

K. Taylor

Moor House, Westmorland: 8th Annual Progress Report

1966 - 67

by M. Rawes

GENERAL

This report covers the period 1 October 1966 to 30 September 1967. During this time Dr. D. Jenkins (Deputy Director (Research) Scotland) has been responsible for the scientific direction.

Mr. D. Welch was promoted to E.O. in December and transferred to Banchory on 1 January as S.O. The vacancy was filled by Mr. M.W. Read (A.E.O.). Mrs. Norris resigned from the part-time post of shorthand-typist in September 1967.

The main research event in the year has been the start of the International Biological Programme (I.B.P.), Moor House being the United Kingdom main site for upland moorland production studies within the Programme's Terrestrial Productivity section. The Moor House staff will to some extent be concerned in I.B.P. which is being co-ordinated by Dr. O.W. Heal, Merlewood Research Station. Contributions by individual scientists involved, appear later and Dr. Heal has provided the following general introduction:-

"The five year main study period of I.B.P. started in July 1967 and during the year a number of projects began. The aim of the Moor House programme is to provide an assessment of primary and secondary productivity in a moorland ecosystem and an understanding of the factors influencing this. With such a broad aim and with limited funds, I.B.P. must draw heavily on available information and new studies will be designed to fill obvious gaps.

Dr. Cragg recognised the lack of information on the microbiological process in Moor House soils. Under him Miss Latter worked at Merlewood and he encouraged further research by Miss Vera Collins (Freshwater Biological Association) and Dr. A.J. Holding (Edinburgh University). Because of the lack of information and of available techniques for estimating production, microbiological studies have started with the identification of the micro-flora and a study of their activities. Quantitative studies will develop later.

Soil fauna studies have continued at Durham University under Dr. J.C. Coulson. In these, and in studies by Dr. J.A. Springett (Moor House) and Dr. A. Ibbotson (Newcastle University) some of the effects of climate are being investigated. Despite the many studies on soil fauna we are remarkably ignorant of their food. Knowledge of the quantity and quality of food consumed is essential in understanding the part played by the fauna in the movement of energy and nutrients in the soil. Dr. Springett and Dr. W.B. Banage (Makerere University College, Uganda) have co-operated with Merlewood staff in studies on the food of enchytraeids and nematodes. It is intended that similar studies on other animals will be developed.

Despite the predominance of blanket bog on the Reserve we have less biological information on this than on the limited area of grasslands. As the Moor House programme will consider the moorland ecosystem as a whole more emphasis is now being placed on blanket bog.

Dr. G.I. Forrest takes up an I.B.P. post as Scientific Officer in October 1967. His work on the measurement of primary production will include estimates of root production. Miss Sheila Carrick, who was

appointed Scientific Assistant in September, will assist Dr. Forrest and she will also service the recording instruments used in the projects of the Programme".

A SCIENTIFIC RESEARCH

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

Routine meteorological observations continue and recordings feature in the Meteorological Office Monthly Weather Report, although recently autographic records of wind have not been published.

The I.B.P. solarimeter has been unsatisfactory. The integrator has failed, but has been run continuously since 8 August and a trace has been obtained for future analysis.

II. Vegetation

(a) Measurement of changes in vegetation and soil following the removal of sheep grazing and in its presence. (M. Rawes, M.W. Read, and D. Welch)

1) Exclosures:

Chemical analyses of the top 5 cm of the red-brown limestone soil show that the contents of Ca, P and K are approximately twice as high in the Knock Fell enclosure compared with under grazing. There is little difference between the peaty soils inside and outside the enclosure.

The blanket bog site on Burnt Hill was re-examined in August/September. The area had previously been burnt around 1950 and was drained in 1953. The enclosure was erected and the first botanical analyses (1,950 vertical point quadrats) completed in 1954. The first repeat analysis was in 1960. Small differences, especially in bryophyte composition, were noted in 1960 but in 1967 the difference between enclosure and grazing and between draining effects was small. The only significant difference (2%) was shown by Eriophorum angustifolium, which was more frequent near the drains, whereas in 1954 the reverse was the case (not significant at 5%).

