significant reduction in Eriophorum angustifolium and Calluna vulgaris was recorded.

3. Modified grazing

a. The reaction of blanket bog to increased grazing.

This trial, started in 1968, was described in last year's Report. Management (different stocking rates, burning and draining) is aimed to create conditions favourable to Juncus squarrosus establishment.

The botanical analyses, using the point quadrat method, were repeated and showed a drastic reduction of Calluna vulgaris under heavy grazing, where only a few mature plants remain partially alive. Calluna seedlings, however, are widespread and grass species, Chamanerion angustifolium and Juncus squarrosus have been found.

b. Study on the establishment of Juncus squarrosus on blanket bog.

This study was started at the same time and is directly related to the above investigation. Small plots on two blanket bog sites have received treatments of cutting, treading and sowing with Juncus squarrosus, whose performance has then been recorded. Cutting and removing the standing vegetation appears to provide the most satisfactory conditions for the sown Juncus seeds and very few seedlings are found where no treatment has been given. The numbers of seedlings have in all cases fallen in the past two years, some by as many as from 3550 to 100 seedlings per $\frac{1}{4}m^2$. Winter mortality accounts for a reduction of about 75% and the dry period in June killed a further 60% of the remainder.

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

The object is to create a few ungrazed and natural communities which include species not found but considered suitable for habitats on the Reserve. The trial is limited in both species and habitats selected. Small enclosures were erected in 1955 on Little Dun Fell (830 m), Knock Fell (750 m) and Hard Hill (680 m) and a larger enclosure by Rough Sike, near the Field Station, in 1956.

It has been another good flowering year, occurring two to three weeks earlier than in 1969. Plants have done particularly well in the Rough Sike Enclosure. Further seedlings of Draba incana, Alchemilla alpina, Saxifraga aizoides and Salix arbuscula have been found while Solidago virgaurea has flowered profusely for the first time.

A paper with D. Welch, describing the performance of the introduced plants has been drafted and will be submitted for publication shortly.

c) Grass species trial - Project 1/04 (M. Rawes, T.H. Davies (N.A.A.S.) and Miss L. Teasdale)

The testing firstly for survival and then for some aspects of performance, of 40 varieties of grasses has been completed. A report, a copy of which is in the Reserve Record, concluded that Festuca rubra, Lolium perenne, Poa pratensis and Phleum pratense all had varieties suitable for this environment. Varieties of F. rubra (Ello), L. perenne (S.23 and 24) and P. pratensis (Fylking) have survived satisfactorily under grazing since 1969.

A few bred strains, so far not released commercially, are now being tested. These are: Dactylis glomerata (Saborto BC5754), Hybrid Lolium (Sabrina, Tetraploid), Agrostis (Saboval, BR963), Lolium italicum (Sabalan Bb1241 Tetraploid) and several Clovers. It will be particularly interesting to see whether the tetraploid grasses survive the winter and how their performance compares with the previously tested grasses.

d) The effects of ski-ing - Project 1/04 (M. Rawes)

This has been the third year of the trial period during which ski-ing on the higher parts of Great Dun Fell has been permitted under licence, from the beginning of November to the end of March each winter.

During the past two years a number of measurements and observations have been made to record vehicles, people, preference of ski-runs and any effects ski-ing may have on the area.

We found that nearly two thirds of the skiers come from outside Cumberland and Westmorland, some from as far afield as London and Bristol. Mostly they come once, only 27% returning more often and rarely for more than four occasions.

By far the most popular month in the last two years has been March, when around 1,000 skiers have visited the area. Most skiers will use Run No. 1., an east-facing gulley, if road conditions allow them to get to the Silverband Car park. This occurred in 1970 (320 skiers in March) but not in 1969 when there were no skiers, the road being blocked for most of the month. This run is monitored by photographs (M. Rawes, and J. Dale and B. Grimes). Botanical change in Run No. 8, a west facing gulley, is monitored also, but here the degree of use in 1969 was not repeated in 1970. Measurements of species presence showed, as might be expected, little difference between years.

An assessment of ski-ing conditions, made up of daily values of snow condition, suitable weather and road accessibility, support the view that other factors, (perhaps alternative attractions such as ice skating on frozen tarns and lakes or possibly press or broadcast interest) often decide whether skiers will use the Reserve or not. This is shown by the following graph.

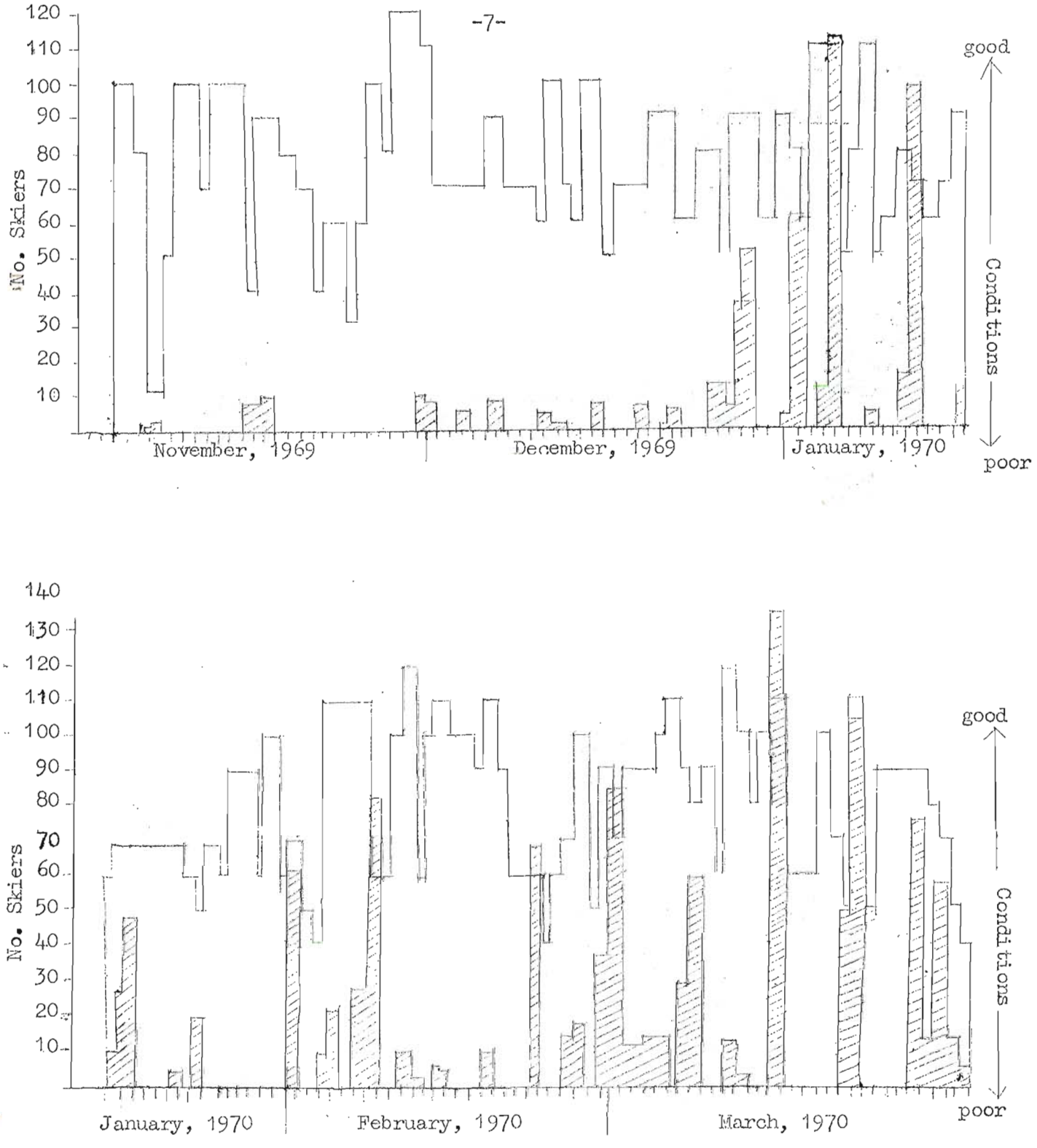


Figure I. The relation between ski-ing conditions and number of skiers. The value for "Conditions" (unhatched) is derived from integrated figures of extent of snow lie, depth of snow, weather conditions and road accessibility.

IV. INTERNATIONAL BIOLOGICAL PROGRAMME

Introduction (O.W. Heal, Merlewood)

During the past year three general aspects of the programme have been apparent: 1. clarification of the programme in the closing phase of the Moor House project, 2. the completion of a number of individual research projects, 3. the development of a small number of research projects to examine specific aspects.

1. Funds for research projects will finish in 1972 but it is obvious that synthesis of results will not be completed until 1974. Results from individual projects will be published in scientific journals, but these results need to be combined and analysed further to produce an integrated picture of the blanket bog ecosystem and its components. This was emphasised during the meeting at Moor House in November 1969, and working groups discussed the synthesis of results for the various subsystems. Individuals are now responsible for developing these syntheses, and producing the final documents by 1974 as follows:

Primary production	- G.I. Forrest
Herbivores	- J.B. Whittaker
Soil fauna	- J.C. Coulson
Microflora	- A.J. Holding
Decomposition	- O.W. Heal

The integration of the results for the ecosystem is the responsibility of Dr. O.W. Heal in close association with the leaders of the subsystem groups. A.J.P. Gore with Dr. Helen Jones, is responsible for mathematical modelling of the system. To develop the computer simulation of the energy and dry matter transfer in the ecosystem, Dr. Helen Jones has been appointed to a specially allocated Nature Conservancy post, based at Merlewood from April 1970 to March 1974.

The soil fauna and microflora groups met during 1970 and it is essential that the synthesis efforts increase from now on.

2. A number of projects were completed during the year, although in most cases the final analysis of results and publication are still in hand. A non I.B.P. sponsored study, but one closely related to I.B.P. has been completed by J. Grace (see p. 36) and a first paper on the effects of temperature, light and humidity on the growth of Calluna and Sphagnum has been published. J. Reddaway and N. Martin completed their periods as Research Assistants with Dr. R.S. Clymo and Dr. A.J. Holding respectively and the results of these projects are being analysed. A paper by Dr. R.S. Clymo and E.J.F. Reddaway on "Productivity of Sphagnum (bog-moss) and peat accumulation" was given at an IBP/[illegible] meeting in Rumania in September 1970.

Funding for the projects on facultative and anaerobic bacteria (Dr. Vera G. Collins and Barbara [illegible] D'Silva) and on production of Enchytraeidae (Dr. Valerie Standen) [illegible] and again the results are being analysed and prepared for publication.

3. Some new research projects were developed during the year to fill gaps in our knowledge, and these should be completed in 1972. Dr. P. and Dr. Dianne Evans began sampling for small mammals and are also attempting to obtain some information on grouse populations; Dr. Valerie Standen, through Professor D. Barker, was awarded a Research Grant to study the influence of enchytraeid and tipulid populations on litter decomposition; the microbiological studies of Dr. A.J. Holding have been developed by R. MacDonald who replaced N. Martin and a new project to estimate nitrogen fixation is being carried out by Dr. Vera G. Collins and Barbara T. D'Sylva. Jennifer Butterfield began an unsupported study on Tipula subnodicornis supervised by Dr. J.C. Coulson (see p.36).

In addition, a few small projects were carried out by students, for example, to obtain primary estimates of populations of phalangids.

International links of Moor House I.B.P.

