MOOR HOUSE

22nd ANNUAL REPORT, 1981.

THE NATURE CONSERVANCY
MOOR HOUSE FIELD STATION
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Dear Ken,

Moor House Annual Reports.

I enclose this the last Annual Report from Moor House Field Station and thank you, and previous contributors, for your support.

Michael

M. Rawes.

29 October 1981.

THE NATURE CONSERVANCY COUNCIL

MOOR HOUSE

1981

22nd ANNUAL PROGRESS REPORT

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C O N T E N T S

I. GENERAL.

The Report covers the period 1 October 1980 - 30 September 1981, during which time the agony of the Field Station, which has been left without personnel and funds, continued and increased. The house complex has remained empty, and during the winter months was visited only once a week. An ineffectual system of heating operated sporadically throughout the winter, and local efforts were, and continue, to be made, with very little assistance, to preserve the property. During the summer the laboratory has been open, but with few exceptions, has been little used by universities. In view of the uncertainty and withdrawal of facilities this could be expected: the future looks bleak. What was once a thriving Station, considered a valuable asset in the days of the Nature Conservancy, is being allowed to decay and as far as N.C.C. is concerned will almost certainly close in 1982.

The assistance of I.T.E. (Merlewood Research Station) in providing accommodation and facilities at Merlewood is gratefully acknowledged. Two Occasional Papers, the publication list (No. 2), which now has 350 entries, and the botanical species lists (No. 12), have been computerized by I.T.E. In the future amendments and additions can be made more readily.

II. SCIENTIFIC.

It may at this stage be opportune to summarise the staff research programme as I organised it nearly twenty years ago. Before this time there were a number of separate projects originated and run by different research workers, who had now mostly moved elsewhere. This year, with only one other member of staff, the amount of work that can be done is very limited. The projects are:-

I Studies of sheep grazing and its effect on vegetation.

II. Introduction of plant species to re-create floristically rich habitats

III Studies on moorland management.

IV Studies on tree establishment.

V Climatological and hydrological recordings.

These projects were aimed at establishing improved methods of management in terms of resource, and are, in general, interrelated. The principle was usually to look at a problem in a wide sense, first by survey, and follow this in an intensive manner, concentrating on small representative sites. Thus in Project I both sheep and vegetation were surveyed and mapped on a Reserve scale and selected sites have been analysed for sheep utilisation and botanical composition. It was expected that the surveys, or parts of them, would be repeated every 20 - 30 years, but the representative sites at nearer to 5 yearly intervals.

Project I Sheep - vegetation studies.

The small scale site investigations have involved looking at a) sheep density, food preference, intake, live weight performance, nutrient transfer etc.; these ceased a number of years ago, and b) the effect of different management regimes, such as the removal of sheep, on botanical composition and production, and where possible recording soil and animal changes.

1. Removal of sheep: In the case of b) above, there are nine major sites where sheep have been excluded for periods of up to 27 years, and the vegetation has been recorded at varying intervals. Three methods have usually been employed, 1) mapping the whole enclosure, 2) mapping small quadrats, 25 x 25 cm size, and 3) vertical point quadrat recording at set intervals on a grid.

The sites are:- Bog Hill (the largest and earliest exclosure) on typical blanket bog, Silverband and Trout Beck Head (two impoverished and degrading high altitude blanket bog sites, Knock Fell (Agrostis-Festuca grassland), Little Dun Fell and Hard Hill (both Festuca-Deschampsia sub-montane grasslands), N1 (alluvial Nardus grassland), J1 (Juncus squarrosus grassland), and Moss Burn (calcareous flush).

Latest published results from Bog Hill are included in Rawes & Hobbs, 1979, and the grassland exclosures are brought up to date in Rawes, 1981.

The enclosures are of particular value due to their long-term nature and care needs to be taken 1) to ensure they remain sheep-proof, and 2) that other research workers, who may view them with particular interest for use in their own sphere, are not allowed unrestricted entry: the primary purpose of the enclosures could be quickly destroyed. It is, however, possible and, indeed of benefit, if some sampling is permitted in certain enclosures, and this has been done in the past.

2. Free range grazing: Nearby, and on similar vegetation to the exclosures are plots open to sheep grazing, employing a similar lay-out. In addition there are plots on four Agrostis, two Nardus and one Juncus squarrosus grasslands, and a flush.

Project II Recreation of floristic richness.

This project was started by K.J.F. Park, who introduced arctic-alpine and montane plant species not now on the Reserve. The range of species and habitats selected was small, but the project is closely related to the exclosure studies, and can be regarded as a short cut to demonstrating a more natural vegetation.

There were four sites: Rough Sike, the largest, Knock Fell, Little Dun Fell and Hard Hill. All introductions have failed in the last two enclosures and the Hard Hill fence has now been removed.

Records of presence and performance (flowering, seeding) are made each year.

The last publication was by Rawes & Welch, 1972.

Project III Moorland management.

There have been numerous fundamental studies the results of which are pointers to management; an example of this was the work on ageing Calluna, a knowledge of importance in burning and grazing management.

The following have been the main staff investigations:-

1. The effect on the vegetation of different sheep grazing regimes.
2. The effect on the vegetation of burning at two rotations, with and without sheep grazing.

3. The effect of moor gripping on vegetation and hydrology.

4. Surveys of grouse numbers and production.

1. Much of the sheep grazing work was terminated a number of years ago and published in Rawes & Williams, 1973. The recovery of a heavily grazed plot has however, been followed.

2. The heather burning experiment on the eastern slopes of Hard Hill has a well replicated and spacious layout involving four enclosures and two rotations (burning every 10 and 20 years) and controls. The next botanical analysis (every 10 years) is due in 1982 and next burning in 1984. The experiment was started in 1954. In the light of experience it would be worth introducing a more drastic rotation of burning every 5 years (when) possible). Some results have appeared in Rawes & Williams, 1973, and Rawes & Hobbs, 1979, and the experiment has received detailed appraisal in Hobbs & Gimingham, 1980, and the former has used the site and data in his Ph.D. research completed this year. Separate work on how the Cloudberry (Rubus chamaemorus) is affected by fire has been undertaken by Dr. K. Taylor, and currently he has a student pursuing further nutrient studies (see page 13).

3. Moor gripping and hydrological studies have been completed. Data from these studies featured in A.J.A. Stewart's contract (A.J.A. Stewart, 1979. The environmental impact of moor gripping. A Report to Chief Scientist's Team, N.C.C.). All the earlier catchment studies, the first by Dr. V.M. Conway, have terminated and been written up.

4. Grouse surveys date back to counts by Bruce Campbell in 1953, but it was not until the International Biological Programme that methods (under supervision of the Grouse Unit, Banchory) and the employment of a dog were adopted. Census plots were set up (Taylor & Rawes, 1974) and, with a few exceptions, counts have been made yearly to date. Of recent years the recording of nesting birds and performance has had to be reduced, although this has coincided with the restriction of heather burning to two main areas, each of 80 ha, of the Reserve.

Project IV. Trees.

