

THE NATURE CONSERVANCY

MOOR HOUSE FIELD STATION

Annual Progress Report

M. Rawes

Correction

Pages 25 and 26 have been put in wrong order

Page 25 should be 26

Page 26 should be 25

Natural Environment Research Council,  
The Nature Conservancy,  
Moor House Field Station,  
Garrigill,  
Alston,  
Cumberland.

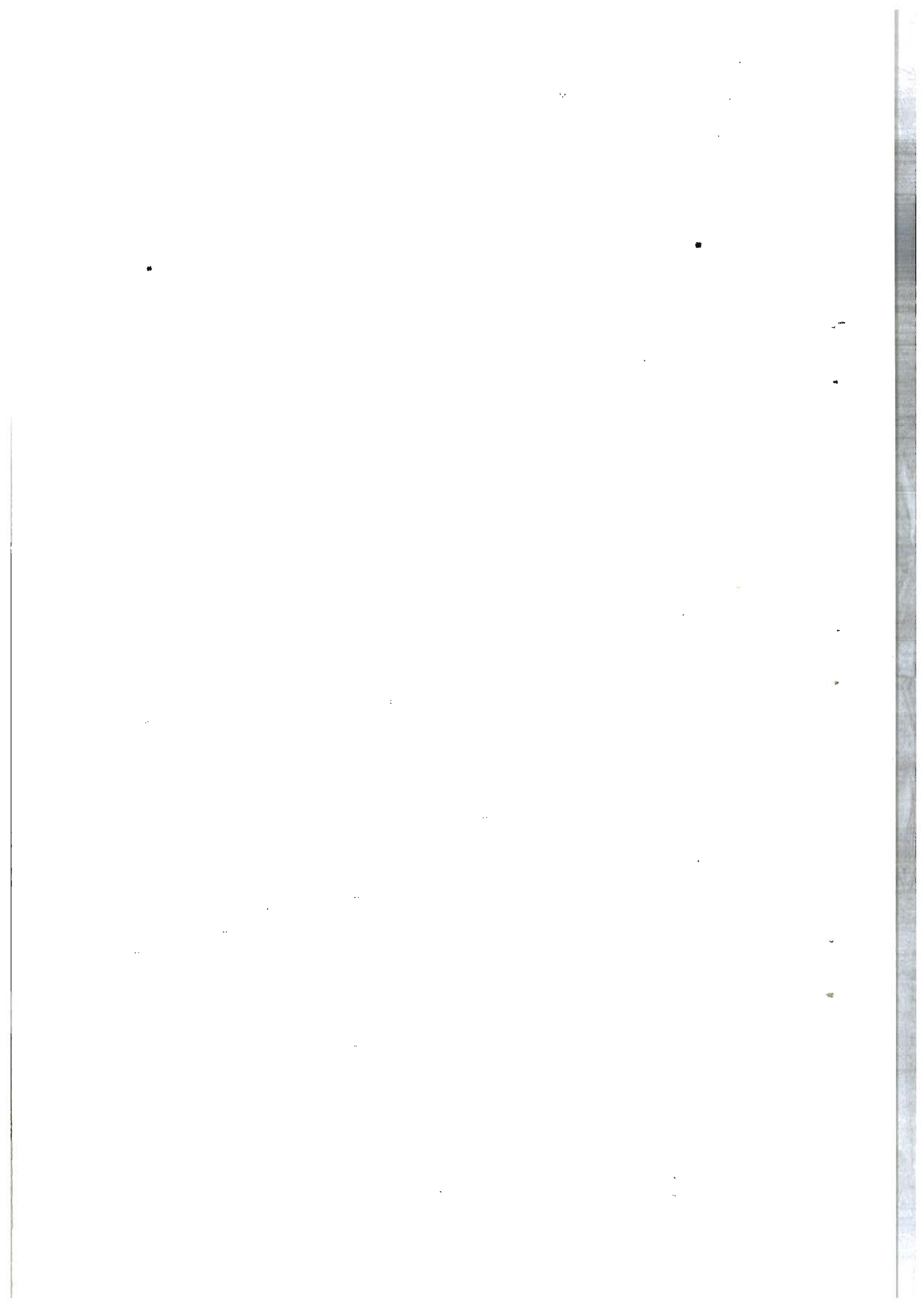
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Alston 435

*With the Compliments of*

Officer In Charge,  
Moor House Field Station.

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## MOOR HOUSE

### 10th. Annual Progress Report

by M. Rawes

#### I. GENERAL

This Report covers the period 1 October, 1968 - 30 September, 1969. The style differs slightly from previous reports. In future, more account will be taken of events that affect and have taken place on the Reserve. An attempt is made to collate the research reports by grouping them under directional responsibility, whilst, where possible, we hope to make the programme more referable to the conservation interests of the North Region and the Conservancy generally.

Staff research is mainly concerned with the effects of sheep grazing, moorland management and human impact. Reports on the individual International Biological Programme studies follow, with a summary on the whole project, by Dr. Heal, the Co-ordinator. Research reports by Merlewood staff, the Freshwater Biological Association, other organisations and by Universities follow. The attempts that are being made to bring Moor House I.B.P. project into closer contact with international projects, in particular as a member of the Tundra group, are an example we hope will be followed elsewhere. However, much of the research at Moor House has, in the past, been done by Universities, and the independent lines that have been pursued, have provided the Reserve with its excellent background of biological information. The continuation of University links is much valued.

An aspect of Reserve management, that is common to much land management, is the problem of the increase in public pressure. Also, there has been a proportionate increase in interest in the work at Moor House. Both these aspects make large demands on staff resources. To meet the increase in visitors, footpaths are being marked, Reserve signs altered and leaflets prepared. A leaflet on the Pennine Way, as it passes through the Reserve, is sold through local shops and a further edition of the Reserve pamphlet has been published. A number of people have visited the Nature Trail sited by the Field Station. Two "visiting days", 12 July and 20 September, were organised and about 300 people, mainly from the northern counties, but some from further afield, visited the Station. Demonstrations illustrating two aspects of research - the sheep:vegetation studies and primary production aspects of the I.B.P. project were on view in the laboratory together with displays of information about the Reserve and the Nature Conservancy. Field demonstrations of sheep work and electro-fishing by the F.B.A. were arranged and parties were conducted around experimental sites.

M.W. Read resigned on 30 September and Miss S. Carrick (I.B.P.) in July. The I.B.P. vacancy has been filled by Miss V. Blanckley. Dr. D.T. Crisp, previously a member of the Moor House staff and now with the Freshwater Biological Association, has been given laboratory facilities and is continuing his freshwater survey (see p. 33) of the Tees, and eventually the Cow Green Reservoir. Miss Carrick is his assistant.

## II. SERVICES AND CLIMATOLOGY

Regular attention is given to recording instruments for the I.B.P. project, F.B.A., Durham University and the Northumbrian River Authority. Data have been provided and facilities utilised by a variety of organisations and individual research workers. The Central Electricity Generating Board for instance, have at Moor House, as part of a country-wide survey, a material under atmospheric test. The availability of accurate climatological information is, of course, a prerequisite for the choice of sites in this type of survey.

### a) Climatology (R.B. Marsh)

Averages are given for 1968 in appendix 3. There are now 17 years of complete records for the Station. The year covered by the report has been characterised by extremes in snow-lie, temperature, rain and wind. Snow was exceptionally heavy, lying for 94 days compared with the annual average of 68 days (based on 15 years of recording) and 97 days in the winter of 1962-63, the severest since records have been kept at Moor House.

Spring was later than usual but in the late summer it was warmer and drier than average. In July and August the average temperature was more than a degree centigrade higher than usual, while during the period, July - September, rainfall was 320 mm less than average, and, for the whole year, 410 mm below the average, of 1960 mm.

## III. STAFF RESEARCH

### a) Studies on the interactions between sheep and vegetation (M. Rawes, M.W. Read, R.B. Marsh and Miss. L. Teasdale)

Research on the effects of sheep grazing has been in progress for 14 years and there have been a number of related studies, previously reported separately. These are now brought together under the one project heading, this project being the main topic of permanent staff research.

The aim is to study, and eventually predict, the effects on habitats of changes in sheep management, with particular reference to the productivity and botanical composition of hill vegetation. There are three main facets of study.

1. No grazing
2. The present free-range grazing regime
3. Modified grazing regime.

1. No grazing

Exclosures have been erected on a number of swards representative of the more widespread or sheep-important vegetation types of the Reserve. Changes have been followed by measuring standing crop and botanical composition (Welch & Rawes, 1964, *J. appl. Ecol.*). During the present year species cover in a few permanent quadrats has been re-examined in two of the earliest grassland exclosures. The changes observed indicate that a more intensive investigation is due.

2. The present free-range grazing regime

An account of the amount of herbage produced and eaten by sheep, and the distribution and live-weight production of the sheep has been given in Rawes & Welch, 1969, *Oikos*. There remain gaps in knowledge; an understanding of species and sward reaction to grazing (defoliation), manuring and treading at differing intensities and times of year; of the effects of different animal behaviour; and of food eaten and the determinants of intake.

The studies therefore comprise:

- (a) long-term field measurements, normally on swards with a permanent recording grid where botanical composition is assessed periodically and
- (b) small studies in which plant competition and defoliation effects are measured and palatability and intake values obtained.

a) Botanical change is followed by point quadrat, species presence and charting methods. During the current year charts of a scale 1:2 and 1:4 have been re-drawn after an interval of two years. Cover of Juncus squarrosus, Nardus stricta and Calluna is being followed in a number of swards. There appears to be little change in Juncus except on blanket bog where it has increased. Nardus seems to have increased generally, but Calluna growing in an alluvial Agrostu-Festucetum shows no change.

b) A study on herbage digestibility, undertaken with the assistance of P. Taylor (Leicester University), produced data from penned sheep of intake and digestibility of Calluna and Eriophorum vaginatum using hay as a standard feed for comparison. Daily intake was found to average 800 g dry wt. for the moorland species compared with 1000 g of hay. Individual sheep live-weight varied from 35-40 kg. Food to dung ratios (dry wt.) varied from 2:1 with Calluna, 2.4:1 with Eriophorum and 2.6:1 with hay. Ash content of the faeces is closely related to the food consumed and when sheep were restricted to different swards the content varied from 3.5% on blanket bog to 10.7% Agrostu-Festucetum, with 4.6% when grazing Juncetum squarrosi.

Other trials have been made to assess dung distribution and methods of measuring rates of decomposition.

### 3. Modified grazing regimes.

It is usual to enclose swards and apply stocking treatments to show the effect of differing grazing pressures. Small scale trials simulating grazing can also be adopted and it is probable that in the absence of large experimental (controlled) areas a combination of methods is required; this is because the small size and the restriction in feed variety that enclosed plots provide results in a grazing behaviour peculiar to the enclosure not to that of the sward type when it is part of a free-range system. However, in the absence of a more satisfactory method enclosures are being used.

#### a) The reaction of blanket bog to increased grazing.

This trial was started in 1968 with the intention of creating a change in bog vegetation, a sward of *Juncetum squarrosi* in the place of *Calluneto-Eriophoretum*. This was to test the hypothesis of Welch & Rawes (1966, Ir. J. Agric. Res.) that increased sheep grazing led to the introduction of *Juncus squarrosus* and the development of a *Juncetum squarrosi* on blanket bog.

A number of fenced plots were erected and a programme of light and heavy stocking rates with burning and draining treatments started.

In 1969, the amount of vegetation available for sheep in the heavily grazed plots has been small; grazing was deferred until late June (April in 1968) and only 570 sheep hours have been possible compared with 2660 in 1968. It is unlikely that the plots will be grazed much more this year.

The present plans are for the plots to be examined next year, botanical and other measurements repeated and the trial terminated.

#### b) Study on the establishment of *Juncus squarrosus* on blanket bog

This investigation is linked also with the hypothesis on seral succession and grazing pressure and involves small plots in which micro-habitat variables, such as competition and compaction of the surface, are being tested. Two sites were chosen, one with *Juncus* already present in small amounts and the other where it is absent. The treatments are cutting, treading and seeding. Counts of seedling presence in August showed that cutting, and especially treading provided good conditions for seedling establishment, whilst very few survivals were recorded on the otherwise untreated bog. The site without *Juncus* plants gave the best results. Charts of the mature *Juncus* plants do not, as yet, show that any significant change has taken place under differing treatment.

The study will continue for another year.



b) The establishment of natural grassland communities (M. Rawes, and Miss L. Teasdale)

The aim of this study is to create a number of ungrazed swards, similar to natural communities. A number of plant species, either absent or rare on the Reserve, were planted and their survival, and in some cases, performance has been recorded annually over the past 13 years. The most extensive planting has been in the largest enclosures, Rough Sike, near the Field Station.

It has been a particularly good year for the angiosperms. Among the naturally occurring species, Primula farinosa, Galium boreale, Saxifraga hypnoides, Hieracium spp., Alchemilla glabra and Veronica officinalis have flowered profusely and increased their coverage. Of the introduced plants, Polygonum viviparum and Draba incana (many seedlings) have grown particularly well, whilst although the Salix spp. showed promise (and the first seedlings have been found) caterpillar attack has almost completely defoliated some.

Measurements of the leaf size in Alchemilla alpina have continued. A number of plants, grown at first under the protection of a fence, have been open to sheep. The plants have been grazed but remain alive.

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

10 grass species and 40 varieties have been tested over a period of two years for survival and some aspects of performance. In the spring of 1969, the outstanding species was Poa pratensis, the varieties Fylking, Newport and Commercial all growing well, Festuca rubra also survived the winter well, Ello, Rainier and Monmersteegs being good varieties. With Phleum pratense, S.48 was the best whilst S.24 was more hardy than S.23 in the Lolium perenne strains.

The plants were cut, dried and weighed in August. The heaviest yield was from Festuca rubra (Rainier), which, however, had a very high flowering stem to leaf ratio (48:1). Most leaf was given by Alopecurus pratensis (Moor House seed) with flower to leaf ratio of 1:1 and a total yield similar to the average of all plants under test. Poa pratensis proved a difficult plant to differentiate because of its rhizomatous growth. The yields appear to be average in all varieties with a flower to leaf ratio of ~~35:1~~ Lolium perenne gave below average yields, but it is a palatable species and agriculturally important.