These were strengthened during the year and the Tundra Biome meeting in Finland in September 1970 clarified the aims and organisation of this I.B.P. group. This meeting was attended by A.J.P. Gore, Dr. O.W. Heal, Dr. A.J. Holding and Dr. J.B. Whittaker. Co-operation with the Tundra group is valuable to Moor House in providing results for direct comparison. These comparisons covering a range of climatic and biological variables should help us to interpret the factors influencing the Moor House system, especially as the range of conditions being examined at Moor House is very restricted. In certain aspects co-operation on technical matters will be valuable, e.g. analysis of climatic data, mathematical modelling of the systems and exchanges of soil samples to test comparability of chemical analyses.

Moor House must also recognise its contribution to the International programme. Having started before many of the other projects, our achievements and failures can be of value in the development of projects in other countries. Information has already been contributed towards International synthesis and the effort will increase greatly in the next year as a result of the development of working groups at an International level. These parallel the Moor House groups mentioned above and Moor House representatives on these International groups are at the moment:

Ecosystem	:	A.J.P. Gore
Primary Production	:	G.I. Forrest
Cryptograms	:	G.I. Forrest
Vertebrates	:	P.R. Evans
Invertebrates	:	J.B. Whittaker
Microflora	:	A.J. Holding
Decomposition	:	O.W. Heal
Soils	:	O.W. Heal
Climate	:	O.W. Heal

These working groups of research workers will collate results from the various National Projects and develop International synthesis. It is intended that these working groups should work by correspondence plus meetings at irregular intervals. Some group meetings are already planned, for example the microflora group will meet in Paris in November at the PT Microbiology Conference. Availability of funds for the increased International effort is a major question for immediate action.

Direct contact with other International studies was maintained by visits to Moor House of G. Gyllenberg (Finland), T. Rosswall and J. Olson (USA), P.J. O'Hare, G. Doyle, M. Keating and P. Killfeather (Ireland). There was also increased contact with the Bi-Polar Botanical Project through M.C. Lewis. A visit to the Swedish Tundra site at Abisko was made by K. Taylor and T. Marks.

a) Primary production of blanket bog - Project 2/01 (G.I. Forrest, I.B.P. Moor House)

Between-site variation

(i) Site description

The productivity of the seven sites listed in Table 1 has been measured. The vegetational structure at four of the sites has been examined by a stratified point-quadrat analysis, the results of which are being evaluated.

Table 1 Site descriptions

Year	Site	Vegetation	Peat depth m.	Point quadrats	% Sphagnum cover
1968	Sike Hill (Dry)	Calluneto-Eriophoretum	1.8	Yes	15
1969	Sike Hill (Wet)	Calluneto-Eriophoretum	1.4	Yes	61
	Bog Hill	Calluneto-Eriophoretum	1.5	Yes	51
	Green Burn	Calluna/Sphagnum	4.0	Yes	80
1970	Bog End	Calluneto-Eriophoretum	1.2	No	17
	Cottage Hill (A)	Trichophoretum	4.0	No	9
	Cottage Hill (B)	Calluna/Eriophorum angustifolium	3.5	No	61

At each site 800 pins were recorded; for higher plants four 10 cm strata were distinguished, and bryophytes and lichens were also recorded.

An attempt was made to compare the wetness of the sites by recording fluctuations in height of water-table in holes (100 cm^2 cross section) bored in the peat. Over a period of six weeks in summer the height of the water-table fluctuated by as much as 22 cm at a given site. Differences between sites were relatively small. The mean rainfall (about 0.2 in/day) was not sufficient in summer to maintain a constantly high table, although after a period of drought one inch of rain completely restored the water-table to the highest levels.

An important distinguishing factor between sites is the Calluna age structure. This has been derived by measurements of the basal diameter of a large number of stems and then using regressions of age on diameter. The regressions usually differed significantly between sites. The data in Table 2 show the apparent large number of stems and the young age structure generated in the wettest sites by vigorous encroaching Sphagnum growth. Also included is Dodgen Pot, a site characterised by a dry peaty podsolic substratum, old dense Calluna, and very little Sphagnum.

Table 2 Data on Calluna population age structure

Site	Mean age, yr.	Modal age, yr.	Mean no. of stems/m^2
SH (D)	11.54	8	110
SH (W)	6.26	5	173
BH	8.48	9	159
GB	4.97	1	343
BE	10.21	6	107
CH	3.09	1	951
DP	12.78	12	107

(ii) Production

Methods were similar to those used in 1968: Calluna shoot growth was measured directly, annual net wood production was derived from the age structure by regressions of live wood weight on age, output to standing dead was measured from the age structure curves and also from the net annual wood accumulation (where a steady state could be assumed), and litterfall was measured directly. Certain production parameters derived in 1968, for example those for the belowground production of Eriophorum vaginatum, were applied to the data. Belowground data for Eriophorum angustifolium and Trichophorum were obtained from seasonal changes in the partition of dry matter between component parts by morphological analysis of individual plants, so that estimates of shoot-base, rhizome, and root production were made by conversion to the cropping biomass data. Sphagnum production was estimated by applying Clymo's (1970) data to percentage cover values, except for S. magellanicum at Green Burn where cranked-wire measurements were made by myself.

Preliminary analysis of the data is given in Table 3. The total production on Cottage Hill (B) was significantly greater than that on Green Burn, but there was no significant difference between the remaining sites. The low production at Green Burn is due to inhibition of Calluna growth by active Sphagnum overgrowth, while the biomass of tussocky cyperaceous species is low. The latter form almost a pure stand on the highly productive Trichophoretum, while the addition of Calluna and Sphagnum leads to the very high productivity of the densely-vegetated Cottage Hill (B) site.

Competition between Calluna and Sphagnum is an important factor influencing the production of the wetter blanket bog sites. Data from Green Burn showed that the volume of Calluna stems overgrown was 8.63 $cm^3/m^2/yr$ on hummocks and 7.42 $cm^3/m^2/yr$ on lawns, or a total biomass of Calluna overgrown of 8.1 $g/m^2/yr$. The difference in mean above ground Calluna biomass on areas with and without active Sphagnum growth was 157 g/m^2 - a reduction of almost one-third. The effect of the Sphagnum growth may be expressed as the replacement of 40 stems/m^2 over the age of 8 years by 379 stems/m^2 younger than 8 years. For Erica at Green Burn, with a mean live aboveground biomass of 19.5 g/m^2, the corresponding values for volume and biomass of stem overgrown are 1.26 $cm^3/m^2/yr$ and 0.95 $g/m^2/yr$ respectively.

Table 3 Production ($g/m^2/yr$) on different sites

	SH(D)	SH(W)	BH	GB	BE	CH(A)	CH(B)
Year	1968	1969	1969	1969	1970	1970	1970
Calluna							
green shoots	130	240	181	71	210	5	219
total	351	420	456	210	320	7	303
Empetrum nigrum	11	4	2	-	4	-	1
Erica tetralix	-	-	-	11	-	0	-
Vaccinium myrtillus	0.1	0.2	0.0	-	0.1	-	-
Drosera rotundifolia	-	-	-	0.0	-	-	-
Rubus chamaemorus	1.9	1.4	1.9	-	2.2	-	-
Eriophorum vaginatum							
leaves	56	81	84	36	57	-	6
total	221	190	198	84	225	-	45
E. angustifolium							
leaves	-	0	-	1	-	53	178
total	-	0	-	2	-	120	399
Trichophorum cespitosum							
leaves	-	-	-	-	-	138	1
total	-	-	-	-	-	581	2
Listera cordata	0.3	0.1	0.1	-	-	-	-
Narthecium ossifragum	-	-	-	0.1	-	-	-
TOTAL VASCULAR SPECIES	585	616	658	308	551	708	750
Sphagnum cuspidatum	-	-	-	0	-	-	-
S. magellanicum	-	-	-	68	-	-	-
S. papillosum	0	-	-	122	-	35	109
S. recurvum	31	135	101	10	43	0	89
S. rubellum	14	21	16	13	6	0	9
TOTAL SPHAGNA	45	155	117	213	48	35	208
TOTAL	635	771	775	521	599	743	958
95% confidence limits	±170	±267	±304	±144	±178	±100	±250

Between-year variation

The Sike Hill (Wet) site is designed to run for three years as a between-year reference. The data in Table 4 show that there was no difference between 1969 and 1970 in Calluna shoot production, whereas the Eriophorum leaf production was significantly greater in 1969.

Table 4 Between-year variation in production at Sike Hill (Wet), with 95% confidence limits

	1969	1970
Calluna green shoots	240 ± 59	319 ± 34
Eriophorum leaves	81 ± 25	41 ± 8
Rubus leaves	1.4 ± 0.6	1.5 ± 0.6

b) Systems analysis of Moor House I.B.P. - Project 2/09 (Helen E. Jones, Merlewood)

A simple descriptive model with 5 compartments based on shoots, live wood, litter, standing dead and roots was developed initially incorporating the biomass data collected by Dr. G.I. Forrest, to estimate annual growth and decay in Calluna vulgaris. The output confirmed his estimates of net production. It was felt that there could be little further progress unless some attempt was made to explain the variability of the field results. One source of variation might be due to variable presence of Eriophorum vaginatum but on examination it was not possible to show an inverse relationship between the standing crops of Calluna vulgaris and this species. Regressions of age against mean basal diameter, and age against live wood and green shoot weight were used, with the number of stems cropped in each quadrat, to estimate the weight of plants in each of an arbitrary number of age classes. From these estimates almost all the variability in the cropping measurements made on Sike Hill (June-October, 1968) could be accounted for by variation in age class distribution:

(Observed = 1.006 (Estimated) + 29.89; $r = 0.911$)

The plant compartment was therefore split into a series of age classes and transfers between the age classes modelled in addition to transfers to litter and standing dead. The number of age classes was limited to four in the first instance for two reasons; firstly, convenience in computer manipulation, and secondly, because the idea of four phases of plant development in Calluna had already been used (Watt, 1955; Gimingham et al, 1960; 1964; 1970) to describe the cyclical processes of regeneration, maturation and death in uneven-aged stands.

The following assumptions have been made about the growth of plants on peat at Moor House:

1. the growth rate is proportional to the amount of plant material and to the amount of available nutrients,

2. the decay rate is proportional to the amount of plant material.

In mathematical terms this 'word model' can be represented by the following equations:

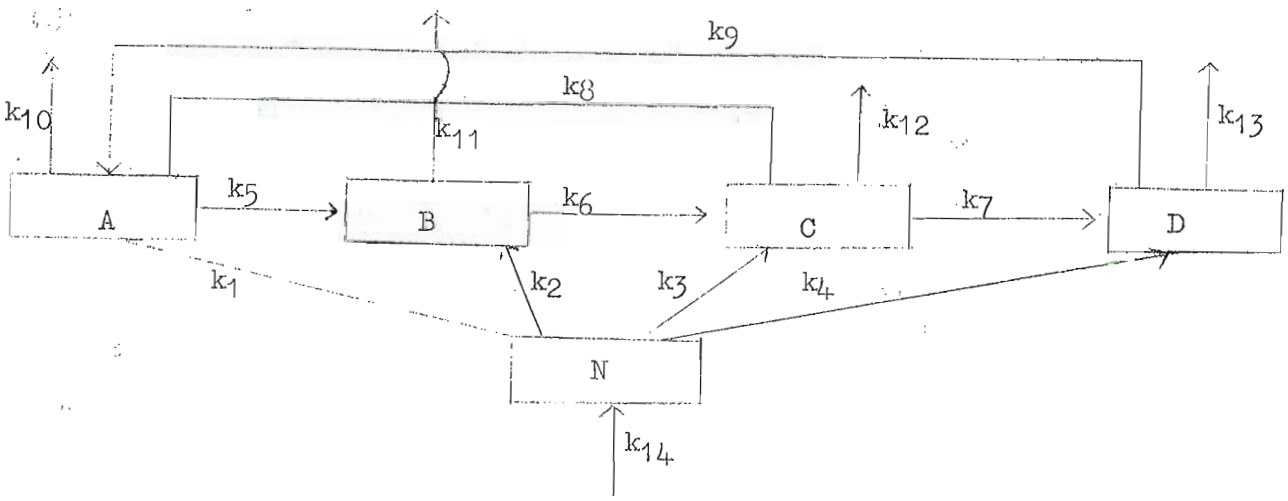
$$\frac{dP}{dt} = k_1PN - k_2P$$

$$\frac{dN}{dt} = k_1PN + k_3$$

where P = plant material
N = available nutrients
k_1, k_2, k_3 = constants

k_3 implies a constant input into N but is only an approximation since it is thought to be related partly to the decay of the peat, which is not explicitly mentioned in the model above.