The first plantings in 1954 had the aim of seeing whether "woodland" could be established. Most of the planting, in five sites, has been prior to 1963 and involved species trials and fertiliser treatments. The earliest plantation, Green Hole, was of native species only. The vegetation and soils of Green Hole have been mapped and quadrats for long-term vegetation changes established. Some results are given in Rawes, 1981. Other plantings have consisted mainly of Lodgepole, Mountain and Scots Pines, but Willows, Bird Cherry and Swedish Whitebeam have been successful.

Data on the number of trees surviving have been kept and measurements of height and girth increment made every 5 years.

The last publication on nutrition, was by Carlisle & Brown, 1973.

Project V Climatology.

Professor Gordon Manley started climatological recording at Moor House in 1932. A full Meteorological Office Climatological Station was installed in 1952 and maintained until May 1980. Only rarely has information on the climate not been essential to every research project and it remains our most sought after subject of enquiry from a wide range of researchers. At present to meet a need we continue to record temperature, rainfall and windspeed, and

with the employment of an Institute of Hydrology Automatic Weather Station, solar radiation. Chart recording, on which we now rely because of inability to make regular daily recordings, has not to date been very successful, but the repair of a more accurate recorder should permit much better reliability. Monthly rainfall totals are supplied to the Northumbrian Water Authority who also have an interrogeable rainguage on the Station.

There have been numerous publications on the climate, the most recent being by Manley (1980), using temperature data from 1932 to 1978.

During the reporting year the following projects have received some attention:

Project I. The vegetation of Silverband and Trout Beck Head exclosures was mapped and the results will support last year's point quadrat data on species change over 14 years. The mapping has shown the more dynamic changes, the invasion of large areas by Narthecium ossifragum, Rubus chamaemorus and Carex nigra in Silverband, at the expense of Eriophorum vaginatum and bare peat, and in both exclosures the increase of Empetrum nigrum and Calluna vulgaris and decrease in Sphagnum.

The botanical composition of the following grasslands open to sheep grazing have been recorded by point quadrat analysis:- N1 and N2 (Nardus dominated grasslands), J1 (Juncus squarrosus sward), A3 and Rough Sike (Agrostis-Festuca grasslands). The results will be compared with earlier data.

Project II. Records of introduced plants have been maintained and flowering noted.

Project III. Survey of grouse has been hindered by lack of staff time and injury to the pointer dog, but P. Holms reports as follows:-

Although Spring counts were carried out successfully in April, the temporary absence of the pointer restricted counts of nesting and chicks and only a few counts were made of young birds in the Autumn.

Density of grouse per study site 1981.

Site	Area (ha)	No. Adults	Birds/ha
Bog End	10.2	6	0.59
Burnt Hill	20.3	8	0.39
The Drive	20.2	4	0.20
Hard Hill A	21.2	6	0.28
Hard Hill B	24.5	5	0.20
Green Burn A	15.6	6	0.38
Green Burn B	14.7	6	0.41

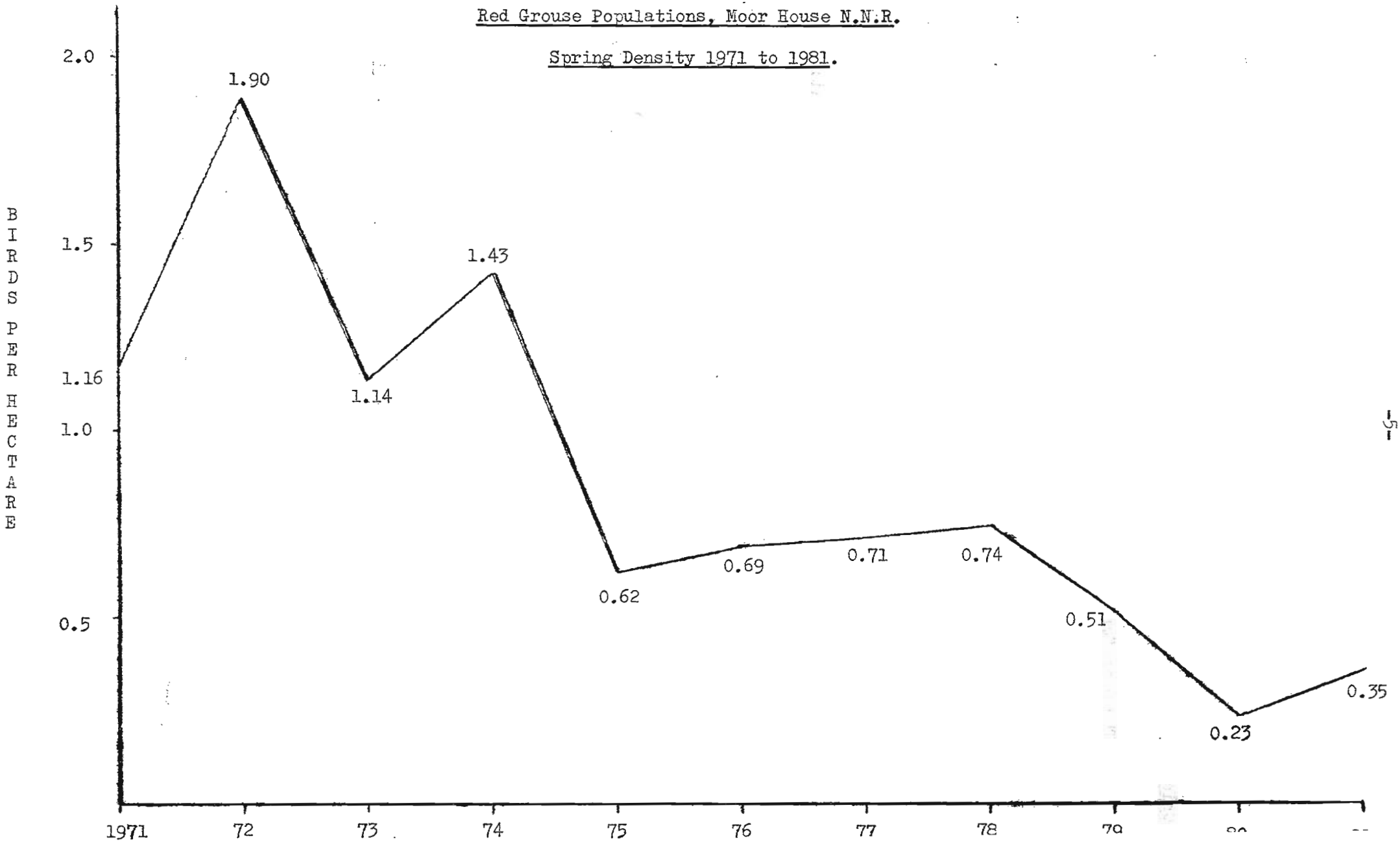
Overall average = 0.35

Spring counts.

Numbers of territorial birds increased to 0.35/hectare compared to last year's 0.23. Following an exceptionally mild winter, the heather was in good condition when the first counts were carried out in April.

Red Grouse Populations, Moor House N.N.R.