The survival, under grazing, of Lolium perenne (S.23 and S.24), Poa pratensis (Fylking) and Festuca rubra (Ello) is being followed and a number of varieties are being tested further in a re-seeding trial at Redesdale Experimental Husbandry Hill Farm.

d) The effects of ski-ing (M. Rawes and M. W. Read).

Some 200 ha of Great Dun Fell has been designated an area on which ski-ing, under licence, will be permitted for a trial period. During this period of 3 years some effects of ski-ing are being assessed.

The investigation is divided into examination of

- 1) Number, distribution and habits of skiers and associated people.
- 2) Number of vehicles.
- 3) Litter and damage records.
- 4) Botanical effects.
- 5) Trampling effects.

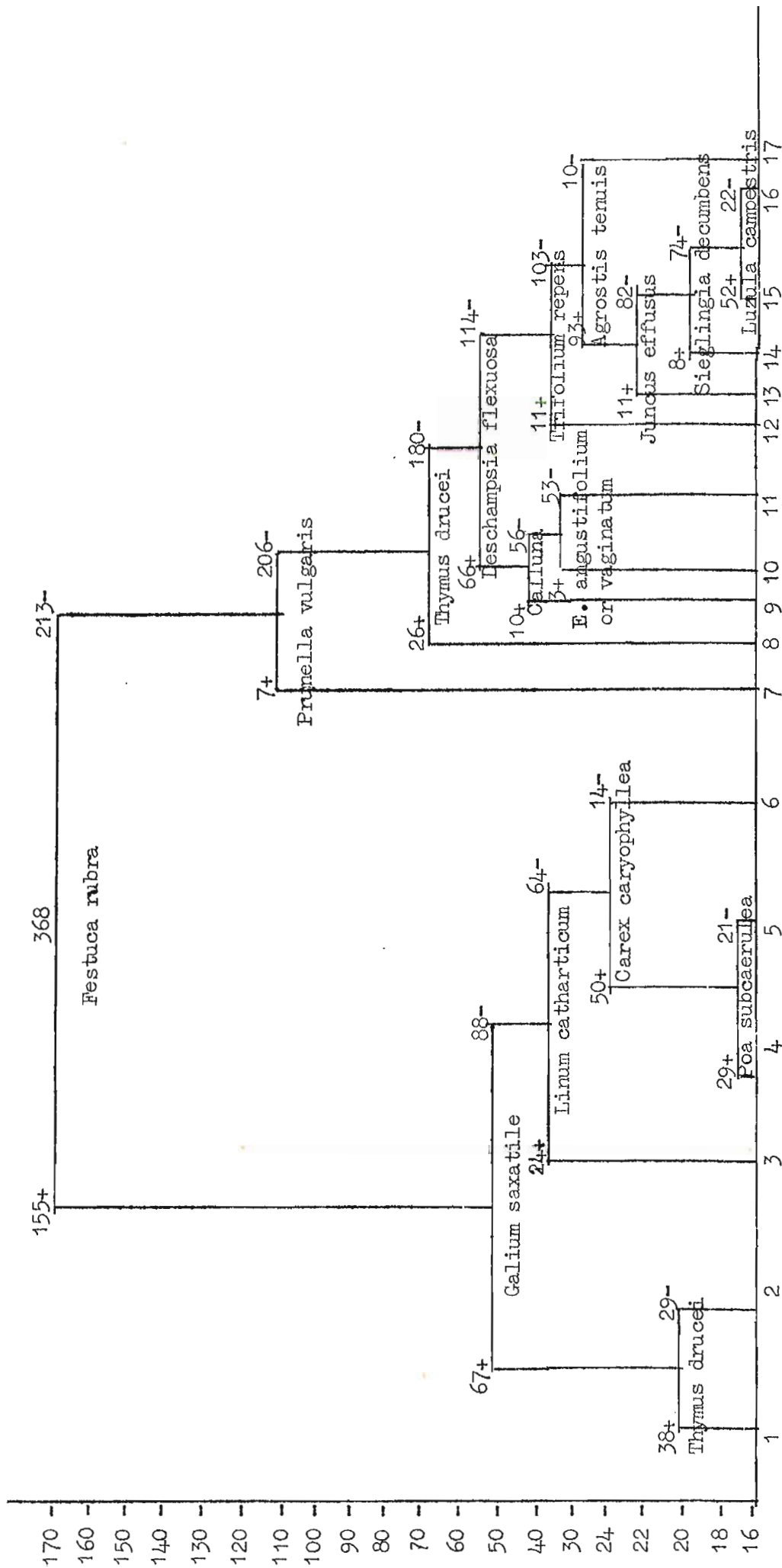
Most of the behaviour information is noted on daily recording sheets and the number of vehicles are recorded with car counters, one at the entrance to the Reserve and the other on the route to the car park. The two most used ski-runs, an east-facing gully, and, on the west side of Dun Fell, a gully sloping in a south-west direction, have been chosen for botanical examination. Floristic composition is recorded, using photography and species presence within 50  $\frac{1}{2}$ m<sup>2</sup> plots, while a combination of photography and plant association analysis is being employed by B. Grimes and J. Dale. A pilot trial to assess the influence of compacting snow, by treading, inferred that there were likely to be significant effects in sward composition the following summer. The average growth and number of capsules of Polytrichum commune in blanket bog were halved and the amount of dead moss doubled. Some effect was shown with Agrost-Festucetum and the soil temperatures (sugar method, J. Horobin) in both soils were probably significantly lower.

e) A study of variation in limestone grassland (M.W. Read,  
M.Sc. Study)

The investigation is of floristic variation in Agrost-Festuceta developed on soils over limestone. Species presence in 0.5 m<sup>2</sup> quadrats was recorded using a systematic site lay-out.

The data collected in 1968 have been subjected to a normal association analysis (carried out at Southampton University by Dr. Bunce of Merlewood), as a preliminary step in interpreting the sample variation. The results are presented as a dendrogram, the division beyond the  $\chi^2$  level of 16 not being shown. Of the species showing associations Festuca rubra, was the most frequent and 155 quadrats containing it were extracted first. In these Galium saxatile was the most frequent species. Successive correlations are made and further analyses will be attempted. A table of the species frequencies is available for consultation.

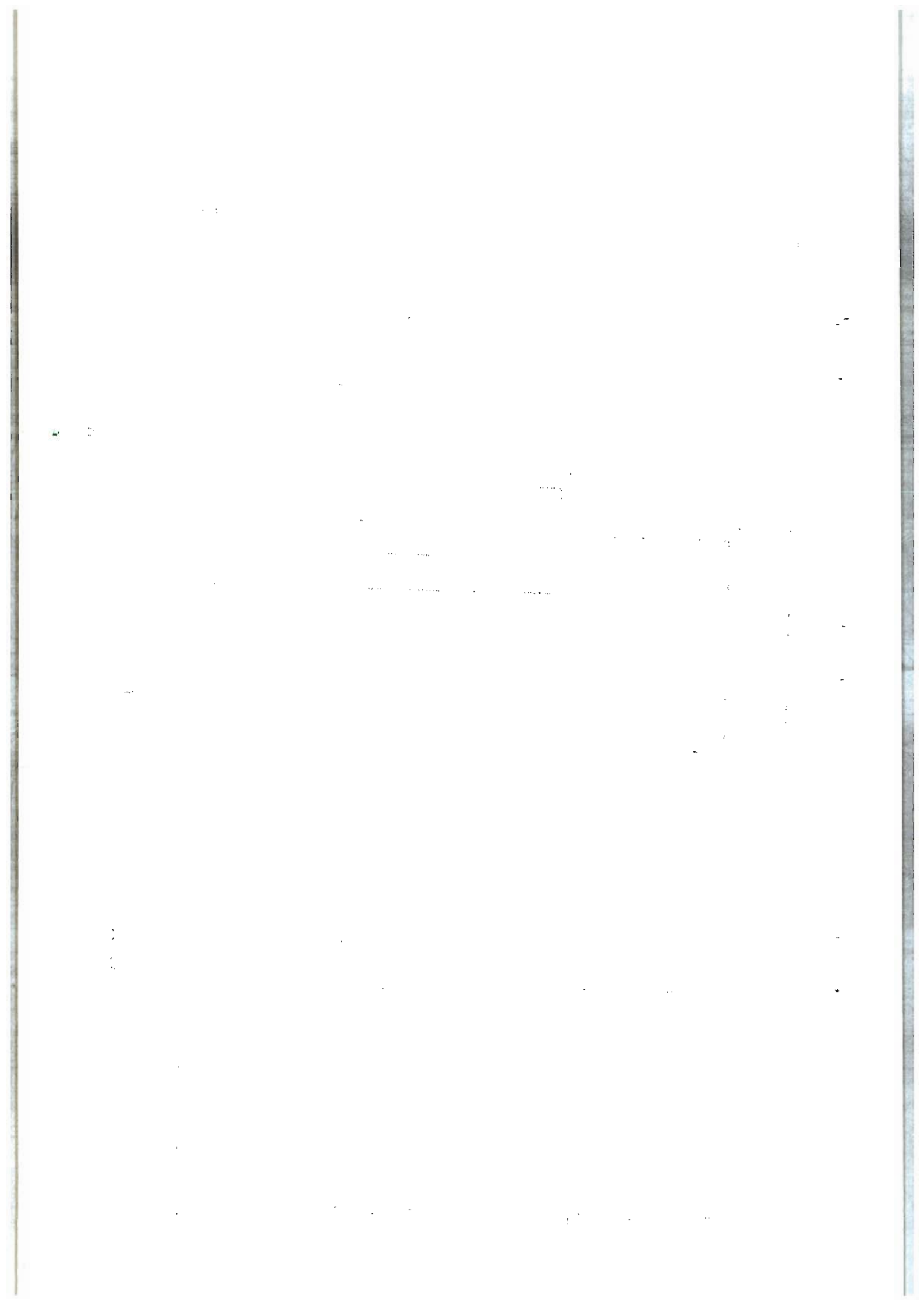
Normal association analysis of non-alluvial Agrost-Festucetum grasslands



1..... 17 = Groups defined at  $\chi^2$  level 16.

+ or - = indicates presence or absence of species determining the subdivision.

n = indicates number of quadrats assigned to a group.



#### IV INTERNATIONAL BIOLOGICAL PROGRAMME

##### Introduction (O. W. Heal)

During the last 12 months one of the main developments has been the improvement in contact and co-operation within the Moor House project, between British projects, and internationally. For example, Barbara T. D'Sylva and N. Martin carried out a joint sampling for bacteria to clarify the effect of differences in their techniques; G. I. Forrest and J. Grace are working closely to enable field estimates of primary production to be used to test the validity of the model being developed from controlled environment data; Helen Jones is using models developed by A. J. P. Gore and applying them to G. I. Forrest's data; J. Grace is co-operating with Helen Jones and A. J. P. Gore on the linking of their models; temperature data collected by O. W. Heal are being used by J. Horobin and J. Grace; Valerie Standen and Pamela Latter are comparing feeding and production studies on Enchytraeids.

At a national level a first attempt has been made to compare primary production data from Calluna dominated sites at Banchory (Scotland), Dorset (South England) and Moor House (Northern England); invertebrate collections from these three areas are being examined by J. B. Whittaker; Barbara T. D'Sylva is starting work on nitrogen fixation at Moor House and Meathop Wood. At an international level J. S. Brown, (U.S.A.) and S. Kejelvik (Norway) visited Moor House to discuss comparisons with other Tundra sites and details of methods; J. Baker (British Antarctic Survey) has spent three weeks at Kevo (Finland) starting some microbiological work which links with Moor House and the Antarctic. Calluna samples were sent from Norway to J. B. Whittaker to examine for psyllids; G. I. Forrest and O. W. Heal visited the Glenamoy Project in Ireland; O. W. Heal visited Sweden for discussion on the development of the Swedish Tundra project and was also present at discussions on the setting up of the Canadian Tundra project.

These developments are essential to the functioning of IBP and every attempt should be made to improve co-operation at a research level. This is essential because much of the research requires the linking of various components of the ecosystem, and there is a strong development now towards synthesis within Moor House and between projects nationally and internationally. Every effort should be made to overcome the limited contact which results from the Moor House participants being spread between nine universities and research stations.

Other developments during the year have also been welcome. Representatives of the U.K. PT Sub-Committee, Dr. C. G. Johnson and Professor P. J. Newbould, attended a meeting of the Moor House group and reported on the state of the programme as a whole. Their report, which was circulated, gave a satisfactory picture of the work and partly as a result of this, grants to A. J. Holding and V. G. Collins were extended. The work on mites by W. C. Block has received very limited financial support, but we hope that the work can be continued

at a reduced level. One project, on potassium circulation, has been dropped because of lack of funds, but as a result, Helen Jones has now started work with A. J. P. Gore on mathematical models to simulate primary production at Moor House. Another valuable addition to the programme took place when Diane and Peter Evans (Durham University) started to estimate small mammal populations.

The only unsatisfactory feature during the year has been the failure of the solar radiation recording. A Lintronic Solarimeter and Recorder was installed in April to replace the Kipp Solarimeter and Kent Recorder, but a series of faults have prevented good data being obtained. The Grant temperature recorder has continued to work satisfactorily and data from 29.4.68 to 16.2.69 are available on punch tape. Some of these have been translated on to card by J. Grace and J. Horobin. Data from 16.2.69 to the present will be processed as soon as possible. A set of punched cards with daily meteorological data from 1959 to 1968, inclusive, are now available.

a) Primary production of Blanket Bog (G.I. Forrest)

## 1. Primary production on Sike Hill.

Studies on production of Eriophorum vaginatum tussocks and on litterfall of Calluna have been completed.

(i) Eriophorum vaginatum

Growth was divisible into 3 main periods (shown in Fig 1). Assuming a steady state, the dry weight production was about 220 g/m<sup>2</sup>/yr. Of the total dry matter assimilated, only 25% was ultimately retained as "aerial" leaves: 63% was converted to components of the shoot-base layer, and 12% to roots. Major sources of variation were tussock density and age of rhizomes. Root growth, which was followed in the shoot-base layer and through three 10 cm horizons, showed 2 peaks, in July and in December. The mean rate of root growth in summer was estimated, by the successive rate of appearance of the peak in the different horizons, as 1 cm/day. The turnover rate from white to yellow roots was 1 - 2 months.