The present stage of development of the Moor House model for Calluna is therefore one in which the nutrient dependent model described above has been combined with a four age class model.



The model has been tested by simulating the conditions of a burn and setting the initial conditions of the three older age classes at zero. The changes studied thus occur over several years (until the steady state assumed from the field results is attained), seasonal changes have been ignored for the present.

In this model a large overshoot occurs in the youngest age class in the years following a burn. This is the theoretical equivalent of a substantial increase in available nutrients. Obviously the youngest age class of Calluna cannot and does not exploit this increase, but the known behaviour of Eriophorum at this stage suggests that this species could now be incorporated into the model realistically.

A paper was presented at the I.B.P. Tundra meeting in Finland, September, 1970. "First stage of a model for the growth and decay of Calluna vulgaris at Moor House", H.E. Jones, G.I. Forrest and A.J.P. Gore.

c) Studies on Sphagnum - Project 2/02 (E.J.F. Reddaway and R.S. Clymo, Department of Botany, Westfield College, London)

1. Estimates of growth in length of S. rubellum (using the cranked wire method) have been continued. In the conditions of use, this method is probably reliable, but it seems doubtful if it can give reliable results in wetter (lawn) habitats. Net productivity estimates ($g\ dm^{-2}yr^{-1}$)

Area	Healthy	Moderate	Poor
Sike Hill	1.9	1.2	0.6
Bog Hill	1.9	1.3	0.6
Burnt Hill	2.0	0.9	0.5

(RMS error 0.38). These estimates are the mean for the two years April 1968-70. Sphagnum growth in 1969-70 was less than in 1968-69, a result confirmed by other methods.

2. Transplant estimates of growth were continued on the Burnt Hill site. Three sets of annual estimates have now been made. Of the species S. cuspidatum, S. papillosum and S. rubellum each has greater net production than the others when all are growing in its own habitat (pool, lawn, hummock), but this is not necessarily the habitat in which it has greatest net production.

	Habitat			
Species	Pool	Lawn	Hummock	
S. rubellum	2.9	2.2	1.8	Data are
S. papillosum	2.8	3.4	1.6	$g\ dm^{-2}yr^{-1}$
S. recurvum	4.4	3.1	1.3	Largest in a
S. cuspidatum	4.4	2.4	*	habitat are underlined

3. An analysis of the vegetation on the Sike Hill, Bog Hill and Burnt Hill sites is being made. This is a restricted analysis, complementary to that of Eddy, Welch and Rawes. We are trying both ordination and classification, and hope to be able to relate the vegetation to the Habitat features of these restricted areas.

4. Rates of loss of weight by bagged Sphagnum have been made in two years, using a method which does not involve any preliminary drying. Rates of loss appear to be about 10% in a year for material in the aerobic zone. This figure is similar to that found and reported earlier (J. Ecol., 53, 747-758, 1965) using a preliminary drying. (In detail the results are not easily summarised).

5. Depth/density profiles have been made. The density in Sphagnum peat varies from about 10 g/l at the surface to about 50 g/l at about 30 cm depth, below which there is a sharp increase to about 150 g/l. Density profiles are needed for an overall check on dry matter balance.

6. Gas loss (as CO_2 and CH_4) measurements have been continued. The data are not easily dealt with since most sites have shown occasional very high values (perhaps due to bubbles of gas escaping during the sampling time). Integrating over the year 1969, the losses (as $gC\ dm^{-2}yr^{-1}$)

	Pool	Lawn	Hummock
as CO_2	0.54	0.31	0.50
as CH_4	0.07	0.04	0.01
total C	0.61	0.35	0.51
calculated as CH_2O	1.5	0.9	1.3

These figures are higher than those suggested from last year's data, mainly because the gas losses continued at a high level for longer in 1969. They account for about 1/4 to 2/3 of net production by Sphagnum.

7. Measurements of pH and conductance were continued. In addition samples were collected, and analysed for most of the (quantitatively) important ions by Mr. Allen at Merlewood. Additional analyses were made in London, including organic matter. The results are not easily summarised, except to repeat the conclusion of the previous year that more acid conditions develop especially on hummocks during the summer.

8. From items 1, 2, and 4-7 it is now possible to produce a tentative balance sheet (for dry matter) on Sphagnum dominated parts of Burnt Hill. This was presented at an I.B.P. (PF)/UNESCO (IHD) meeting in Rumania, and should appear in Hidrobiologia in 1971.

9. The microclimate measurements have continued (last year's report gives details). Their main use is in attempting to check production measurements from physiological measurements, but they have a secondary value simply as a record of the microclimate and for predicting litter and peat temperatures. Various methods are being explored that will summarise the data, without throwing away most of the information contained in it. For example, for 10 days of hourly temperature records (240 records) a Fourier fit up to third harmonic (7 constants) accounts for about 20% of the variance, but an ad hoc equation of the form:

$$T = K_1 + K_2 \sin (K_3 + a) + K_4 t + K_5 t^2$$

(where T = predicted temperature, t = time elapsed and a = time in a 24 hour cycle) can account for 40% or more of the variance. The parameters (K) of this equation have physical meaning, but are unfortunately not uniquely determined.

10. The system for making physiological measurements of CO_2 and CH_4 exchanges with nearly undisturbed Sphagnum + peat cores is, after many difficulties, now working. These measurements will be continued next year.

11. Methods of measuring Sphagnum growth are reported in J. Ecol., 58, 13-49 1970.

d) Small mammal studies - Project 2/11 (Dianne and P.R. Evans, Department of Zoology, University of Durham)

In mid-September, 1969, a trapping grid for small mammals was laid out on the blanket bog near Bog End. The grid conformed to the specifications suggested for I.B.P. studies on small mammals, namely 16 rows, each of 16 traps. Rows and traps were spaced at 10 m intervals. Most of the grid lay on the Calluna/Eriophorum/Sphagnum bog but a few trapping points fell outside this, on the "hushes".

Longworth live traps (one at each point) were set for 4 days in mid-September when mammal population densities might be expected to be at their peak (in the calendar year). The traps were "baited" with oats. Although any mammals present were unlikely to have encountered such a diet before, it is believed that they enter traps through exploratory behaviour and not necessarily because they are attracted by the "bait" (though this serves to keep herbivores alive until the traps are emptied).

Only one young male Microtus agrestis was caught in the 1024 trap-days available; two Sorex minutus and one S. araneus were also taken. The weather was foul, with driving rain and fog on three of the four days. This might have restricted feeding excursions of the animals and reduced catches.

With such apparently low densities of small mammals, the effort of carrying and setting 256 Longworth traps for a mark/release/recapture study seemed wasted, so the grid was trapped with 'Museum Special' break-back traps in 1970. The first trapping period was in late May. Traps were baited with peanut butter on 21 May and checked on 24 and 28 May. Again one male Microtus agrestis was caught, in breeding condition and weighing 28 gm. Also trapped were 4 male and 9 female Sorex minutus and one male and one female S. araneus. These had probably been attracted by the large numbers of ants which fed on the peanut butter (without springing the traps!).

The traps were replaced on 9 September 1970 and examined daily for 6 days. On this occasion 9 Microtus and 51 Sorex were caught.

Together with the largely negative information from other workers who used pitfall traps on the blanket bog at Moor House, our results suggest that the Microtus numbers on blanket bog are very small. However it is possible that we are witnessing the aftermath of a crash in vole numbers, so break-back trapping will be repeated.

If enough Microtus are caught we hope to make comparisons of gut contents, fat levels and reproductive condition with animals grom grassland populations in Southern England (D.M. Evans unpublished work).

e) Grouse studies - Project 2/15 (P.R. Evans, Department of Zoology, University of Durham)

The need for such a study as part of the I.B.P. Moor House project has been outlined in the report of November 1969 meeting. (Newsletter 3, February, 1970).

Grouse might affect the primary production of the blanket bog in two ways:

(i) as herbivores

(ii) as predators of other herbivores and soil fauna

As herbivores they are known to take a high proportion of Calluna in their diet. In Scotland, however, they also take a wide variety of other plants at certain times of the year. These include Vaccinium, which occurs on the blanket bog in some areas near Bog End. In Scotland, it has been shown that grouse feed selectively on heather rich in N and P, so their effect on the vegetation calculated from a "biomass eaten basis" may be very misleading.

It is not known whether grouse chicks take an appreciable proportion of animal material in their diet in the first few weeks of life, but the chicks of certain other game birds do so. It would be desirable to study this in detail when funds for such a project become available. Since Psyllids are the commonest invertebrate herbivore, these might be taken in appreciable quantity; alternatively or additionally, tipulids and spiders might suffer considerable predation. Grouse may therefore effect primary production and the rate of decomposition indirectly as well as directly.

At the very minimum it is desirable to get estimates of the population density of grouse on the Reserve and in particular on the I.B.P. study areas. Autumn counts should give an estimate of the number of pairs that bred and the (fledgling) success of the broods. These counts should be repeated at yearly intervals to look for stability or fluctuations in population density. Taken together with data on clutch size, the autumn counts can give an estimate of chick mortality. Ideally, dates of hatching of individual clutches and the subsequent success of these broods should be followed. A full study of factors affecting chick survival, particularly of food requirements, is needed as soon as possible.

The behaviour of grouse in areas where they occur at low density may be very different from their behaviour as recorded in Scotland. This needs to be checked, as preliminary results from the I.B.P. study area in Ireland suggest such a difference.

A preliminary survey was carried out by two students in September 1970. They beat two areas on a number of occasions, usually dragging a rope, but one one occasion four beaters were present with a dog. Counts from 12 ha between Netherhearth and Rough Sike and 36 ha at Dodgen Pot, Bog End gave population estimates of the order of 1 grouse per 1 ha to 1 per 2 ha. These estimates are similar to those recorded by a number of other workers in previous preliminary surveys at Moor House.

f) Studies on Strophingia (Aphalaroida) Ericae (Curt) - Project 2/03 (I.D. Hodkinson and J.B. Whittaker, Department of Biology, University of Lancaster.)

1. Population studies - have been continued throughout 1970 on the Sike Hill site and have been extended to sites on Burnt Hill and by the second gate on the Bog End track. On all sites mortality in the population is highest when the psyllid moults, although on the Sike Hill site high mortality was recorded in September 1969 due to the effect of parasitic hymenopteran Tetrastichus sp. The long dry spell in June 1970 caused vary heavy mortality on all three sites and as this period coincides with the reproductive phase of the life cycle, recruitment to the population was low. Mortality on the gate site, although high was much less than on the other two sites. This is probably because the heather plants are very short and grow among clumps of Eriophorum so that the relative humidity is much higher. Population cages containing adult psyllids were set up in the field to permit estimation of adult longevity and egg hatching time.

2. Calorimetry - has been completed on all instars. The calorific values of the overwintering 2nd and 5th instars are the highest (5,400 cal/gm) while those of the summer 3rd and 4th instars are 5,100 cal/gm. The 2nd and 5th are the main overwintering instars and it appears that they probably store fat which is used up over the winter. The calorific value for overwintering 3rd and 4th instars will be studied next winter. Sufficient excreta and exuciae have been obtained for one calorific determination to be made on each (excreta = 4,000 cal/gm, exuviae = 5,000 cal/gm). The calorific value of adults - 5,300 cal/gm.