Spring Density 1971 to 1981.



Nesting.

Three nests were located with clutches of 7, 8 and 10 being recorded. Harsh weather conditions in April accounted for many failed nests on other grouse moors, but hatching success on Moor House was observed to be good.

Chicks.

The earliest recorded harching date was 8th May which is exceptionally early. The mean for the last 5 years is the 22nd.

Autumn population.

Some counts were carried out flushing birds without the use of the dog. This information, together with brood numbers observed by people walking the area, gave a young to old ratio of 2.8/1.

An early Spring with good heather growth produced broods of a good size and a healthy Autumn population.

Project V. Climatological recordings. Judith Scott reports on the weather, October 1980 - September 1981, as follows:-

The most outstanding feature of the weather this year was the relatively mild, snow-free winter, days of snow-lie for the winter months being 54, compared with 65 days of snow-lie in 1980, which in itself was considered a reasonably good winter. The 28 year average for days of snow-lie is 69 days.

Another notable feature of this year's weather was the Spring storm of late April. The temperature began to fall after a few days (15 - 18 April) of warm, dry weather, resulting in a cold week with some snow showers. On 24 April blizzard conditions began with heavy snowfall, high winds and severe drifting, giving 4 days of snow-lie, when the ground was completely or more than half covered, with patches of snow remaining at Moor House into May.

After a wet beginning to the summer, August proved to be the driest (57.7 mm) since 1976, and also one of the driest August's recorded.

The summary table for 1980 is given in the appendix.

III. RESEARCH BY THE INSTITUTE OF TERRESTRIAL ECOLOGY.

a) Assessment of a soil phosphate bioassay for field grown trees. (J. Dighton, Merlewood Research Station).

The phosphate bioassay of Harrison & Helliwell (1979) has been applied to the differentially fertilised Pinus contorta blocks of the Bog End plantation (Carlisle & Brown (1973), Brown (Moor House Annual Report 1980). In June 1980 feeder roots were carefully teased out of the top 5 cm of peat in the field, washed and subjected to the P-bioassay. The phosphate demand of the tree is correlated to the amount of ^{32}P taken up from the bioassay solution, high uptake indicating high phosphorus demand. The results of the P-uptake by roots was compared with first whorl needle analyses for phosphorus taken in February 1981.

P-uptake and needle analysis of Lodgepole Pine.

Site Code	P fertiliser added (kg P ha^{-1})		P-uptake (pg P mg^{-1} root)	% P in needles
	1962	1980[a]		
C	0	0	425	0.15
[b]P_1-	16	0	601	0.13
P_1+	16	51	223	0.18
[c]P_2-	20	0	439	0.16
P_2-	20	51	187	0.17

$F = 117.61$
$P < 0.001$

a. as 20:20 P.K.
b. P_1 as orthophosphate
c. P_2 as ground mineral phosphate

Uptake of phosphorus from the 1980 addition of fertiliser reduces phosphate demand in both previously fertilised blocks. The effect is of greater magnitude in P_1 probably as a result of the greater availability of orthophosphate-P to the trees than from ground mineral phosphate. This would result in an initially more rapid growth rate of P_1 trees over P_2 or control (C) resulting in a greater P deficit.

The root physiology suggests that all trees are deficient in phosphorus, but needle analysis of current year's growth are very similar regardless of fertiliser addition. This strongly suggests that needle analysis is less sensitive in response to total P demand by the tree due to nutrient redistribution to the apical region.

These results corroborate a similar series of results from a Forestry Commission fertiliser experiment on Lodgepole pine in Clocaenog, North Wales.

Mycorrhizal assessments were made in the small root samples counted for ^{32}P. There is some suggestion that the species composition of the mycorrhizal fungi is dependent on the fertiliser history. This aspect of the work is currently being examined in greater depth.

b) Annual growth of trees in relation to climate.
(A. Millar, Merlewood Research Station).

Investigation continues.

c) Microfungal community structure in forest and mountain ecosystems.
(P. Widden, Merlewood Research Station).

Studies have started.

IV. RESEARCH BY FRESHWATER BIOLOGICAL ASSOCIATION.

a) Fish populations.
(D.T. Crisp).

The routine observations on fish populations at Cow Green are continuing, but at a rather reduced level of effort.

During the Autumn of 1980 a number of reservoir trout were caught and tagged during their spawning run up the River Tees within the Moor House N.N.R. We continue to be indebted to N.C.C. for access to these waters.

V. RESEARCH BY NORTHUMBRIAN WATER AUTHORITY.

a) Hydrological studies at Moor House. (D.R. Archer).

A streamflow gauging station was in operation on the Trout Beck at Moor House from 1962 until 1980. Several recent investigations on the flood hydrology of catchments in the Northumbrian Water Authority area have made particular use of this record.

1. Flood estimation on ungauged catchments (Archer 1981)

Equations were presented in the Flood Studies Report (1976) for the estimation of flood magnitude of given return period from catchment characteristics. The equations were based on an analysis of gauged catchment data up to 1970.

Flood data from Northumbrian catchments up to 1979 were re-examined. It was shown that the FSR equations underestimate the mean annual flood on upland catchments such as Moor House and to overestimate the flood growth rates, as shown by the ratio of the 30 year return period flood to the mean annual flood.

2. The seasonality of flooding (Archer in press (A)).

The seasonal occurrence of floods in the Northumbrian area was investigated by determining for each gauging station the proportion of floods above a given return period in each month. On lowland catchments, in spite of the late summer maximum of storm rainfall, it was found that few floods occur in this season. This is due to the higher summer soil moisture deficits which must be restored before runoff occurs. At higher elevations with higher rainfall and lower evaporation, there is a progressive increase in the proportion of floods that occur during the late summer. However, Moor House, the highest and wettest catchment, is the only one on which the seasonal flood maximum occurs in late summer to coincide with the storm rainfall maximum.

3. Severe snowmelt runoff and its implications (Archer in press (B))

Meteorological studies of melting snow (Jackson 1978) suggested that severe rates of melt were of the order of 1.75 mm/hour. This rate was incorporated in the Institution of Civil Engineers (1978) procedure for estimation of the probable maximum flood for spillway design, in combination with storm rainfall. Studies in North East England with particular reference to events in 1978 and 1979 on the Trout Beck, Harwood Beck and Langdon Beck have shown that peak rates of runoff from melting snow, in spite of catchment attenuation, may be much higher than 1.75 mm/hour. Rates up to 7 mm/hour have been recorded on the Trout Beck.

Part of the discrepancy is due to the liquid water storage capacity of the snowpack. This causes a delay from the onset of melt to yield at the base of the pack. The duration of yield is shorter and peak intensities may be much higher.

Studies are continuing on the computer modelling of the snowmelt runoff process.

References.

Archer, D.R. 1981. A catchment approach to flood estimation. J. Inst. Water Engin. Sci. 35(3), p. 275-289.

Archer, D.R. (in press, A). The seasonality of flooding and the assessment of seasonal flood risk. J. Instn. Civil Eng.