Exclosures have been erected on two other important vegetation types, Juncetum squarrosi and Nardetum, and in each case 1,000 point quadrats have been recorded on permanently marked transects. A similar lay-out of 100 10 pin frames has been set out and recorded in grazed swards adjacent to each enclosure. Information of herbage production, sheep utilisation and dung deposition exists for each of these two sites.

The build-up of soil and the subsequent colonisation of the stream-flushed limestone pavement in Rough Sike enclosure has been measured again this year. On the five m² quadrats, each having 100 point quadrats, the average soil depth has increased from 23 mm in 1963 to 75 mm in 1967. The number of plant "hits" has in the same period risen from 256 to 395.

2) Grazing:

The extent of change in sward composition under the existing sheep grazing regime is unknown for the Reserve as a whole. It is generally assumed to be small. The vegetation survey of Eddy (Eddy, Welch and Rawes, in preparation) provides a base against which major changes can be measured in the future, but more detailed studies are needed.

On the Reserve there are eight sites at which permanent point quadrat records are kept. These sites, which also have enclosed plots, represent the main sward types present. Additionally, other methods of analysis, such as cover-abundance and photography, have been used to record botanical change. Data are also available for sward described in the course of other research.

During 1967 a number of m^2 quadrats were charted so that the performance of small clumps of Juncus squarrosus and Nardus can be measured over a period of time. The scale of mapping was 1:4. Previous vegetation mapping has been on the grazed areas of Knock Fell and Nard Hill (in each case 90 m^2 area was covered) but no change either in the extent or position of these two plants has been noted in the past four years. However, the scale (1:120) was probably too small to detect change in a short time.

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

Measurements have continued to record survival and performance of the introduced species and particular emphasis has again been placed on Alchemilla alpina. Assistance has been given by T. Whiffin (Cambridge) during the field season. An account of this investigation, which has now been in existence for 12 years, is being prepared for publication.

(c) Tree growth and nutrition (A. Carlisle, A.H.F. Brown and E.J. White, Merlewood)

Species trials:

Conditions have been favourable for some species. At Green Hole Scots pine (P. sylvestris) has recovered, some trees having increments of 25-35 cm. In Pasture enclosure it is also growing well, equalling Lodgepole pine (P. contorta). Needle colour of Scots pine throughout is good, even on blanket bog.

The small groups of Sitka spruce (Picea sitchensis) and the few remaining Hybrid larch (Larix eurolepis) have also made above average height growth. Sorbus intermedia on mineral soil are vigorous. Height growth of Lodgepole pine has only been average or even less than last year, with great variation in the condition of the Nether Hearth trees. Although one or two groups still have dense canopies, resulting from needle retention of 5 or 6 years, needles on the remaining trees are often yellow or brown and are only retained 1 or 2 years. Trees on the blanket peat at Nether Hearth are markedly smaller and are showing some chlorosis. All species have failed to grow on the bare mining spoil and few remain alive.

Rowan (Sorbus aucuparia) also looks less promising than formerly. The outer trees of the tall group in Green Hole are dying back and others show premature leaf browning due to the activities of a leaf-mining insect (as yet unidentified). Smaller trees die back annually. Birch (Betula spp.) have now virtually failed, those remaining having been defoliated by sawfly larvae. The hybrid aspen (Populus tremula) are now also moribund.

Tree Nutrition:

The experiment at Bog road end on studying the effects of adding different elements in slow and rapid release forms on the growth and nutrition of Lodgepole pine was sampled for the fifth time in the autumn of 1966. Adding $NH_4 NO_3$ either on its own or in combination with P and/or K has reduced height increment in all cases. Early in the experiment N applied as urea formaldehyde slightly improved height growth, but the present evidence is that added N has no beneficial effect on Lodgepole pine growth. Where P has been added in a soluble form there is a general improvement in height growth, particularly if K is

added also. Better results are obtained however, where P is added in a slow release form which also contains Ca. The greatest height increment is obtained when this fertiliser is supplemented with K. A combination of soluble N + P + K had early beneficial effects on increment but this is now fading. Fisons PS₂ (an N + P + K fertiliser) also had marked effects on height gain in the second year (1963), but growth is now little better than control.