3. Respirometry - This has been carried out through the year on 4th, 5th and adult instars using a Gilson Oxygraph respirometer with a platinum electrode. Because of the small size of the psyllids measurements had to be made on 20 individuals at a time. More accurate results could probably be obtained using Cartesian divers but in view of the difficulty encountered by other I.B.P. workers in using them and the inherent errors present in relating laboratory respiration to field respiration, other experiments were deemed of higher priority.

4. Excretion - Field experiments carried out in May 1970 to supplement last years laboratory experiments suggest that excretion in the field is only 1/2 to 2/3 that observed in the laboratory.

5. Studies on the effect of the Psyllid on Calluna

a. Laboratory Study - These experiments were carried out in co-operation with John Grace (Sheffield University). One hundred 5th instar Psyllids (100x field densities) were placed onto each of 7 small heather plants (0.3 gm dry wt green matter) and left for a week with an equal number of Psyllid-free controls. There was a significant drop in the rate of photosynthesis in the psyllid infected plants compared with the controls.

b. Trial field studies - 10 x 1 m^2 quadrats on Sike Hill, were sprayed in July with Malathion insecticide to kill the psyllid population, 10 other quadrats were left unsprayed. It is planned to harvest the quadrats in late September to see what effect the exclusion of psyllids has on heather growth.

6. P32 labelling for predators - A technique has been evolved in the laboratory for P32 labelling of psyllids. Surprisingly stem injection has proved more effective in getting P32 into heather plants than stem-wall methods. It is hoped that this work can be continued in the field.

g) A survey of the invertebrates associated with Calluna at Banchory (Scotland), Moor House (N. England), and Furzebrook (S. England)
(J.B. Whittaker, Department of Biology, University of Lancaster)

In the summer of 1969, samples were taken in July, August and September at Furzebrook (2 sites) and Moor House for comparison with some taken previously at Banchory. The objects were:

1. To find out whether those groups of invertebrates considered to be important at one site were also important at the others.

2. To discover whether any important animals had been overlooked when I.B.P. projects were planned.

Methods

1. Pitfall traps - in the soil and litter below heather canopy.

2. Heat extraction of clippings of green material from heather canopy.

3. Suction samples of the heather canopy.

4. Emergence traps.

Summary of results

1. Ground and litter predators and scavengers

(i) Arne, Furzebrook - Spiders and staphylinids the most abundant groups. Ants and harvestmen next in abundance. Dermaptera fairly common. Carabids unimportant.

(ii) Middlebere, Furzebrook - Spiders most abundant. Ants and harvestmen less abundant than at Arne but still numerous. Staphylinids and Carabids unimportant. Woodlice fairly common.

(iii) Moor House - harvestmen extremely abundant. Spiders much less numerous in pitfalls. Ants not numerous. Carabids much more numerous than at Furzebrook sites.

(iv) Banchory - Spiders and harvestmen both abundant. Carabids fairly common.

Many species of Diptera abundant at all sites.

2. Herbivores on the Calluna canopy

(i) Arne, Furzebrook - Lochmaea abundant. Mites, Thrips, Psyllids also numerous. Lepidopterous larvae, though not numerous may be important because of their large size.

(ii) Middlebere, Furzebrook - Lochmaea relatively scarce. Mites Thrips and Psyllids numerous. Lepidoptera as for Arne.

(iii) Moor House - Psyllids and herbivorous mites numerous. Thrips rare. Lepidoptera rare.

(iv) Banchory - Mites, Thrips and Psyllids numerous. Lepidoptera more numerous than at Moor House.

The four sites differ considerably in the relative abundances of the four main faunal components. At Moor House, the most important understudied herbivore group is the mites on the Calluna canopy. Some data on these is being collected in the course of psyllid studies and shows that at some times of year they can be as abundant as the psyllids.

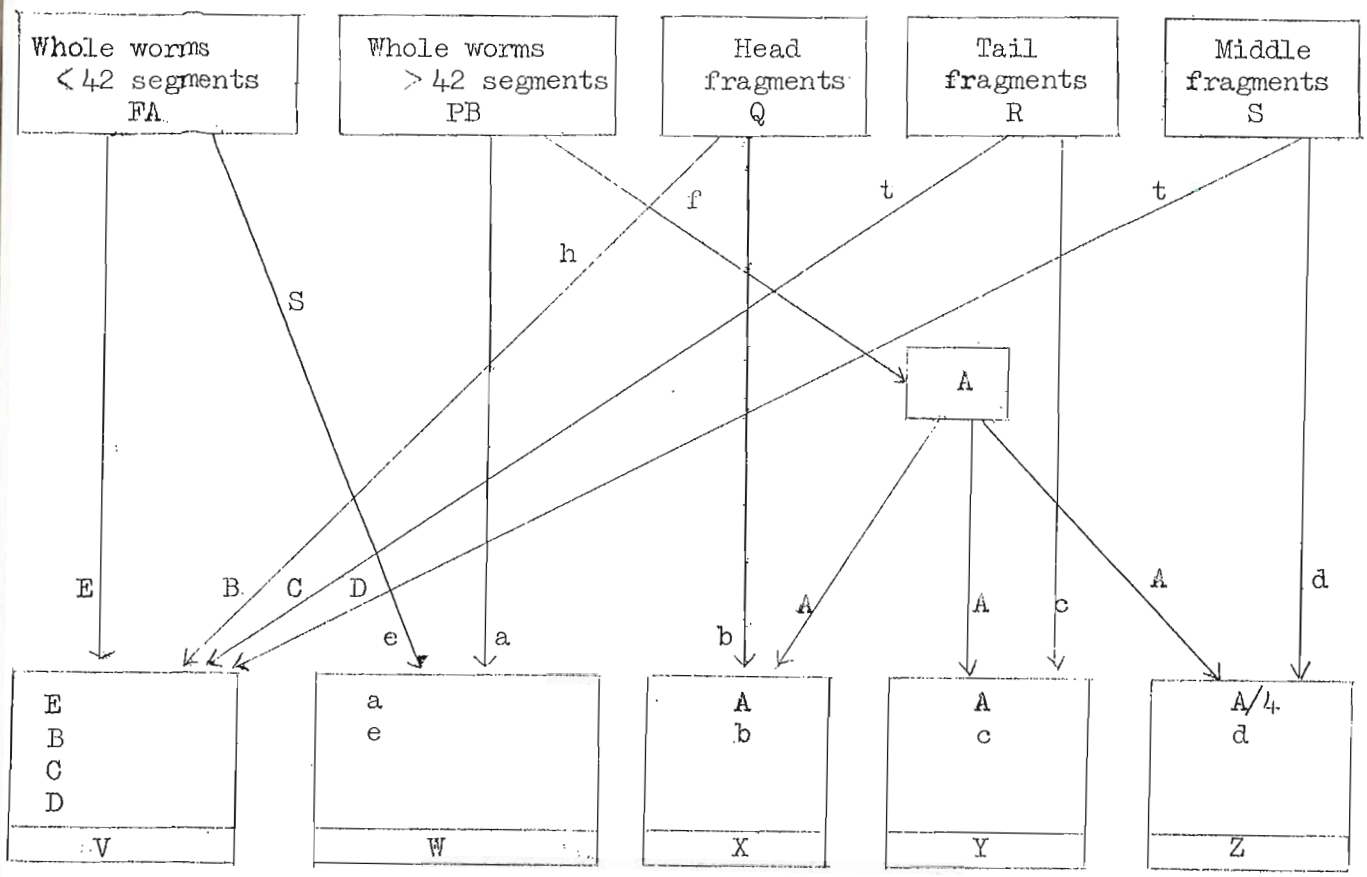
The material on which this preliminary report is based was collected by a number of field workers and sorted into major groups by students at Lancaster.

b) Production studies on Enchytraeidae - Project 2/05 (Valerie H. Standen, Department of Zoology, University of Durham)

Cognettia sphagnetorum is the dominant enchytraeid of blanket bog and has been studied intensively. Data from field samples at Bog End and from laboratory cultures have been used to determine the structure of the population of C. sphagnetorum in order to estimate annual production.

The species reproduces throughout the year - by fragmentation and because of this a simple compartmental model described below has been developed to estimate mortality and hence annual production. Measuremets of the respiration of these enchytraeids using Cartesian Divers have been carried out at different temperatures and will be used together with the production estimate to give the total energy utilization by the enchytraeid populations.

The following compartment model defines the components and transfers used in estimating mortality.



Population data from field sampling are used in conjunction with laboratory estimates of fragmentation and regeneration rates, to predict the field population at the next sampling occasion. The difference between predicted and observed populations represents mortality. In the following example numbers are expressed per m^2.

	Small worms	Large worms	Fragments Head	Tail	Middle
26.04.68 observed	8555	17728	1588	3616	882
29.05.68 predicted	14560	11744	5075	6823	1400
observed	10408	11025	706	3881	970
mortality	4152	719	4369	2942	430

In this example the mean field temperature over the period, from Grant readings, was 5.7°C; fragmentation rate per day of large worms was 0.34; the regeneration rate of fragments into small whole worms per day was heads - 0.60, tails and middles - 0.78; growth rate of small worms was 0.15 segments per day.

Preliminary results indicate that individual worms require about 1 year to complete a life cycle and annual production is about 2x the overwintering standing crop.

Respiration studies at 5, 10 and 15°C give no evidence of acclimatization, but individuals taken at different periods of the year show marked differences in respiration rate at a given temperature as follows (results in $\mu l O_2$/g live wt/hr x 10^{-3}):

	Sample date		
Temperature	12.2.70	31.6.70	21.7.70
5°	120	140	-
10°	180	250	280
15°	-	320	360

This study is now in the process of analysis and writing up. A new study on the influence of populations of enchytraeids and tipulid larvae on rates of litter decomposition will begin this autumn.

i) Feeding studies on Enchytraeidae - Project 2/06
(Pamela M. Latter, Gillian Howson and O.W. Heal, Merlewood)

The investigation of the micro-organisms eaten by Enchytraeid worms commenced in 1967 and has been extended to include comparison with the natural vegetation in varying stages of decomposition. It is hoped to establish whether the worms, particularly Cognettia sphagnetorum are involved in the primary decomposer or in the microbivore pathway of the food chain, or both, and to estimate their contribution to the decomposition of the different vegetation types. Together with data on respiration and production of worms in the field (Dr. Valerie Standen) their part in the annual transfer of energy and carbon will be assessed for use in the I.B.P. models.

A number of substrates have now been tested as food for C. sphagnetorum, in laboratory cultures. Substrates are selected from the field, washed to remove particulate material and cut into pieces approx. 2-3 mm long. The cultures are set up in perspex slides with four cavities, 15 x 22 mm and 5 mm deep with substrate equivalent to 7.5 mg o.d.w. For growth studies one measured worm is added to each cavity and cultures are kept just moist with water obtained from a bog pool. Worms are re-measured after 6 weeks in culture.

The numbers found in the different substrates in the field have also been examined with Dr. V. Standen. Worms showed best growth and occurred in the highest numbers (30-48 x $10^3/m^2$) on the older litter of Calluna and Eriophorum. Growth was poor and numbers were lower (20 x $10^3/m^2$) on Sphagnum and from lower horizons ('Green' and 'Rust' zones) of peat.

In the field, the fungus Marasmius androsaceous causes bleaching of leaves and wood of all substrates except Sphagnum. Worms showed growth on leaves of Rubus chamaemorus affected by this fungus but died on unbleached leaves. In the field bleached leaves also show more rapid loss in dry weight (preliminary figures 63% in one year against 46% for unbleached leaves).