Archer, D.R. (in press, B). Severe snowmelt runoff in North East England and its implications. J. Instn. Civil Eng.

Institution of Civil Engineers. 1978. Floods and Reservoir Safety - an Engineering Guide ICE, London.

Jackson, M.C. 1978. The influence of snowmelt on flood flows in rivers. J. Inst. Water Engin. Sci. 32, p. 495.

Natural Environment Research Council. 1975. Flood Studies Report.

VI. RESEARCH BY UNIVERSITIES.

a) Ecological studies on Strophingia ericae associated with Calluna vulgaris.

(J.B. Whittaker, Department of Biology, Lancaster University).

Routine sampling of the population of S. ericae at Sike Hill has continued, giving an almost unbroken series of samples since 1968.

In 1978, the population on a 10 m x 10 m plot was reduced to one half of the density of a control plot by spraying. The effect of this on the subsequent dynamics of the population has been carefully monitored but it is too early to draw final conclusions. Various characteristics of the Calluna on the treated and control plots have also been measured and a significantly greater amount of flowering was detected in 1980 on the control compared with the treated plot.

The study is continuing, but publication is planned in the next year or two.

A very interesting observation made at Dorth Gill and again at Rough Sike in July 1980 was the feeding (and spittle production) of Neophilaenus lineatus (a xylem feeder) on Polytrichum commune.

b) Biological studies on certain varieties of the harvestman Mitopus morio (Fabricius) (Opiliones, Arachnida).

(Amanda Jennings, Department of Zoology, Durham University).

The study has been directed towards an evaluation of the status of some of the forms of Mitopus morio, and whether certain of these forms should be raised to species status.

One of the main collecting sites for Mitopus was at Bog End on the Moor House Reserve at 549 m. Specimens were obtained from here to compare with those from the lower altitude sites in Co. Durham.

1. An ecogeographical examination has provided evidence for:-
   (a) A cline of variation with altitude for Mitopus morio,
   (b) The existence of a new species of Mitopus for upland Britain.

2. Three well described varieties have been identified for M. morio in Britain, two from upland and one from lowland regions. Field studies have provided quantitative information concerning the ecology and developmental histories in various parts of the range of these varieties, together with specimens from laboratory studies, including cross-breeding experiments.

3. A series of biometrics taken from specimens from the different altitude sites have provided the evidence for intraspecific character differentiation in M. morio; this species exhibits an altitude-linked cline of size variation in northern Britain.

4. The differences found in the ecology, morphology and biometrics combined with traditional taxonomy are the basis for the description of a new upland species of Mitopus.

c) Eco-physiological studies of Eriophorum vaginatum L. in a moorland habitat.
(K. Robertson, Department of Plant Sciences, Leeds University).

The Ph.D. thesis of the above studies is summarised as follows:-

Eriophorum vaginatum L. is a dominant or co-dominant species of the communities inhabiting many of the cool upland regions of the United Kingdom. This investigation is concerned with the adaptations of this species for carbon assimilation in one such environment, Moor House National Nature Reserve in the northern Pennines.

The response of leaf photosynthetic rate, stomatal conductance and residual conductance to variations in photon flux density, temperature and vapour pressure deficit was measured for leaves enclosed in a controlled micro-environment, in the laboratory, using infra-red gas analysers. The light response of photosynthesis was typical of that of a C_3 species, with an high apparent quantum efficiency and light saturation occurring at c. 1000 $\mu mol\ m^{-2}s^{-1}$. The maximum rates of photosynthesis were comparable with other temperate and arctic species, the temperature optimum being 15 - 20°C. The decline at suboptimal temperatures was associated with a decline in residual conductance while the decline at supraoptimal temperatures was due to an increase in the rate of dark respiration and a decline in stomatal conductance.

The seasonal dynamics of leaf area was examined in situ by destructive harvesting and a demographic study. This latter study established that leaf area expansion at the start of the growing season was due both to the appearance of new leaves and the renewed growth of leaves appearing in the latter part of the previous growing season. The age structure of the leaf population becomes increasingly juvenile-dominated as the season progresses, the highest birth rates of leaves occurring in June - August. In this period the death rate of leaves is low but this increases in August - October due to the mortality of overwintering leaves and those leaves appearing in the early part of the current season. There is considerable mortality in the winter but this is restricted to particular cohorts.

The demographic study formed the basis of the sampling strategy for field measurements of photosynthesis by a $^{14}CO_2$ incorporation method. Overwintering leaves maintained appreciable photosynthetic rates in the cool conditions at the start of the growing season. By August, those leaves appearing in the current year exhibited photosynthetic capacities which were c. 2.5 times those of the overwintering leaves, the photosynthetic rates of the current year's leaves being comparable with those obtained in the laboratory, from June - August. Unlike the overwintering leaves which did not exhibit any seasonal trend in photosynthetic capacity, the current year's leaves showed a marked decline in this capacity in the latter part of the growing season, due partially to a deterioration in environmental conditions but also to ontogenetic changes, the early season cohorts in particular showing a marked decline, concurrent with the onset of visible senesence.

Finally these results are formulated in a model and the adaptive significance of these findings discussed, particularly with reference to radiation interception and nutrient conservation.

d) The Carbon Dioxide exchange of Sphagnum capillifolium (Ehrh.) Hedw. growing in a blanket mire habitat.
(S. Daggitt, Department of Plant Sciences, Leeds University).

The Ph.D. thesis of the above study is summarised as follows:-

Investigations were carried out into the response of the CO_2 exchange of Sphagnum capillifolium to three variables: light, moss temperature and moss water content.

Field measurements of photosynthesis in this species were made on the blanket mire at the Moor House National Nature Reserve, during 1979 and 1980, using a $^{14}CO_2$ assimilation technique. Maximum photosynthetic rates were low in the Spring of both years and this is considered to have been a consequence of unfavourable environmental conditions over the winter. In July 1979 and May 1980 droughts occurred on the mire. Colonies of S. capillifolium became dehydrated and photosynthetic rates were depressed. Maximum photosynthetic rates were high during the Autumn of 1979. The apparent quantum efficiency of photosynthesis increased during the latter half of the 1979 growing season.

Plants of S. capillifolium growing in the open develop red pigmentation and often have a denser capitulum than plants growing underneath a Calluna canopy. The photosynthetic rates of red plants were found to be lower than those of green plants.

Laboratory measurements of CO_2 exchange were made using infra-red gas analysers. Light compensation points were high (30 - 150 μmol m^{-2} s^{-1}) and varied with temperature. Red plants were found to have lower net photosynthetic rates than green plants over a range of photon flux densities. No inhibition of net photosynthesis was found during measurements at high photon flux densities. A broad optimum temperature range (10 - 30°C) for net photosynthesis was measured at saturating photon flux densities. This optimum declined as photon flux density decreased. The optimum water content for net photosynthesis was in the range 700 to 1700% of dry weight and strong inhibition of net photosynthesis occurred at greater or lesser water contents.

A model is presented, based on laboratory measurements, which predicts field photosynthetic rates from inputs of light, moss temperature, and moss water content data.

e) Post-fire succession in heathland communities.
(R.J. Hobbs, Department of Botany, University of Aberdeen).

