Dr. K. Taylor.

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14th Annual Report, 1973

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THE NATURE CONSERVANCY COUNCIL

MOOR HOUSE

1973

14th Annual Progress Report

M. Rawes

CONTENTS Page

I. GENERAL

The Report covers the period 1 October, 1972 to 30 September, 1973. It is the last report in the time of the present Nature Conservancy, the staff of which on 1 November is divided between the new Nature Conservancy Council and a new Institute of Terrestrial Ecology. Moor House will, with the conservation branch of the present Nature Conservancy, be part of the Nature Conservancy Council financed by a grant-in-aid from the Department of the Environment. Merlewood Research Station with whom Moor House has, in the past, been linked, remains in the Natural Environment Research Council, but it is hoped that previous contacts and present projects, although far fewer than at one time, will be maintained.

Throughout the greater part of the summer there have been 14 persons on the Station including 5 employees of the Freshwater Biological Association, an organisation that is grant aided by N.E.R.C. Laboratory accommodation has been provided and use made of laboratory equipment and station transport.

In many ways it has been a disappointing year, for research and the hostel. The early promise of new projects failed to materialise and the uncertainty of the Conservancy's future seemed to affect outside confidence. Interest by the research branch of the Nature Conservancy has been less than it has ever been, but use of past research data continues to be made. However, there are signs of University involvement increasing, and, with new plans for the Reserve being made, a more active form of management may be instituted.

Mild weather towards the end of the reporting year resulted in more grass growth at this time of the year than usual, and despite a late start to spring it has been a good year for the vegetation. Heather burning was again restricted to the Green Burn - Force Burn area, where a regime of small narrow strips has been started.

New records have been added to the Reserve plant list and flowering has been particularly good in a wide range of vascular species. The Warden's Quarterly Reports, which are available in the columns of the Reserve Record, show that another five macro-fungi have been found and identified, making a total of around 35 new species since P. Houlton became Warden.

Public Pressure

Everywhere pressures on hill land continue to increase, and this has been evident at Moor House. Locally, mining has re-started at two places. On the Reserve, barytes is being extracted at Silverband Mine, by open cast means. The operation is at present a small one, but planning approval has been given for the erection of a washing plant and output during the next two years, for which permission has been granted, can be expected to rise. The mineral is being taken to Aberdeen for use as ballast in oil rigs. Another development, this one just off the Reserve, by the access track from Garrigill, has started. Should preliminary work prove fruitful fluospar will be extracted from the Tynehead mine and moved down the Moor House track.

On Great Dun Fell, the Post Office have laid new cables for the Radio Station, beside the bridleway, from the fell top to the Reserve entrance. Considering the nature and size of the operation there has been surprisingly little damage by the contractors J. Murphy & Sons, Carlisle, whilst the Post Office and Civil Aviation Authority have been most cooperative.

The absence of much snow, in one of the mildest winters recorded, was a disappointment to the Skiers, fewer of whom visited the area than in 1971-72, also a mild year. The Dun Fell scheme was once again supervised by the part-time Warden, Mr. J. Rose. Road conditions for access were good and only on two occasions were cars unable to get as far as the Reserve entrance. The fact that more than half the skiers come from Lancashire and Cheshire, is evidence of the improved communications provided by the Motorway. Mr. B. McArthur (honorary Warden) took over the wardening duties during the latter part of the season, when Mr. Rose moved to Ravenglass Nature Reserve.

The Pennine Way is used to a greater extent than formerly and the track made by walkers, the majority of whom are walking north, follows a definite pattern; when the ground is well drained the path is narrow, but on wet land it spreads out to become 20 and more feet in width. Erosion is now occurring all along the line, which this year has changed its course on Knock Fell for no apparent reason. Where damage is becoming serious remedial steps will be required in 1974.

A new venture has been the advent of pony trekking. The track, where it exists, up Trout Beck is a bridleway. It joins the tracks from Moor House to Garrigill and Trout Beck Head to Knock. It is therefore a legitimate right of way for riders. There are at present two local riding establishments, one of which has passed through the Reserve on a few occasions.

An unwelcome activity is that of fossil and mineral hunters, both of whom can do irreparable damage. The Geological Section of the Nature Conservancy is able by means of its influence with Universities to prevent much damage by student parties, but many societies, schools, clubs and individuals are beyond their reach.

Surveying by the Northern Cavern and Mining Research Society has continued and a number of interesting finds reported (see Report p.20). A survey of a different nature has been that undertaken by Air Force Cadets locating crashed aircraft, a map of which appears in the Appendix.

Three honorary Wardens have been appointed to help look after the west side of the Reserve, which is the part subject to greatest public pressure.

Students

Without student help it would be impossible to continue the present programme of field work. David Tattersfield (Leeds) returned to study some of the Sphagnum-rich sedge flushes on the higher parts of the Reserve and Cross Fell, whilst Lindsay Gregory, Tony Rees and Maureen Doherty, also from the Leeds Botany Department, have assisted in the collection and processing of field data. The F.B.A. team were assisted by Martin Capper (Bath) and John Foster (Liverpool Polytechnic).

Among the Ph.D. students, only Michael Ashmore (Leeds), who has continued his physiological study of Calluna, has been a frequent visitor. Projects by Tusi Butterfield, on Tipula subnodicornis, and Roger Wotton, on Simuliidae, both of Durham, have been completed. This year new studies will be started by David Tattersfield (Leeds), examining the physiology of some upland blanket bog species with special reference to Sphagna, and R. Beattie (Durham), working on the development of Tadpoles at different altitudes and temperatures.

C. Edwards, a Liverpool Polytechnic graduate, working from the Moor House laboratory is studying fish movements in Cow Green reservoir primarily by the use of a portable echo-sounder. He is supervised by Dr. Crisp, F.B.A.

Visits and Talks

During the year P. Houlton, attended an Induction Course for Wardens at Furzebrook and P. Holms went to the Grouse Unit, at Banchory, for a week's training in grouse counting techniques.

M. Rawes and R. Williams attended the Hill Land Use and Ecology Group Meeting in the Scottish Borders in May. M. Rawes also attended part of the Recreation Ecology Research Group's meeting at Brathay, Ambleside, and a Muirburn discussion at Edinburgh. R. Williams went on an Aerial Photograph Interpretation Course for staff of the Nature Conservancy and Countryside Commission.

During the winter talks were given by M. Rawes (Eden Field Club) and P. Houlton (Alston Toc H), and M. Rawes read a paper at the British Ecological Society and Royal Society meeting in Liverpool (see p.30).

Visitors

Friends of staff were invited to the Field Station in October and some 90 people came to view exhibits and were conducted on field trips.

Visits during the summer have been made by three local Natural History Societies, the Eden Field Club, the Grange-over-Sands Natural History Society, and the Arnside Natural History Society. Three School parties and groups from Bolton Institute of Technology, Brighton Polytechnic and St. Peter's College of Education have received instruction, whilst parties from similar establishments have been given permission to view the Reserve.

Fourteen students and staff of Professor Sjörs' Department of Plant Ecology, Uppsala University, Sweden, stayed at the Field Station for two days.

At Easter, the University College of London, M.Sc. Conservation Course stayed in Appleby, and, joined by R. Williams and M. Rawes, undertook an investigation of a transect within our N.E. Westmorland Conservation study area. The transect ran from Great Dun Fell to the River Eden beyond Kirkby Thore, and aimed to make an ecological assessment by using parameters to which ratings were given. A report of this survey is held in the Field Station Library (see publication list).

In July, the British Ecological Society Summer School held a week course in Ecology, Land Use and Reserve Management at Brathay. On one day aspects of moorland ecology and management were discussed and demonstrated at Moor House by M. Rawes, Dr. D.T. Crisp and Dr. J.B. Whittaker.

Some fourteen members of the Northern Ireland Committee for Conservation visited the Reserve in July. A talk and conducted tour were given by M. Rawes.

In September, members of Biology Departments from University College, London University, under Drs. K. Taylor and R. Fisher, stayed and worked at the Field Station for a week.

Among individuals who have visited the Field Station have been the following:- Mr. John Harris of Brackenburgh, Penrith, son of the shooting tenant (1898-1917); Dr. V.M. Conway, former Director of Merlewood; Dr. G. Van Dyne, of Colorado State University, U.S.A.; Dr. L. Bliss, University of Alberta, Canada; Paul H. Patrick, University of Windsor, Ontario, Canada, Helène Lundkvist, Uppsala University, Sweden; Hugh G. Miller, Macaulay Institute; Dr. B. Matthews and I. Kilgour, Soil Survey of England and Wales; P.A. Tallentire and Asbjorn Moen, Trondheim University, Norway.

The Uppsala party included Dr. Mats Waern, Ejvind Rosen, Catarina Johannsen, Lise-Lotte Norin, Cristina Skarpe, Per-Arne Andersson, Roger Bergström, Gunnar Engström, Håkan Hytteborn, Sven Erik Jonasson, Crister Nordling, Börje Klasvik, Rupert Siemerling and Lars-Olof Åkerlind.

Publicising information

Research findings from Moor House are usually published in scientific journals, Occasional Papers or deposited in the Reserve Record. The Reserve Record, of which there are 9 volumes, includes a wide variety of material from species lists to small experiments and notes of historical interest; it also holds copies of the Management Plan and Annual Progress Reports. There are copies in the London Library and the North Region Office, at Merlewood. Information held in these records is available, but may not be quoted without the permission of the Conservancy and the Author. This year, the Annual Report includes a few short articles, or longer reports, that previously might have gone straight into the Reserve Record, where they would not have been read by many people. 150 copies of the Report are produced. They are distributed within the Nature Conservancy and among past and present research workers of Moor House as well as being sent to a number of organisations and people who have expressed a wish to be on our mailing list.

II. SCIENTIFIC - MOOR HOUSE STAFF

General

Monitoring of botanical change at sites on blanket bog and grassland is an annual commitment that depends to a large degree on having student help, the amount of field work completed being otherwise determined by the weather. At most sites change is followed by the vertical point quadrat method. The number of point quadrats required to show significant change, and the frequency in which they have to be made, are very important if the most economical use is to be made of staff resources. P. Rothery, Statistics Section, has been looking at the first aspect and tests on earlier data by R. Williams, helped by members of the Botany Department at Newcastle, have gone some way to showing that the original 1000 points per plot to follow each treatment is unnecessarily large. Where a 10 pin point frame is used in a grassland plot, at fixed intervals, the number has been reduced to 500. But with trials of more recent origin, started in 1967, lay-out has been based on randomly selected 1 m^2 quadrats, within which 10 points have been selected. This has allowed the number per plot to be reduced to 240 which is adequate for records of cover by vascular species. The recording of plant structure, obtained by recording the number of hits per vertical level (strata of 10 cm width), and the following of bryophyte and lichen change, may require more points in the former case and a different technique in the latter. With the lower plants we have this year recorded presence within a 5 cm^{-2} quadrat placed at the base of each pin.