Worms have been observed to ingest soil bacteria extracted from peat, but subsequently died unless antibiotics were present in the culture.

Results to date indicate that Cognettia sphagnetorum is involved in the primary decomposer pathway of the food chain. It thus contributes to one stage of the decomposition of the main vegetation types (with the exclusion of Sphagnum) after these have been partially decomposed by micro-organisms.

j) Studies on Molophilus ater (Tipulidae) - Project 2/04 (J.C. Coulson and J.C. Horobin, Department of Zoology, University of Durham).

Investigations have continued to determine the factors which influence the population densities of Molophilus ater on peat soils over a wide altitude range.

Even within the Moor House Reserve, annual climatic differences in temperature occur which are equivalent to those between the south coast of England and Edinburgh. For example, the annual temperature sum (ignoring negative Centigrade values) at 847 m is about 1,435 day-degrees (°C). Under both of these situations Molophilus ater larvae develop at the same rate (in fact slightly faster at the higher altitude) and since there is no diapause in this species, it is evident either that food assimilation is more efficient at the lower temperature or acclimatization occurs to compensate for the temperature difference.

Evidence so far obtained suggests that acclimatization is the main factor involved and that the individual adjusts its metabolic rate to produce almost constant development rate at different temperatures. The implication of this conclusion on the application of Q10 or other such relationships is obvious and raises the whole question of how metabolic processes in other soil animals relate to their ambient temperature. How can respiration data from animals at, for example, Meathop, be applied to the same group at Moor House or elsewhere ?

Using data from 1963-70, the final instar larval density of Molophilus ater at Bog End Juncus squarrosus site was 1,350/sq m while the neighbouring Blanket Bog held only 400 larvae/sq m. In no year did the density on the Blanket Bog approach or exceed that on the Juncus site. There is no indication that the dry summer of 1970 had any influence on the survival of Molophilus ater eggs and larvae.

k) Decomposition of plant remains - Project 2/07 (O.W. Heal and Pamela M. Latter, Merlewood)

The dry weight loss and changes in chemical composition of the main vegetation types are being recorded for up to ten years, on samples laid down in 1966 (Calluna, Eriophorum) and 1967 (Rubus chamaemorus). Samples are enclosed in nylon mesh bags with the exception of Calluna stems which are tied directly to the label.

The project will link with those on primary production and litter fall to estimate decomposition per unit area blanket bog and to indicate rates of accumulation for the different vegetation types.

All samples are now partially decomposed, darker in colour and covered with faecal material, but are still recognizable. The depth they have reached in the profile caries from 0 - 9 cm and all types of sample are penetrated by rootlets of Calluna and Eriophorum the internal tissues have been decomposed leaving the outer tissues largely intact. The Rubus leaves on the other hand show the mull-forming type of decomposition, only the veins remaining in some parts. The tissues beneath the bark of the Calluna stems has been decomposed and some of the bark has disappeared but the central wood is still firm.

The preliminary results to date are shown below:

	% dry weight loss			
	1yr	2yr	3yr	4yr
Calluna stems	8	16	15	23
Calluna shoots	15	29	35	40
Eriophorum leaves	26	37	44	67
Rubus leaves	38	60	67	

Further experiments will be set out in 1970 to estimate between year and between site variation and to obtain information on decomposition rates of other plant components.

Investigation of the use of cotton strips as a simple rapid indicator of decomposition rate is being continued. The loss in tensile strength is measured since this is independent of organic or inorganic contamination. It is hoped to obtain a relationship between loss in tensile strength per unit time and the loss in cellulose so that results for different sites, for different periods of time can be compared in terms of cellulose loss. The method is being used at some other I.B.P. tundra sites. A description of the method is available for private circulation to anyone interested.

1) Study of anaerobic and facultative bacteria in peat - Project 2/08 (Vera G. Collins and B.T. D'Sylva, Freshwater Biological Association)

Two groups of micro-organisms - the denitrifying bacteria and the nitrogen-fixing bacteria - were examined to complete the selective groups of bacteria studied in the project.

Denitrifying bacteria: Two peat cores under Sphagnum and one core under Calluna were studied. The four horizons were sampled and serial dilutions inoculated into 10 ml of yeast extract medium (YE) supplemented with KNO_3 and glycerol (Stanier et al, 1966), contained in test tubes. The tubes were incubated at 25°C and after 48 hours tested for denitrification. 5ml of solution from the test tubes was removed and a few drops each of α-napthylamine acetate and sulphanilic acid were added. A reddish-brown colour indicated a positive test, i.e. nitrite was present.

To test if nitrate reduction had taken place beyond the nitrite stage, a little zinc dust was added to the tubes showing a negative nitrite test. A reddish brown colour showed that nitrate was still present. 1 ml of suspension from the positive nitrite test tubes was inoculated into 2% agar plates of Stanier's medium and incubated at 25°C. After 48 hours colonies were picked off onto agar stabs of the same medium, and pure cultures were subsequently tested for denitrification in liquid medium of the same composition. Identification of these cultures will be preformed at a later date.

The nitrite test showed that the denitrifying capacity of the organisms was higher in the 'litter' (0-8 cm) and 'black-brown' (8-14 cm) horizons than in the 'green' (14-28 cm) and 'red brown' (28 cm and below) zones. About two-thirds of the tests were positive in the upper horizons compared with one-third in the green and red brown horizons. These results are in agreement with Pochon and Haghib (1965) who obtained higher numbers of denitrifying organisms in the surface layers of acid peat and these decreased with depth.

Nitrogen-fixing organisms: The sampling regime was the same as that for denitrifying bacteria. Enrichment of organisms was carried out in 100 ml conical flasks containing 30 ml of liquid glucose, nitrogen-free medium (Norris 1959), and incubated at room temperature for isolation 1 ml of material from the flasks was inoculated into agar plates of the same medium. A pure culture collection of isolates, about 50 in number were subcultured onto agar slopes of Norris' medium for the purpose of identification.

The results showed that of the bacterial isolates that had developed on the nitrogen-free medium, 40% were from the 'litter' horizon, 40% from the 'black brown', 10% from the 'green' and 10% from the 'red brown' zone. Of the 20 fungal isolates 33.3% were from the 'litter', 38% from the 'black brown', 9.5% from the 'green' and 19% from the 'red brown' horizon. These isolates will be tested for their ability to fix nitrogen by the acetylene reduction method (see below).

Stanier, R.Y., Palleroni, N.J. and Doudoroff, M. (1966) J. Gen. Microbiol., 43, (2), 159-271.

Pochon, J. and Naghib, A.I. (1956). Ann. Inst. Pasteur, 90, 510-512.

Norris, J.R. (1959). Lab. Pract., 8, 239.

m) Studies on nitrogen fixation - Project 2/16 (Vera G. Collins and Barbara T. D'Sylva, Freshwater Biological Association)

The objectives of this project are: 1) to determine the amount of N_2 fixed/m^2/year with an estimation of variation within the year, and with depth in the peat; 2) to determine the proportions of N_2 fixed aerobically, anaerobically and photosynthetically, and 3) to test for a possible correlation between the numbers of nitrogen-fixing bacteria and the amount of nitrogen fixed.

The method used is a modification of the acetylene reduction technique of Hardy et al (1968). Three gas mixtures are employed to obtain aerobic, anaerobic and photosynthetic conditions in the samples A definite amount of acetylene is injected in the samples and they are incubated in situ for 1 hour. The reaction is stopped by the addition of trichloracetic acid, and the samples are analysed in a gas chromatograph for the production of ethylene from acetylene. The enzyme nitrogenase is a versatile catalyst; among the many reactions it can catalyze are the reduction of N_2 ——— NH_3. The reduction of C_2H_2 ———C_2H_4, and HCN———CH_4 + NH_3. The acetylene reduction technique therefore, is an indirect but sensitive method of measuring N_2 fixation.

In the preliminary investigation the four horizons from two peat cores under Sphagnum and Calluna vegetation, and one core under Eriophorum vegetation were examined. The samples were tested for acetylene reduction under aerobic (A + O_2), anaerobic (A), and photosynthetic (A + O_2 + CO_2) conditions. A dilution count for nitrogen-fixing bacteria was done on the same samples using a mineral salts medium with lactate as the carbon source (Biggins and Postgate, 1969). The agar plates were incubated under aerobic and anaerobic conditions at 25°C.

The samples are being analysed in the gas chromatograph for acetylene reduction, and the relationship between numbers of bacteria and the amount of nitrogen fixed will be examined later.

Comparative studies on nitrogen-fixation are being done on an I.B.P. woodland site, Meathop Wood.

Hardy, R.W.J., Holsten, R.D., Jackson, E.K. and Burns, R.C. (1968). Plant. Physiol., 43, 1185-1207.

Biggins, D.R. and Postgate, J.R. (1969). J. Gen. Microbiol., 56, 181-193.

n) The influence of microflora on the cycling of inorganic ions in Moor House soils - Project 2/14. (A.J. Holding, R.M. Macdonald and N.J. Martin, Department of Microbiology, University of Edinburgh)

The object is to demonstrate 1) the role of micro-organisms in the release and immobilization of selected inorganic ions in peat, 2) the influence of inorganic ions availability in peat on microbial activity.

Previous reports have provided brief summaries of data available on the following aspects investigated by N.J. Martin.

1. Pure culture studies. Data on the distribution and some of the biochemical and taxonomic characteristics of the predominant types of bacteria.

2. Respiration studies on peat macerates. The effect of the addition of various organic and inorganic materials and of static and shaking conditions on the uptake of O_2.

3. Continuous percolation studies. The percolation of salts through a peat-sand mixture has demonstrated changes in the size and composition of the microbial population and data on the release of certain major plant nutrients.

4. Field experiments. The large variation in the response of the bacterial population to the addition of organic and inorganic materials to the dark-brown horizon requires further investigation.

5. Profile description. A detailed description of the profile at Bog End is being prepared.

During the current year the following studies have been undertaken by R.M. Macdonald. The investigations are being developed to show the precise location in the ecosystem where microbial activity exerts most influence in the cycling of metal ions.

1. Chemical analyses. Variation in hydrogen ion concentration, cation exchange capacity (CEC) and water content have been determined in order to devise further experiments on factors affecting the flow of nutrients.

Hydrogen ion concentrations (g ions x 10^{-4}/litre) of peat

Colour zone	Peat - KCl mixture	Peat-water mixture	Expressate
Litter	15.9	1.26	4.0
Dark-brown	12.6	1.59	1.0
Green	12.6	1.59	1.0
Rust	12.6	1.26	0.8
Deep rust	10.0	1.0	*

* Not available

Cation exchange capacity (m.e./100 g dry wt) and moisture content of peat expressed as a percentage dry wt.

Sample	C.E.C.	Moisture content
Live Sphagnum	156.2	865
Litter	199.2	1146
Dark-brown	245.7	1418
Green	188.2	1358
Rust	157.2	1088
Deep rust	155.0	930

In addition to demonstrating the variation within the profile, the salient features of the data presented in the above 2 tables are the high figures for the dark-brown horizon; lower figures usually being obtained in the deeper horizons.

2. Nutritional requirements of strains of Bacillus. This investigation was undertaken since the nutritional requirements of bacteria are likely to be an important factor in controlling their distribution in soil. The nitrogenous compound requirements were determined in relation to both obligate requirement for visible growth in liquid media and the requirements to give maximum growth.