Data collected from the experimental plots on Hard Hill during 1978 - 80 have been analysed and incorporated in a study of the effects of stand age at time of burning on post-fire vegetation response. Plots subjected to short and long-rotation burning provided stands that were 10 and 20 years old respectively when burnt. Results showed increased dominance by Eriophorum vaginatum and E. angustifolium in the short rotation plots. Calluna vulgaris regrowth was considerably more abundant in the long-rotation plots, where formation of extensive Eriophorum mats was prevented. Results from this site conformed with those from drier heath sites, in that the vegetation composition before fire had a large effect on the post-fire recovery pattern. The data were found to fit with a first-order Markov process, and a Markov model provided relatively good predictions of vegetation development.

f) Gas production during peat formation.
(Jane Claricoates, Department of Botany, Westfield College, London).

A study of gas production during peat formation was started in October 1980.

Earlier work has shown that, although the decay of plant material in the uppermost 15 - 20 cm of a bog is fairly rapid, at greater depths where the peat is waterlogged and anaerobic decay processes occur, the decay rate is very much slower. It appears that, slow as it may be, it is this rate which determines the ultimate depth of peat which can accumulate.

In order to determine what these decay rates are, the efflux of CH_4 and CO_2 from the bog surface is being used as an integrating measure of decay rate.

In early December 1980, thirty five peat cores (32 cm diameter x 35 cm deep) were taken from Burnt Hill pools, lawns and hummocks, and installed in buckets sunk in the garden at Westfield College. Gas production by these cores is being measured above the peat at approximately monthly intervals, while continuous climatic records are being taken. It is planned to determine the effects on the anaerobic decay processes of altering the water table in the peat now that this can be controlled in the garden cores.

The site at Burnt Hill (amongst others) is also to be used for field measurements of efflux of CH_4 and CO_2, both at the bog surface and at intervals through the peat profile, in order to estimate decay rates and movement of gases in the anaerobic peat at the different depths.

g) The effect of altitude, climate and soil status on the growth of Agrosto-Festucetum grass swards at Moor House National Nature Reserve. (J.C. Hatton, Department of Botany, University College London).

Grassland productivity generally declines with increasing altitude and harsher climate. Rawes (1963) found that grassland productivity at Moor House N.N.R. varied from 60 g dry weight/m^2 (Festucetum) at 840 m O.D. to 270 g/m^2 (Agrosto-Festucetum) at 510 m O.D. The present research project aims to identify the separate effects of climate and mineral supply, and to determine the extent of these effects contributing to reduced grassland growth at Moor House N.N.R.

Four altitudinal sites have been chosen, the choice of sites was determined by three main factors:-

1. All soil types to be brown earths overlying carboniferous limestone.
2. No site to have been subject to fertilizer treatment.
3. All sites subject to similar grazing regimes.

On this basis the four sites chosen were:-

Low Cairn	490 m
Rough Sike	580 m
Johnny's Flush	640 m
Knock Fell	750 m

The main aim is to collate microclimatic data from each of the four sites with above ground productivity and availability of soil nutrients throughout the growing season. Preliminary measurements were made during May - September 1981.

At three points throughout the growing season small amounts of soil have been removed from each altitudinal site to the laboratories at University College London to determine N-mineralization rates (at field temperatures at the time of sampling) and P-availability.

Preliminary results indicate that ammonium-N is of the order five times higher than that of nitrate-N in these brown earth soils. This would appear to indicate that nitrification of ammonium to nitrate is inhibited at these higher altitudes. Another obvious feature is the low levels of available N found at the highest site (Knock Fell, 750 m), indicating a general suppression of the nitrification process at the highest altitude.

Air dried soils are being held at University College London to determine "available" P. A resin extractable technique has been developed which will indicate to what extent, if any, P-availability varies with altitude and season.

Tillers of Festuca ovina from each of the four altitudinal sites have been used to carry out a ^{32}P "stress test" (Harrison and Helliwell, 1980) at I.T.E. (Merlewood), Grange-over-Sands. The preliminary results are extremely interesting and appear to show that this plant may be used as an indicator to determine P-availability: plants from the highest altitude show extreme stress with regards to P-deficiency.

Productivity measurements will have been made for three periods between 22 May 1981 and 4 October 1981. Productivity under grazing is determined by placing two aluminium frame cages (exclosures) randomly in the study area at each altitudinal site. 0.36 m^2 quadrats are cut within each cage, the samples removed to laboratory for drying and weighing. The final productivity measurements are to be determined at the end of the growing season.

It is also hoped to examine the effect of fertilizer treatment on grass productivity. N, P and K in 2 x 2 x 2 factorial combination (viz in all combinations) will be applied at each of the four altitudinal sites. Although fertiliser plots were laid out for the 1981 growing season, these have had to be abandoned as the exclosures have been breached.

Reference.

Harrison, A.F. and Helliwell, D.R. 1979. A bioassay for comparing Phosphorus availability in soils. J. appl. Ecol. 16, 497 - 505.

h) Mechanisms of plant interaction in a Blanket bog community.
(C.H. Thomson, Department of Botany, University College London).

1. Response of Rubus chamaemorus to fertilization.

Introduction.

In experimental plots on the east flank of Hard Hill, a study investigating the mineral nutrient status of Rubus chamaemorus in relation to burning and sheep grazing established that nutrient supply (N, P, K, Ca,Mg) was not the major factor limiting growth of Rubus (Marks & Taylor 1972). The evidence, however, was indirect, and was based firstly upon the effects of a removal of the Calluna vulgaris canopy which led to an increase in shoot numbers, dry matter yield and nutrient uptake, though no change in seasonal nutrient concentrations, and, secondly upon the effect of ash deposition onto cropped plots, which showed no significant increase in shoot numbers over similar plots not receiving ash. It was concluded that the major factor limiting growth was some aspect of microclimatic change resulting from canopy removal.

In order to directly establish the relative importance of mineral uptake, it was necessary to test the effect of an increase in mineral nutrients through fertilizer addition on unburned controls. An increase in the total content of an element, and in the dry weight of shoots per unit area, in the presence of a Calluna canopy would indicate that the element was limiting.

Description of the experiment.

The research site was located on the east flank of Hard Hill at around 610 m. Plots within the experimental enclosures blocks B and C, previously used to follow the response of Rubus to sheep grazing and rotational burning were set aside for fertilizer treatment. Only the fenced control plots, last burnt in 1954, B/NF and C/NF were used in the experiment.

A randomised block design with ten replicates was set out in plots B/NF and C/NF, five in each. Each block consisted of a square grid of sixteen, 1 x 1 m plots separated by 1 m buffer strips. N, P and K as analor grade salt powders were applied singly and in combination, at high and low levels, giving fourteen treatments plus two controls.

The rates of application and salts used are shown in Table 1. Dosage was based upon levels used in fertilizer trials carried out upon similar communities. The low rate was the minimum that was thought might produce a response, and the high rate the maximum that would not exceed 80 - 120 gm^{-2} of combined fertilizer which may damage the plants.