(ii) Calluna litterfall

Total litterfall, was 108 g/m<sup>2</sup>/yr., Table 1 summarises some of the data.

Table 1 - Litterfall of Calluna on Sike Hill, 1968-69

No litter fell in Feb. - Mar. due to snow-cover

		Short shoots	Long shoots	Stems	Flower buds	Flower capsules	Total
Weights g/m <sup>2</sup> .	Aug	4.29	2.42	1.52	0.03	0.03	8.29
	Sep.	5.33	1.54	2.68	0.14	0.18	9.87
	Oct.	5.84	2.21	0.72	0.06	1.46	10.29
	Nov.	2.57	1.29	2.05	0.03	1.65	7.59
	Dec.	3.70	2.24	3.83	0.02	1.52	11.30
	Jan.	2.16	2.37	7.47	0.01	2.46	14.47
	Apr.	3.37	2.72	3.18	0.02	1.32	10.60
	May.	1.97	1.60	1.27	0.02	0.36	5.22
Total wt	Jun	6.04	3.47	3.74	-	0.77	14.02
	Jul	<u>5.54</u>	<u>3.93</u>	<u>6.50</u>	<u>..</u>	<u>0.61</u>	<u>16.58</u>
	g/m <sup>2</sup>	40.81	23.79	32.96	0.33	10.36	108.23
Total wt	/m <sup>2</sup>	29184	4188	2020	700	8352	44444

There was reduced fall of short shoots in winter, when the peaks in capsule and stem-fall occurred. Over the year the numbers of short shoots, as a percentage of the total components, were almost exactly the inverse of the numbers of capsules, each forming about 45% in mid-winter. The period of maximum litterfall was coincident with the period of maximal growth of young green shoots - it is suggested that this may be a causal relationship; a secondary maximum occurred in winter and was largely due to the greater size of stem fragments broken off by gales.

## (iii) Total primary production

See Table 2; total production of 615 g/m<sup>2</sup>/yr from a standing crop of 2200 g/m<sup>2</sup> gave a mean biomass accumulation ratio of 3.6. Estimates of "production" for the standing dead and below ground categories of Calluna were based on regressions of biomass on time. Lichen production was estimated by two similar methods involving separation of individual plants into different years' growth, assuming annual polychotomy: each method showed that 50% of the biomass of Cladonia impexa was 0 - 7 years old.

Table 2 - Primary production and biomass on Sike Hill, 1968.

	Mean summer biomass, g/m <sup>2</sup>	Production g/m <sup>2</sup> /yr
<u>Calluna vulgaris</u>		
green shoots	230	110
wood	430	60
standing dead	200	120
litter	--	108
below-ground	<u>740</u>	<u>160</u>
Total	1600	<u>330</u>
<u>Eriophorum vaginatum</u>		
above-ground	151	56
shoot-bases	254	137
roots	<u>74</u>	<u>26</u>
Total	479	<u>219</u>
<u>Empetrum nigrum</u>	50	20
<u>Rubus chamaemorus</u>	2	2
<u>Vaccinium myrtillus</u>	0.3	0.2
<u>Listera cordata</u>	0.3	0.3
Total vascular species	2132	572
<u>Sphagnum</u> spp.	(cover 15%)	c. 40*
Other Bryophytes	3	3
Lichens	40	3
GRAND TOTAL (approx)	2200	<u>615</u>

\*Estimated from data of Dr. R.S. Clymo.

(iv) Calluna production estimates from regression techniques and population age-structure.

The age structure of the Sike Hill Calluna was derived by measurement of stem diameter and by the regression of age on mean basal diameter, as measured by growth ring counts. Further regressions of dry weight of green shoots and of wood on age, enabled the biomass of shoots and of wood to be estimated for a given age-structure.



The regression equations were:-

$$\text{age} = 76.52 (\bar{d}) + 1.22 \quad (r = 0.86)$$

$$\log (\text{dry wt. of green shoots}) = 2.0732 \log (\text{age}) - 2.0829 \quad (r = 0.884)$$

$$\log (\text{dry wt. of wood}) = 2.3970 \log (\text{age}) - 2.1372 \quad (r = 0.931)$$

where  $\bar{d}$  is the mean basal diameter of the stem in inches and  $r$  is the correlation coefficient. The modal age of the population, based on measurement of 5517 stems, was 8 years, the mean age 12 years. Annual shoot production was estimated as  $110 \text{ g/m}^2$  and annual wood production was estimated as  $60 \text{ g/m}^2$ . The most productive part of the population was that in the age-class 10 - 20 years old.

A relationship was derived enabling the dry weight of a Calluna stand to be calculated from the stem density and the basal diameters of the stems:

$$\log (\text{DW}) = 0.78 \log (\bar{N}\bar{d}^2) + 2.53 \quad (r = 0.87)$$

Where DW is the dry wt in  $\text{g}/\frac{1}{2}\text{m}^2$ ,  $N$  is the number of stems per  $\frac{1}{2} \text{ m}^2$ , and  $\bar{d}$  is the overall mean diameter of the stem bases in inches. This relationship has been found to hold on three separate sites differing markedly in wetness and in stem density and age.

Contingency table analysis showed significant differences in age-structure in only one direction across the sampling area; this was largely due to localised clusters of regeneration by young plants.

Regressions have also been obtained for Empetrum. The growth trajectory for total Empetrum wt was very similar to that for Calluna green shoot wt. In both spp the ratio of green shoots to wood fell towards an asymptotic value with increasing age (Calluna: 0.69 at 1 yr falling towards 0.43 after 35 years; Empetrum: 2.83 at 1 yr, falling towards 1.03 after 35 years).

## 2. Primary production on 3 sites, 1969.

Production is being measured on 3 sites (Sike Hill, for inter-year comparison; Bog Hill, moderately wet; and Green Burn, very wet) using four sampling times with  $15 \frac{1}{2} \text{ m}^2$  quadrats per site per time. Table 3 compares some site parameters; a major differential is the very active Sphagnum growth at Green Burn, leading to overgrowing of Calluna and hence a reduction in the apparent age-structure.

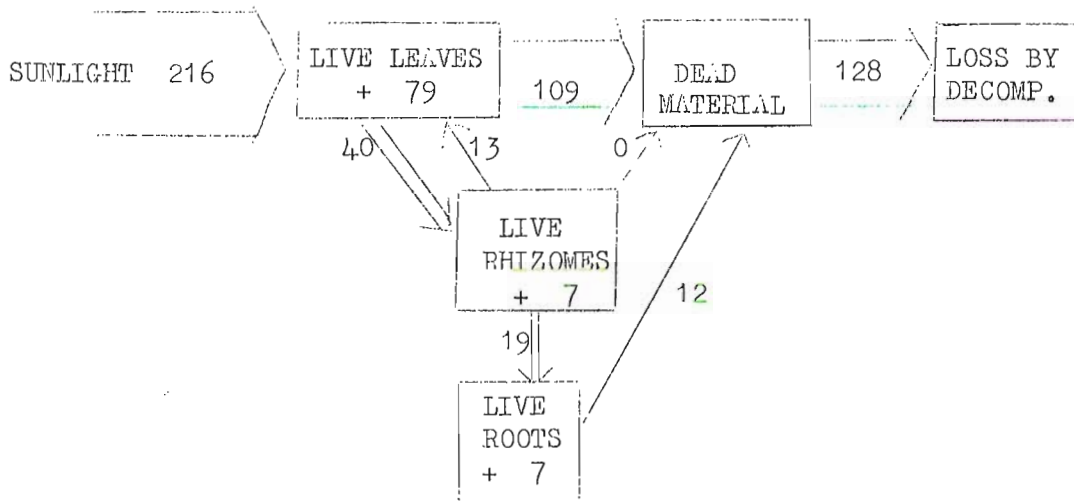
The dominant Sphagnum is S. magellanicum, the growth of which is being measured by the cranked-wire method of Dr. Clymo: during May-July the mean increment on lawns was 0.67 cm and on hummocks 0.77 cm.

Table 3 - Comparison of three sites, June, 1969.

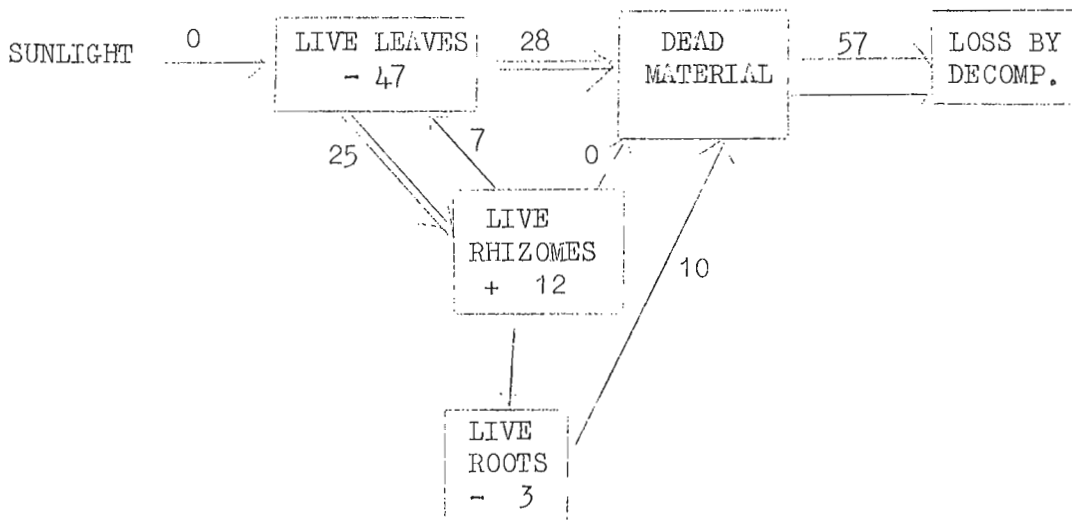
	<u>Sike Hill</u>	<u>Bog Hill</u>	<u>Green Burn</u>
<u>Calluna</u> live, g/m <sup>2</sup>	610	638	419
green shoots, g/m <sup>2</sup>	148	165	130
total aboveground, g/m <sup>2</sup>	911	948	584
litterfall, May-July, g/m <sup>2</sup>	25	41	22
modal age, years	7	11	2
mean age, years	9	11	6
No stems/m <sup>2</sup>	173	159	343
<u>Eriophorum vaginatum</u> g/m <sup>2</sup>	42	57	32
Total above-ground, g/m <sup>2</sup>	972	1016	634
Live below-ground, g/m <sup>2</sup>	773	536	470
Below-ground/Above-ground, live shrubs	1.24	0.83	1.08
<u>Sphagnum</u> cover	62	52	80

FIG. 1 -- Seasonal conversions of dry matter in tussocks of *Eriophorum vaginatum* (simplified)  
 Arrows show conversion in g.DM/m<sup>2</sup>. Figures in boxes show net production or loss in the period in g.DM/m<sup>2</sup>.

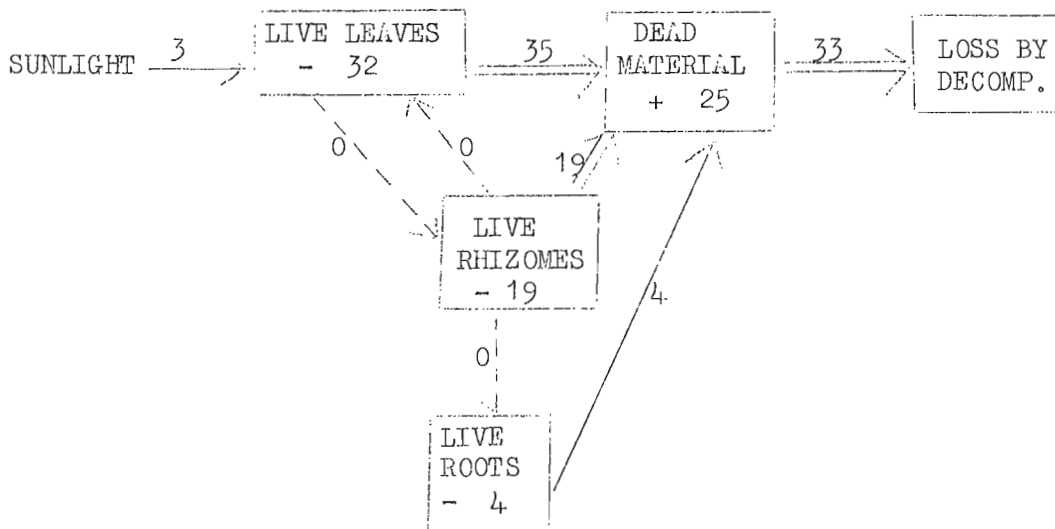
(A) MAY-SEP. (5 months)