The amount of time taken to record plants depends on a number of factors, not the least being the time spent in moving from one point, or frame, to another. On Hard Hill 18 plots on blanket bog, involving 6 treatments - 1800 points - (and a move between each point) were completed in 26 days by a two-man team whereas on a Juncus squarrosus sward, nearer the Field Station, above Trout Beck, 1000 points, in 10 pin frames, were completed in 9 days. Neither of these two vegetation types however, contained a wide range of species, so it can be seen that in species-rich swards, such as an Agrostis Fescue or calcareous flush, the field work can be considerable. Of necessity it is therefore important to restrict the frequency of measurement and to be concerned only with changes of a significance greater than 5%.

During the summer, the staff has been primarily concerned with continuing the botanical monitoring programme of sheep exclosures and grazed plots on sites representative of Nardus (White Bent) and Juncus squarrosus (Moor Rush) dominant grasslands, as well as the heather burning experimental plots. The management of the sheep trial, in which different grazing regimes are imposed on blanket bog, continued into its sixth year, but no analyses were made. Samples of vegetation and soil were taken from the limestone site on Knock Fell to see if there are now changes in the available mineral holding, after 16 years sheep absence. The results will be compared with similar analyses of the Moor House meadow.

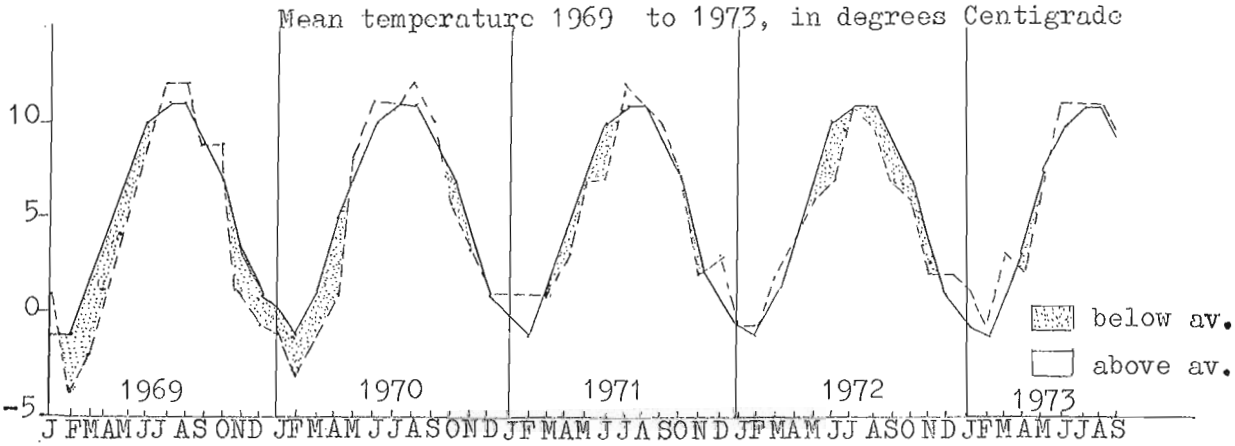
The build-up of information for the north-east Westmorland Survey area continues slowly. Adjustments have been made to the vegetation map of the 150 square mile area. The project (see p.16) on woodland potential by Ross Hynes is of particular value to this survey and studies such as those by the University College of London M.Sc. Course reference on p45), by Dr. D.T. Crisp, on Trout (see p39) and the survey of plant species (Dr. A.J. Richards) provide additional data.

The survey of the Reserve red grouse population has been continued by P. Holms, whose report on p 32 shows that numbers remain high for the third year in succession.

a) Climatology (R.B. Marsh)

The weather summary for 1972 is to be found in the appendices.

Following the trend since November, 1970, the winters have been warmer and the summers cooler than average (records began in 1953) while the temperature for the year as a whole is about average (see figure below):



During 1972 the mean temperature from May to November inclusive never rose above the average; this and other climatological attributes are shown for the reporting year in the table overleaf. There have been fewer days with snow lying during the last three winters. In 1972-73 there were 54 days, 17 days below average and 7 days less than the previous year. However, it is interesting to note that days with air frost numbered 127, 11 more than last year and only 3 days less than average. The months of October, November, April and May had more days of frost than average while the four winter months, December to March inclusive had fewer. Despite higher average temperatures, taking the year as a whole, there were 24 more days of ground frost than usual.

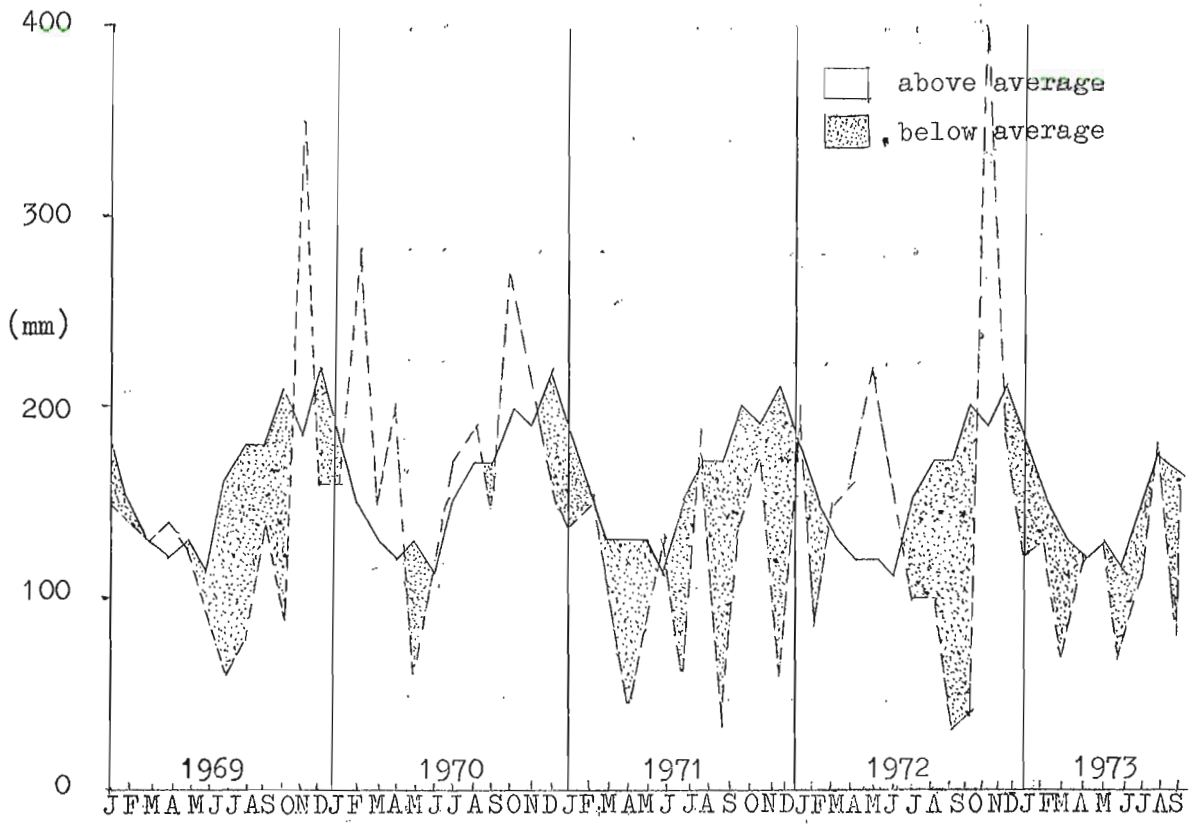
In the 34 month period since December 1970 only 8 months have had above average rainfall, of which November 1972 when 398.2 mm fell, was the wettest November recorded, while the driest (41.8 mm) October recorded was in 1972. This year (1662.9 mm) was the fourth consecutive year to have a below average rainfall.

Moor House Weather - October 1972 - September, 1973.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Average
Maximum °C	9.9	4.2	4.6	3.2	2.6	5.9	5.4	10.5	14.6	15.0	15.3	12.3	8.6
(19 years)	(9.7)	(5.2)	(3.4)	(2.1)	(1.6)	(4.0)	(7.1)	(10.8)	(13.8)	(14.7)	(14.4)	(12.7)	(8.3)
Minimum °C	2.7	-0.6	-1.0	-1.4	-2.9	-0.7	-1.4	3.0	6.8	7.5	7.4	6.5	2.2
(19 years)	(4.0)	(0.2)	(-1.9)	(-2.7)	(-3.6)	(-1.7)	(0.0)	(2.6)	(5.4)	(7.1)	(7.3)	(5.9)	(1.9)
Mean °C	6.3	1.8	1.8	0.9	-0.1	2.6	2.0	6.7	10.7	11.3	11.3	9.4	5.4
(19 years)	(6.9)	(2.7)	(0.7)	(-0.3)	(-1.0)	(1.1)	(3.5)	(6.7)	(9.5)	(10.9)	(10.9)	(9.3)	(5.1)
Earth temperature °C	7.6	4.8	2.9	2.0	2.3	2.7	3.4	6.2	10.1	11.8	12.1	10.9	6.4
(16 years)	(8.0)	(4.7)	(2.7)	(1.6)	(1.4)	(1.9)	(3.8)	(6.9)	(10.0)	(11.5)	(11.7)	(10.3)	(6.2)
Days with sunshine	3.10	0.94	1.16	1.25	2.66	4.11	3.90	4.93	5.51	4.85	5.14	3.16	3.39
(18 years)	(2.61)	(1.36)	(0.91)	(1.01)	(1.71)	(2.65)	(3.99)	(5.16)	(5.80)	(4.59)	(4.24)	(3.42)	(3.12)
Rainfall (mm)	41.8	398.2	206.3	123.2	128.7	73.8	120.9	130.7	65.5	112.3	178.5	83.0	1662.9
(19 years)	(200.5)	(193.3)	(206.2)	(180.6)	(151.6)	(128.7)	(124.4)	(127.8)	(113.1)	(144.3)	(167.8)	(160.3)	(1898.6)
Days with snow lying	0	7	7	10	17	6	7	0	0	0	0	0	54
(19 years)	(0)	(6)	(11)	(17)	(18)	(13)	(5)	(1)	(0)	(0)	(0)	(0)	(71)
Days with air frost	7	17	17	19	16	20	21	8	1	0	0	1	127
(16 years)	(3)	(14)	(21)	(23)	(22)	(21)	(15)	(7)	(1)	(1)	(0)	(2)	(130)
Days with ground frost	15	23	29	27	22	24	25	13	5	6	1	5	195
(19 years)	(9)	(18)	(22)	(25)	(24)	(24)	(19)	(12)	(6)	(4)	(3)	(5)	(171)

Figures in brackets = average

Rainfall in millimetres, 1969-1973



The sunshine records correspond with the temperature to some extent in that the months December to March had above average hours of sunshine, March being the sunniest since records began with an average of 4.11 hours/day, while April, May and June fell below average in a similar way, but not to the same extent as last year 1972. For the last two years, September was above average in sunshine, but this year there was only 3.16 hours/day which is below average.