Fertilizer placement was in the main rooting zone of Rubus, established on site to be at approximately 15 cm depth. This ensured a maximum selective uptake of applied fertilizer. The measured quantities of fertilizer were poured into a single hole 3.7 cm in diameter at the centre of each 1 m^2 plot and pushed to the required depth.

Plant sampling and analysis.

Since the seasonal drift of shoot numbers, dry weight and nutrient concentrations has already been established (Taylor & Marks, 1971), only one sampling was necessary for plants at full maturity. In early August all above-ground shoots of Rubus were collected from within the 1 m^2 plots. Due to an unusual growing season, Rubus had matured early and was starting to reverse. Some leaves had become detached from their stems, so that it was no longer possible to accurately determine shoot numbers/m^2. An approximation was obtained by counting the number of single and double stems and comparing them to leaf number. Total leaf area was determined for each plot. Samples were then separated into leaf laminae and petioles and dried at 80°C to constant weight and then weighed. Nutrient analyses are to be performed on the leaf and petiole tissue.

Calluna shoot samples were taken in the high NPK treatments and the controls in each of the ten replicates as a check for fertilizer uptake. Nutrient analyses will be performed on the samples.

To establish whether or not fertilizer had spread laterally from the point of application, soil cores were taken from three high NPK treatments and the corresponding controls, two cores adjacent to the placement hole and two on the perimeter of the 1 m^2 plots. Extractable P and K will be measured for each sample core.

Results.

To be analysed.

Mineral nutrient treatments, Block C C/NF
Thursday, 9 April.

UP

H - HIGH
L - LOW

NP H	NPK L	NP L	N L
CN	P L	K L	PK L
K H	N H	NK L	NPK H
NK H	CN	PK H	P H

CN	NPK H	K L	NK L
NK H	N H	CN	P L
NPK L	NP L	NP H	PK L
K H	PK H	N L	P H

NP L	CN	CN	N H
NP H	N L	K H	NK H
NPK H	NK L	K L	PK L
PK H	NPK L	P L	P H

CN	PK H	NP H	N H
N L	NP L	NPK H	K L
P H	P L	NK L	K H
NK H	PK L	CN	NPK L

NK L	NPK H	CN	NK H
NPK L	PK L	PK H	CN
N L	N H	NP L	P H
K L	K H	NP H	P L

Mineral nutrient treatments, Block B B/NF
Friday, 10 April.

UP

H - HIGH
L - LOW

P L	P H	K H	K L
NK L	CN	N H	NP L
NPK H	NK H	PK L	NP H
CN	NPK L	N L	PK H

N L	K H	NP L	K L
P L	PK L	NPK L	CN
NPK H	NK L	P H	CN
N H	NK H	NP H	PK H

PK L	NK H	P L	K L
NP H	NPK H	N H	K H
CN	NPK L	NK L	N L
CN	PK H	NP L	P H

PK L	NK H	K L	P H
NPK H	NP L	CN	NK L
N H	N L	K H	P L
NP H	CN	NPK L	PK H

K L	CN	NPK H	NP H
NP L	NK L	N H	N L
NK H	CN	P L	PK L
P H	NPK L	K H	PK H

Table 1. Rates of fertilizer application.

Element	Compound	% element in compound	Rate of application element gm^{-2}		compound gm^{-2}
N	$(NH_4)_2SO_4$	21.2	low	0.84	4.0
			high	8.40	40.0
P	$NaH_2PO_42H_2O$	19.9	low	0.90	2.0
			high	9.00	20.0
K	K_2SO_4	45.0	low	0.40	2.0
			high	4.00	20.0

2. Morphological studies: cropping experiments.

Introduction.

It is evident from the results of the Hard Hill experiment that one of the main effects of burning on Rubus chamaemorus was an increase in shoot density. Since this increase occurred in the same year that the treatment was applied, the response must be either directly or indirectly caused by the regulatory influence of the limiting factor on the development of already formed shoot or rhizome buds. Field observations of bud position and sympodial branching patterns, and dissections from turves, of intact rhizome systems, established that there was a large reserve of buds from which shoots could develop in any single growing season.

The morphological studies were concerned with the factors determining potential and actual shoot production. The potential production depends on the size and position of the bud reserve, and the length of time buds can remain dormant. The factors determining actual production can be deduced by examining the origin of the present season's shoots relative to the position and number of other shoots, aborted buds and potentially developing buds.

Description of the experiment.

The basis of this experiment was to stimulate an increase in shoot numbers by cropping plots and comparing the morphology of the shoot - rhizome system and the development of buds to that in intact control plots.

In mid-May, eight 1 x 10 m plots arranged in two rows, and separated by 1 m buffer zones were established on House Hill (Figure 1). The site was Calluna-Eriophoretum on blanket peat. Half of the plots were cropped to the bog surface, with the other half left intact as control plots. Treatments were assigned at random.

Plant sampling.

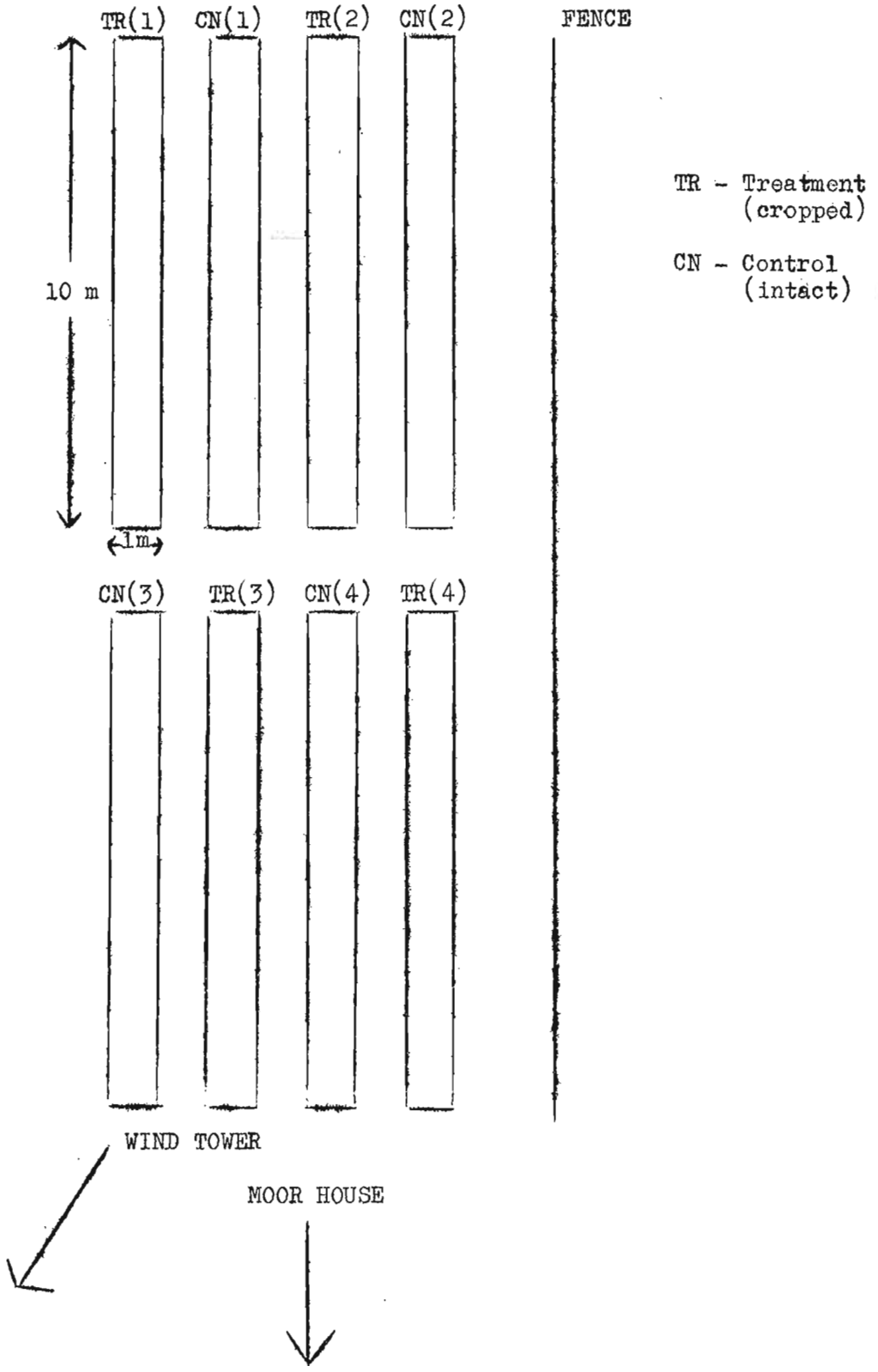
The plots were subdivided into ten, 1 m^2 sub-plots. 0.5 m^2 quadrats were positioned in the centre of these sub-plots at each sampling date. Samples were taken at random, and consisted of the following:-