Nitrogen Source	Visible growth	Maximum growth
Inorganic	60*	17
Yeast extract (YE)	5	20
Soil extract (SE)	10	22
YE + SE	-	31
YE or SE	25	10

* % of cultures tested

These results emphasize that many of the organisms which give maximum growth in the presence of growth factors, do not have an obligate requirement for these factors. It is possible therefore that increased availability of growth factors in soil may not preferentially promote growth of organisms with an obligate requirement for these factors.

o) Production studies on oribatid mites under Calluna vulgaris Project 2/10 (W.C. Block, Department of Zoology, University of Leicester)

Feeding studies on mites are in abeyance and respiration studies have been limited owing to lack of time and technical assistance. However, some respiration measurements have been made on juvenile stages of the three main species and a full-time M.Sc student, D. Goddard, has begun work on respiration of Moor House mites.

p) Climate (O.W. Heal, Merlewood)

Daily meteorological measurements at Moor House for the period 1959-1969 inclusive have been supplied on punched cards by the Meteorological Office and are available from O.W. Heal at Merlewood.

The Lintronic radiation recorder has worked reasonably well during the year and a full years run of data should soon be available. Results from the Lintronic and Kipp Solarimeters are highly correlated ($r = 0.836$) but the input recorded by the Kipp is only about 70% of that recorded by the Lintronic. Processing of the temperature information from the Grant recorder has proved difficult because of the amount of data, but results have been supplied to a number of research workers. Comparison of maximum and minimum temperatures recorded by the Grant at Sike Hill and in the Stevenson screen at the Field Station show discrepancies. Tests are in progress to determine if this results from differences in site or in probe shielding.

V. RESEARCH BY MERLEWOOD STAFF

a) A Report from the Systems Unit (A.J.P. Gore)

A meeting at Kevo, Finland (see also pages 8, 9 & 13 of this Report) reaffirmed the resolutions reached at the previous meeting of the Tundra Biome in Norway 1968. There was strong emphasis on the use of systems analysis in the development of models and a preliminary attempt is to be made by the Systems Unit to construct simple models using the plant production data from three sites, namely Hardangervidda, Norway (60°N), Barrow, Alaska (70°N) and South Georgia (54°S) for comparison with similar models already developed for Moor House.

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

(i) Factors limiting plant growth on peat.

The experiment was carried out on peat at Moor House (Summit of Cottage Hill) and at Deer Dike Moss. The objects of the experiment were to estimate 1) the role of inorganic nitrogen in promoting maximum growth rates and 2) the role of inorganic macro- and micro-mineral nutrients in relation to nitrogen nutrition.

The separation and measurement of dry matter of remaining plant material from this experiment was completed this year. All the primary data are now assembled and await the writing of computer programmes to produce the appropriate secondary data such as relative growth rates and net assimilation rates. This data reduction phase will not receive priority until the current work (see below) has been completed.

(ii) Productivity of blanket bog vegetation

The assembly of the data from this experiment has taken most of the current year and continues. The experiment was designed to measure the consequences of different intensities of removal of bog vegetation by cropping. The longest cycle was a five year one so it was appropriate to regard two cycles of five years as being a minimum necessary for the collection of results. Consequently the data presently being assembled cover the ten year period 1959 to 1968. The experimental work is being continued and will form an important validation study by including longer runs of climatic variation effects.

Model development is proceeding and a simple non-linear model of Eriophorum growth and decay has been subjected to simulated cropping for comparison with the field results.

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

Since 1954 trees have been planted at Moor House to find suitable species. Methods of planting and treatment, mainly with fertilisers, have been tested. The background to this high elevation (548-571 m) work has been covered in previous reports. The three pine species Pinus sylvestris, P. contorta and P. mugo var. rostrata continue to

grow quite well having produced leading shoots similar to those of previous years. On the better parts of the Pasture plot, the native P. sylvestris is achieving height growth equal to that of the hardier exotic P. contorta. There has been no obvious snow-damage this year, and in general the colour of Scots Pine foliage is a healthy blue-green. In the fertiliser (N, P and K applications) experiment with P. contorta on blanket peat at Bog End, the trees continue to exhibit the yellow-tipped needles typical of potassium deficiency, although height growth appears to remain similar to that of the last year, or two. It is apparent that further additions of fertiliser will be necessary.

The most obvious feature of the tree plots this year is that a proportion of the pines are suffering from die-back. This is occurring in all the plots and varies from small one-year shoots to whole branches or even complete trees. All three species are affected, with something over 5% (visual estimate) showing symptoms in the P. contorta at Bog End. A reason for this die back is being sought, although a possible explanation could be the exceptionally dry weather experienced in early summer.

The few examples of Sitka spruce (Picea sitchensis Alaskan provenance) on sites other than mining spoil have grown well this year, as have the few remaining Hybrid larch, Larix eurolepis.

A further year's experience with the hardwoods (mainly Sorbus aucuparia and Betula spp.) confirms the conclusion that as pioneers at least, none is suited to the degree of exposure occurring at these elevations. However, a small number of Sorbus intermedia planted in the immediate shelter of older Pinus contorta are showing better growth and it seems likely that hardwoods will grow given sufficient shelter.

VI. RESEARCH BY FRESHWATER BIOLOGICAL ASSOCIATION

a) Studies on freshwater fauna - Project 4/01 (D.T. Crisp, R.H.K. Mann, Miss J. McCormack and P. Armitage)

During 1969 Sheila Carrick was appointed as assistant for the fish studies and during 1970 Dr. P. Armitage was appointed to continue and expand the invertebrate work started by Mrs. Crisp and Miss MacHale.

The thrice-yearly fish census and collection of invertebrates in four streams on the Reserve has been continued. At the end of 1970 filling of the reservoir will bring an end to the pre-inundation phase of the work at Cow Green and detailed analysis of the data collected at Cow Green and at Moor House during the period 1967-1970 will begin. Meanwhile, there is little to add to the tentative summary of results given in the last report.

During 1970 two probes from the I.B.P. Grant recorder have been installed in Great Dodgen Pot Sike to give records of the water temperature.

Most of the expansion of the invertebrate work, as a result of the appointment of Dr. Armitage, will be in the Cow Green part of the project. However, the provision of a portable light-trap should provide some adult caddis which can be used to check the identification of larvae collected from the Reserve.

VII. RESEARCH BY UNIVERSITIES

Research on the Reserve is being done by a number of University Departments. During the Easter vacation students from Leicester, under the supervision of Dr. W.C. Block and Dr. S. Salmon, undertook the following projects:-

1. Survey of micro-arthropods of the Calluna canopy. An average of 3000 arthropods (Psyllids and Mites in equal number) was estimated for a m^2 of Calluna canopy (430 g dry weight).

2. Survey of arthropods occurring in small hummocks of Festuca ovina. Eight groups were separated. Collembola and Acarina were found to be the most numerous.

3. Survey of small mammals. Longworth traps were set in six localities but few animals were caught. The cold weather and continuous snow cover contributed to the lack of success.

4. Survey of grouse and other birds. Counts were made in the manner of Campbell (1954). Estimates of the Reserve's grouse population varied from 150 to 500 pairs, and Meadow Pipits 250 pairs.

5. Study of the micro-climate in and above blanket bog, with major reference to temperature. Thermistors were placed in 24 positions. Snow cover was found to reduce temperature fluctuations.

6. Sheep feeding study. Hay (mean daily dry weight intake 89.5 g) and crushed oats (79.4 g) were compared using 3 penned sheep.

During the summer students from Durham undertook projects on the Reserve. S. Gamble studied the behaviour of Tipula subnodicornis during the emergence period in May/June, while Miss Statham and Miss Welbourn trapped small mammals and made a preliminary survey of grouse (see Dr. Evans' report in the I.B.P. section).

Copies of the reports of most of these studies are kept in the Moor House Library.

a) The effect of burning and sheep grazing on the nutrient status of Rubus chamaemorus L.- Project 6/01 (K. Taylor, Department of Botany, University College London)

Details of this project were given in the Moor House Annual Report for 1968/69.

Samples of the standing crop of R. chamaemorus in the Hard Hill experiment (Block C*), which were collected during the 1969 growing season, have now been analysed for total mineral elements.

Results

The levels of nitrogen, phosphorus and potassium percentage over-dry weight of the above ground plants were similar in all treatments and showed the same downward trend as the growing season progressed. In contrast the concentrations of calcium and magnesium, although they were similar for all treatments, increased at each harvest. Data for the harvest of 5 August only is presented in Table 1.

With the single exception of calcium, the concentrations of the mineral elements in the rhizomes and roots were also essentially the same in all treatments (Table 2).

Conclusions

Additonal nutrients were taken up by R. chamaemorus in response to burning but the concentration of nutrients in the various parts of the plant are similar in all treatments in spite of differences in growth response. The results suggest that the plant is not responding directly to the fertilising effects of the mineral nutrient-rich ash which was added to the peat surface when burning was carried out.

Supporting evidence is provided by the results of the experimental separation of the effects of fire in terms of the addition of mineral ash and removal of the plant canopy. This shows that addition of plant ash has no significant effect on the development of shoot numbers (see report by T.C. Marks, Project No. 6/02).

A detailed analysis of the seasonal nutrient status of R. chamaemorus in the Hard Hill experiment is being prepared for publication.

Table 1

Treatments effects on the concentration of mineral elements in the total aerial dry matter samples on 5 August, 1969

Treatment	% oven-dry weight				
	N	P	K	Ca	Mg
Burned and ungrazed (C/SF)*	1.88	0.12	1.17	0.63	0.55
Ungrazed (C/LF)	1.70	0.12	1.18	0.58	0.55
Burned and grazed (C/S)	2.00	0.12	0.93	0.60	0.60
Grazed (C/L)	1.72	0.11	1.11	0.54	0.52

(* refers to plot code, see Reserve Record Vol. IX, Experiment on long-term effects of heather burning)

Table 2

Treatment		% oven-dry weight				
		N	P	K	Ca	Mg
Burned and ungrazed (C/SF)	Root	1.36	0.12	0.89	0.59	0.45
	Rhizome	1.10	0.09	0.43	0.42	0.18
Ungrazed (C/LF)	Root	1.47	0.13	0.44	0.49	0.36
	Rhizome	1.39	0.10	0.40	0.36	0.13
Burned and grazed (C/S)	Root	1.34	0.09	0.81	0.41	0.22
	Rhizome	1.35	0.11	0.32	0.42	0.15
Grazed (C/L)	Root	1.23	0.08	0.41	0.49	0.34
	Rhizome	1.24	0.10	0.27	0.35	0.15

b) The effect of burning and grazing on the production of Rubus chamaemorus L. - Project 6/02 (T.C. Marks & K. Taylor, Department of Botany, University College London)

This work was part of a wider study of R. chamaemorus involving the use of controlled environmental conditions and the measurement of CO_2 flux over plant parts in an attempt to relate plant growth response to specific environmental factors. The object of the recent field work carried out at Moor House has been to gain information on the growth response to R. chamaemorus following a burning treatment in areas both grazed and ungrazed by sheep.

In order to separate the effects of ash deposition and canopy removal resulting from a normal burn, an experiment was set up on Block C of Hard Hill in April, 1969 as previously described (10th Moor House Annual Progress Report, 1968-69). This experiment was extended into the recently ended growing season.

Results

At the end of the first season's growth there was no significant difference between shoot numbers in squares which had received ash and those which had not, whether in grazed or non-grazed treatments. This picture of ashing having no significant effect on the development of shoot numbers has persisted in the second growth season.

However, the effect of canopy removal has been more dramatic.

Mean shoot no/m^2 of all squared (ashed and non ashed) following canopy removal

	Control (9 July '69)	9 July '69	15 July '70
Ungrazed	82	109	162
Grazed	37	28	36

The control shoot numbers are subject to sampling fluctuations and the overall pattern of the "growth curve" for the grazed treatment is of a slight increase in shoot number which is probably statistically insignificant. In contrast, the modest increase of shoot numbers in the ungrazed treatment seen during the first season's growth has been followed by a further and greater increase in the second season which has almost doubled the mean shoot no/m^2.