An article on the climate at Moor House for the period 1953-1967 has been received from E.H.W. Green and A. Millar. A copy is found in the Moor House Reserve Record.

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

Sites representative of the main vegetation types are monitored to a set programme. The management regimes followed are:-

1. Existing common range sheep grazing,
2. Exclosure from sheep grazing,
3. Modified grazing, burning and draining regimes.

1. Some effects of the present sheep grazing regime

Previously there has been evidence of a change in botanical composition of some swards in regard to Nardus and Juncus squarrosus. A re-examination of the point quadrat plots on Hard Hill and Knock Fell, where these species are components of the swards has now been made. Little change in the status of J. squarrosus has been found, the same number of hits being recorded both on Hard Hill, where it is widely distributed, and on Knock Fell, where it is confined to patches. Nardus, however, has a very patchy distribution on Hard Hill and is possibly extending the boundaries of these patches.

2. Some effects of removing the grazing factor

Exclosures on the Nardus and Juncus squarrosus sites were examined. Both areas were fenced in 1967 and botanical composition recorded then and in 1970. In the former sward the changes are an overall increase in cover of vascular plants, which relates largely to the structure of the vegetation. Agrostis spp. have decreased being replaced by Deschampsia cespitosa. Nardus has changed little - a possible increase in total stratified hits. Galium saxatile has, as usual, increased, as have the Carex spp. Atypically, Juncus squarrosus appears to be surviving and possibly spreading as it flowers well. Like D. cespitosa and D. flexuosa the distribution of J. squarrosus in the enclosure is patchy. Lophocolea bidentata, always closely associated with the Juncus rosettes, has also increased. Pleurocarpous mosses have spread, due mainly to the change in habitat caused by litter build up and the burrowing activity of small mammals. Structurally, the change has been for most leaf to be in the 10-30 cm level above the ground rather than in the lowest stratum due not only to increased growth, but to build up of litter.

In the Juncus sward there has been a steady reduction in the dominant and an increase in Deschampsia flexuosa. Structurally, there has been a considerable increase in height with an accumulation of litter. Burrowing by small mammals has also changed the lowest stratum of 10 cm height, into a honeycomb of tunnels.

In a series of small plots on blanket bog, established Juncus plants and seeded plants have responded to treatments. The results after 5 years of trial during which time grazing has been prevented are:-

1. Where all vegetation, including Juncus squarrosus, was cut annually Juncus has shown an increase in cover of 59%.

2. Where the surrounding vegetation, but not Juncus was cut the increase in cover has been in the order of 100%.

3. Where the vegetation was uncut there has been a decrease of 63% in the cover of Juncus.

4. Juncus seeded direct onto blanket bog, and given a treading treatment twice a year, was unsuccessful in 3 cases out of 4 (total 8 plots).

5. However, when the blanket bog was cut annually and given the same treading treatment 2.2% cover was achieved by Juncus (5.8% in one area of 4 plots and 0.7% in another).

6. Treading was probably not significant in the latter plots, as without it, Juncus cover reached 0.6%.

The results confirm those observed and recorded in larger exclosures that Juncus squarrosus is light-demanding and that treatment to establish it requires to be severe - such as heavy grazing and treading.

In the course of sampling the vegetation and soil of the Knock Fell site, referred to on p 5 the standing crops of the Agrostis/Festuca and Juncus squarrosus areas were measured and found to be seven and two times greater respectively under exclosure than grazing. The percent of live green material however, was much greater in the grazed sward (Agrostis/Festuca four times and Juncus twice). The results of the chemical analyses are expected in the near future and will be incorporated in a paper on grassland studies.

Productivity is an aspect that undergoes much change with an alteration in management. Whereas most of the present survey of sites and habitats is restricted to the botanical composition there is for the Reserve a considerable background of studies in production ecology. In so far as primary production is concerned published information is largely confined to above-ground growth. This summer whilst completing the IBP project Dr. Rosalind Smith and Selwyn Van Zeller measured total biomass in a number of vegetation types, and found that the ratio of above-ground to below-ground live biomass (dry weight) of vegetation in August, open to grazing, was of the order of 1:3 in a Juncetum squarrosi and 1:9 in the case of an Agrosto-Festucetum. The effect of different management, such as removal and increase of grazing on this aspect of productivity forms an interesting study, that may be investigated at a later stage.

3. Effects of increased grazing, burning and draining

During last year one block of the heather burning experiment on Hard Hill was surveyed and results from this, together with those from the sheep grazing trial on House Hill were used by Rawes and Williams (1973) to show some deleterious effects of burning and grazing. The remaining three blocks were surveyed this year, using the point quadrat method. Each block contains 6 plots, half fenced and the others open to range grazing. The superimposed burning treatments are a short-rotation, every 10 years, (now carried out twice), and a long-rotation, every 20 years (now carried out once). The other two plots are controls.

Results show differences between plots of the same treatment, but there are nevertheless significant differences between the treatments. Under a short rotation there is less Calluna more Eriophorum vaginatum, more Campylopus flexuosus, Dicranum scoparium, Pohlia nutans, Lophozia ventricosa, Mylia taylori and Coriscium viride as well as more bare ground and algae.

The House Hill sheep grazing trials support the theory that persistent heavy grazing of blanket bog leads to vegetation change, with the introduction of Juncus squarrosus, and its eventual dominance over parts of the bog. Conversely the removal of grazing from Juncus squarrosus dominated swards has resulted in its reduction at one site and possible elimination on another (Knock Fell). A trial has been started this year to follow botanical change in a grazed Juncus sward that is subjected to a very much greater sheep grazing pressure than usual.

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

The enclosures with introduced montane and arctic-alpine species continue to provide much interest not only in the performance of these plants but in natural changes and self introduction of other species. The limestone gorge of Rough Sike is the most varied site with thirty introduced flowering plants. It is already a species rich site with over 110 indigenous species. This year, Primula veris has increased considerably and a Dactylorchis mascula (a species new to the Reserve) appeared and flowered.

d) The composition of Sphagneto-Caricetum alpinum flushes in the northern Pennines (D.M. Tattersfield)

The purpose of this investigation was to examine the species composition of a number of Sphagneto-Caricetum alpinum flushes (see Eddy, Welch & Rawes, 1969) on and off the Reserve and to suggest reasons for any variation in composition.

The association occurs usually on sloping ground below acid spring lines, and to a lesser extent around the margins of some calcareous flushes. Most stands occur above 750 metres on east to north facing slopes.

Five examples of the association were selected for analysis. Random 25 cm square quadrats were taken within each 2 m square of 10 x 10 m area. Cover of all species present was estimated by eye using the 10 point Domin. scale. Additional species outside the quadrat were ignored. Copies of the data sheets are held in the Reserve Record.

Sphagnum species form an almost continuous cover. Sphagnum subsecundum var. auriculatum, the most prominent species, is the only characteristic constant of the association. Sphagnum recurvum and Polytrichum commune are constants and Scapania undulata, a near constant. Of the higher plants Carex echinata, C. nigra, Eriophorum angustifolium, Agrostis canina and Festuca ovina are constants. Saxifraga stellaris and Viola palustris, although in relatively small numbers, occur in all stands of the association.

Variation between flushes appears to be due to the base status of the water supply. The more species-rich flushes on Great Dun Fell and Little Dun Fell contain small areas of calcareous spring vegetation. The spring water feeding all flushes examined has a pH of approximately 6, Deschampsia cespitosa often reaching high cover values near the spring line.

The presence of Carex curta, C. bigelowii and Saxifraga stellaris particularly in sheltered depressions near the spring line on north-facing slopes suggest that late snow-lie may influence the composition of the vegetation.

Flushes of this type usually show a distinct small-scale vegetation pattern probably governed by the base-status and movement of ground-water. A flush at 810 m on Little Dun Fell facing north-east was mapped (copy in Reserve Record) in detail and is now numbered among the Reserve sites for monitoring. It is hoped to carry out further analysis to determine the factors influencing the vegetation pattern.

III. RESEARCH BY MERLEWOOD STAFF

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

No report received.

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

(i) Factors limiting plant growth on peat
(ii) Productivity of blanket bog vegetation

Work continues on the completion of these projects.

(iii) A paper entitled "The redox characteristic of four peat profiles" is expected to appear in the October issue of "Soil Biology and Biochemistry".
(iv) Erosion reclamation, no further work has been done this year on this project.

IV. RESEARCH BY THE FRESHWATER BIOLOGICAL ASSOCIATION

a) Studies on freshwater fauna - Fish (D.T. Crisp)

As indicated in earlier reports, routine observations on fish in the bulk of the streams of the Moor House National Nature Reserve have now ceased. The results of our observations made in Tees tributaries on the Reserve from 1967 to 1972 are now being prepared for publication and abstracts from the results have been supplied to the IBP.

Observations on fish populations at Cow Green have continued. During recent years there has been an autumn run of reservoir trout up the Tees for spawning purposes. Most of these fish spawn in tributaries rather than the Tees itself, and a minimum of 20 such fish have entered Force Burn each autumn. Routine observations on the fish population of Force Burn, therefore, began in 1972 and will continue for some years. Similar studies are being made in Crook Burn and Greenhurth Sike.

During August 1973 a preliminary survey was made of fish populations in Knock Ore Gill and Swindale Beck. The results are given in a preliminary report (see p 39).

b) Studies on freshwater fauna - Invertebrates (P.D. Armitage)

Studies of stream invertebrates in the Moor House Nature Reserve have now been written up and the following are all additions to the lists of previously studied groups on the Reserve. Capnia bifrons (Newman) /Plecoptera/; Paraleptophlebia pennatulum Eaton /Ephemeroptera/; Plectrocnemia geniculata (McLachlan), Cyrnus trimaculatus (Curt.), Lepidostoma hirtum (Fabr.), Hydropsychidae (Larvae indet.) and Philopotamidae (larvae indet.) /Trichoptera/.

A similar study of stream invertebrates in the Cow Green Basin has been accepted by Freshwater Biology.

Studies on the reservoir and on the Tees below the dam have continued and reports on the data collected will be written in the coming year.

V. RESEARCH BY UNIVERSITIES

a) Studies on Tipulidae (J.C. Coulson & Mrs. J.E.L. Butterfield, University of Durham)

Studies have continued on the emergence pattern of adults of Tipula subnodicornis and Molophilus ater on a series of sites on the Reserve.