An initial sample in May of each shoots' sympodial branching system, including as much of the preceding years shoots, which are remaining on the axis, as possible in each 0.5 m^2 quadrat. One quadrat was taken from each plot. A final set of samples collected from each plot in early August - two samples taken in a similar way to the first sample, and three samples of the above ground shoots from each plot. So a total of five quadrats per plot were taken at the second sampling to determine differences in shoot numbers and leaf areas, with two samples for morphological-developmental examination.

Results.

To be analysed.

Figure 1. Cropped plots: House Hill.



3. The effect of an increase in light received by Rubus chamaemorus interacting with Calluna vulgaris for mineral nutrients.

Introduction.

One of the principle aims of the research project is to separate experimentally in field conditions the effects of light and mineral nutrition on the growth of Rubus. This can be done in either of two ways: by supplying adequate nutrients and experimentally varying the light received, or by ensuring adequate light and experimentally varying the nutrient supply.

In this pilot experiment, the second approach was used in a simplified form. By pulling aside the Calluna canopy it was ensured that Rubus received full daylight, while still interacting with Calluna for nutrient supply.

Description of the experiment.

The pilot was located in the control plot, Block A (A/NF) of the Hard Hill experiment (Marks & Taylor, 1972)

In an area of fairly homogenous Calluna-Eriophorum, ten 1 m^2 plots were established. Each plot contained Rubus buds beneath a Calluna canopy. In half of the plots, the Calluna canopy was pegged aside exposing the Rubus buds to full daylight. The other plots were left intact as controls. Treatments were assigned at random (Figure 2).

Plant sampling and analysis.

To prevent damage to Calluna shoots, the pegging aside was restricted to small areas within the 1 m^2 plots where Rubus buds were visible. Since many buds were still below the surface, and the number of buds varied between plots, the area of treatment within each metre square varied, so necessitating a largely qualitative assessment of treatment effect. A random selection of shoots was collected from each plot for morphological examination. If the samples are of a sufficient size, nutrient analysis will be performed.

Results.

To be analysed.

A comment on the field observations.

Though the experimental results have not yet been analysed, a few comments can be made on the field observations.

Earlier work (Marks & Taylor, 1972) has shown that microclimate and in particular light and temperature (Grace and Marks, 1978) is an important factor regulating Rubus growth at Moor House.

Climatologically, the 1981 growing season has been slightly unusual (data from the weather station has yet to be analysed). The winter was relatively mild, and there were periods during the growing season when the surface of the bog dried out. Rubus has responded to the unusual conditions morphologically and developmentally. The response was clearest in the cropped experiment on House Hill. Shoot development has been rapid, and leaf senescence which usually occurs in early September was well advanced by early August. Another feature has been the appearance of a second flush of shoots in both cropped plots on House Hill and Hard Hill plots, a phenomenon which has not been previously observed. Very few fruits were found. The dark red anthocyanin pigmentation, a characteristic response of Arctic/alpine plants was well marked in shoots of the cropped and intact plots.

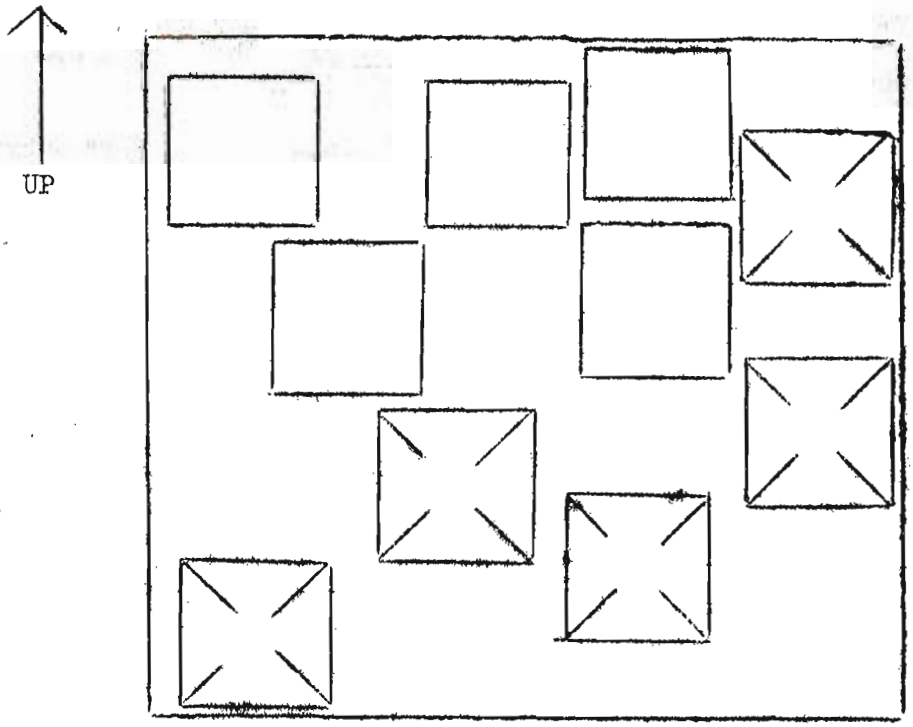
The unusual pattern of development will be considered when analysing the results of the three field experiments.