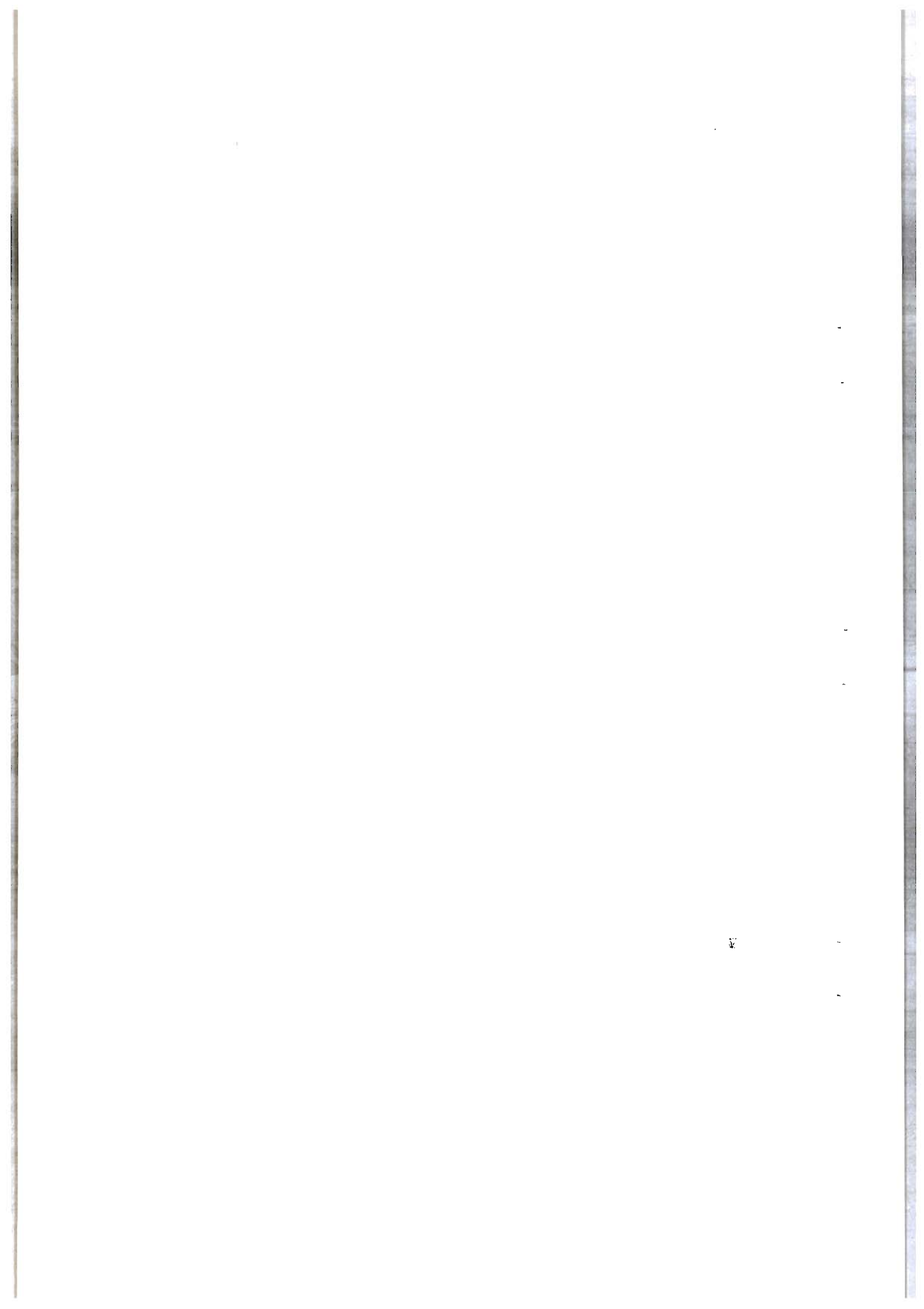


(B) OCT -JAN. (4 months)



(C) FEB.-APR. (3 months)





b) Production of Sphagnum (E.J.F. Reddaway & R.S. Clymo,  
Department of Botany, Westfield College)

1. Records of microclimate were continued on Burnt Hill, these include temperatures, solar radiation, rainfall, water level in a bog pool, and wetness of Sphagnum surface. Improved sensors for wetness have performed much better (since April, 1969) than the old ones. Conductance of water in the bog pool was also measured from April, 1969. By the end of the year about  $3 \times 10^5$  records should have been obtained. The programmes for dealing with these data are nearly complete.

The Grant recorder has performed very satisfactorily, apart from two brief breaks.

2. A complete season's growth of Sphagnum has been followed. In 1967/68 net production on Burnt Hill was  $1.1 - 2.6 \text{ t ha}^{-1}$  ( $\text{t} = 1000 \text{ kg}$ ) measured on plants cut to known initial length, depending on species and site. These estimates are rather lower than those for 1963/64 (Clymo, in press, J. Ecol.). Measurements by cranked wire on S. rubellum at the same site gave similar estimates; up to  $2.3 \text{ t ha}^{-1}$  in the healthy clumps. This compares with  $2.2$  and  $2.0 \text{ t ha}^{-1}$  on Bog Hill and Sike Hill in the same period and in healthy clumps.

3. The efflux of  $\text{CO}_2$  and  $\text{CH}_4$  from the bog surface has been followed since June 1968. These effluxes appear to be largest in the warmer months, reaching  $3 - 4 \text{ mg C dm day}^{-1}$ . Integrating over a complete year would indicate that losses, as gas, from the peat are roughly 10% of the net production.

4. It can be predicted (Clymo, 1966, J. Ecol) that in conditions when Sphagnum is growing rapidly and/or net precipitation is low, then the pH of water around the plants should drop. Regular measurements on pools, lawns and hummocks show that on Burnt Hill a fairly uniform pH of about 4.5 existed in April, 1967. During the summer this dropped, especially on hummocks to 3.3 - 3.5 and to 3.8 - 4.2 in pools. In autumn 1968 the whole bog returned to pH about 4.5. Measurements in 1968-69 showed the same features.

c) Studies on the Heather Psyllid *Aphalaroida ericae* Curt.  
I.D. Hodkinson and J.B. Whittaker, Department of Biology,  
Lancaster University)

1. The aim of the project is to study the population dynamics, feeding behaviour and energetics of the psyllid and to construct an energy budget from which the effect of the psyllid on the heather can be assessed.

## 2. Population census

## (i) Sike Hill (Moor House).

Intensive sampling is being carried out on Sike Hill to study the population dynamics and determine the life cycle. A circular 25 m radius sample site has been chosen as close as possible to the primary production site, so that figures of Calluna primary production can be related to the psyllid project. The sample unit used is 72 groups each of 5 sprigs of heather and the results are expressed as number of psyllids/gm green shoot material. Vertical heat extraction into alcohol has been found to be the best method for removing both nymphs and adults from the heather (efficiency 96%).

The psyllid has been shown to have five nymphal instars. The population on Sike Hill consists of two overlapping generations; one overwintering as mainly 2nd instar nymphs and the other as mainly 5th instar nymphs. The 5th instar nymphs produced the first generation of adults, in June and July of this year, but the second instar nymphs developed only to the late 4th instar by the middle of August. It therefore appears that the psyllid has a two-year life cycle. In early February, 1969, the number of nymphs/gm heather was 45; by August this figure fell to 13 (discounting the new generation). A chalcid wasp is parasitic on 4th and 5th instar nymphs but the level of parasitism is very low.

## (ii) Studies on other sites

- a. Moor House. The psyllid was present on Calluna at every site examined.
- b. Elsewhere. The psyllid was present on all Calluna sites examined in N. England and Scotland. A psyllid is present on Calluna and Erica cinerea from Dorset and Hampshire, but the male genitalia differ from the northern type.

## 3. Feeding behaviour

Feeding nymphs have been killed in situ on the plant and embedded in glycol methacrylate to enable ultra thin sections to be cut showing the plant element on which the psyllid feeds. These have yet to be interpreted. Studies on the duration of feeding of adults have been carried out using the feeding psyllid as a make and break in an electrical circuit. The results show that the adult feeds for a total of about  $1\frac{1}{2}$  hours/24 hours. Unfortunately this method cannot be applied to the smaller nymphs.

## 4. Energy budget

Material is being collected and stored for bomb calorimetry. However, the very small size of the psyllid remains a big problem and it has so far proved impossible to collect sufficient excreta and exuviae. Therefore these have been collected from the larger psyllid (Psyllopsas fraxini L.) (on ash trees) and it is hoped to relate the excretion of the two species on a volumetric basis. Respirometry studies will start later.

One of the most interesting facts to emerge is the very low winter mortality (50% from 4 February - 17 June) of the psyllids in spite of the low temperature ( $-10^{\circ}\text{C}$ ) recorded in the heather canopy where they overwinter. Preliminary studies using a chromatographic technique suggest the presence of glycerol.

d) Studies on Tipulidae (J. C. Coulson and J. C. Horcbin,  
Department of Zoology, Durham University)

1. The study of the life cycle and the life tables of Molophilus ater have continued. In particular more efficient extraction methods for larvae have facilitated improved estimates of the biomass of this species, and final instar larval densities of almost 3000 per sq metre have been recorded.

2. A proportion of the larvae of Molophilus ater fail to pupate. Since in some areas this amounts to 20%, the fate of these larvae is important and further attention has been given to this problem. It is clear that many of these larvae survive to the following autumn, but after that time they become merged into the final instar population derived from eggs laid in that year. It seems likely that these animals have a two year life cycle but studies are in progress to identify these individuals during the winter and early spring so that their life-table can be continued to pupation. This part of the study is of particular importance, since should these individuals fail to pupate, or produce large individuals with more eggs or even a biased sex-ratio, then their influence on the life-table fecundity and rate of turnover of materials will be pronounced.

3. Temperatures

The studies on the populations of Molophilus ater have been directed towards an understanding of the variations in biology between different sites. One of the most important factors is temperature and this is also basic in the evaluation of metabolic rates in the field. An integrating sucrose method has been used to give measures of temperatures in the soil, where the animals are living, and diurnal variations in temperature can be estimated from the Cambridge and Grant continuous recorders set up on 5 sites. Since some of the study areas are at successively higher altitudes these readings also give some indication of the influence of altitude over a small change in horizontal distance.

4. Respiration studies

During the coming year, detailed studies will be made on the respiration rates of larvae of both Molophilus ater and Tipula subnodicornis. Attention will be paid to the effects of acclimatisation and the influence of fluctuating environmental temperatures.

5. Density effects

The weight (and number of eggs) of females of Molophilus ater show an inverse relationship with the larval density. Further studies on this effect are in progress.

c) Studies on Enchytraeidae (Dr. Valerie Standen,  
Department of Zoology, Durham University)

Cognettia sphagnetorum is the dominant enchytraeid of blanket bog and studies have been concentrated on this habitat. The main site under investigation is at Bog End and two other sites have been sampled for comparison of population characteristics. Work, based on field samples and laboratory cultures, has been concentrated on determining the structure of C. sphagnetorum in order to estimate annual production. This species reproduced by fragmentation and has presented some unique problems.

The density of C. sphagnetorum and population changes have been assessed from soil cores taken at intervals throughout 1968 and 1969. In 1968 the population rose from 20,000/m<sup>2</sup> (90 mg/m<sup>2</sup> dry weight) in May to 65,000/m<sup>2</sup> (340 mg/m<sup>2</sup>) in early October and then declined. A similar pattern of abundance has been found in 1969 and all three sites yield similar numbers. The variance of densities from the samples is high and related to the mean. If log variance ( $s^2$ ) is plotted against log mean ( $m$ ), a straight line relationship can be seen.  $s^2 = cm^b$ ,  $b = 0.6$ . Some of this large variance is due to the fact that blanket bog vegetation provides many different micro-habitats. A preliminary investigation of three of the recognisable micro-habitats has shown that Eriophorum cores yield higher numbers of enchytraeids than cores of Calluna litter and Calluna cores higher numbers than Sphagnum.

<u>23 July, 1969</u>	<u>No/m<sup>2</sup></u>	<u>S.E.</u>
<u>Eriophorum</u>	72,889 ±	6,821
<u>Calluna</u>	59,359 ±	6,438
<u>Sphagnum</u>	21,225 ±	7,466

C. sphagnetorum reproduce when whole worms fragment and the fragments regenerate their missing parts and continue to grow in length by adding on segments at the rear until they again fragment. Fragments are found throughout the year comprising between 25% and 50% of the total population. All the worms in the samples were examined and the number of seta-bearing segments recorded for each individual.

Cultures of C. sphagnetorum have been maintained at constant temperature in the laboratory to find the length of time taken for fragments to regenerate their missing parts. Using this information it is possible to age the fragments. Also the growth-rate of worms under laboratory conditions, is now known and used to age whole worms in the field samples. The total population of each age group has been found and the change in population throughout the year due to death and fragmentation will provide the basic data for construction of a life table.

In order to predict the disappearance of worms due to fragmentation the behaviour of worms in respect to fragmentation has been studied in laboratory cultures. Worms fragmented at any size over 40 segments but the rate of fragmentation was higher at higher temperatures.



Studies on the oxygen-consumption of enchytraeids are now beginning, using the Cartesian Diver Respirometer which has been built and tested. The respiration of C. sphagnetorum at different temperatures will be compared with enchytraeids of similar size reproducing sexually. Investigations will also be made of the effects of acclimatisation on respiration rate.

f) Fauna - microflora relationships (O. W. Heal and P. M. Latter, Merlewood)

The investigation of the micro-organisms eaten by Enchytraeid worms commenced in 1967 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. V. Standen) their part in the annual transfer of energy and carbon will be assessed for use in the I.B.P. models in 1970.

In the first feeding test worms showed better growth on non-sterile decomposing Calluna litter than on a sterile dark fungus. Worms feeding on Calluna litter have been observed to suck loose material from the outside of fragments and to enter through the end of the broken stem pieces to remove softened plant tissues. In this way they help to disintegrate partly decomposed fragments of vegetation rather than using already disintegrated particles in suspension as was previously supposed.

To carry out certain laboratory experiments worms free from micro-organisms are required. These are now obtained using a mixture of antibiotics; Framycetin, Penicillin and Streptomycin, each at 250 µg/ml. Sterile worms continue feeding and the effect of the treatment on their growth is now being tested.

g) Decomposition of plant remains (O. W. Heal and P. M. Latter, Merlewood)

The decomposition rate of the main vegetation types is being recorded for up to ten years, on samples laid down in 1966 (Calluna and Eriophorum) and 1967 (Rubus chamaemorus). The 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 of blanket bog and to indicate rates of accumulation for the different vegetation types.

All samples to date are still intact, and recognisable. Rubus leaves are most decomposed and continue to show the highest weight loss, but the rate for the other three types has declined to a loss of 0-7% per year.

The results to date are shown below:-

	% dry weight loss			Respiration µ10 <sup>2</sup> /g/hr 10°C			
	1 yr	2 yr	3 yr	0 yr	1 yr	2 yr	3 yr
<u>Calluna</u> stems	7.9	16.1	15 *	14.2	11.1	10.3	7.0
<u>Calluna</u> shoots	14.7	29.3	35 *	36.8	32.7	39.0	29.3
<u>Eriophorum</u> leaves	26.2	37.3	44 *	62.6	49.8	42.5	24.8
<u>Rubus</u> leaves	38.1	60 *	-	86.1	66.3	38.5	-

\* Preliminary results only

The fungus, Marasmius is present as rhizomorphs on all samples and had caused bleaching of leaves or wood. Animals present include collembola, mites and enchytraeid worms, the latter were common on all samples at two years.