In the treatments, foliar concentration of N, P and K are falling rapidly. In most treatments N and P concentrations are little better than in the control. There is still a residual effect of K but this element's concentration is falling rapidly. This decrease is greatest where ground mineral phosphate was used, possibly because of an effect of Ca in this fertiliser on the uptake of K. K deficiency should be obvious shortly.

Effects of treatments on height growth are clear and mostly the addition of fertilisers only caused temporary increases in foliar concentrations.

(d) The vegetation of Moor House (M. Rawes, M.W. Read and D. Welch)

Species additional to those already recorded in the herbarium and card index continue to be found. The herbarium, which is now reasonably extensive, provides an invaluable service to staff and visitors.

Dr. C. West made a further visit to the west side of the Reserve and was able to identify another five species of Hieracia. Eddy and Welch have published a species list of flowering plants and ferns and all available data for the four 10 km squares that are included in the boundary of the Reserve have been sent to the Biological Records Centre. Six new lichens and over thirty fungi have been collected and identified as new to our records. The lichens, which include Usnea subfloridaria have been found by M.W. Read, who with T. Whiffin (Cambridge), was responsible for the collection of fungi.

(e) A quantitative study of limestone grassland (M.W. Read)

A study has started involving the phytosociological ordination of various grasslands with a view to elucidating their variation. It is hoped to correlate floristic and environmental variation. This research is for a MSc degree at Sheffield University and is under the supervision of Dr. I.H. Rorison.

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

Regular sampling continues but the rate of decomposition of plant material on Knock Fell is very slow compared with similar material at other sites in Scotland and Roudsea.

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

Whilst no detailed work has been carried out, a student Miss M. Studley in the course of a study of Calluna performance, has measured the current years shoot growth and the number of flowers in the experimental area of Hard Hill. The longest shoot length (mean 4.17 cm) was obtained under the short rotation treatment, there was little difference between fenced and grazed plots. Most flowers (2448/m²) was given by the controls and least (89/m²) by the short rotation plots. Samples were taken from blocks A and D and other measurements included dry weight of different components of Calluna.

Observations on Rubus chamaemorus have been made at these plots by Dr. Taylor.

Visitors

- (h) Autecology of *Rubus chamaemorus* (K. Taylor, Botany Department, University College, London)

In the germination experiment in the Bog Mine enclosure, reported previously (1966), seedlings have established successfully in situ and are now in the second year of growth.

Samples of the above-ground parts of the plant have been taken at random in the various treatments of the Hard Hill burning experiment. Total leaf area and total dry matter (at 105°C) per unit area of ground show a striking increase in the fenced short rotation burn treatment. The mineral nutrient content of the samples is being determined. A count of the number of fruits in the same experiment revealed differences between fenced, unfenced and short rotation burn treatments. Outside the fence no fruits were found, inside the fence fruits were found in most treatments with the greatest numbers in the short rotation burn. A survey of other enclosures on the Reserve showed similar differences between fenced and unfenced areas.

III Fauna

- (a) Invertebrates of an area of moorland (J. M. Nelson)

During the past five years the invertebrates occurring on six sites considered typical of the dominant vegetation types present in an area within $\frac{1}{2}$ mile radius of the Field Station, have been sampled regularly using detergent pitfall traps. This has been supported by general collecting and in the past year by light trapping. Attention has been concentrated on those groups not studied by Durham University Zoology Department. Identification of the material, which can at present be determined, has nearly been completed. To date 589 species have been recorded. To these may be added practically all the 422 species of arthropod so far recorded by the Durham zoologists, giving a total of over 1000 species occurring within this relatively small area. While it is possible that this still represents only a fraction of the total species present the data collected gives a good idea of the abundance, distribution and phenology of the species recorded and indicates those groups requiring further study. When it is realised that detailed studies have been made on less than a dozen species the magnitude of this field becomes apparent. The data are being prepared for publication.