Investigations have continued on the larval population densities of Molophilus ater following the marked population decline over the past three years and on most areas the population is below one-tenth of that found throughout 1960-1968.

b) Nitrogen and Phosphate content of moorland vegetation as a factor determining the distribution and abundance of some moorland animals. (J.C. Coulson, University of Durham)

Preliminary studies have been made on Juncus squarrosus and blanket bog sites prior to a more detailed investigation commencing in September, 1973.

Plots have been treated with ammonium nitrate at the rate of 10 g N/m^2 and superphosphate at the rate of 5 g P/m^2, singly and in combination to supply a source of N and P rich plant material.

A series of field and laboratory experiments are now in preparation to determine whether soil invertebrates select plant material and litter relatively rich in P and N.

Samples of Tipula subnodicornis larvae, taken within six months of site treatment with N and P, showed a significantly greater weight than those from control areas. This implies a greater fecundity in the adults and this aspect will be investigated further.

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

Intermittent sampling of the heather psyllid (Strophingia ericae) has been continued as part of a long term project concerned with the population dynamics of upland Homoptera.

d) Studies on black-flies (Simuliidae) breeding in bog streams in Upper Teesdale (R.S. Wotton & L. Davies, University of Durham)

Little fieldwork has been undertaken this year and material from the extensive 1972 season has been identified, measured and analysed. The species given as S. latipes (Meigen) in last year's report has been re-named S. vernum Macquart with the same characters as given in the keys for S. latipes.

Using the percentage species composition of each sample it was possible to determine the actual numbers of larvae from the maximum likelihood prediction on each sampling occasion. The numbers of larvae in each instar were obtained from the percentage instar composition. As the sampling unit on each occasion was the same - ie. 3 x 15 minute removal collection - graphs of change in numbers for each instar through the season could be constructed. Thus, the predicted number of instar I

on each sampling occasion was plotted against time and similarly for the other instars. The area under each of these graphs will provide an instar x dry total for the season and, by reference to the frequency distributions, a similar product for each generation.

Summer generation larvae last 40-50 days and a measure of the duration of each instar could be obtained from the frequency distributions, the collecting dates being sufficiently close together. A high and low range of duration were determined and these are given below. (The number of days between successive instar peaks in the life-history data will be between the medias of the development time of these instars).

Instar	Duration (Days) Low	High
I	1	1
II	2	2
III	3	4
IV	5	7
V	8	10
VI	10	12
VII	11	14
	40	50

By dividing the instar x day values obtained from the graphs by the range of days given above the actual number of larvae in each instar can be determined.

As an example, the numbers of the first summer generation of S. vernum in MBB (the second station in Moss Burn) can be outlined. The relatively low numbers of first instars in the samples was probably a result of the short duration of this stage.

MBB — S. vernum

Instar	Low id	Development d	Time i
I	440	1	440
II	1448	2	724
III	1860	3	620
IV	2112	5	422
V	1479	8	185
VI	1745	10	175
VII	1886	11	171

Instar	High id	Development d	Time i
I	440	1	440
II	1448	2	724
III	1860	4	465
IV	2112	7	302
V	1479	10	148
VI	1745	12	145
VII	1886	14	135

The large numbers of larvae (i) in the various instars will therefore represent the number reaching the median development time of the instar. With 40 day development mortality of instars II - VII is 76% and with 50 day it is 81%. For the first summer generation of S. vernum in MBB mortality from the median duration of the second instar to the median of the seventh is thus 76 - 81%. In this case mortality is mortality + emigration - immigration since there is no estimate of larval movement through the study area. Reference to mean dry weights for each instar enables production estimates to be made and for the example given above these were 273.20 mg to 346.64 mg in the length of stream sampled. With a mean sample length of 18.9 metres this gives 14.46 mg/m to 18.34 mg/m for this generation.

e) Studies of photosynthesis and assimilate distribution in Calluna vulgaris (M.R. Ashmore & Professor H. Woolhouse, University of Leeds)

The major object of this project is to elucidate the relationship between the growth of Calluna at Moor House and environmental factors. To this end, measurements have been made this season of the growth of Calluna green shoots, and of photosynthesis and water potential, in different parts of the plant canopy. These data will be related to gross climatic factors and to microclimatic conditions within the canopy.

The growth of fifty marked shoots has been followed through this season, at fortnightly intervals, the length of long shoots produced this season, the length of the short shoots borne on them, and the increase in length of last season's short shoots. Regressions between these parameters and dry weight have been established at monthly intervals using shoots harvested from the same area.

Photosynthesis has been measured using the technique described in the last annual report and shoot water potential by means of a pressure bomb apparatus. Soil water potential has been measured at various depths using tensiometers. This season soil water potential, even in the top 5 cms of the soil, has not fallen below - 0.1 bar; frequently, however, a considerable depression of photosynthesis has been observed in the middle of the day, when the shoot water potential reaches a value of between -9 and -12 bars. This phenomenon thus appears to be due to stomatal closure, suggesting that the poorly developed root system found in Calluna at Moor House cannot supply water at a sufficient rate to the leaves to compensate for the loss of water through transpiration. The apparatus used to measure photosynthesis is at present being adapted to enable direct measurements of stomatal resistance to be made.

An almost continuous record of temperature in the canopy has been obtained using the Grant recorder and probes on Sike Hill and light intensity and humidity within the canopy have been measured in connection with the determinations of photosynthesis and water potentials.

f) Autecology of the genus Geum (K. Taylor, University College London)

The biology of populations of Geum rivale and G. urbanum, which occur over a wide range of altitude from southern England to the northern Pennines, is being studied in controlled environments. When sufficient basic information is available field experiments will be initiated at Moor House to determine the influence of environmental factors on the distribution and development of G. rivale and the restriction of G. urbanum to the sites below 1500 ft.

Some preliminary experiments have been carried out to determine the effect of temperature on seed germination, seedling development and the requirements for flowering and seed set. Seed of G. rivale collected in September, 1972, from Green Hole and the Meadow gave only 44% germination at 22°C in the light, one month after collection, compared with 100% germination of seed from a site in West Sussex.

The flowering response to G. rivale is daylength neutral but it has a vernalisation requirement for floral induction. So far the youngest seedlings to produce flowers have been raised at 20°C for 10 weeks then transferred to 5°C for 5 weeks before being returned to 20°C to await flower production.

Detailed results should be available for the next annual report.

g) Ecology and conservation potential of woodland in the northern Pennines of England. (R.A. Hynes, University College London)

The study area is the high ground from Alston in the north to Middleton-in-Teesdale and Brough in the south. It includes the Teesdale and Moor House National Nature Reserves, and adjacent areas of high conservation value. Most of this area is treeless moorland, but the existing woods illustrate that there is potential for trees and one objective of the project is to investigate this potential.

During the summer most woods were visited and 12 were surveyed, using a proforma to assess 1) relevant ecological attributes of structure, physiognomy, floristics, general environment, woodland habitat with management and historical features, 2) conservation status and potential.

Dendrometer measurements of annual girth increment are being made on Ash, Birch, Sycamore, Wych Elm and Rowan in Helbeck Wood (near Brough) and Rowan in Swindale Beck and at Green Hole (Moor House). Age and increment studies are being made with 20 species of tree and the ratio of basal area to canopy cover is being investigated. Seedlings of Birch and Sycamore are being reared in London for experimental work in growth chambers at University College and for planting out at different altitudes in the study area next spring.

h) Biosystematic studies of Alopecurus alpinus (Dr. G.M. Fearn, Sheffield Polytechnic)

The survey of bryopyte flushes in the Moor House area was continued. Population size of A. alpinus is being maintained and may be increasing in one flush, 50 tillers and 4 flowering stems being counted in 1973 compared with 20 and 2 respectively in 1972. In general, the species has flowered well in summer 1973 but no ripe inflorescences containing seeds have been found.

Another flush containing A. alpinus has been discovered at a height of 830 m, about 20 m higher than those found previously. This flush has a similar floristic composition to the others and is probably the site described by Ratcliffe & Eddy (1960). 30 tillers were counted at this site but no flowering stems were seen.

Cytological studies and breeding experiments are being continued but no conclusive results are yet available.

i) Nitrate utilisation in acidic soils (D.C. Havill, J.A. Lee & G.R. Stewart, University of Manchester)

Nitrate utilisation in acidic soils has been measured by the enzyme nitrate reductase. This enzyme, which is found mainly in the shoots of higher plants, is inducible by nitrate and the enzyme level for a given species is proportional to the rate of supply in the soil solution. Nitrate availability in acidic soils has usually been considered to be minimal because of the known effects of acidity on nitrifying bacteria, however, our results have shown that nitrate is available in acidic soils and that in some soils at least represents an important source of nitrogen.

Four acidic sites have been compared using this technique:

Moor House (altitude 570 m, blanket peat and peaty-gley soils close to the house):

Eyam Moor, Derbyshire (altitude 370 m, shallow blanket peat and podsolized soils):

Hutton Roof, Westmorland (altitude 200 m, podsolized brown earth soils); and

Lindow Common, Cheshire (altitude 70 m, podsols).

The two lowland sites were freely drained. Some of the Eyam Moor samples were from well-drained soils. The results are shown in the table. Nitrate is available at each site but the activities observed from Moor House are extremely low. This is particularly true of Calluna vulgaris samples from blanket bog. Rubus chamaemorus sampled from the same site also had very low activities. Both species responded to nitrate fertiliser with large increases in nitrate reductase, The mean activities at the various sites increase with decreasing altitude and with waterlogging. At Hutton Roof the activities in species which grow in both acidic and adjacent calcareous soils, Festuca ovina and Sieglingia decumbens, are similar. Fertilizer additions to both soils yield similar increases in activity and it can be concluded that in this acidic soil nitrate is a significant nitrogen source.

Nitrate reductase activity (μ Mol. NO_2/hour/g. fresh wt.)

	Moor House	Eyam Moor	Lindow Common	Hutton Roof	L.S.D. .05
Calluna vulgaris	0.10	0.54	0.51	0.42	0.12
Potentilla erecta	0.57	0.72	1.20	1.15	0.27
Galium saxatile	0.54	0.58	-	0.87	0.11
Deschampsia flexuosa	0.74	0.72	1.00	0.74	0.13
Nardus stricta	0.24	0.24	0.64	0.85	0.07
Mean activity*	0.38	0.55	0.84	0.83	0.23

Values represent the average of 3 determinations at each site

* Mean nitrate reductase activity is for species determined at every site.

j) Pennine Plant Survey (A.J. Richards, University of Newcastle upon Tyne)

Thirty four 1 Km squares of the higher fell country, from Hartside to High Cup Nick have been searched in the past two years. A number of rarities have been found, old localities being confirmed, as well as new ones recorded. Among the plants found in 1973 has been Alchemilla glomerulans, Dryopteris assimilis, Euphrasia scottica, Taraxacum drucei and T. pycunostictum. Three bryophytes now to the Reserve have also been found.