The poor response in the grazed treatment is somewhat puzzling but may be due to a selective grazing pressure following removal of Calluna which results in a larger depression of shoot number than would take place under normal grazing.

Temperature recording

In connection with this study a Grant 9 channel temperature recorder was placed inside the fenced sector of Block 'C' on Hard Hill on 25 April, 1970 and set to sample once each hour. The temperature sensors were standard Grant 2" sheathed probes. Those probes positioned above ground were fitted with cylindrical, aluminium foil covered, radiation shields which permitted through ventilation.

Probe positions:	1	+152 cm	
	2	+ 20 cm	Eriophorum vaginatum dominated area. (Low canopy).
	3	+ 8 cm	
	4	Bog surface	
	5	- 6 cm	
	6	+ 20 cm	
	7	+ 8 cm	Calluna dominated area. (High canopy)
	8	Bog surface	
	9	- 6 cm	

Sampling continued until 14 July, 1970 and all data has been placed on 80 column punched cards. The data is available as printed 10 x 24 matrices and in card form.

c) Studies on Cercopidae - Project 6/03 (J.B. Whittaker, Department of Biological Sciences, University of Lancaster)

A population study of the Cercopid Neophilaenus lineatus on Juncus squarrosus and Nardus areas was begun in 1961 and continued since that date. From 1964 to 1970 a population of N. lineatus at Wytham Woods, Oxfordshire has been studied so that the dynamics of the species at the edge of its range (Moor House) could be compared with that nearer the centre of the range (Wytham). This comparative study has now been written up and is in press (J. Anim. Ecol.). The main conclusions were that the Wytham population (coeff. of variation 47.5) was much more stable than the Moor House ones (c. of v. 92) and that although regulatory processes (including the effects of an insect parasitoid) could be detected at Wytham, they could not be demonstrated at Moor House. The two Moor House populations showed parallel changes in every year from 1961-67. In the latter year the density of one of them (Nardus site) was experimentally reduced. Since then, the 2 populations have remained significantly different in density. The Nardus population has not yet (1970) adjusted to the effects of being disturbed.

Preliminary calculations suggest that the Homoptera on the Juncus site may in some years have an annual production comparable with that of the sheep grazing on the area.

d) Thermal characteristics and related low flow hydrology of upland catchments - Project 6/04 (K. Smith, Department of Geography, University of Durham)

Continuous records of streamflow and water temperature have been obtained from Netherhearth Sike during the year. Once again, these data could not have been collected without the regular chart-changing assistance from Moor House staff both at this site and at the Trout Beck station.

The data collection phase of this project ends on 30 September, 1970 and, because of an unavoidable gap in the records for a station further down the Tees, it has been decided to restrict the detailed analysis until data are available for the whole of the second summer. However, preliminary examination indicates that there are appreciable differences in the diurnal range of streamwater temperature between Netherhearth and the experimental catchment in Weardale. These differences appear to be related to the contrasting flow regimes of the areas, and increased attention is now being given to the baseflow recession characteristics of these streams.

e) A study on the relationship between egg number and density in Tipula subnodicornis Zetterstedt.) Project 6/06 (Jennifer Butterfield, Department of Zoology, University of Durham)

Population studies have continued on Tipula subnodicornis; larval densities have been determined on a series of sites from soil cores. Adult abundance has been estimated by pit-fall traps and adhesive traps, and the best indication of adult abundance has been found to be obtained by the former method which had correlation coefficient of +0.77 with the density of final instar larvae.

Investigations have continued into the effects of vegetation type on larval density and the size and egg production by adult females. The information is now being analysed. The summer of 1970 was one of the driest at Moor House in the last 20 years and extensive drying out of the peat occurred in May and June. Previous studies have shown that this type of climatic effect drastically reduced egg and first instar survival. This type of drastic reduction has occurred on Juncus squarrosus sites at Bog End and Netherhearth. At the former site, the density of larvae in September, 1970 was 18 larvae/sq.m (37/sq.m in 1969) whilst on the latter site the population density was below 10/sq.m (80/sq.m in 1969). On the blanket bog no reduction has been found and even an increase in density has been found at certain sites. It is believed that these differences result from differential drying out of the peat; the better drained J. squarrosus sites drying out to a greater extent.

Respiration studies have been started on larvae and further investigations on acclimatization are in progress.

f) An experimental evaluation of the influence of climate on the growth of moorland plants - Project 6/07 (J. Grace, Department of Botany, University of Sheffield.

Laboratory measurements of selected physiological parameters in Calluna vulgaris and Sphagnum rubellum have been made and these measurements, together with climatic data have been used to compute the annual dry matter/input into Calluna in the field.

Net photosynthesis was measured on sample plants, brought into the laboratory from the field. Physical differences between the laboratory and the field situation were measured and technical differences involved in stimulating natural conditions and in the laboratory studied. The evidence collected indicates, that net photosynthesis of Calluna

depends on light, present temperature, previous temperature, the age of the foliage and the presence or absence of flowers on the plant. In Sphagnum photosynthesis depends on light, temperature and water content.

Light interception by Calluna was studied using a physical laboratory model and a parallel light-beam, and in these experiments more light was intercepted by Calluna when illuminated from low angles. It was shown how the results could be related to the field situation given the distribution of brightness over the sky. The photosynthetic response of Calluna in direct and diffuse light confirmed that the directional distribution of the light was of considerable importance in determining the shape of the light-response curve.

The significance of the assimilate distribution pattern in determining the growth rate of the plant was studied. In Calluna during the early part of the season, available food reserves are directed to the production of leaf material.

The FORTRAN model of Calluna growth attempts to predict the hourly input of carbon between the atmosphere and various plant parts, given hourly values of temperature and solar radiation. The computed annual input of dry matter has been checked against four different estimates made by others from field measurements. Although the extent of the agreement is encouragingly good, stringent testing is precluded by the variability encountered in the field measurements.

Computed input of dry matter into Calluna between May 1, 1968-February 12, 1969

Treatment	$g/m^2/41$ weeks
Using actual temperature and solar radiation data	217
Increasing the temperature by 2^o	295
Decreasing the temperature by 2^o	132
Decreasing solar radiation by multiplying each value by 0.6	125
Estimates made by Forrest (1970) at the same site over the same period	168
Estimates by Rawes & Welch (1969) on Reserve	100
Estimates by Bellamy & Holland (1966) on Cronkley Fell	177

g) The distribution of Hordeum murinum L. in Britain - Project 6/08
(A.W. Davison, Department of Botany, University of Newcastle upon Tyne)

In 1968 an experiment was set up at Newcastle, Allenheads and Moor House to determine the reasons why the annual grass Hordeum murinum L. is restricted (Davison 1970) to lowland areas with low rainfall. Fruits were sown at the three sites in polythene pots of garden loam and then flowering, seed set and re-establishment were recorded in 1969 and 1970.

The experiment showed that in 1969 fewer grain were produced at Moor House (Table 1) and they were much smaller in size than at Newcastle. Ripening was delayed by several weeks.

Table 1 Number of grain produced per plant and the weight per grain

	No. grain/plant	Wt. grain (mg)
Newcastle	812	11.5
Moor House	235	6.3

Hordeum murinum has a short primary dormancy (Davison, in press) and this, coupled with the delay in ripening, resulted in germination of the grain produced at Moor House being very late. As a result the seedlings produced little growth in autumn and there was very high mortality in the winter of 1969/70. The surviving seedlings grew very poorly in 1970 and few flowers were produced. At the time of writing the grain have still not ripened.

Laboratory examination of grain produced at Moor House has suggested that it has a lower relative growth rate than genetically similar grain, produced at Newcastle. If this can be confirmed it explains the very poor growth of the seedlings in the 1969/70 season.

h) A comparison of the flowering times of East Durham and Teesdale populations of Primula farinosa L. - Project 6/09 (J.B. Frankton, Department of Botany, University of Newcastle upon Tyne)

In 1921 Heslop Harrison (Vasculum 7, 21-25) noted that on Widdybank Fell, Upper Teesdale, Primula farinosa usually flowered earlier than did the small mutually isolated colonies of the same plant on the coast of Co. Durham.

In 1969 five winter buds of East Durham plants were taken from each of two colonies, a coastal site (A) at 50 ft., and an inland site (B) at 450 ft. They were transplanted to Rough Sike Enclosure near the Field Station at Moor House, for comparison with selected specimens of the native population (C) near the upper altitudinal limit of the species in Britain. A reciprocal transplant of Teesdale stock originally collected from Cetry Bank (D), had already been established at site B for 2 years and given consistent results. Mean dates for the opening of half the flowers on individual plants at sites B and C in 1970 were as follows:-

	Specimen			
Site	A	B	C	D
B	10/6	6/6	-	21/5
C	21/6	15/6	5/6	-

In both situations the flowering times of the upland and lowland plants would overlap sufficiently for cross pollination to occur.

The differences in rates of growth and development of the winter buds were greatly accentuated when grown under artificial conditions. The winter bud of Primula farinosa requires no prior frost treatment and opens to exhibit a sessile flower head the initials of which are formed at the end of the previous growing season. As the scape elongates a new vegetative shoot develops at its side and is well grown at the time of flowering. In artificially illuminated cabinets, particularly at higher temperatures, scapes of many of the plants only partially elongate and the flower buds fail to develop. A comparison of development rates of four specimens from A, B and D has therefore been based on the number of days taken for the mature winter bud to open sufficiently for the sessile capitum to be visible. Where scapes had reached their full extent, the times are appended in brackets

	18°C 18 hr. illumination	9°C 8 hr illumination
A	37	165 (273)
B	29	122 (240)
C	15 (34)	63 (147)

The fourfold difference between development rates over a gap of 9°C is too large to be explained purely by a temperature effect and points to a dependence on available light in even the earliest stages of growth.

Measurements of the rates of net photosynthesis by mature leaves of specimens A and D over a wide temperature range have given differences too small to account for the disparity between the development rates of their winter buds. Consequently the difference between the upland and lowland forms may reside in some way in which assimilates are utilised in growth.

i) Studies on periglacial activity - Project 6/10 (L. Tufnell, Cambridge College of Art and Technology)

Examination of periglacial phenomena and measurements of movement have been made by the author since 1965 when he was at the Geography Department, Newcastle University.

The main features examined have been : fossil congelifluction deposits, polygons, stripes, block fields, erected stones and screes. In 1970, particular attention has been given to the limestone screes of the upper parts of Knock Ore Gill. Other sites on the Reserve are on Little Dun Fell, Great Dun Fell and Knock Fell.

VIII. RESERVE MANAGEMENT

The main feature of the year has been the dryness of the fell during the early part of the summer, especially in June, when a number of sikes ceased flowing; Moss Burn and Nether Hearth Sike were two such streams. The vegetation on the higher fells, the Dun Fells in particular, was the most affected. On such an occasion, the greeness of the grasses in the exclosures on Little Dun Fell was very noticeable.

Whereas yet again weather conditions made it impossible to burn heather in early spring, a spectacular fire, which in places caught the peat, was started in June by lightning strike on the eastern slopes of Meldon Hill. Meldon is just outside the Reserve boundary, but it is a hill apparently prone to catastrophic phenomena, having had a similar peat fire earlier in the century and peat slides around 1850, early in this century and in 1962. The fire lasted for 16 days and some 400 acres was burnt, mostly in a manner similar to a normal heather fire but in parts the surface peat has been severly burnt. A report on this fire has been placed in the Reserve Record.