While it is possible to identify the adults of many of the flies occurring, with a few notable exceptions e.g. Tipulidae, the larvae of many of the commonest species are unknown. To attempt to remedy this situation larvae extracted in Tullgren funnels have been reared. By this means larval skins, pupae and adults can be associated. Most of the common Empidids together with the various Dolichopodids, Scatophagids, Muscids and Anthomyiids have been reared. It is hoped to describe and figure these.

- (b) Faunal survey of Knock Fell enclosure (B.P. Springett)

The populations of micro-arthropods on Knock Fell have a similar species composition and show similar numerical fluctuations as populations on limestone grassland at lower altitudes. The numbers of micro-arthropods within the enclosure are generally lower than the numbers outside, and the same is true for the Enchytraeidae. Many of the predatory invertebrates (beetles, spiders) are more common inside the enclosure than outside, but this may be a result

of the sheltering effect of the vegetation. Rodent activity (Microtus) is very marked within the enclosure. The results of this survey are being written up for publication.

(c) Secondary production on blanket bog (B.P.Springett)

A preliminary survey of the phytophagous insects of Calluna - Eriophorum moor was initiated in 1967 as part of the Moor House I.B.P. study. The results indicate that lepidopteran caterpillars, and a species of psyllid (Strophingia ericae) are likely to be the main herbivores on Calluna shoots. Mites are also common on shoots, but their feeding biology is unknown, as is the effect and identity of root feeders. The heather beetle, Lochmaea suturaeis, has not been found on the Reserve. A more intensive survey is being designed for 1968.

(d) Grouse population (B.P.Springett)

Grouse counts on selected areas have continued and a dog was purchased to help with the work. The population in 1966 was probably the highest for many years, but the 1967 counts are considerably lower.

(e) Feeding studies with grouse chicks (B.P.Springett)

A study of the role of insect food in the survival of grouse chicks was started in 1967, in co-operation with the Grouse Unit, Banchory. The study is designed to yield data on crop contents of chicks compared with the amount of insect food available. Preliminary results indicate that the insect fauna of Kerloch (150 m O.D.), near Banchory, is much richer and more diverse than the Moor House insect fauna, but detailed results are not yet available.

(f) Sheep production and ecology (M.Rawes, R.B.Marsh and M.W.Read)

The recording of live weight increment over the fell-grazing season has continued with the same sheep flocks. Ewe hoggs in a further two flocks were also weighed in April, and at this time of the year a large difference (on average 20 lb) was found between sheep of the same age but in different flocks.

Observations on the distribution of sheep on the Reserve have continued. Thirty more hoggs were numbered in the spring and there are now 55 tagged sheep on the fell. Daily observations are made and the locations of numbered sheep recorded. Information on habitat preference and differing performance (live weight gain) are being obtained for different parts of the Reserve. Additionally, the extent of home range and territorial behaviour of a number of sheep is being studied. Some of this data has been used by Rawes and Welch (in preparation), although the current year's field work is incomplete there is strong evidence that sheep tagged in 1966 have taken up similar territories in 1967.

(g) Vertical migration of enchytraeidae (J.Brittain, B.P.Springett and J.A.Springett) (I.B.P.)

A field sampling programme was designed to study the vertical movement of enchytraeids in response to changes in water content of an area of blanket bog. A decrease in water content of the 0-3 cm. zone of the peat was accompanied by a decrease in the percentage of worms in that zone. Cernosvitoviella briganta appeared to be more sensitive to change than Comettia sphagnetorum. A change in the water

content from 87-84% in four hours produced a drop in the number of worms in the surface layer, 75-21% for C. briganta and 80-61% for C. sphagnetorum with a corresponding rise in proportions in the 3-6 cm layer. The results of this study are being prepared for publication.