The use of strips of cotton material as a simple rapid indicator of decomposition rate is being investigated. The loss in tensile strength is recorded for different levels down the profile. On the grazed and ungrazed plots at Knock Fell the rate at the surface is higher on the grazed plot but the reverse occurs below 4 cm.

Three Moor House sites (Limestone grass, Juncus moor, Mixed moor) were included among 11 soils in a preliminary study to compare methods of measuring biological activity. Dehydrogenase and cellulose decomposition were correlated to pH of the soils, the two Moor House peat soils showed the lowest activity.

h) Methods of studying the cycling of selected ions during the decomposition of vegetation (A. J. Holding and N. J. Martin, Department of General Microbiology, University of Edinburgh).

The object is to demonstrate 1) the importance of microbial activity on the release and immobilisation of selected inorganic ions in peat and 2) the influence of inorganic nutrient availability in peat on microbial activity.

### 1) Pure culture studies

The commonly occurring strains of Bacillus seem to be closely related to B. circulans. The organisms have been divided into 4 groups based largely on morphological characteristics. Of the less frequently occurring Gram-negative non-spore forming bacteria, 50% of the strains occurring in the litter layer and 10% in the dark-brown horizon belong to the genus Pseudomonas. The numbers of these organisms are very low in the green-brown and red-brown horizon.

### 2) Respiration studies

Using a Clark Type O<sub>2</sub> electrode, a comparison was made of the O<sub>2</sub> uptake of 25% (w/v) aqueous macerate of fresh bog peat previously held either static or shaken in an orbital incubator for 3 days at 29°C. Static macerates exposed to air and macerates shaken under reduced O<sub>2</sub> tensions showed higher respiration rates than shaken macerates exposed to air, suggesting an inhibition of respiration by O<sub>2</sub>. Negligible O<sub>2</sub> uptake was observed in macerates sterilized at the start of the experiment. Macerates sterilized or treated with 0.01M azide after incubation but prior to the O<sub>2</sub> electrode observations showed a rate of O<sub>2</sub> uptake similar to the unsterilized unshaken peat. The results indicate that the greater O<sub>2</sub> uptake levels in the unshaken peat are primarily chemical, the oxidizable materials being produced mainly by the reducing activity of micro-organisms.

Other studies have shown that the addition of sodium glutamate, promoting an O<sub>2</sub> uptake of 49 l O<sub>2</sub>/hr/g wet weight compared with 10.5 l in the unamended unshaken peat produced a larger response than glucose, NaNO<sub>3</sub>, CaCl<sub>2</sub>, or KCl.

### 3) Continuous percolation studies

Dilute solutions of single salts were passed through columns (2.5 x 25 cms) of peat-sand (15:85) mixture at a rate of approximately 1.5 ml/hour.

Further studies have been made on the stimulatory effects of  $\text{Ca}^{++}$  ions which produce up to a tenfold increase in bacterial populations.  $\text{Sr}^{++}$  ions produce a similar increase but  $\text{Mg}^{++}$  promoted a smaller response. A gram-negative rod-shaped organism producing a yellow non-diffusible pigment was isolated from the  $\text{CaCl}_2$ ,  $\text{SrCl}_2$  and  $\text{MgCl}_2$  percolated columns but not from columns percolated with other salts.

An unexpected result was an eightfold increase in the bacterial population promoted by  $\text{NaNO}_3$  + glucose or Na glutamate but not by  $\text{NaNO}_3$  alone. Na glutamate but not  $\text{NaNO}_3$  + glucose promotes the development of a large population of facultative anaerobes similar to those isolated from the rhizosphere of Eriophorum plants.

Figures for the release from the peat of certain major nutrients are shown in the table:

Percolating solution	Quantity released into effluent in 30 days*					
	K	Ca	Mg	$\text{NO}_3\text{-N}$	$\text{NH}_4\text{-N}$	$\text{PO}_4\text{-P}$
Dist. $\text{H}_2\text{O}$	7	7	4	0.4	3.5	1
0.002M. $\text{CaCl}_2$	8		18	2.2	5	0.6
0.002M. $\text{NaH}_2\text{PO}_4$	7	31	18	0.6	7	

\*  $\mu$  moles/g dry weight peat

The results indicate that the net release of K is unaffected by the nature of the percolating solution whereas percolating solutions containing exchangeable cations increase the release of Ca and Mg. These three nutrients are released by leaching and by ion exchange reactions. Microbial activity plays at most a secondary role. However, there is substantial immobilisation of K and Mg in bacterial cells (see Moor House report, 1968).

The release of both  $\text{NO}_3\text{-N}$  and  $\text{NH}_4\text{-N}$  occurs partially by leaching but microbial activity plays a major role. Percolation with  $\text{CaCl}_2$  stimulates both mineralization of organic nitrogen and nitrification whereas percolation with  $\text{NaN}_2\text{PO}_4$  only stimulates mineralization. More nitrogen and phosphorus is immobilised in bacterial cells than is released from the columns. The  $\text{PO}_4$  in the effluent is released by leaching.

#### Field experiments

1. Aqueous solutions of  $\text{NaCl}$ ,  $\text{NaNO}_3$ ,  $\text{NaH}_2\text{PO}_4$ ,  $\text{KCl}$ ,  $\text{CaCl}_2$ , Na glutamate and glucose were each inoculated into the dark-brown horizon of cores taken randomly from a 6' x 8' plot at Bog End. The cores were replaced immediately after the inoculation. After 4 weeks the bacterial populations in the immediate vicinity of the inoculation points were estimated. Only the Na glutamate produced a marked response, with a 10-fold increase in population. The reasons for the differences between these data and those reported last year are being further investigated.

2. A joint experiment was undertaken with B. T. D'Sylva (F. B. A.) to compare techniques for the enumeration of bacteria in the blanket bog peat.

The significant effects of differences in technique for dilution counts using the pour plate technique are summarised:-\*

Dispersion of sample by maceration gives 4-fold higher aerobic counts than dispersion by hand-shaking of samples taken from the litter horizon; otherwise, counts are the same.

Dispersion by hand-shaking produced higher facultative counts.

Casein peptone starch (CPS) medium gives higher counts than tryptone soya (TSA) medium. The difference is highest for samples from the litter horizon (4-fold) and insignificant for samples from the green-brown horizon.

Aerobic counts are consistently higher than facultative counts (10-fold for samples dispersed by maceration and 2 - 3 - fold for samples dispersed by hand-shaking).

3. A survey of the depths of the various colour horizons was undertaken. The data are presented in the table below.

	Normal range of depths of TOP of horizon	Extreme range	Normal thickness range
Litter	surface	surface	4 - 10 cm
Dark-brown	4 - 10 cm	0 - 15 cm	2 - 4 cm
Green-brown	7 - 13 cm	2 - 20 cm	10 - 18 cm
Red-brown	19 - 25 cm	12 - 36 cm	?

The depth of the top and thickness of each horizon is expressed as a range rather than a mean figure because of the very considerable variation in both thickness and depth of each horizon.

i) Study of anaerobic and facultative bacteria in peat  
(V. G. Collins and B. T. D'Sylva, F.B.A.)

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

Sulphate-reducing organisms

A peat core was examined for sulphate reducing bacteria at every cm down to 6 cm and then at 2 cm intervals down to 42 cm.

\* See p 16 for facultative results

maceration. The Calluna cores also showed an increase in numbers with increasing depth on both T.S.A. and C.P.S. by shaking; by maceration there was a decrease in numbers with increase in depth up to the "black brown" zone, and then an increase in number in the "green" zone on both T.S.A. and C.P.S. Comparison of the counts with previous results shows an increase in numbers of bacteria in the "green" zone in Sphagnum peat in both cases.

The counts are being analysed statistically to determine the variation in numbers within the site.

The fungal counts for the Sphagnum cores ranged from  $4 \times 10^5$  to  $1 \times 10^6$  ("Litter" zone),  $4 \times 10^5$  to  $1 \times 10^6$  ("Black brown") and  $1 \times 10^5$  to  $4 \times 10^6$  ("Green"). For the Calluna cores the counts were from  $3 \times 10^5$  to  $1 \times 10^6$  ("Litter"),  $5 \times 10^5$  to  $2 \times 10^6$  ("Black brown") and  $1 \times 10^5$  to  $5 \times 10^5$  ("Green").

Two cores from Sphagnum were examined at 9 depths down to a depth of 80 cm. The counts ranged from  $1 \times 10^3$  at 25 cm to  $3 \times 10^3$  at 80 cm on T.S.A. and from  $1 \times 10^3$  at 25 cm to  $4 \times 10^3$  at 80 cm on C.P.S.

Work is in progress on the enumeration and isolation of nitrogen-fixing and denitrifying bacteria from Sphagnum and Calluna peats (B.D'S) and also on the identification of the pure cultures, the study of their biochemical activities and their response to varying oxygen tensions (V.G.C.).

j) Potassium circulation in the Blanket Bog (Helen E. Jones, Merlewood)

The project was originally intended to be a detailed study of the circulation of potassium in blanket bog. It was proposed to undertake field trials, and experimental work to determine the importance of leaching in the loss of this ion, and the degree and rapidity with which recirculation occurred from dead plant material. Because of lack of funds, however, the project was terminated, in its early stages in April.

A preliminary summary of data from existing publications was drawn up in the form of a simple flow diagram. This was discussed in a Merlewood Research and Development Paper, No. 10, which is available from the author.

k) Systems analysis of Moor House I.B.P. (Helen E. Jones, Merlewood)

Objective

The project is designed to use the production data collected for Moor House I.B.P. to build a mathematical model to describe the flow of dry matter through the system.

Initially the study will be confined to the turnover of dry matter in Calluna. It is hoped that a dynamic model, which takes into account simultaneous transfers of dry matter, will give a more accurate estimate of total net primary production than can be obtained by summing the estimates of production of individual plant parts obtained over a period of time. It will also provide a check against the type of model being produced by J. Grace (p ) based on physiological data of the Calluna plant.

Calluna is assumed to have reached a steady state equilibrium

There was a strong smell of  $H_2S$  from the "green" zone in the original core material. Sulphate reduction was detected mainly in the "green" zone (for zones see Holding and Martin p. 14), after about 2 months' incubation at  $30^\circ C$ .

#### Chitinoclastic organisms

Two peat cores were sampled in October 1968 and July 1969; all four zones were examined for chitin-decomposing bacteria on Willoughby's medium which was modified for the July sampling, the chitin (K and K Labs: U.S.A.) being ball-milled and used as a 3% solution instead of reprecipitating it with conc.  $H_2SO_4$ . On serial dilution plates (aerobic and facultative) growth occurred but there was no visual evidence of chitin decomposition i.e. there were no clear zones around the colonies except for one aerobic plate from the "red brown" zone. In October the aerobic counts ranged from  $1 \times 10^4$  ("Litter" zone) to  $1 \times 10^2$  ("Red brown" zone); the facultative counts were from  $3 \times 10^4$  ("Black brown" zone) to  $1 \times 10^1$  ("green" zone). In July the aerobic counts ranged from  $3 \times 10^4$  ("green" zone) to  $1 \times 10^4$  ("Litter" zone) while the facultative counts were from  $3 \times 10^5$  ("Litter" zone) to  $3 \times 10^4$  ("Red brown" zone). Generally the counts decreased with increasing depth.

#### Thiosulphate oxidizers

One peat core in November 1968 and two in May 1969 were examined for thiosulphate-oxidizers in Starkey's liquid medium, using the serial dilution technique. Thiosulphate utilization was detected by titration of 10 ml of inoculated medium against N/10 Iodine solution (B.D.H. standard). The amount of Thiosulphate utilized ranged from 2.1 ml for the "Litter" zone to 0.5 ml for the "Red brown" zone. Two of the three cores showed a decrease in Thiosulphate oxidation with increasing depth of core.

#### Within Site variation

A joint experiment with N. Martin (University of Edinburgh) in June 1969 determined the variation in bacterial numbers within a site. Three cores from Sphagnum and three cores from Calluna vegetation were sampled down the profile. Comparative counts were made between shaking and maceration of the original material using Tryptone Soya Agar (T.S.A.) and modified Casein Peptone Starch Agar (C.P.S.). The agar plates were incubated under aerobic and facultative conditions at  $22^\circ C$ . The results given are for the facultative counts only.\* In the Sphagnum cores the bacterial counts varied from  $1 \times 10^6$  to  $6 \times 10^6$  for the "Litter" zone,  $9 \times 10^5$  to  $3 \times 10^6$  for the "Black brown" zone and  $8 \times 10^5$  to  $6 \times 10^6$  for the "green" zone. In the Calluna cores the counts ranged from  $5 \times 10^5$  to  $9 \times 10^6$  for "Litter",  $9 \times 10^5$  to  $2 \times 10^7$  for "black brown" and  $3 \times 10^6$  to  $1 \times 10^7$  for "Green".

Shaking gave consistently higher counts than maceration on both T.S.A. and C.P.S. in Sphagnum and Calluna cores. In the Sphagnum cores there was an increase in numbers with increasing depth on both T.S.A. and C.P.S. by the shaking method but a decrease in numbers with increasing depth by

\* See p 14 for aerobic results

in the area studied at Moor House, and therefore, the system provides an interesting contrast with other Calluna-dominated I.B.P. sites, in which the vegetation is repeatedly burnt, and is in transitional stages. It also provides a comparison with the type of model being constructed by A.J.P. Gore on the behaviour of Eriophorum vaginatum in the years following cropping.

Although the initial model is envisaged as purely descriptive, it is possible to alter parameters on computer models to simulate grazing or burning for example, and study the resulting changes. To this extent even a simple model has predictive capacities, and can be a valuable tool in ecosystem studies.