The North Pennines area, from Hartside to Middleton-in-Teesdale and across to Brough, is one of considerable species richness. It contains more than 64 montane plants of interest. To date 15 rare vascular species have been found in Teesdale and a further 16 on the higher fells and western escarpment.

k) Studies of periglacial phenomena (L. Tufnell, Huddersfield Polytechnic)

For the eighth consecutive year data were obtained on the movement of 5 ploughing blocks situated above 680 m on the Reserve. In general, displacements for the period August 1972 - August 1973 were similar to those of the previous 12 months. The exception was a block in the upper Knock Ore Gill valley which moved 7.9 cm during the 1972-3 period. This represents the greatest annual displacement recorded by any ploughing block during the 8 years of the survey. A major factor responsible for this is the increased gradient down which the block is now moving.

Small scale hummocks examined on the Reserve (see p.24 of the 1972 report) have been compared with similar features on parts of the Cross Fell inlier (at Knock Pike, Flagdaw, etc.) and on the western edges of Dartmoor (chiefly the Sourton Tors and Cox Tor areas). The hummocks at these localities are thought to be the result of periglacial activity, but those on the Reserve are smaller and of more recent origins than their counterparts at the other localities.

Comparative work has also been done on limestone screes. Those in the upper Knock Ore Gill valley were investigated during 1970-1 (see p.12 of the 1971 report). Their characteristics have now been compared with those of limestone screes at 2 localities immediately west of Kendal: these are Cunswick Scar and Scout Scar.

l) Report on the snowmelt flooding project at University of Newcastle-upon Tyne (D. Archer, University of Newcastle upon Tyne)

A research project supported by the Natural Environment Research Council is currently being carried out at the University of Newcastle upon Tyne on the forecasting of river flood run off resulting from snowmelt. The principal objects of the project are:

I. to analyse recorded data from snowmelt river floods throughout Britain involving river discharges, snowmelt water equivalents, precipitation, temperature and other meteorological data and to determine significant correlations between flood discharges and their causitive factors.

II. to examine a few representative catchments in more detail, carrying out surveys of snow water equivalent before melt occurs.

III. to combine the results of I and II to investigate the variability of estimation and forecasting parameters between catchments.

Two related approaches have been used to date. The first is a simplified method whereby the accumulated snowmelt runoff is related to accumulated temperature above freezing at mean catchment elevation to give a value for a parameter referred to as the degree-day factor, in mm per degree C - day. This factor varies from event to event on the same catchment and also between catchments, and this variation can be shown to be related to catchment area, the volume of the snowpack prior to melt, and to the incident liquid precipitation during the melt. This approach has been used in several catchments throughout Britain including the River Tees.

The second approach involved simulation modelling of the snowmelt runoff process on a physically more realistic basis, still using temperature as the energy input but varying the energy and moisture inputs to the model in different elevation bands and routing these distributed inputs through a series of concentrated non-linear storage to produce an outflow. Investigations on this model have so far been concentrated on the River Tees catchment for several reasons: the comparatively frequent occurrence of heavy snow on the upper part of the catchment; the significance of snowmelt flooding and snowmelt plus rainfall flooding on the lower part of the catchment (eg. 6th March 1963 and 23rd March 1968); the availability of runoff data from several gauging stations on the Tees and tributaries and of meteorological information from the high level stations of Great Dun Fell and Moor House.

It is intended that the project will develop practical methods for forecasting and estimating river floods, with an acceptable degree of accuracy for direct adoption by River Authorities.

VI. RESEARCH BY OTHER ORGANISATIONS

a) Survey of Moths (Dr.C.A. Edwards, Rothamsted Experimental Station)

Moor House Field Station cooperated in an ecological survey based at Rothamsted Experimental Station, Harpenden, Hertfordshire. The aim of the survey is to correlate seasonal flight activities of noctuid moths and craneflies with climatic factors, in particular temperature.

A continuously recording thermograph and mercury vapour light trap operated from May to October 1973. Moths and craneflies were collected daily and identified. Fifty-four species of moths were recorded, and a reference collection was built up. One Xestia (Amathes) alpicola (Zett.) - the Northern Dart was of particular interest because this species has been recorded from the area only once as a single individual in 1963. The large numbers of moths caught indicate that caterpillars must be numerous on Moor House but this remains to be confirmed. As expected from previous records on Moor House, craneflies were very numerous throughout the trapping period. However, only a few of the species previously recorded from Moor House have been caught in the trap in 1973.

It is proposed to sample nearby sites for leatherjackets and cutworm larvae in order to correlate their numbers with the species found in the trap catches. The survey has provided valuable information for the overall project.

b) Survey of old mine workings by Northern Cavern and Mining Research Society. (Mr. & Mrs. McChesney)

The few available documents and plans relating to mining in the Moor House Reserve have been consulted, copied and where necessary, rendered into modern English. Additionally, tracings have been made of plans both of the general mineral ground around Moor House and of individual mines.

We now have sufficient information to enable us to expand on the information on mines given in "The Geology of Moor House".

Our field work so far this year has mainly consisted of exploration of the north-east area of the Reserve, including levels up Troutbeck as far as the Overhearth level, where in spite of locating and descending 40 metres of shaft, the bottom was blocked. A dig here will however be organised. Other interesting finds have been that the "hole" about 50 metres beyond the old Troutbeck shop has connected with the Troutbeck mine and in fact can be followed under the track and under the river. The mine enters what has been an underground stream bed.

Our main efforts have been in the Troutbeck Hardshins mine where we should soon be able to connect between the waterblast shaft (G.R. 743336) and the No. 2 shaft of Hardshins Level (G.R. 755338). At present the untravelled gap is a distance of 200 metres and a descent of approximately 40 metres.

Assistance has been given in surveying surface landmarks - such as cairns and posts.

VII. INTERNATIONAL BIOLOGICAL PROGRAMME

a) General (O.W. Heal)

The IBP research effort in the current year has been spent almost entirely at the desk. Research workers have been writing papers at three levels: individual research projects, Moor House synthesis, and international Tundra synthesis. Research details from individual projects have been covered in previous Annual Reports and therefore this year's report will provide only a general coverage.

A general description of the IBP sites and other vegetation and soil types at Moor House was prepared by R.A.H. Smith (1973). This draws together much of the background information on site characteristics collected during IBP and provides an introduction to more detailed data available elsewhere.

A small sampling programme to obtain rough estimates of the live, below ground standing crop and nutrient concentrations of plants on Juncetum squarrosi and Agrosto-Festucetum was carried out, to improve comparison with data from the IBP study on blanket bog. Only five cores were examined on each site on 26/7/73 but the results (Table 1) indicate that a much higher proportion of the plant biomass is "below ground" than on the bog. The shoot:root ratio being 1:9.0 on the grasslands compared with about 1.0 on the bog (Forrest 1971). The total live standing crop, including bryophytes, is about 1850 g m^{-2} for the Juncetum squarrosi and 2000 g m^{-2} for the Agrosto-Festucetum. These are above the range (1068-1724) recorded for blanket bog sites (Smith & Forrest in press).

The nutrient analyses were carried out to extend the very limited data on below ground vegetation components on the blanket bog (Table 2) and the Juncus and Agrostis-Festuca sites (Table 3). A small number of above ground samples were analysed and showed concentrations in the ranges recorded previously (Smith 1973).

Papers from individual research projects were published during the year by Grace (1973 a,b), Hodkinson (1973), and Standen (1973). In addition Clymo and Reddaway reproduced their paper from Hidrobiologia, which contained a number of editorial errors, as a Moor House Occasional Paper (No. 3).

Table 1 The dry weight (g/m^{-2} ± s.e) of above ground, shoot base and root components of the vegetation of Juncetum squarrosi and Agrosto-Festucetum. The shoot:root ratios for Juncetum are calculated with the shoot base included with the root component, no shoot base component was recognised in the Agrosto-Festucetum.

	Juncetum squarrosi	Agrosto-Festucetum
Above ground	207 ± 17	201 ± 27
Shoot base	266 ± 21	absent
Roots	1377 ± 193	1785 ± 203
Shoot:Root	1:8.5± 1.4	1:9.3 ± 1.2

Table 2 and Table 3 - P.T.O.

IBP Synthesis

The British Ecological Society, together with the Royal Society, sponsored a meeting at Liverpool University at which the results of the three main sites (Moor House, Snowdonia and Meathop Wood) and supporting IBP studies were presented. One day was devoted to Moor House programme and the three related projects on dwarf shrub communities in Banchory (G.R. Miller & A. Watson), Cairngorm (C.F. Summers) and Dorset (S.B. Chapman & N.R. Webb). Each of the eleven Moor House papers represented the combined work of a number of individuals and aimed to integrate data in particular subject areas, from IBP and relevant non-IBP studies. Although emphasis on the blanket bog was continued, many of the papers drew on results from the grassland areas at Moor House for comparison of populations and processed under different soil conditions but within the same climatic regime.

Summaries of the presented papers are given below and the papers will be published, by Springer Verlag, in conjunction with Chapman-Hall, in their Ecological Studies Series, under the title "The ecology of some British moors and montane grasslands". The volume will include papers from the three supporting moorland projects and from the main grassland study in Snowdonia.