Visitors

- (h) Studies on Cercopidae (.J.B. Whittaker, Biology Department, Lancaster) (I.B.P.)

As part of a long-term study on the population dynamics of Neophilaenus lineatus (a grassland and moorland froghopper), censuses have again been made of the species at two sites on the Moor House Reserve. (Juncus squarrosus at Bog End and a nearby Nardus stricta area). Changes in the populations on these two areas have been in close parallel during the last six years (1961-66) and in the first part of 1967. The population on the Nardus site was experimentally reduced to one half of its natural density in July 1967, and the Juncus population was left untouched. The effects of this reduction are under study.

- (i) Studies on freshwater Fauna (D.T. Crisp, F.B.A.)

In the course of investigations on the effects on the fauna of the new Cow Green Reservoir sampling has taken place on the Reserve. Sites in the Tees, Trout Beck and Moss Burn, all of which had been sampled in previous years, were studied. Estimates on the fish population and the growth and stomach contents of trout and bullheads have been made. The results are being analysed.

- (j) Ecological studies on Moorland Carabidae (Ground Beetles) (K. Houston, Zoology Department, Durham University)

Throughout the year intensive trapping at various altitudes has been in progress. All Carabids caught here have been dissected and details on their distribution and breeding biology are now known. Detailed analysis of these results has shown that it is likely that the adults of certain species can be aged from the state of their mandibles.

Satisfactory marking techniques have been developed which makes possible the individual and permanent marking of the adults.

Numerous frogs and shrews have been caught in the pit-fall traps. Their stomach contents have been examined and their effect as predators in the moorland ecosystem is being assessed. Publication, in the near future, of these results is envisaged.

- (k) Studies on Crane flies (Tipulidae) (J. Horobin, Zoology Department, Durham) (I.B.P.)

These studies follow those by Dr. J.C. Coulson and Dr. M. Hadley on the biology of Crane flies and particular attention is being paid to the effect of altitude.

- (1) Studies on the genus *Oscinella* (Diptera: Chloropidae) at high altitude (G.P. Vickerman, Agricultural Zoology Department, Newcastle) (I.B.P.)

The distribution of the genus *Oscinella* in relation to altitude and vegetation and the phenology of *Oscinella frit* L at high altitudes was studied between June and September 1967. Preliminary results suggest that *Oscinella frit* L does not occur above 2,300 ft; no *Oscinella* spp. were collected above this altitude. *Oscinella nitidissima* was found up to 1,300 ft; five species of *Oscinella* occurred below 1,100 ft. Smaller numbers of *Oscinella* spp. were found on limestone grasslands than on alluvial grasslands; the former were heavily grazed by sheep and produced many fine tillers which were probably unsuitable for oviposition.

At 1,900 ft. *Oscinella frit* L emerged in the second week in June and there was one generation of imagines. At 1,100 ft. peak emergence occurred in the first week in June and a partial second generation of imagines was found. In the low lying coastal belt of N.E. England peak emergence occurs in late May to early June and there are two generations of imagines with a partial third in favourable years; in southern England there are three generations with a partial fourth in some years.

The work is under the supervision of Dr. A. Ibbotson. Further work on the speciation and morphology of *Oscinella* is in progress.

IV. Hydrology

Visitors

- (a) The propagation of flood waves in natural channels. (R.B. Painter, Civil Engineering Department, Newcastle)

A study has been made of the effect of varying meteorological characteristics of storm rainfall, catchment form, and channel characteristics on the formation of flood waves on twenty six catchments in northern England, including Trout Beck at Moor House. It was found that the duration of storm rainfall and the average minimum infiltration rates of the soils within a catchment were by far the most significant factors.

The results of the research have then been used to predict the time of arrival of flood crests on small or ungauged catchments, and the application of the technique developed, called the "time to peak" method, has been compared with the use of flood routing and unit hydrograph studies for a number of catchments.