Rarely have deer been seen on the Reserve. In February, however, a roe deer was disturbed in the tree enclosure, by the house, and in June another was seen near to the source of the South Tyne. More roe deer have been seen in the neighbourhood than usual.

Some 15 foxes have been killed on the Reserve. Rabbits are common although myxomatosis has recently been noticed at Dorthgill, on the Garrigill side of the Reserve. Several pairs of Peregrine Falcons and Dotterel nested successfully in the district this year. Swallows, which nested in the outbuildings of Moor House last year returned and 7 young were reared. Also, for the second year blackbirds have built nests in the Lodgepole Pines of Nether Hearth tree enclosure. One hundred and thirty birds have been ringed during the year and a number of recoveries from last year were recorded.

There is little doubt that there is an increase in visitors to the Reserve each year, both in the winter (for ski-ing) and in summer. The west side of the Reserve receives the greatest attention by the public. The Pennine Way probably carries 30-40 people a day during July and August, whilst about 4,500 vehicles, excluding those concerned with the Board of Trade's Radio Station, have entered this part of the Reserve in the past year, with an average of 133 a week during the period May to September. 683 vehicles entered the area in August.

To overcome lack of wardening during the greater part of the year, leaflets are sold to the public through shops in fellside villages and at Garrigill. In the last 12 months, 206 leaflets on the Pennine Way, as it passes through the Reserve have been sold. A note prepared in collaboration with the Warden of the Teesdale National Nature Reserve on the birds of Teesdale is likewise available for sale.

On the east side of the Reserve, visitors, sometimes parties, frequently come to the Field Station especially at week-ends. A number of talks and slide shows have been given to such parties by the Warden, who has shown similar films to the Alston Young Farmers Club, the Over Sixties, Toc H and the Secondary School.

With the increase in fell walking and ski-ing it is inevitable that more people will get into difficulties, either on the Reserve or in its vicinity. Two skiers were lost temporarily in the winter, one skier broke a leg, two students were missing in April and distressed walkers have sought rest at the house. Thus the Penrith Mountain Rescue Team were invited to visit the Field Station to familiarise themselves with the area and discuss procedures.

The main estate work has once again been in maintaining and re-surfacing the access road from Garrigill. About 300 yards of road has been built up with material from Hardshins Mine and 23 loads of limestone quarry waste have been brought in to surface this and other parts of the road. Enclosure fences on Little Dun Fell, where even the strongest wire rarely lasts more than 5 years, have been repaired.

appendix 1

Staff List

Officer-in-Charge

M. Rawes (Senior Experimental Officer)

Scientific Staff

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

R. Williams (Assistant Experimental Officer)

R.B. Marsh (Scientific Assistant)

Miss V.R. Blanckley (Scientific Assistant I.B.P.)

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

Warden

T.L. Hodgson

Estate Worker

D.W. Craig (until April 1970)

P.L. Elliott (from June 1970)

Housekeeper

Mrs. M. Hodgson

Part-time Wardens

J. Rose (December - March)

A. Mason (1962 - June 1970)

Mr. Mason, who was a keeper on the Appleby Castle Estate until his retirement has for long been of great help to us. Having spent his earlier days at Birkdale, where his father was keeper, he knows the fells as well as anyone and better than most.

F.B.A. Staff

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

Dr. P. Armitage (Experimental Officer)

Miss S. Carrick (Scientific Assistant)

appendix 2

Publications

CLYMO, R.S. 1970. The growth of Sphagnum: methods of measurement. J. Ecol., 58, 13-49.

CRISP, D.T. & LE CREN, E.D. 1970. The temperature of three different small streams in North-West England. Hydrobiol., 35, 305-323.

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SPRINGETT, J.A., BRITTAIN, J.E. & SPRINGETT, B.P. 1970. Vertical movement of Enchytraeidae (Oligochaeta) in moorland soils. Oikos, 21, 16-21.

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TUFNELL, L. 1969. The range of periglacial phenomena in northern England. Biuletyn Peryglacjalny No. 19, 291-323.

WELCH, D. & EDDY, A. 1969. Bryophyte species list for the Moor House National Nature Reserve in Upper Teesdale. Trans. Northumb. Durham & Newctle. Nat. Hist. Soc., 17, 47-56.

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WHITTAKER, J.B. 1970. Cercopid spittle as a microhabitat. Oikos, 21, 59-64.

Ph.D. Durham

HOUSTON, K. 1970. Ecological studies on moorland ground beetles. Coleoptera: Carabidae.

Merlewood R & D Papers

GORE, A.J.P. 1969. Ecosystem Simulation. No. 12.

GORE, A.J.P. 1970. A method of estimating optimum sampling numbers with an application to productivity studies on vegetation. No. 18.

Meteorological Summary for Moor House 1969 (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	3.1	-1.2	0.2	5.9	9.9	14.2	16.0	15.9	12.6	12.4	3.3	2.2	7.9
Mean Minimum Temperature	°C	-0.9	-7.2	-4.1	-1.5	2.5	4.8	8.0	8.8	6.2	6.0	-2.3	-2.6	1.4
½ (Max. + Min.) Temperature	°C	1.1	-4.2	-1.9	2.2	6.2	9.5	12.0	12.3	9.4	9.2	0.5	-0.2	4.7
Highest Maximum Temperature	°C	7.8	3.9	5.0	14.4	14.4	19.4	23.3	21.7	17.8	19.4	11.7	6.7	23.3
Lowest Minimum Temperature	°C	-10.6	-18.3	-11.7	-8.3	-2.8	-4.4	2.8	1.7	0.0	0.0	-8.3	-8.3	-18.3
Lowest Maximum Temperature	°C	-0.6	-7.2	-2.2	1.1	3.3	8.3	11.7	10.0	6.7	5.6	-0.6	-3.3	-7.2
Highest Minimum Temperature	°C	6.1	0.6	1.1	3.9	8.3	10.6	12.8	13.9	11.7	10.6	7.2	2.8	13.9
Lowest Grass Min. Temperature	°C	-13.3	-20.0	-14.4	-11.1	-6.1	-4.4	-0.6	-1.7	-3.3	-3.3	-12.2	-12.2	-20.0
Av. Earth Temperature at 1 ft.	°C	1.7	1.0	0.6	1.4	6.4	10.1	11.8	12.8	11.0	9.1	4.2	1.7	6.1
Av. Vapour Pressure at 0900 GMT, mbs.		6.8	4.5	5.1	6.7	8.8	9.8	11.8	12.6	11.2	10.9	(6.6)	5.9	8.4
Av. Rel. Hum. at 0900 GMT,	%	97.0	92.5	94.1	88.8	87.7	75.1	82.0	84.3	89.5	90.5	(94.8)	95.8	89.3
Av. Dew Point at 0900 GMT,	°C	0.4	-4.8	2.4	1.0	4.8	6.5	9.1	10.0	8.2	7.8	(0.6)	-1.0	3.4
Av. Cloud Amount at 0900 GMT, oktas		7.2	5.7	7.1	5.6	6.9	5.5	6.3	5.7	6.6	6.1	6.3	6.4	6.3
Total Sunshine, hours		(11.5)	57.3	55.3	147.1	97.5	228.1	170.2	161.1	73.8	10.37	32.4	22.1	1160.1
Rainfall, inches		5.88	5.60	4.95	5.34	4.66	4.49	2.54	3.08	5.64	3.44	13.78	6.40	65.80
Greatest Daily Rainfall, inches		.96	.76	.94	1.03	.54	1.25	.52	.69	1.36	.54	1.64	1.82	1.82
Duration of Rainfall, hours						72.8	72.0	82.5	43.1	85.5	52.5			
No. Rain Days		28	24	25	19	27	14	18	17	16	20	27	18	253
No. Wet Days		25	16	18	15	20	12	13	13	16	14	25	14	201
Days with Snow or Sleet		11	25	16	8	1	0	0	0	1	0	16	12	90
Days with Snow lying at 0900 GMT		11	28	31	8	0	0	0	0	0	0	20	12	110
Days with Hail		4	2	4	7	1	0	1	1	0	0	5	1	26
Days when thunder heard		0	0	0	0	1	2	0	1	0	0	0	0	4
Days with Fog at 0900 GMT		8	7	9	2	5	1	7	2	1	6	6	4	58
Days with Air Frost		20	27	30	21	7	2	0	0	1	1	24	23	156
Days with Ground Frost		20	28	30	23	12	11	3	1	6	4	25	24	187
Av. Wind Speed, knots (anaemograph record)		13.5	17.7	15.6	11.9	9.7	9.7	12.9	10.8	12.1	15.9	17.3	14.3	13.5
Days with Gale		3	3	1	3	0	0	3	0	5	4	5	3	
Total snow fall at station, inches		3	88	105	12	0	0	0	0	0	0	86	8	302
Maximum snow depth at station, inches		2	10	14	10	0	0	0	0	0	0	17	5	17
Potential Evaporation Data for Apr./Sept.														
Potential Evaporation, inches					(0.4)	1.8	3.1	2.9	2.6	1.1				
Rainfall, inches					5.3	4.7	4.5	2.5	3.1	5.6				
Potential Water Deficit, inches					0.1	0.3	1.4	0.9	1.2	0.4				
Potential Water Surplus, inches					5.0	3.2	2.8	0.5	1.7	4.9				

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

Meteorological Summary for Great Dun Fell 1969

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	1.2	-3.7	-1.7	3.2	7.5	12.1	13.0	13.5	10.5	9.9	0.3	0.0	5.5
Mean Minimum Temperature	°C	-1.1	-6.5	-4.9	-1.8	1.7	4.8	7.3	7.9	6.1	5.3	-3.2	-3.3	1.0
½ (Max. + Min.) Temperature	°C	-0.1	-5.1	-3.3	0.7	4.6	8.5	10.1	10.6	8.3	7.6	-1.5	-1.7	3.3
Highest Maximum Temperature	°C	6.3	1.2	5.5	11.2	12.1	22.8	22.0	19.0	16.2	17.7	9.9	5.2	22.8
Lowest Minimum Temperature	°C	-6.6	-13.5	-7.4	-6.6	-3.5	-1.5	2.0	2.1	0.0	-1.5	-9.8	-11.0	-13.5
Lowest Maximum Temperature	°C	-2.5	-9.5	-4.2	-1.1	2.6	5.1	8.0	7.0	4.5	3.6	-8.1	-6.4	-9.5
Highest Minimum Temperature	°C	4.7	-1.0	0.2	1.0	6.1	9.2	13.0	12.4	9.4	9.2	4.3	0.4	13.0
Total sunshine, hours		13.7	52.8	62.2	123.5	67.9	197.5	117.0	122.6	57.2	71.1	29.2	20.8	935.5
Days with snow or sleet		(21)	(22)	(19)	(17)	(8)	0	(0)	0	(1)	(1)	(25)	(15)	(129)
Days with snow lying		23	28	31	11	1	0	-	0	0	0	24	16	134
Days with hail		-	-	-	(7)	(2)	0	-	0	-	-	(1)	-	(10)
Days with thunder		-	-	-	-	-	0	-	(2)	-	-	(0)	-	(2)
Days with fog at 0900 GMT		24	19	24	13	18	9	19	13	22	22	23	20	226
Days with air frost		23	28	29	25	9	2	0	0	0	3	27	29	175
Days with gale		(8)	(7)	(10)	(10)	(3)	1	(6)	(3)	(12)	(15)	(8)	(8)	(91)
Av. hourly wind speed		17.7	21.6	19.6	17.4	13.4	14.1	18.1	14.7	18.7	21.7	20.3	18.4	18.0
Greatest snow depth, inches		6	9	10	8	0	0	0	0	0	0	7	4	10

NOTE: Maximum temperature is from 9h. to 21h.
Minimum temperature is from 21h. to 9h.