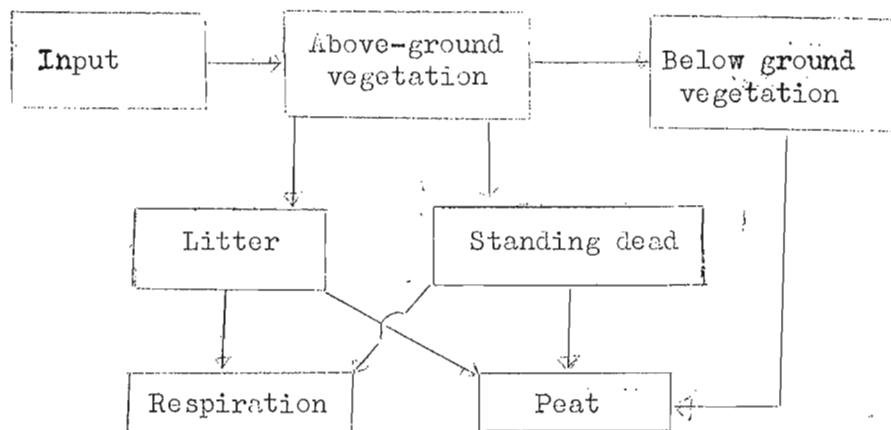
### Methods

The problem is being approached in several ways:-

1. Second degree polynomial regressions are being fitted to the production data collected by G. I. Forrest for Calluna on the Sike Hill site. Confidence limits can only be ascribed to those parts of the curve that cross the x axis, and for this reason an estimate of when growth should start has been made from temperature records for 1968. As these confidence limits are necessary as estimates of the extremes of production of the various plant parts, for the purposes of the model any production data of less than the weight recorded for this time is treated as a minus quantity (equivalent to loss to respiration).

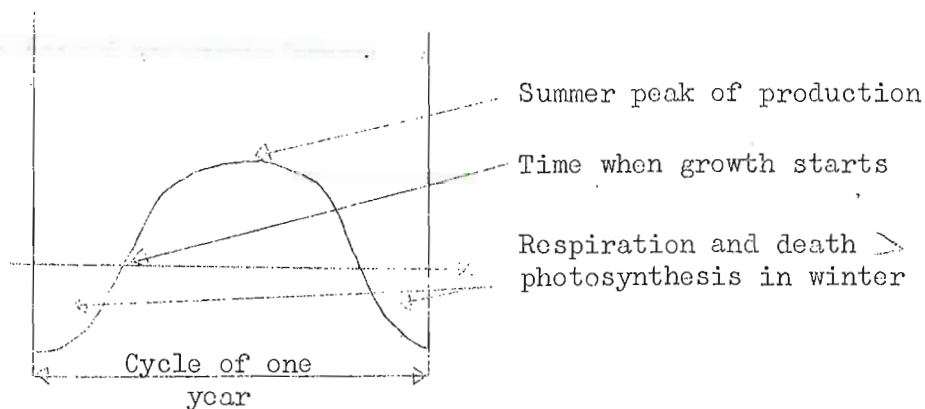
2. A simple model has been constructed on an analogue computer based on the flow diagram in Figure 1.

Figure 1.



The input compartment is based on the assumption that the seasonal variation in the net photosynthesis (i.e. production) can be simulated by a partial cosine wave (see Figure 2). Hence the need for the manipulation of the data described in 1. above.

Figure 2



This model will be used as a first approximation. It may be further defined later, by introducing a feedback between the below-ground and above-ground parts. Too great a complexity in the preliminary model may not be justified, however, because of the difficulty in obtaining reliable data on below-ground parts.

3. When the approximate parameters have been defined on the analogue computer model, a model using the digital computer will be developed, in which it is hoped that the limitations on accuracy inherent in the analogue machine can be overcome.

- 1) Production studies on oribatid mites under *Calluna vulgaris*  
(W. C. Block, Department of Botany, Leicester University)

Object

To estimate food consumption, respiration and production for previously estimated field populations of the most abundant species of oribatids associated with *Calluna* litter at Moor House. This links up with my previous studies on mite populations of the Reserve.

Methods

Attempts to obtain estimates of food consumption by weighing on an electro-micro balance have failed. The work has been concentrated entirely on respiration measurements. These have been started using the Cartesian Diver technique and adults of three species have been used to date; *Platynothrus peltifer*, *Carabodes minusculus*, *Libstadia similis*.

Results

These results at present are very preliminary and it is planned to continue respiration work and to extend to younger stages as more time becomes available this year.



## V. RESEARCH BY MERLEWOOD STAFF

In last year's report, under the subject heading of 'Reclamation of eroded peat areas', by A.J.P. Gore, it was recommended, on economic criteria, not to continue active research within the Conservancy on this topic as far as Manchester's Catchments are concerned.

Mr. Gore reports however, that since that time, Manchester Corporation Water Works have approached the Ministry of Agriculture for a grant to continue reclamation of their catchments. On the strength of successful reclamation trials, set up in collaboration with the Nature Conservancy, the Ministry officials have recommended a grant for a further 50 acre trial. The reason for this recommendation is given as being to support the Landlord's responsibility in the interests of long-term soil fertility.

However, since the recommendation was made, there has been a change of tenant on the area involved. This new tenant is grazing only one quarter the number of sheep of his predecessor.

The result has been a flowering of naturally occurring Deschampsia flexuosa on the mineralised eroded areas, which represent about half of the 50 acres proposed for reclamation. Consequently, Manchester do not intend to exercise their grant option until they have seen how the new situation develops. The original trial experiments have shown the Deschampsia flexuosa requires fertiliser to set seed on mineral free peat even in the absence of grazing. Future grant applications will presumably be aimed primarily at the reclamation of peat only.

It is considered that this may well be a case where conservation research, see "The United Kingdom Contributors to the International Biological Programme" (Section 3.5.3. p. 42) Royal Society 1967, is leading to a development directly concerned with conservation for its own sake.

### a) Plant ecological studies on peat (A.J.P. Gore)

#### Factors limiting plant growth on peat

The processing of data from the growth analysis experiment using Molinia caerulea is continuing. A programme to compute leaf and stem areas has been written for the new PDP 8/1 computer and has already indicated the advantages of rapid, on the spot data reduction.

#### Productivity of blanket bog vegetation

Development of models for productivity of blanket bog vegetation is continuing. Main emphasis this year has been on learning how to use the Hybrid (Analogue) Computer at the Systems Engineering Department of the University of Lancaster, who have kindly made their facilities available to us. This type of machine greatly facilitates

the initial estimation of model parameters. After this initial phase, the digital computers like the Harwell Atlas and our own PDP 8/1 computer are more appropriate. Programmes are now being developed for the PDP 8/1.

Systems Unit and Tundra biome of I.B.P.

Dr. H.E. Jones (p.26) is collaborating in the development of models along similar lines for I.B.P. studies and is now training and working part-time in the systems unit.

Proceedings of the Tundra biome meeting of the I.B.P. reported in last year's Moor House Annual Progress Report were prepared in conjunction with the Norwegian I.B.P. and circulated widely. Copies (Dahl and Gore, 1968) are available from A.J.P. Gore.

b) Chemical changes during plant decomposition (S.E. Allen)

An investigation into the changes occurring during the decomposition of twelve different species of grasses and sedges laid and cut on these contrasting sites is being carried out by the Chemical Section at Merlewood Research Station. The sites are at Roudsea Wood, Lancashire (sea level); Carron Valley, Stirlingshire (243 m) and Knock Fell, Moor House National Nature Reserve (701 m). The objectives of the investigation are to measure the rates of decomposition, by estimating the dry weight losses and the changes in the composition of chemical nutrients, and proximate organic constituents during the various stages of the decomposition process.

The investigation commenced in 1964 and the last samples will be collected during 1969. It is hoped that all analyses will be completed and the results published during 1970.

c) Tree Growth and Nutrition (A.H.F. Brown and E.J. White)

The purpose of trials with trees has been to find species, planting methods, and fertiliser treatments suitable for the type of upland habitats available on the Reserve.

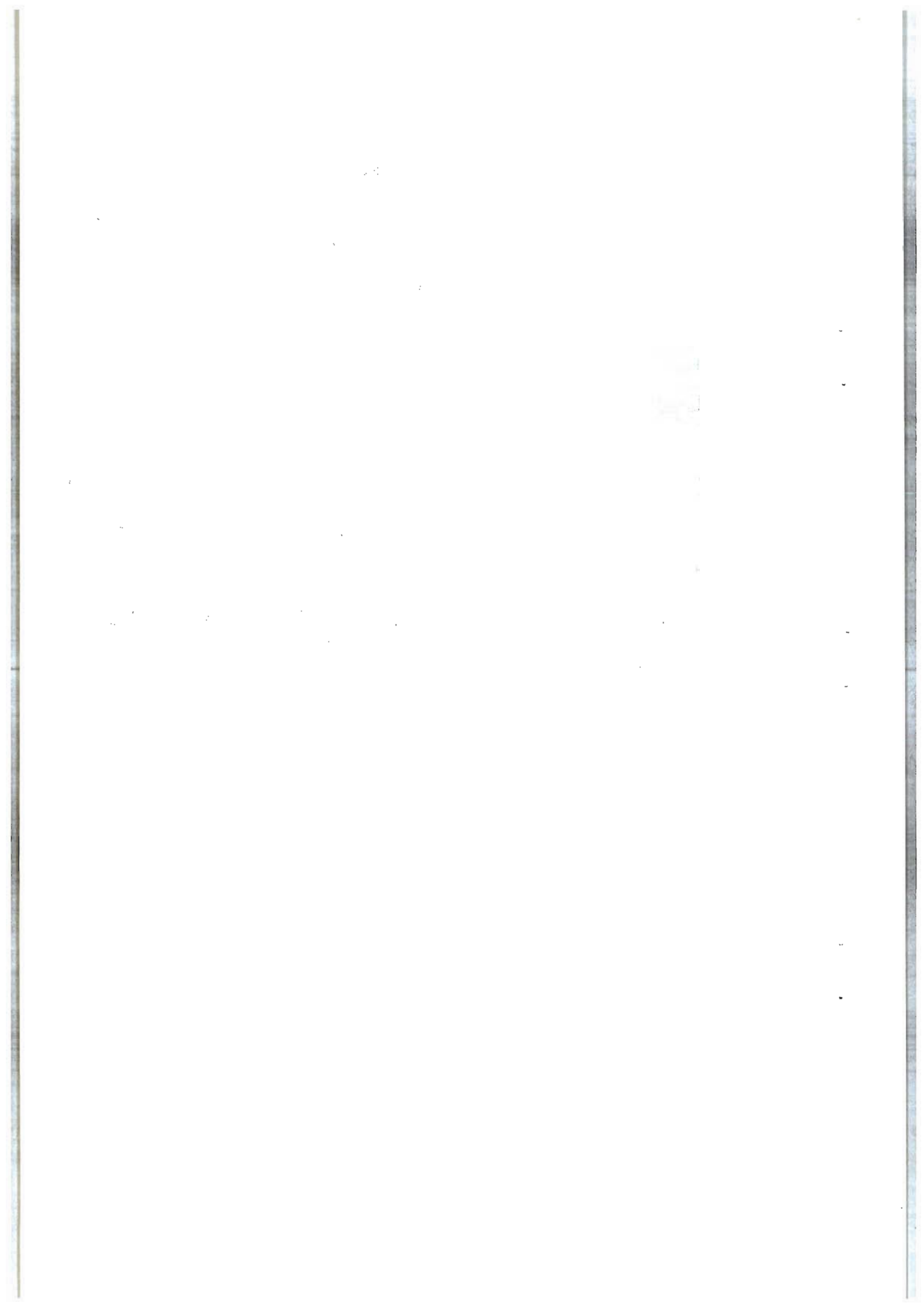
A particular study has been made of the nutrition of pines on peat, whilst growth is being followed in a number of species planted in several enclosures, predominantly of peat soils. Only exotic conifers have shown promise on peat whilst on the mineral soils the growth response of rowan (Sorbus aucuparia), birch (Betula spp) and Swedish Whitebeam (Sorbus intermedia) in the early years has not been continued. The addition of fertilisers, N, P and K, in a trial of Lodgepole Pine (Pinus contorta) on blanket peat gave a response in height increments for the first three years, since when this has been less noticeable.

During the current year the situation has remained similar to that previously reported (see 9th Annual Progress Report), although snow damage has been more severe than usual. Growth of coniferous species remains similar to that of the previous year or two. The Scots Pine on blanket peat at Green Hole are moribund, the earlier addition of fertilisers apparently having provided insufficient stimulus to overcome the combined adverse effects of climate and substrate.

The older "standard" birch at Green Hole have now all died, any remaining having assumed a shrubby habit. The latter produce vigorous shoots afresh each year from ground level, but these die back each winter. This form of growth is in fact general for all the hardwood species growing at Moor House, other than some Rowan (*Sorbus aucuparia*). Specimens of the latter species which originated from extra large plants continue to increase in height.

An attempt on a small-scale is being made to assess the effects on tree growth of removing the competing grassy vegetation; the vegetation surrounding some of the young or checked trees has been sprayed with paraquat.

The fertiliser experiment at Bog End has been re-assessed this autumn, although data are not yet summarised. From observation increment appears to be similar to last year's, but with a more general presence of yellow-tipped needles. The latter is probably a symptom of potassium deficiency, the trend towards which had already been suggested by previous years' foliar analyses.



## VI. RESEARCH BY FRESHWATER BIOLOGICAL ASSOCIATION

### a) Studies on Freshwater Fauna (D.T. Crisp, R.H.K. Mann, J.C. McCormack and A. MacHale.

The Freshwater Biological Association's Cow Green Project began in 1967 with the primary aim of tracing the effect of the construction of the Cow Green reservoir upon the population dynamics of the fish within the reservoir basin and in the Tees downstream of the reservoir. Moor House has been used as a laboratory-base throughout the project and some streams on the Moor House National Nature Reserve have been studied for comparison with the streams of the Weel basin. Details of the whole project are given in the annual reports of the F.B.A., and the present account deals only with the results of fieldwork on the Moor House Nature Reserve.

#### Methods:

Fish census data have been collected three times each year (May, August and October) from representative reaches of Moss Burn, Nether Hearth Sike, Trout Beck and Great Dodgen Pot Sike by means of a portable electro-fishing apparatus. (Moore 1968, J. appl. Ecol.). The repeated catch method (Seber & Le Cren, 1967, J. Anim. Ecol.) has been used to estimate the fish population density in each reach. In addition some general collections of stream invertebrates have been made, and a Cambridge thermograph, serviced by Moor House staff, has been operated in the River Tees near to Tees Bridge.