Table 2 The concentration, as % dry weight, of six elements in components of various blanket bog plants. Means ± standard errors calculated from a number of samples (n) are given.

	n	N	P	K	Na	Ca	Mg
Calluna							
Current years shoots	2	1.59±0.06	0.12±0.03	0.71±0.015	0.74±0.002	0.37±0.005	0.20±0.005
Live Wood	2	0.55±0.04	0.04±0.002	0.23±0.05	0.03±0.004	0.13±0.015	0.06±0.007
Below Ground Wood	8	0.34±0.01	0.02±0.001	0.16±0.008	0.03±0.002	0.08±0.004	0.04±0.003
Roots	8	0.52±0.02	0.04±0.003	0.18±0.011	0.05±0.004	0.14±0.016	0.06±0.004
Standing dead	2	0.82±0.16	0.04±0.014	0.09±0.007	0.02±0.002	0.14±0.010	0.04±0.006
Eriophorum vaginatum							
Above ground	1	1.88	0.15	0.73	0.024	0.13	0.16
Below ground stems	4	1.31±0.13	0.21±0.007	1.25±0.09	0.03±0.003	0.13±0.006	0.23±0.006
Rhizomes	4	1.16±0.24	0.21±0.050	0.38±0.05	0.02±0.003	0.07±0.005	0.11±0.010
Roots	2	0.48±0.00	0.06±0.002	0.22±0.01	0.10±0.004	0.14±0.005	0.15±0.005
Eriophorum angustifolium							
Above ground	1	1.59	0.12	0.55	0.095	0.17	0.13
Below ground stems	4	2.01±0.27	0.27±0.04	1.33±0.14	0.31±0.06	0.20±0.03	0.27±0.03
Rhizomes	4	1.34±0.11	0.10±0.01	0.45±0.06	0.12±0.01	0.09±0.01	0.13±0.003
Roots	2	0.83±0.02	0.06±0.01	0.29±0.02	0.12±0.00	0.25±0.01	0.25±0.02
Trichophorum caespitosum							
Above ground	1	1.77	0.11	0.95	0.020	0.10	0.16
Below ground stems	3	0.92±0.08	0.08±0.01	0.59±0.06	0.05±0.01	0.07±0.002	0.13±0.01
Roots	4	0.59±0.03	0.03±0.002	0.17±0.01	0.06±0.01	0.04±0.007	0.05±0.003

Table 3 The concentration, as % dry weight, of six elements in mixtures of plant species on Juncetum squarrosi and Agrosto Festuceta. Means ± standard errors calculated from a number of samples (n) are given.

	n	N	P	K	Na	Ca	Mg
Juncetum							
Above ground	5	1.40±0.13	0.18±0.02	0.89±0.12	0.15±0.04	0.15±0.03	0.14±0.02
Shoot bases	5	0.83±0.03	0.20±0.02	1.18±0.13	0.32±0.02	0.05±0.004	0.13±0.007
Live roots	5	0.57±0.03	0.08±0.01	0.24±0.02	0.10±0.01	0.14±0.016	0.04±0.002
Agrosto-Festucetum							
Above ground	1	1.59	0.14	1.4	0.038	0.81	0.15
Live roots	5	1.19±0.03	0.10±0.008	0.39±0.04	0.05±0.005	0.73±0.057	0.08±0.008

b) Introduction and site description (O.W. Heal & R.A.H. Smith)

Moor House National Nature Reserve has been the main UK site for studies of moorland ecosystems. The programme has involved:

I. measurement of primary and secondary production
II. study of the factors influencing production, and
III. an examination of the main transfers of dry matter, and to a lesser extent nutrients, within a blanket bog.

Research has concentrated on lightly grazed blanket bog with Calluna, Eriophorum, and Sphagnum as dominant plants. Comparisons have been made with adjacent grasslands on podsolic and brown earth soils. The programme has been carried out by a research team involving ten universities and institutes.

The research has centred on blanket bog sites at about 600 m above sea level. The meteorological data show that August is the warmest (10.7°C) and February the coldest (-1.3°C) month. Solar radiation is in the order of 70 kcal $cm^{-2} yr^{-1}$. Annual rainfall is about 200 cm and potential evaporation estimates show that water deficits occur only occasionally in mid-summer. The vegetation is classed as Calluneto-Eriophoretum with variation towards Trichophoretum-Eriophoretum and Eriophoretum, the last being mainly derived from burning. The peat varies in depth up to a maximum of 4.0 m, with pH 3.0-4.0 and water table close to the surface. The peat profile shows a colour zonation which probably reflects the reducing conditions associated with waterlogging.

c) Field estimates of primary production (R.A.H. Smith & G.I. Forrest)

Production values were compared from a range of Calluneto-Eriophoretum blanket bog sites at Moor House. The blanket bog vegetation at Moor House is regarded as constituting a steady state situation, rejuvenation of Calluna occurring by Sphagnum overgrowth.

The first primary production estimates were obtained by Rawes, and Gore and Olson. Later work by Clymo was mainly on Sphagnum spp. and gave a mean value of 90 g $m^{-2} yr^{-1}$ for the net primary production of S. rubellum.

Forrest measured total net primary production on seven blanket bog sites and obtained a mean value of 699 g $m^{-2} yr$. There was a twofold variation in the values on individual sites from about 500-900 g $m^{-2} yr^{-1}$. The highest values were on recently burnt sites in a seral condition, the remaining variation is largely related to water table and species composition - the wettest Sphagnum dominated sites having a low productivity. No significant between-year differences in production were found over a three year period.

Forrest's work showed that on the Moor House blanket bog nutrient and microclimate differences were probably unimportant in affecting total productivity, but other work by Taylor and Marks on Rubus chamaemorus and Gore on Eriophorum vaginatum demonstrated that the absolute value of productivity of individual blanket bog species on a particular site is probably largely influenced by climatic and nutrient factors.

Total production ranged from 2.80-4.90 g m^{-2} per growing season day, and efficiency of conversion of photosynthetically active radiation over the growing season from 0.95-1.71%.

d) Physiological aspects of production of bog vegetation. (J. Grace & T.C. Marks)

Physiological work relevant to the IBP production studies at Moor House was reviewed. The light climate for Rubus chamaemorus and Sphagnum is a function of the Leaf Area Index of the dominant species, Calluna vulgaris. Photosynthesis response curves in relation to temperature and light were discussed, there being pronounced inter-specific differences in the light saturation point, the absolute rate of photosynthesis, and the response to temperature. This is especially marked when Calluna and Rubus performance is estimated over the course of a warm summer's day. Other factors influencing photosynthesis by Calluna are the presence or absence of flowers on the shoot, and light direction; whilst Sphagnum is sensitive to water content. Distribution of assimilate, and its role as a determinant of growth was reviewed. To explore the consequences of the photosynthesis and other data, models have been developed to integrate hourly performance over the course of an entire season. The models of Calluna and Rubus behave in a contrasting manner in relation to temperature, high temperatures increasing Calluna growth but decreasing that of Rubus. The relationships seem to reflect each species status in relation to its geographical distribution. The Rubus model was used to investigate the effect of removing the Calluna canopy, as in the management practice of burning. The overall results were discussed in relation to earlier ideas on how plant growth is regulated in the British uplands.

e) An analysis of fauna populations at Moor House (J.C. Coulson & J.B. Whittaker)

Studies of the fauna at Moor House began in the early 1950's and have been previously reviewed by Cragg (1961). The heterogeneity of the area (blanket bog dissected by streams with mineral soils along their banks) is reflected in two recognisable fauna components on the peat and mineral soils respectively. The animals on the former are predominantly upland, sub-arctic species with a restricted emergence patters with a peak in June. On the mineral soils, emergence of animals takes place over a much longer period. Predators have to be mobile or choose between a longer season but little cover on the heavily grazed mineral areas, and a short season but more cover on the blanket bog. Predators, especially large ones, and parasites are scarce, and rates of parasitism are low.

Long term population studies suggest that the lowland species at the edges of their ranges at Moor House are not well regulated and fluctuate widely, whereas the species which are well adapted to upland life are probably better regulated. Secondary production on the mineral soils is three or four times that on the peat soils but the proportion of herbivore production which is assimilated by predators is greater on the peat areas than on the mineral soils. Below ground grazers and decomposers account for about 60% of the energy flow on the mineral soil areas where there is heavy sheep grazing, and about 90% on the blanket bog where there is very little.

References

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f) Microbial populations in peat (V.G. Collins, B.T. D'Sylva & P.M. Latter)

Samples of material from peat cores have been subjected to standard bacteriological and mycological techniques designed to enumerate the populations of bacteria and fungi.

With reference to fungi the amount of stained (2200-2800 m/g.o.d.w.) and unstained (4900-9300 m/g.o.d.w.) were greatest in the litter and black-brown horizons respectively. For bacteria (direct counts), the numerical range in the litter was 43-212 x 10^8/g.o.d.w. and this zone yielded the maximum overall population as compared with other zones studied, dilution counts were 260 x 10^5/g.o.d.w.

Some specialised physiological groups of bacteria have been enumerated. For groups of bacteria involved in breakdown mechanisms 3 x 10^6 were proteolytic, 2 x 10^3 - 2 x 10^4 participated in denitrification processes, 10^6 - 10^7 organisms were potentially capable of fixing N_2 and autotrophic ammonia-oxidisers were absent.

Thiosulphate oxidising bacteria gave counts of 5 x 10^3/g.o.d.w. in the litter zone, sulphate reducing organisms gave counts of 6 x 10^3/g.o.d.w., these organisms demonstrated that their greatest activity takes place in the green brown zone of peat cores. Bacterial groups capable of hydrolising certain organic compounds were also studied and the numbers of cellulose decomposing bacteria obtained from the litter zone were 2 x 10^3 organisms capable of hydrolysing cellulose. 5 x 10^6 bacteria were capable of performing the hydrolosis of starch, that is about half of the estimated bacterial population within the litter zone of peat soils, is capable of converting starch into sugar containing compounds.

Tests for response to temperature were carried out on pure culture isolates of bacteria, 100% of the isolates grew at 20°C and 50% grew from 0°C to 5°C. Of the pure culture isolates of fungi tested from Moor House 53% grew well at 1°C.

Bacterial cultures from peat tolerated from 3-110% saturation with O_2, fungal isolates preferred aerobic conditions of incubation for growth. The isolates were tolerant of high concentrations of CO_2 and the best growth occurred with high O_2 and 5% CO_2.

It was concluded that the microbial populations of Pennine peat soils are selected for survival at low nutrient, low pH conditions and low temperature. It would appear that the following environmental parameters act as the main "conditioners" with regard to microbial populations in peat: the water-logged condition of the natural material and low oxygen tensions within the peat profile, the acid conditions of the peat soil environment, the quality and availability of the organic matter in peat, low cation content and its effect on nutrient cycling and the broad ceiling parameter of the effect of temperature.

g) Microbial activity in peat (N.J. Martin & A.J. Holding)

1. Organic and Inorganic Nutrients Limiting Microbial Activity.

Studies using laboratory non-cyclic percolation systems showed that microbial activity, as indicated by bacterial population studies, is limited primarily by the low availability in native peat of both organic energy sources and nitrogen compounds. Both physical and chemical factors which appear to be restricting the availability of potential substrates may be partially removed by macerating the peat. The percolation of both a utilisable source of carbon and nitrogen promotes a greater stimulation of microbial activity than if either is added separately. These data indicate that the limitations are, to some extent, interdependent.

Phosphate, calcium, magnesium or a mixture of trace elements were of secondary importance as limiting nutrients. The response to calcium and probably magnesium appears to be due to a chemical interaction, probably reducing some inhibitory effect, rather than supplementing limiting levels of the element. Potassium did not promote detectable changes in the microbial population.

The response of microbial populations in the field to the amendments, and laboratory respiration data obtained with both macerated and unmacerated peat have confirmed that energy and nitrogen sources are the main nutrients limiting microbial activity.