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

Following the injection of 47 cm of tritiated water at each of five positions in a sloping area of blanket peat at Moor House on the 14 October, 1966, one of the sites was sampled on the 5th and 6th September, 1967.

A grid of 49 sample positions was set out covering an area adjacent to and downslope from one of the 75 cm deep injection points.

The coverage was at metre intervals adjacent to the injection and spread more widely to cover an overall downslope distance of 13 metres with a width of 10 metres. Samples were taken using a coring instrument, 120 cm long, modified from a design of the Macaulay Institute.

The results show very little movement of the water. A hole adjacent to the injection point contained tracer over the full 75 cms depth of the peat indicating vertical transport of the tracer. The lateral spread was less than 1 metre and further samples will be taken in the immediate locality of the injection point to delineate the actual lateral spread. The high concentration found near the injection point indicates that all the tracer could still be retained in the immediate vicinity of the injection point.

V. Soils

(a) Soil physiology on Knock Fell (P.T.A. Howard, Merlewood)

Measurements of field CO₂ evolution have been discontinued. This is partly due to the difficulties associated with the use of the present equipment in such exposed conditions.

Laboratory measurement of O₂ uptake of cores will continue until November, when the study will be completed. Cores are being taken from contiguous areas within and without the enclosure, the areas being on the brown limestone soil.

The cores are divided into: a) L/F layer, b) 0 to 7 cm. mineral soil. Oxygen uptake is measured first at field temperature (at 5 cm. depth) then at 10°C. moisture content, organic matter content, bulk density, of the cores are also determined.

(b) Visits have been made during the year by the Department of Soil Survey, Macaulay Institute for Soil Research. Comparisons are being made between the "Fell Top Podzols" on the Dun Fells and some "Alpine Soils" on higher hills in Scotland.

VI. Microbiology

(a) Fungi and bacteria associated with moorland soils (P.M. Latter and W.W. Heal, Merlewood)

The results of this study initiated by Dr. J.B. Cragg, have now been published in three papers. Observations on the decomposition of Juncus squarrosus leaves in nylon nets continues. After 3½ years in the field the leaves are still recognizable. Changes in the last year have been very slight and the leaves are still in the F horizon, at a depth of 2.0 cm.

(b) Microbiology of grazed and ungrazed grassland (P.M. Latter and O.W. Heal, Merlewood)

The removal of sheep grazing from Agrostis-Festuca and Juncus squarrosus grasslands causes marked changes in the composition of the microflora. However, it is not yet possible to say whether these result from changes in sward composition and production, micro-climate and soil conditions, or direct effects such as the absence of dunging.

Isolation from washed particles show that on ungrazed Juncus grassland Penicillium, Mucor and gram-negative rods predominate while Mortierella, sterile dark fungi, Bacillus and Arthrobacter predominate on grazed areas.

No marked differences in the quantities of bacteria, fungi and amceba or the rate of decomposition of cotton strips have been recorded so far but analysis of results is not yet complete.

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

Samples of Calluna stems, Calluna shoots and Eriophorum leaves were laid down in blanket bog vegetation on Bog Hill in September 1966. In the first 12 months loss in dry weight of about 8.17 and 26% respectively were shown. This compares with annual losses of 2% for Juncus squarrosus and 1% of Sphagnum recorded by Latter and Cragg (1967) and Clymo (1965) from Moor House. Rates of O₂ consumption of the Calluna and Eriophorum samples, measured by P.J.A. Howard (Merlewood) were positively correlated with dry weight loss.

(d) A food study on a Nematode (W.B.Banage (Makerere University College and O.W. Heal, Merlewood)

During the year Dr. Banage and Dr. Heal collaborated in a short quantitative study of the food of a rhabditid nematode. Newly hatched nematodes were sterilised and cultured in a bacteriostatic medium containing known numbers of Pseudomonas stricta as food.

Growth of the nematodes and food consumption were recorded daily for up to 7 days. Respiration rates of different stages of the life-cycle of the nematode have been measured independently by Dr. Banage and from these data an attempt is being made to calculate an energy budget for the nematode.