On the Moor House Nature Reserve the Bullhead (Cottus gobia L) occurs only in the River Tees, Trout Beck and the lower reaches of Nether Hearth Sike. In the latter region bullhead production has been tentatively estimated as 0.5 to 1.0 g/m<sup>2</sup>/yr (fresh weight).

The brown Trout (Salmo trutta L.) is widespread in the streams of the Reserve. Provisional estimates suggest a fresh weight production of 5 - 10 g/m<sup>2</sup>/yr in the Trout Beck system, though there is evidence that the production varies considerably from year to year. Generally about 75% of the trout production occurs as eggs and fry less than one year old.

Most of the aquatic invertebrate material collected from the Reserve during 1967 and 1968 has now been identified to species and collecting is to continue during 1969.

#### Future development:

During 1969, D.T. Crisp was transferred to full-time work on the Cow Green Reservoir project and a full-time assistant has been provided. This will result in a more intense research effort. The project is likely to continue until at least 1980.

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VII. RESEARCH BY OTHER ORGANISATIONS

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

The rate and extent of water movement at different levels in the blanket peat is being investigated. Tritium was injected in 1966 and since then samples have been removed annually. During the current year, although cores have been taken, no results of value are available yet. The average movement of tritium has been slow, approximate distance travelled has been 1 m downslope in the first 21 months.

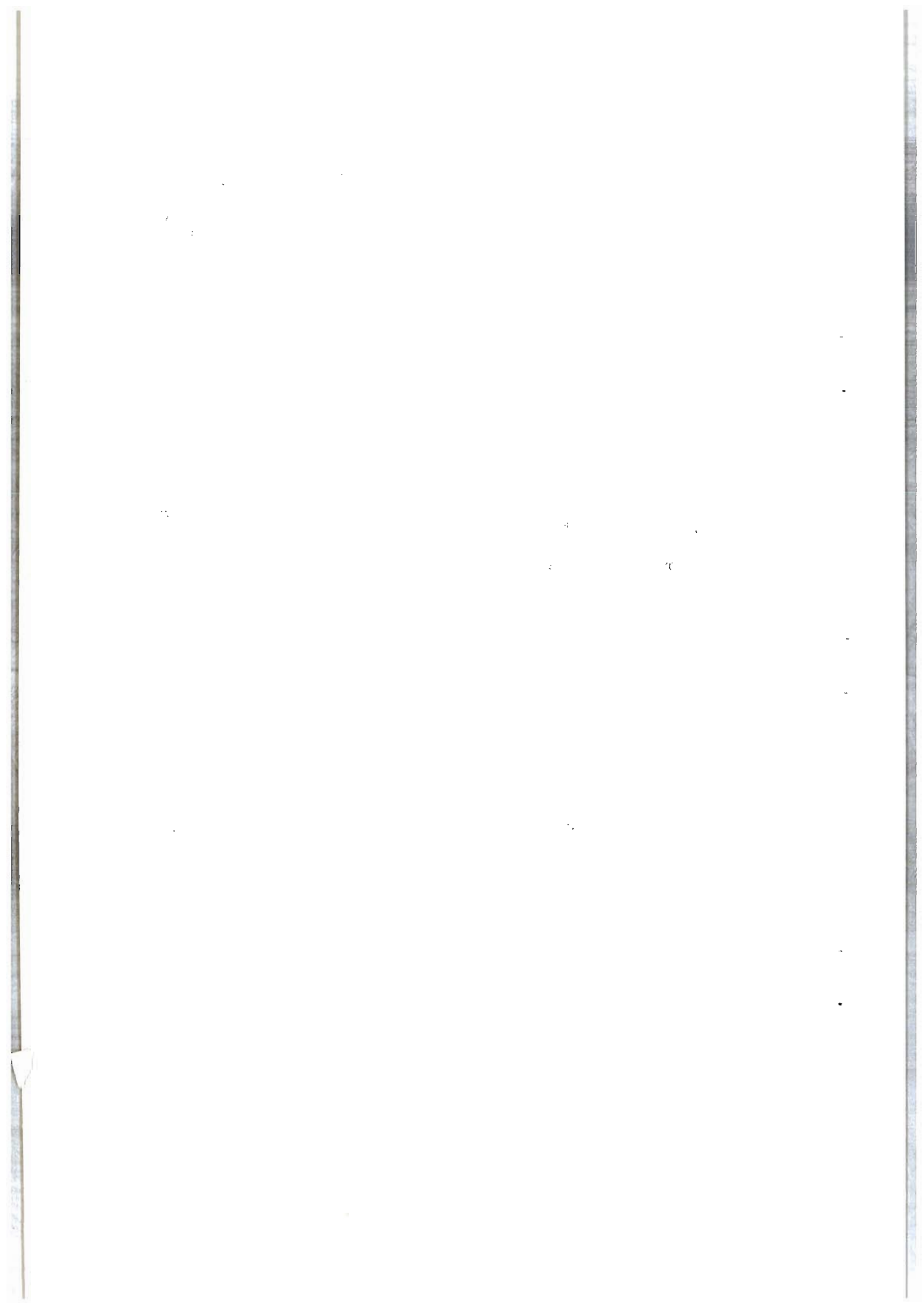
- b) The hydrology of the Trout Beck Catchment (U.T. Burstin,  
Chief Engineer, Northumbrian River Authority).

1. River flow records.

Continuous flow records of the Trout Beck, which is a tributary of the River Tees, have been taken at the Authority's Gauging Station since October, 1957. The station, which is situated near Moor House, has a catchment area of 4.41 square miles and consists of a compound Crump weir having an overall length of 41.9 feet. Water levels are recorded by a Minro autographic recorder and a Fischer and Porter punched tape recorder. The water level records obtained from the punched tape recorder are processed on the Water Resources Board computer to obtain the rates of flow of the Beck. The stage/discharge calibration was calculated by formula, due allowance being made for velocity of approach, and current meter gaugings are being carried out to check the calibration. The flow records are published in the Surface Water Year Book.

2. Interrogable Rain Gauge.

An interrogable rain gauge was recently installed at Moor House for Flood Warning purposes. This instrument, which was manufactured by Thorn Bendix Ltd., consists of a tipping-bucket raingauge, connected to an electronic transmitter which is connected to a G.P.O. telephone line. Each time the bucket mechanism tips 1mm. of rainfall is recorded on a counter, and whenever the instrument is contacted the value of the total rainfall registered on the counter in mm is denoted by a series of audible tones.





## VIII. RESEARCH BY UNIVERSITIES

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

This investigation is part of a longer term study of the ecology of *Rubus chamaemorus* in the British Isles. The work is being carried out in conjunction with the sampling programme described by T.C. Marks in this report (see below) and is a development that follows an autecological study of the species shortly to be published in the "Biological Flora of the British Isles."

The object is to extend preliminary work on the effect of burning and grazing of the blanket bog (Moor House 9th Annual Progress Report 1967-68) on *R. chamaemorus* to a seasonal analysis of the nutrient status of the plant.

The samples of the standing crop were subdivided into leaves and stems. They were then dried, ground and are now being analysed for total nitrogen, phosphorus, potassium, calcium and magnesium.

- b) The effect of burning and grazing on the production of *Rubus chamaemorus* L. (T. Marks & K. Taylor, University College London).

### Introduction

This work is part of a wider study of *R. chamaemorus* involving the use of controlled environmental conditions and the measurement of CO<sub>2</sub> flux over individual leaves in an attempt to relate plant growth response to specific environmental factors.

Earlier work by Dr. K. Taylor (Moor House 9th Annual Progress Report 1967-68) has shown that grazing pressure and the pattern of burning can have a marked effect on the long-term performance of *R. chamaemorus*.

### Object

The object of this section of the project is to gain more information on the effect of grazing and burning on the growth pattern of *R. chamaemorus* throughout a season and to elucidate which are the effective environmental factors amongst those altered by such grazing and burning.

### Methods

The Hard Hill exclosures (in particular Block C) have been used for production sampling at frequent intervals throughout the growing season.

The sampling of the standing crop (representing the season's growth) was made on a m<sup>2</sup> basis, ten samples being cut at random in each of four treatments at each sampling time.

In addition to this sampling an experiment was set up in April to form a preliminary step in the isolation of the factors responsible for producing the great rise in shoot number observed following a burn. Twenty m<sup>2</sup> in fenced and unfenced long rotation burn areas were cropped and half of the cuttings (of all types of vegetation) ashed. This ash was returned to half of the cut plots. Shoot density has been recorded at frequent intervals of time throughout the year and will be recorded for a further year.

At the close of this season's active growing period (August) a number of 8 in diameter cores were taken in all treatments so that an estimate of rhizome and root dry weight per unit dry weight of above ground parts could be made. This material is at present being dried.

#### Results

The provisional "growth curves" for this season show that there is a peak of shoot number and total dry weight for both unfenced treatments in early July after which a pronounced decline takes place.

Results showing the July peak in Total Dry Weight and Shoot No.

UNFENCED	Mean Total Dry Wt/m <sup>2</sup>			Mean shoot No/m <sup>2</sup>		
	25/6	9/7	5/8	25/6	9/7	5/8
Short rotation burn (Burned 1965)	7.92	10.21	7.22	95	135	101
Long rotation burn (Burned 1954)	1.82	2.93	2.04	31	37	26

The fenced treatments show no peak, but a general flattening to a plateau level.

#### Canopy removal experiments

The development of shoot density has been slow in the unfenced plots. In fact the shoot number is no greater than in the uncut areas.

In the fenced areas shoot density of cut plots was approximately 20% greater at the end of the season than on the equivalent uncut plots.

Difference between ashed and non ashed plots was negligible in both fenced and unfenced areas.

These results would suggest that major response in shoot number is likely to take place in the second season following a burn.

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

Populations of Neophilaenus lineatus (L) have again been sampled at two study areas at Moor House as part of a long-term study of population changes in this species. Nine years data are now available.

Peak density has varied by a factor of about 65 on both sites during this period ( $2.0/m^2$  to  $130/m^2$ ) and the mean peak density over nine years is  $16/m^2$  compared with a mean peak density of  $56/m^2$  over 6 years in a lowland population of N. lineatus near Oxford.

The two Moor House populations showed parallel changes in every year from 1961-1967. In the latter year, the density of one of them was experimentally reduced to less than one half of its former density, and in 1968 the two population densities remained significantly different during the first (nymphal) part of the season though there was evidence of increased adult survival on the site with reduced density. In 1969, the nymphal densities still remain significantly different ( $66/m^2$  and  $28/m^2$  resp.). Nymphal survival up to the beginning of instar 5 in the dense population was approximately 70% and in the reduced population was c. 50%. Adult survival, however, has again been significantly higher in the low density population than in the high (38% and 25% resp.). The low density population has not yet adjusted to the effects of being disturbed two years ago.

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

The object of this investigation is to measure some climatic and hydrologic factors that influence the thermal regime of a river.

The two-year project started in October 1968 when the field instrumentation was completed by the installation of the mercury-in-steel thermograph for air and water temperature measurement at the Trout Beck gauging station. Earlier in the summer, a thin-plate rectangular weir was established on Netherhearth Sike at an altitude of 560 m together with a stream water thermograph, in order to extend the information for the Tees above Trout Beck.

The project is still in the data-collection stage, and considerable assistance which is greatly appreciated, has been obtained from the Moor House staff in terms of chart-changing.

At present the emphasis is on the computerisation of the chart information for subsequent analysis. Some attention has already been given to the air and water temperature relationship through the use of harmonic analysis, and when more data is available it is hoped to evaluate the discharge effect along the river by means of multiple regression techniques.

The discharge at Netherhearth Sike is being compared with the flow from another experimental catchment in Weardale, and steady anticyclonic conditions during early April, 1969 provided a useful snow-melt period on these streams which is being examined in some detail.

e) The bedload of streams - its origin, characteristics, and movement with special reference to two catchments in the northern Pennines. (B.M. Amir, Department of Geography, University of Durham)

In many ways the studies of sediment movement in streams is governed by the economic importance of such streams. Where streams are vital for agriculture or provide water for dams and irrigation schemes, studies of the volumes of sediments carried by such streams are often of crucial importance. In the northern Pennines, with its high rainfall, a great many streams are, as yet, not utilised by man.

Possibly the lack of such utilisation accounts for the very few studies which have been made of sediment transport in the streams of northern England. In order to provide some quantitative information on the nature of stream bedload and sediment movement two small catchments were chosen for detailed studies. One catchment, the Lanehead catchment is located in Upper Weardale and the other, the Netherhearth catchment is located in Upper Teesdale within the Moor House National Nature Reserve. The methods which have been used throughout this study were as follows:

Two hundred samples were collected from the stream bed and about 60 samples from the banks from both the catchments. The bedload in movement was trapped by placing trays in the stream bed. Unfortunately, throughout this research the writer found great difficulties in trapping bedload in the Nether Hearth catchment. This was due to many factors, the most important being the writers inability to secure the sediment trap into the stream bed which was composed of solid rock.

The statistical analyses of bed material shows that the mean particle size within the stream bed of these two catchments range between  $-2.0 \phi$  to  $-5.0 \phi$  ( $\phi$  = phi units) but systematic changes in bed material characteristics occur. Also the analyses revealed that the bed material was poorly and extremely poorly sorted. This was not surprising because these streams are still in a youthful stage and are highly erosive especially on the banks where soliflucted material occurs.

This study concluded that in spite of the great similarities between the two catchments in terms of geology and vegetation cover, quantitative and statistical measures of bedload proved that great differences are present.

f) A study on the relationship between egg number and density in *Tipula subnodicornis* Zetterstedt. (Jennifer Butterfield, Department of Zoology, University of Durham.)

The object of the study was to establish a relationship between larval density and the number of eggs produced on a site. Counting large numbers of eggs was to be avoided by finding a relationship between the numbers of eggs produced and some aspect of the size of the female.

The densities on five sites were determined by three methods. The larvae were sampled at the fourth instar stage by taking soil cores. The adults were trapped on sticky traps and in pitfalls. Each site was cleaned of copulating pairs, twice a day during the peak of emergence, by hand catching. The combined sticky trap and pitfall catches were used to give a comparative measure of density on each site.

The eggs of 150 females were counted and egg numbers were plotted against various body measurements.