2. Mineralisation, Immobilisation and Release of Inorganic Nutrients by Micro-organisms.

In the percolation experiments, with or without amendments, the production of ammonia (ammonification) was observed, but no nitrate production (nitrification) was detected. If nitrification was taking place, any nitrate formed was being rapidly reduced. Dissimilatory nitrate reduction was shown to be very active in percolation treatments receiving nitrate. Nitrogen fixation rates (D'Sylva and Collins) estimated from field samples using the acetylene reduction technique varied between 0.029 and 21.93 g N/m^2/per annum.

Micro-organisms did not promote a detectable increase in the rate of release of potassium, magnesium or calcium. Although immobilisation of these ions was not observed in any treatment, some immobilisation of phosphate was detected.

Calculations suggest that, in relation to the level of available nitrogen compounds and phosphate, significant quantities are immobilised in microbial cells. These immobilised nutrients may make an important contribution to the relatively small actively cycling nutrient pools.

h) A study of the rates of decomposition of organic matter (O.W. Heal)

This paper combines results from a number of projects in which rates of decomposition have been measured by weight loss from litter bags and pure cellulose, and by respiration. Comparison of weight loss and respiration from litter indicate that the former shows a constant loss rate while the latter declines with time. Respiration losses account for most of the observed weight loss, the remaining loss probably results from leaching and removal by fauna.

The weight losses from a range of litters shows that the main types of litter decompose at 5-20% loss per year while at or near the surface of the blanket bog. Chemical analyses of the initial litters indicate that the relationship between chemical composition and subsequent decay rate is complex and involves interaction between inorganic and organic fractions. Litter and cellulose placed at different depths in the peat show declining decay rates with depth. Microhabitat variations in moisture and temperature regimes influence the rate of decay to a lesser extent than species and depth variation. Measurements on litter in the presence and absence of soil fauna show that weight loss and respiration are increased by 10-20% by the fauna, largely as a result of stimulation of microbial activity. Variation between bog sites and between years were not significant.

Comparison with rates of decomposition on different soil types at Moor House and with similar soil types in lowland Britain show that the within site variation on the blanket bog at Moor House is greater than between site variations, locally and geographically.

i) A simulation of production and decay rate in blanket bog.
(H.E. Jones & A.J.P. Gore)

Production and decay in three major blanket bog species, Calluna, Eriophorum vaginatum and Sphagnum were used to simulate peat accumulation on two blanket bog sites of different peat depths at Moor House.

The peat column was visualised as a series of layers, to allow for the effect of depth on decay rates. The input to the top layer corresponded to observed annual weights and depths of litter deposited per m^2 at each site. Depths deposited were calculated from litter densities. The contents of each layer accumulated according to the equations:-

$$\frac{dW}{dt} = I_W - kW \qquad \text{and} \qquad \frac{dD}{dt} = I_D - kD$$

Rate of change in depth, D, was assumed proportional to rate of change in weight, W, and the decay rate, k, was modified by the depth factor at the midpoint of each layer. When the peat accumulated to the depth of the layer, the remainder of the initial input weight and length became the input to the next layer.

When the different litters were combined as a single input, affected by a mean decay rate, the simulated profile obviously had a constant density. However, when species were treated separately, the different weight and depth inputs, coupled with the different decay rates of the litters, resulted in density changes down the simulated profile, corresponding to some of the characteristics of profiles observed in the field.

Variation in litter production, litter densities, decay rates and effect of depth on these decay rates was simulated.

Constant decay rates, derived from weight losses in litter bag experiments, appeared to over-estimate long term decay, in that insufficient simulated peat was formed when constant rates were used. Respiration of the litters had been shown to decline with time, and decay rates were modified so they declined in the same way. With the modified decay rates the simulation produced a more realistic accumulation of peat.

j) A model of peat bog growth (R.S. Clymo)

Dry matter and length increment rates of a Sphagnum carpet are combined to give the rate of change of bulk density as a function of depth (which, in turn, depends on time). The evidence for the functional relations used is discussed. Dry matter increases at a constant rate due to production at the surface. Loss due to decay is at a rate proportional to the dry matter remaining. The same relations hold for length, but there are additional decreases in length due to compression by the weight of material above and due to creep of the peat dry matter "skeleton". The combination of these processes produces a model with 7 parameters: p (productivity), I (length growth rate), a_1 (aerobic decay), a_2 (anaerobic decay), k (compression), c (creep).

The decay parameter is assumed to have a different (lower) value in anaerobic conditions below the water table.

Two types of test are described. In the first, measured values of the parameters are used to predict profiles of bulk density and age. In the second, a weighted sum of squares of deviations of observed and calculated bulk densities is minimised. There is no unique solution. Parameter values and the age profile are predicted.

For checking the age profiles, the 1963 horizon is established by the peaks in Cs-137 concentration (produced from nuclear bomb tests).

An attempt is made to provide a continuous chronology from the profile of concentrations of Na, K, Mg, Fe, Al, Ti, Pb, Cd, Zn, and Cu.

The shape of the bulk density profile is simple and can be well fitted by 3 parameters. The extra check of the age profile is therefore important.

The model appears to be a moderately good one for times of perhaps 50-100 years, but needs much further development.

k) The distribution and transfer of dry matter and nutrients in the blanket bog ecosystem (O.W. Heal & R.A.H. Smith)

Results from the various projects have been combined to provide a simple description of the distribution and annual rate of transfer of dry matter within the upper 20 cm of the blanket bog. Chemical analysis of various components allows the dry matter description to be converted into a preliminary description of the distribution and transfer of nitrogen, phosphorus and potassium. This synthesis of results shows that of the annual primary production of 650 g m^{-2}, about 1% is consumed by herbivores, the remainder entering the decomposer cycle. Soil fauna consume an equivalent of about 5% of the annual input, the remainder is decomposed by the microflora apart from about 10% which passes below 20 cm and a small loss in runoff. Despite large variations in fauna population densities, and errors associated with the estimates, the pattern of transfer of dry matter remains constant. One feature of the bog ecosystem is the limited number of species involved, with about 90% of the production by flora and fauna usually derived from five species, Calluna vulgaris, Eriophorum vaginatum, Sphagnum sp., Cognettia sphagnetorum and Tipula subnodicornis.

Nutrient results suggest that there are about 200 g nitrogen per m^2 of the bog ecosystem and about 13% of this is in the organisms and in circulation. There are less than 20 g m^{-2} of phosphorus and potassium and up to 50% of this may be in the organisms and in circulation, indicating potential and nutrient limitation.

In contrast with the bog, an adjacent Agrostis-Festuca grassland on brown earth shows lower annual primary production but a greater proportion of this is consumed by herbivores and decomposer fauna, both of which show higher production than comparable trophic levels on the bog. This is related to the greater amounts of phosphorus and potassium in the grassland ecosystem and the higher concentrations in the live and dead plant tissues.

1) The blanket bog as part of a Pennine moorland (M. Rawes & O.W. Heal)

94% of the primary production of the moorland is produced by the extensive blanket bog, but there are a variety of other habitats, all affected by man, and each having an influence on the whole system. These habitats, the grasslands, flushes and streams, are usually more productive and contribute more to the ecology of the system than their size would suggest.

The paper discusses:

1. The present ecological pattern
2. The inter-relationships of habitats
3. Some changes with time

In describing the landscape the overall influence of sheep is stressed. Habitats are shown to have low levels of primary and secondary production, but diversity of species is associated with soil fertility, and, in the case of aerial invertebrates, with structural diversity of the vegetation. This latter aspect is demonstrated in the blanket bog, where the number of animal species is similar to that of the more fertile but closely grazed Agrostis-Festuca grassland. Soil invertebrates, microbial activity, production and utilisation by herbivores and turnover, however, are much higher in the grasslands, where plant growth is more digestible and nutrient rich. Streams are numerous and relatively productive. The annual net production of trout is 70% of its standing crop compared with 36% in the case of sheep. But it is in the movement of inorganic and organic material that the fresh-waters are of ecological significance. Terrestrial invertebrates enter the stream surface at the rate of 20 g/m^2/year, and, although this is less than 1% of the terrestrial invertebrate production it constitutes up to 30% of the food of trout.

International Activities

Ideally the publication of individual research projects would be followed by national, then international synthesis. In reality, the three activities are overlapping and are providing problems in the allocation of time by the research workers and the availability of unpublished, partially interpreted data. However, the international Tundra programme has maintained momentum, aiming at the final meeting in Sweden in April 1974, with publication of the papers in one of the series of Cambridge University Press IBP volumes.

The Primary Production and Ecosystem Working Groups met in Dublin in April. Participation from Moor House was limited because of the clash with the meeting in Liverpool, but Helen Jones and Tony Gore (Merlewood) have continued a comparative analysis of primary production data from a number of Tundra sites. In August, the Microbiology, Decomposition and Invertebrate Working Groups met in Fairbanks, Alaska. John Holding, (Edinburgh University), Vera Collins (F.B.A.), John Whittaker (Lancaster University), and Bill Heal (Merlewood) were present and involved in the presentation of papers comparing population and activity data from a number of sites. Papers presented at both the Dublin and Fairbanks meeting will be published as proceedings volumes within a few months.

Closely linked with the Moor House participation in Tundra, four Visiting Fellows have worked at Merlewood during the year, sponsored wholly or in part by the Royal Society. Dr. T.V. Callaghan collected plant samples from many of the Tundra sites and has nearly completed a comparison of growth rates of individual species. Mr. A.K. Veum (Norway), Dr. P.F. Flanagan (USA) and Dr. P. Dowding (Ireland) developed synthesis of microbiology and decomposition results during their visits and the results were presented at the Fairbanks meeting.

VIII. SHORT ARTICLES

a) A population study of the Red Grouse (Lagopus lagopus scoticus) (P. Holms)

Introduction

The aim of this work was to continue the study begun by Paul Taylor in 1971 and gain an accurate picture of grouse numbers and breeding success on the Moor House National Nature Reserve. Counts of adults were carried out in the Spring, of nests and eggs in the Summer and to establish breeding success in July.

The Study Areas

Three study areas have been used in the past; Bog Eng (25 acres), Burnt Hill (50 acres) and The Drive (50 acres). The total study area was doubled this year by plotting four new sites totalling 154 acres. The sites chosen give greater variation in both altitude, heather growth and grouse numbers.

Method

Counting was carried out on the study areas by the use of a trained labrador which ranged up to one hundred metres on either side of the observer flushing the birds. Care had to be taken to keep the driven birds in view at all times.

On each of the seven study areas twice weekly counts were taken in March to assess the number of adults and again in July to find how well the young had been reared. The positions of the birds and their relative nesting sites were plotted on the area maps.