(e) Fauna - microflora relationships (J.A.Springett and P.M.Latter)

Dr. Springett has collaborated with Miss Latter in studies on the food of enchytraeids. Two methods have been used: examination of the growth of Coenettia sphagnetorum on single species cultures of fungi in the laboratory and trapping of enchytraeids in the field using agar discs containing a suspension of fungi or bacteria.

In laboratory studies best growth (a 25% increase in length in 20 days) was recorded on a sterile dark mycelium (SD3) compared with other fungi. The age of the mycelium was also shown to influence growth of worms. In the field, most of the 23 fungi used as baits attracted enchytraeids and other animals, control baits without fungi do not attract animals. The two dominant enchytraeids (Coenettia sphagnetorum and Cernosvitoviella briganta) showed different preferences. Bacterial baits did not catch enchytraeids but attracted nematodes.

Visitors

(f) Methods of studying the cycling of selected inorganic ions during the decomposition of vegetation (A.J.Holding and N.Martin, Department of General Microbiology, Edinburgh) (I.B.P.)

A visual and microscopical examination of the blanket bog profile showed four horizons, namely with increasing depth, the litter layer (0-6 cm), and the dark-brown (6-10 cm) greenish-brown, (10-20 cm) and rust coloured (20 cm) zones.

The predominant types of bacteria occurring in the four zones were characterised after isolation on peat expressate-yeast extract agar, which was found to be the most suitable medium. In the rust and green-brown zones several types of *Bacillus* made up about 90% of the population. These bacteria occurred as about 50% of the organisms in the dark-brown layer and as a much smaller proportion of the litter microflora. In the litter these organisms occurred mainly as endospores, whereas in the two lower horizons only about 30% of the cells were in the resistant stage. In all horizons the remainder of the bacterial population was made up of various types of Gram-negative bacteria and much less frequently of micrococci.

Respiration studies have been started to determine those inorganic nutrients which might be limiting microbial activity. Constant volume respirometry proved unsatisfactory and a PO_2 electrode was used in later studies, measuring the removal of O_2 in peat macerated in sterile water. Early experiments with adding cations and 0.01% glucose (w/v) to the homogenate emphasized the problem of exchange acidity. On adding Ca^{++} and K^+ ions the pH fell from about 3.7 to 2.8 and a pink-pigmented yeast became the dominant organism. Later the pH was kept at 3.7 and changes in respiration rates of the dark-brown horizon were studied. The Ca^{++} and K^+ ions gave the largest response with the SO_4^{++} and trace element mixture giving a smaller but still marked response. Unexpectedly the PO_4^- and NO_3^- produced only a slight effect. The influence of these ions on respiration rates and microbial populations in the presence of added organic substrates (e.g. glucose) is now being investigated.

The effect on the microbial populations of adding Ca^{++} K^+ PO_4^- SO_4^{--} and NO_3^- to the dark-brown horizon in the field is being investigated. Aerobic bacteria respond to the addition of the nutrients.

The peat liquid expressed in a rotary press has a reaction of about pH 4.4. Several organic substrates added aseptically to the expressed liquid preferentially promote the development of bacteria. Further studies on the inorganic nutrient availability in relation to the unpressed peat are merited. Protozoa are numerous in many of the treatments.

The continuous percolation of inorganic nutrients through sand-peat mixtures is being carried out. The predominant micro-organisms developing will be used in similar experiments, employing ion exchange resins. Both pure and simple mixed cultures will be tried in an attempt to elucidate the factors in the blanket bog which might be influencing the growth of the individual dominant types of micro-organism.

(g) Anaerobic and facultative bacteria in peat soils
(V.G.Collins and B.T. D'Sylva, Biological Association)
(I.B.P.)