A correlation between size of female and egg numbers produced was formed, the regression equation being  $y = 0.092 x^{-2.59}$  ( $r = +0.6$ ,  $p < 0.001$ ) when  $7$  is the cube root of the egg number and  $x$  is the wing length.

A negative correlation ( $r = 0.76$ ,  $p < 0.05$ ) between mean egg number/female and adult density was found. As only five sites were investigated in one year it is not known how extensively this apparent correlation can be applied to other vegetation types and whether the same relationship exists in different years.

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

1,500 observations of carbon dioxide exchange in *Calluna vulgaris*, and 600 in *Sphagnum rubellum* have now been made along the lines indicated in the previous report.

'Total soluble sugar' has been measured in *Calluna vulgaris* throughout the year, to see to what extent a previous year's assimilate can be carried over as sugar and diverted into present year's growth.

*Calluna vulgaris* plants in the controlled environment growth cabinet have been fed  $C^{14}O_2$  at 300 ppm  $\pm$  20 ppm in an experiment to see what proportion of assimilated carbon is diverted into leaf, wood and root material.

A preliminary compartment model for growth of a single heather plant was prepared and run on the University I.C.L. 1907 computer. The model was run for only a single month of 'plant time' and despite its gross simplification of the situation, gave an estimate of growth which was in the correct magnitude when compared

With Dr. I. Forrest's harvest results. Further development of this model into a two year predictive model for a whole community of Calluna vulgaris and Sphagnum rubellum is in progress and is expected to occupy most of the final year's work.

Radiation data has been taken from the Kipp recorder at Moor House, and hourly values from May 1st 1968 to June 1969 are on punch cards. The task of processing the I.B.P. Grant tapes to extract the information required and putting it onto punch cards is under way.

h) The distribution of *Hordeum murinum* L. in Britain  
(A.W. Davison, Department of Botany, University of Durham).

*Hordeum murinum* is an annual grass of Mediterranean origin which is restricted to ruderal habitats in the drier, lowland areas.

The experiment at Moor House is one of a series which was designed to determine which climatic factors limit the range of the species. Using a punch card technique (Davison, in press) the pattern of distribution in Britain was examined in some detail and then 1968 transplant experiments were set up at sites with different climates. In August, 1968 large polythene pots sown with *H. murinum* were set out at Newcastle (altitude 46 m, rainfall 640 mm p.a.), Allenheads (altitude 366 m, rainfall 1290 mm p.a.) and Moor House (altitude 560 m). Seedling establishment, flowering and grain production were recorded over the year and some of the data are given below.

Establishment at Moor House was the same as at Newcastle and there were few fatalities at any site during the winter. However, growth, flowering and ripening of the grain were considerably different at Moor House, in spite of the good summer.

	Number of spikes/ plant	Number of grain/spike	Weight (mg) /grain
Newcastle	27	28	11.5
Moor House	9.8	24	6.3

Previous work (Davison, in press) suggests that the delay in ripening and the smaller grain will have a considerable effect on flowering and grain production next year (1970). Experiments will probably be completed in September, 1970.

### VIII. RESERVE MANAGEMENT

For the second successive year it has not been possible to burn heather: this year, the ground was covered by snow until almost the end of the burning season (30 April). Plant growth was particularly late in starting and the Commoners' sheep were returned to the fell later than usual. However, apart perhaps from bog plants, it has been a year of exceptionally profuse flowering and in the absence of much frost, growth has continued well into September, with no indication of a shortage of sheep feed.

An account of the Bird life is now prepared quarterly by T.L. Hodgson for inclusion in the consolidated Report produced by the Assistant Regional Officer, Teesdale, for the three Reserves in the dale. T.L. Hodgson has been given a B.T.O. ringing licence and a large number of birds have been rung this season. Observations indicate that the grouse population is healthy and flourishing.

16 Foxes have been killed during the year and also a number of rabbits. Cases of egg poisoning and destruction of predator birds have been reported in the district. The position has been watched by T.L. Hodgson.

The horse on loan from Scotland, was returned to Beinn Eighe in April. Both the horse and the wether flock relied on hand feeding for two months of the winter. The sheep were in poor condition by April but at the end of the year had an average individual live weight of over 45 kg.

Weekly visits are paid to the west side of the Reserve. In the winter, during ski-ing season, these visits are, whenever possible, more frequent. Records are kept of the working of the ski-ing agreement and reports are made to the Regional Officer. Some data have been supplied for use in a wide-ranging survey of ski-ing and recreation in northern England.

#### Estate work

Routine repairs to fences have been carried out. Re-surfacing, widening and repairing the access road remains the main item of estate work. Pot holes in the tar sprayed section, from the Dipper Bridge to Mine Rails, have been filled and sealed with bitumen. Limestone quarry waste is being used to surface the section from Mine Rails to Tees Bridge. This latter work is being done by contract.

Snow closed the road from early February to Easter (1st week in April). Much of the snow was eventually cleared by a hired bull-dozer driven by the Moor House staff (D. Craig).

On thawing, floods swept across the road at Tees Bridge, but little damage was done. In Troutbeck, however, the wooden foot-bridge was carried away and broken. It is not intended to replace this bridge at present.

Visitors

A number of visitors, both individual research workers and parties, have come to the Field Station during the year. Talks have been given and experiments explained. The parties include the National Agricultural Advisory Service and the Agricultural Land Service, (Durham), Newton Rigg Agricultural College (Hill Farming Course) and several schools. Among the visitors has been

Professor Mary K. Hartz and Dr. Jerry Brown from the U.S.A. and Sigurd Kjelvik from Norway.



Staff List

Officer-in-Charge

M. Rawes (Senior Experimental Officer).

Scientific Staff

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

M.W. Read (Assistant Experimental Officer).

R.B. Marsh (Scientific Assistant).

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

Miss L. Teasdale (Scientific and Secretarial Assistant).

Warden

T.L. Hodgson

Estate Worker

D.W. Craig

Housekeeper

Mrs. M. Hodgson

Domestic help (part-time)

Mrs. J. Ryding

F.B.A. Staff

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

Miss S. Carrick (Scientific Assistant)

Publications

- EDDY, A., WELCH, D. & RAWES, M. 1969. The vegetation of the Moor House National Nature Reserve in the northern Pennines, England. *Vegetatio*, 16, 239-284.
- HADLEY, M. 1969. The adult biology of the Crane-fly Molophilus ater, Meigen. *J. Anim. Ecol.*, 38, 765-790.
- PARKER, J.R. 1969. The establishment of Cornicularia clavicornis Emerton (Araneae) as a British species. *Bull. Brit. Arach. Soc.*, 1, 49-54.
- RAWES, M. & WELCH, D. 1969. Upland productivity of vegetation and sheep at Moor House National Nature Reserve, Westmorland, England, *Oikos*, Sup 11, 72 pp.

Higher Degree Theses

- HORNUNG, M. 1968. Soil morphology, mineralogy and genesis. Ph.D. Thesis, University of Durham.
- URQUHART, C. 1969. The effects of waterlogging on the growth and mineral nutrition of some moorland plant species, with special reference to the soil redox potential. M.Sc. Thesis, University of Birmingham.

Merlewood Research and Development Papers

- HEAL, O.W. 1968. The International Biological Programme Project at Moor House. Number 2.
- JONES, HELEN E. 1969. A Preliminary Survey of Potassium Circulation in the Moor House Blanket Bog. Number 10.

Meteorological Summary for Moor House 1968 (Met. Office Station No. 7188)  
 58 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
Temperature	3.1	0.3	3.8	7.9	8.9	15.0	13.8	14.4	12.3	10.8	4.5	1.7	8.0
Temperature at 1 ft.	-2.4	-6.3	-0.9	-0.6	1.0	5.5	6.6	7.3	6.3	(6.3)	(1.1)	-3.2	1.7
Temperature at 0900 GMT.	0.3	-3.0	1.5	3.7	4.9	10.3	10.2	10.9	9.3	(8.5)	(2.8)	-C.7	4.9
Temperature at 0900 GMT. mbs.	7.8	6.1	12.2	13.9	17.2	21.1	18.3	21.7	16.7	15.6	9.4	6.7	21.7
Temperature at 0900 GMT. maks.	-12.8	-11.7	-9.4	-8.9	-4.4	0.6	0.6	1.7	-0.6	-0.6	(-6.1)	-7.8	-12.8
Temperature at 0900 GMT. mins.	-3.9	-2.2	-2.2	-1.7	1.7	9.4	8.3	9.4	9.4	6.1	0.0	-3.3	-3.9
Temperature at 0900 GMT. range	6.1	-1.1	4.4	6.1	7.2	10.6	13.9	13.9	10.6	10.6	(5.0)	2.2	13.9
Temperature at 0900 GMT. max.	-16.1	-15.0	-8.3	-10.6	-7.8	-4.4	-5.0	-2.2	-2.8	-2.2	-6.1	-11.1	-16.1
Temperature at 0900 GMT. min.	1.8	1.6	1.8	4.2	6.2	10.7	11.3	11.7	10.4	8.8	4.8	2.8	6.3
Temperature at 0900 GMT. range	6.3	4.8	6.5	7.2	7.5	10.3	11.5	11.9	11.0	10.7	7.2	5.7	8.4
Temperature at 0900 GMT. max.	96.5	92.8	93.6	84.0	80.7	76.4	88.1	87.3	91.0	94.7	96.3	95.7	89.7
Temperature at 0900 GMT. min.	-0.3	-3.6	0.8	1.6	2.4	7.2	8.8	9.4	8.3	7.8	1.9	-1.4	3.6
Temperature at 0900 GMT. range	7.3	6.3	7.1	5.3	6.2	5.6	7.2	6.1	6.9	7.4	7.1	6.3	6.6
Temperature at 0900 GMT. maks.	19.9	83.2	65.7	160.0	126.9	209.7	85.7	128.1	70.1	34.5	26.5	?12.6	77.80
Temperature at 0900 GMT. mins.	8.05	5.78	12.04	4.26	4.90	4.86	5.22	2.30	11.22	9.53	3.96	5.68	2.15
Temperature at 0900 GMT. range	1.23	1.21	2.15	1.1	.64	1.39	1.63	.78	1.58	1.78	1.20	1.08	
Temperature at 0900 GMT. max.					.040	.071	.063	.027	.090	[.013]			
Temperature at 0900 GMT. min.					122.2	68.4	82.6	84.5	125.1	[127.1]			
Temperature at 0900 GMT. range	24	19	23	14	21	16	19	19	21	19	22	21	238
Temperature at 0900 GMT. maks.	20	15	18	11	14	14	15	13	19	18	18	11	186
Temperature at 0900 GMT. mins.	11	22	10	5	6	0	0	0	0	0	8	8	70
Temperature at 0900 GMT. range	14	28	14	8	2	0	0	0	0	0	2	0	82
Temperature at 0900 GMT. max.	1	0	2	1	5	2	1	0	1	0	1	0	15
Temperature at 0900 GMT. min.	0	0	0	1	1	0	2	0	1	0	0	0	5
Temperature at 0900 GMT. range	8	6	11	1	2	0	3	5	3	2	7	13	61
Temperature at 0900 GMT. maks.	19	29	19	11	14	0	0	0	1	2	8	26	129
Temperature at 0900 GMT. mins.	23	29	25	21	18	8	5	7	5	3	15	25	184
Temperature at 0900 GMT. range	6	1	11	1	0	0	1	0	0	1	3	2	26
Temperature at 0900 GMT. max.	20.6	13.2	20.1	13.4	9.8	9.5	8.1	9.7	12.0	14.2	14.7	13.1	13.2
Temperature at 0900 GMT. min.	33	43	28	1	0	0	0	0	0	0	0	35	140
Temperature at 0900 GMT. range	7	9	10	1	0	0	0	0	0	0	0	7	10
Temperature at 0900 GMT. maks.				1.3	1.6	(3.1)	(1.4)	2.0	1.0				10.4
Temperature at 0900 GMT. mins.				4.3	4.9	4.9	5.2	2.3	11.2				32.8
Temperature at 0900 GMT. range				0.6	0.8	1.5	0.6	1.0	0.1				4.6
Temperature at 0900 GMT. max.				3.6	4.1	3.3	4.4	1.3	10.3				27.0

appendix 3

Meteorological Summary for Great Dun Fell 1968  
 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.	YE
Mean Maximum Temperature	1.3	-1.8	2.2	5.1	6.3	12.6	11.4	12.1	10.2	8.4	2.5	-	
Mean Minimum Temperature	-2.7	-5.1	-2.5	-1.2	0.2	5.5	6.1	6.3	5.7	4.6	-1.0	-3.9	1
$\frac{1}{2}$ (Max. + Min.) Temperature	-0.7	-3.5	-0.1	1.9	3.3	9.1	8.7	9.2	7.9	6.5	0.7	-	
Highest Maximum Temperature	7.7	4.0	9.6	11.9	16.0	18.8	16.3	19.2	14.6	13.3	8.5	-	15
Lowest Minimum Temperature	-11.0	-8.4	-2.5	-11.4	-4.0	1.0	3.3	2.4	1.9	-0.5	-5.2	-10.7	-11
Lowest Maximum Temperature	-5.6	-4.6	-1.6	-1.7	-1.0	6.4	7.4	7.4	7.5	3.8	-2.1	-	
Highest Minimum Temperature	4.4	-3.2	1.1	3.9	8.5	11.5	12.0	13.2	9.4	8.8	2.4	3.6	12
Total sunshine, hours	9.8	77.4	52.4	128.4	102.4	166.1	91.5	112.2	60.3	8.0	21.5	34.1	864
Days with snow or sleet	17	14	15	7	15	0	0	0	0	0	10	15	5
Days with lying snow	15	28	19	7	4	0	0	0	0	0	6	13	5
Days with fog at 0900 GMT	22	16	22	15	14	8	16	17	21	26	21	13	24
Days with air frost	23	29	27	14	19	0	0	0	0	1	21	28	14
Average wind speed for months, knots	22.0	13.4	22.9	15.4	13.2	13.0	11.5	16.6	16.7	19.7	21.9	17.7	17.
Days with gale	15	2	14	4	1	1	4	3	7	9	11	7	74
Greatest snow depth, inches	9	12	6	1	1	0	0	0	0	0	1	10	14

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