The second flush of shoots will provide useful information on the morphological and developmental aspects of Rubus growth and response to environmental perturbation.

Other samples.

Turves containing Rubus chamaemorus, rhizome and shoot samples have been collected for laboratory based studies to support the field observations and experimental work.

Figure 2. Calluna canopy pegged aside: Block A.



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i) Surfaces and lines in drainage basins: the influence of three-dimensional form on run-off,
(Sarah A. Bell, Department of Geography, University of Durham).

The aim of this study is to quantify the influence of various measurable attributes of land form on the shape of flood hydrographs, with a view to improving the topographic component of relevant drainage basin run-off models already in existence.

Attention is focused on altitude matrices, which represent land form as spot heights equally spaced in x and y directions; these can be constructed from maps or (more accurately) directly from air photographs. Their use has not gained popularity in geomorphology to the extent that it has in (for example) engineering studies. Measures of gradient, aspect, and profile and plan curvature at each point location may be derived from a matrix using Dr. I.S. Evans' computer program "G"; they will be compared and contrasted in this study with data yielded by the more accepted, linear method, of slope profiling and measurement of plan curvature "in the field".

The Trout Beck catchment (defined as the area draining to the Northumbrian Water Authority's now disused recording weir, G.R. 759336) was chosen for study as the flow records are of high quality, and the drainage basin of manageable size at 11.4 square kilometres. There are also no field boundaries and complex land ownership patterns to interfere with a programme of slope profiling.

Photogrammetrically-surveyed Ordnance Survey maps at 1:10,000 scale of the area have been obtained, and an altitude matrix at 50 m grid mesh is being constructed from them. A more detailed map, at 1:2,500 scale and contour interval 2 m, exists for part of the area - the catchment of Nether Hearth Sike - and another altitude matrix will be made from this, probably at 10 m mesh. This second matrix will therefore be of roughly comparable detail to slope angle measurements taken in the field at 1.5 m intervals along a slope profile.

A pilot study slope profiling in the Nether Hearth catchment with a pantometer has been carried out, with a view to determining a sampling design for a more extensive slope profile survey. There are two very distinct types of slope in this catchment: the long (2.5 km), concave slope from the watershed in the south, to the mouth of the Nether Hearth, roughly followed by the stream's course; and the shorter (eg. 100 m), steeper slopes of the valley that the Nether Hearth has cut into the long slope, especially towards its mouth. The difficulty of locating oneself on the map in this flat terrain argues against a totally random sampling design for slope profiling here: profiles had to be taken in distinctive places (e.g. by a meander of stream), but as long as care is taken to sample all types of slope present in the area, an adequate picture of the land shape may be gained.

Its adequacy will be compared with more complete coverage available on a point basis from the altitude matrices, and also with slope profile data generated by starting from purely random locations within a matrix, and thence tracing a maximum gradient path through its vertices, using a computer program - "Sloprofil" - that has been specially written for the study.

Records of streamflow exist for the whole Trout Beck catchment, and for two years of run-off measured at the mouth of Nether Hearth Sike (by kind permission of Drs. K. Smith and M. Lavis). These will be statistically compared with the various terrain data already described, and with run-off records for another basin being subjected to a similar programme of measurement at Slapton, South Devon.

j) An investigation of the hydrology of a small peatland gully.
(P. Williamson, Department of Geography, Manchester University).

This work was carried out, as part of a B.Sc. degree course in Geography at Manchester University, from July 15 - August 4, 1981.

A small gully on the south-west side of Burnt Hill was chosen as the study site (G.R. 753328). Instruments were set up in various parts of the gully in order to measure the various hydrological flows occurring there. Interest was centred on the way in which these flows responded to variations in rainfall and this meant that delineation of catchment boundaries (which would be almost impossible on the blanket bog anyway) was not needed.

The gully chosen was fed by bog-pools and other wet areas. One large pool system in particular at the head of the gully appeared to provide much of the run-off to the gully. A number of instruments were set up; these were all of a simple nature being made up mainly of plastic sheeting, guttering and piping. They included:-

two rain-guages,

two stream-guages, one at the outlet of the main gully, and one at the outlet of the pool system mentioned above,

two overland-flow meters, one on a vegetated surface and one on a bare, eroded peat surface,

a throughflow meter,

and finally, a cross-section of water-table wells was set up across the gully.

Full results were taken for 14 days.

The first part of this period was very wet and run-off rose to a very high level in the gully. However, the latter half of the period was abnormally dry and run-off had virtually ceased by August 4.

Analysis has not yet been started on the data but the dissertation will be completed by January 1982.

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Appendix 2.

Staff List.

Officer-in-Charge	M. Rawes
Scientific Staff	Judith Scott
Estate Worker	P. Holns (Summer)

Appendix 3.

Meteorological Summary for Moor House 1980
c 558 m OD (Instrument Site) Lat 54° 41' N. Long 2° 23' W Nat Grid Ref NY/758328.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean max temp °C	0.6	3.6	2.0	9.3	10.6*	14.6*	15.0*	15.0*	13.2*	7.5*	5.1*	4.4*	8.4*
Mean min temp °C	-3.3	-0.5	-2.7	0.03	1.2*	5.1*	6.9*	7.5*	7.5*	2.1*	0.9*	-1.0*	2.0*
½ (max + min) °C	-1.4	1.6	-0.4	4.7	5.9*	9.9*	11.0*	11.3*	10.4*	4.8*	3.0*	1.7*	5.2*
Highest max temp °C	5.6	5.9	6.6	15.4	19.4	23.6	22.0	20.4	15.9	12.2	9.9	8.7	23.6
Lowest min temp °C	-10.9	-9.7	-9.1	-5.7	-3.9	-0.9	2.5	1.2	1.3	-6.1	-8.1	-9.7	-10.9
Lowest grass min temp °C	-15.2	-10.9	-13.1	-12.3	-10.5	-4.3	-1.5	-2.6	-3.0	-8.4	-7.0	-11.9	-15.2
Earth temp 30 cm 0900 hr	1.1	1.9	2.0	4.4	6.3*	9.1*	10.7*	12.2*	10.8*	7.2*	4.8*	3.6*	6.2*
Rainfall (mm)	189.0	170.7	166.0	10.2	23.6	219.9	112.4	203.9	168.1	249.2	227.4	265.4	2005.8
Days snow lying	21	9	14	0	0	0	0	0	0	0	[4]	[10]	[58]
Air frost (days)	26	14	26	13	6)	1)	0	0	0	8)	11)	21)	126)
Ground frost (days)	31	18	30	22	21	9	3	5	2	14	20	21	196

Temperatures marked * = estimates reached by using Moor House thermometers or thermometers and thermograph. In the case of mean max. and min. - comparisons made with Widdybank Station.

Days snow lying marked [ ] = estimates using Moor House, Widdybank, Newbiggin and Ainstable data.

Data marked) = results gained from using Moor House and Widdybank data.