The objects of this study are to enumerate, isolate, identify and examine the biochemical activities of the anaerobic and facultative bacteria in the blanket bog peat. In an initial survey, samples were taken from four distinct zones in a peat core (corresponding to depth of 0-6, 6-10, 10-20 and 20 cm). Four plates were made from serial dilutions using three different media. The plates were incubated at 18-20° and 25°C under both aerobic and microaerobic conditions. Aerobic and microaerobic counts on all media were

highest in the 10-20 cm zone with numbers ranging from 2×10^4 to 6×10^5 /g dry weight.

From these plates 240 isolates have been taken and purified for identification and further studies on their response to low temperatures and varying oxygen tensions and their biochemical activities.

XIII Publications

- Banage, W.B. 1966. Nematode distribution in some British upland moor soils with a note on nematode parasitizing fungi. *J. Anim. Ecol.* 35, 349-61.
- Block, W.C. 1966. Seasonal fluctuation and distribution of mite populations in moorland soils, with a note on biomass. *J. Anim. Ecol.* 35, 487-505.
- Block, W.C. 1967. Recovery of mites from peat and mineral soils using a new flotation method. *J. Anim. Ecol.* 36, 323-28.
- Eddy, A and Welch, D. 1967. A species-list of flowering plants and ferns for the Moor House National Nature Reserve in Upper Teesdale. *B.S.B.I. Proc.* 6, 325-36.
- Gore, A.J.P. and Trquhart, C. 1966. The effects of waterlogging on the growth of Molinia caerulea and Eriophorum vaginatum. *J. Ecol.* 54, 617-35.
- Heal, O.W., Bailey, A.D. and Latter, Pamela M. 1967. Bacteria, fungi and protozoa in Signy Island soils compared with those from a temperate moorland. *Phil. Trans. R. Soc. Lond. B.* 252, 191-7.
- Latter, Pamela M., Cragg, J.B. and Heal, O.W. 1967. Comparative studies on the microbiology of four moorland soils in the northern Pennines. *J. Ecol.* 55, 445-64.
- Latter, Pamela, and Cragg, J.B. 1967. The decomposition of Juncus squarrosus leaves and microbiological changes in the profile of Juncus moor. *J. Ecol.* 55, 465-82.
- Tufnell, L. 1966. Some little-studied British landforms. *Proc. Cumb. Geol. Soc.* 2, 50-6.
- Welch, D. 1967. Studies in the germination and establishment of Juncus squarrosus. *New Phytol.* 66, 89-98.
- Welch, D. 1967. Communities containing Juncus squarrosus in upper Teesdale, England. *Vegetatio* 14, 229-40.
- Welch, D. 1967. Notes on Myosotis scorpioides agg. *Watsonia* 6, 276-9.
- Welch, D. and Rawes, M. 1966. The intensity of sheep grazing on high-level blanket bog in upper Teesdale. *Irish J. Agric. Res.* 5, 185-96.
- Welch, D. and Rawes, M. 1967. An erroneous naming of a Callunetum in the northern Pennines. *Field Naturalist N.S.* 12, 25-6

Higher degree thesis:

Jamieson, D.G. 1966. Spatial distribution of storm rainfall.
PhD degree, University of Newcastle.

Painter, R.B. 1967. The formation of flood waves in natural
channels.

PhD degree, University of Newcastle.

Springett, J.A. 1967. An ecological study of moorland
Enchytraeidae.

PhD degree, University of Durham.

Staff List

Officer-in-Charge

M. Rawes (Senior Experimental Officer)
Vegetation and sheep.

Scientific Staff

B.P. Springett (Scientific Officer) Zoology.
J.M. Nelson (Experimental Officer) Zoology.
M.W. Read (Assistant Experimental Officer) Botany.
R.B. Marsh (Scientific Assistant)

Warden

T.L. Hodgson

Estate Worker

D.W. Craig

Housekeeper

Mrs. M. Hodgson

Shorthand/typist (part-time)

Mrs. C. Norris

Domestic Help (part-time)

Mrs. J. Ryding

I.B.P.

Dr. J.A. Springett (part-time)
Miss S. Carrick (Scientific Assistant)