Table 1 Study Areas

Area	Ref.	Height (ft.)	Acreage
Bog End	765330	1825	25
Burnt Hill	754330	1850	50
The Drive	763335	1800	50
Hard Hill 1	741328	1980	30
Hard Hill 2	732344	1950	35
Green Burn	764313	1900	48
Force Burn	771306	1850	45

Table 2 Density of grouse per study area at Moor House 1973

Site	Area	No. of adults	Birds/ha	Birds/acre
Bog End	10.2 ha	16	1.56	0.64
Burnt Hill	20.3 ha	28	1.38	0.56
The Drive	20.2 ha	20	0.95	0.40
Hard Hill 1	12.0 ha	20	1.66	0.66
Hard Hill 2	14.0 ha	14	1.00	0.40
Green Burn	19.2 ha	15	0.78	0.31
Force Burn	18.0 ha	12	0.66	0.26
Average			1.14	0.46

Results

Nesting

A total of 55 nests were located on various parts of the Reserve including the main study area and sample areas. Of these 39 (70.9%) hatched successfully and were further studied. Clutch sizes were noted and used in obtaining average clutch figures with the main study area data.

There was a surprising number of desertions this year and it is unlikely that the unstable weather could have accounted for this. This, together with the fact that many clutches were taken by gulls, made for a large number of unsuccessful nests. The second clutches from these birds had a high success rate though they tended to be considerably smaller on average. Clutches were generally small this year, only 7.4 overall average as compared with last years 8.8.

Of the nests studies, all showed a good fertility rate.

Nest failures on Moor House study areas

Nests	Desertions	Predations	Robbed	Total
55	8 (14.5%)	2 (3.6%)	6 (10.9%)	16 (29.0%)

Table 3 Estimation of clutch size

Area	No. in clutch	Total
Bog End	7 8 6 8 7 5 5	46
The Drive	8 6 7 8 5 10	44
Burnt Hill	6 6 7 8 9 8 6 7 8	65
Hard Hill 1	8 7 6 8 7 7	43
Hard Hill 2	6 7 8 7	28
Green Burn	11 6 6 7 9 8 5	52
Force Burn	7 7 6 6	26
	Total No. of eggs	304
	Main Area Average	7.6

Chicks

Due to the number of second clutches, the chicks differed tremendously in age on final counting in July and some still experienced difficulty in flying.

Of the chicks which hatched successfully fatalities were on a par with 1972. Unsettled weather at the time of hatching seems to have had little or no effect. Large flocks of gulls gave the young chicks a difficult time and there is no doubt a number were taken in this way.

Predation and Robbing

On the Hard Hill 2 area a hen was taken by a fox immediately preceding nesting. The cock maintained the territory. Many nests were robbed on the Green Burn area by black headed gulls but all the birds relaid. One nest robbed by gulls on the Force Burn area was later successful. Bordering the main area a hen was taken by a fox.

Breeding success

On each of the seven areas two counts were made to assess the number of young. The driven birds were identified using binoculars and those doubtful were disregarded. The final overall young to old ratio (2.9:1) compares favourably with 1971 (3.3:1) and 1972 (2.0:1).

Counts to estimate breeding success

	Adults	Young	Young:Old	Av./Site
Bog End				
23.7.73	6	16	2.66:1	2.74:1
25.7.73	11	31	2.81:1	
Burnt Hill				
24.7.73	12	38	3.16:1	3.18:1
26.7.73	15	48	3.20:1	
The Drive				
27.7.73	8	28	3.50:1	3.40:1
30.7.73	13	43	3.31:1	
Hard Hill 1				
20.7.73	8	23	2.87:1	2.98:1
1.8.73	11	34	3.09:1	
Hard Hill 2				
20.7.73	6	18	3.0:1	2.94:1
23.7.73	9	26	2.88:1	
Green Burn				
31.7.73	8	22	2.75:1	2.58:1
2.8.73	14	34	2.42:1	
Force Burn				
31.7.73	12	25	2.08:1	2.54:1
2.8.73	10	30	3.0:1	
		Overall Average		2.91:1

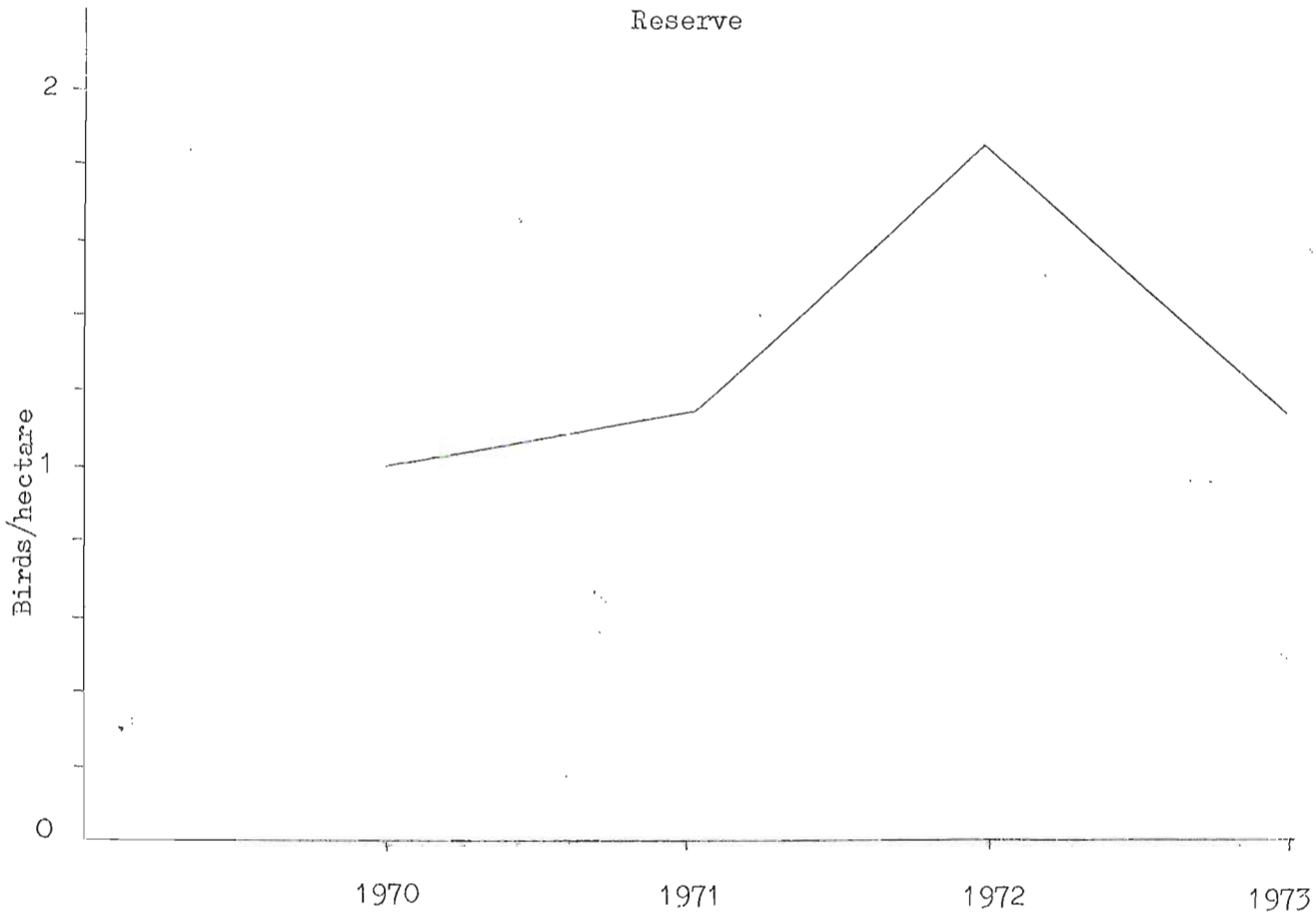
Discussion

As winters have been very mild in the last few years, the heather has been well advanced earlier than usual and so food has been available to the hens just at the critical time of nesting. Conditions have therefore been favourable for large broods as has been the case in the last two years. Clutch size is the lowest it has been for several years and may be linked with simple pressure of numbers. Figures for last year show the birds at possibly a too high a density with a result that nesting failure and territorial

pressure lessened the breeding stock for this year. Going back ten years one can see the rise in density from a fairly constant 1 bird per 2 hectares to a very unstable 1.85 birds per hectare in 1972. Breeding success this year compares very favourably with other recorded years.

It has been a good breeding season and has made for stable numbers following an exceptionally good year. Though the density of breeding birds is still very high there is no proof it has again reached precarious figures. Disease has been forecast for several years and has not come about, even in 1972. I believe the birds have now reached a stable maximum and any further increase will simply mean an increase in the number of surplus birds.

Density of grouse breeding stock
Moor House National Nature
Reserve



b) The control of flowering in a clone of Deschampsia cespitosa (L.) Beauv. from Moor House National Nature Reserve. (K. Taylor & A.J. Davy)

Introduction

Flowering in Deschampsia cespitosa occurs only after certain environmental requirements have been met. In Britain, plants in the field flower freely from late June to August each year, but plants grown in heated glasshouses, with supplementary illumination during winter, have never flowered during 4 years' observation. Thus the requirement for floral induction might reasonably be expected to involve a period of cold vernalisation, a period with a short day regime or a combination of both, such as has been found for another tussock forming grass, Dactylis glomerata (Gardner and Loomis, 1953). Studies ranging from N. America to Scandinavia (eg. Hagerup, 1939; Lawrence, 1945; Kwano, 1963 and 1966; Ward 1969) have shown that considerable cytological variation and ecotypic differentiation with respect to temperature and day-length occur in the species; moreover, vegetative proliferation of floral spikelets (false vivipary) has been induced in normally seminiferous races by subjecting them to short day treatments during floral development (Nygren, 1949); but there appears to be little information regarding the environmental control of floral induction in D. cespitosa.

A tussock was collected from a mine spoil heap close to the Research Station at Moor House in July 1971. At the time of collection it was flowering, apparently seminiferously, but after transference to a glasshouse at University College London many of the spikelets, particularly in the lower parts of the panicles became proliferous. However, no viable seed was obtained from even the apparently seminiferous spikelets. Cytolological examination of root tips revealed that this plant was tetraploid with 2n = 52 chromosomes. Individual tillers of the tussock were rooted and grown into a clone of smaller tussocks and ramets of this were included in two experiments designed to determine the environmental requirements for flowering of diploid and tetraploid clones.

Experiment 1

Procedure:

Plants of the Moor House clone and of three lowland, diploid clones were subjected to factorial combinations of 0, 14, 21 and 35 days' warm, short-day pre-treatment (8 hour photoperiod; 20°C day/15°C night; 1200 foot candles illuminance) with 0, 14, 21 and 35 days cold, long-day post-treatment (16 hour photoperiod; 5°C day/4°C night; 800 foot candles illuminance). After post-treatment all plants were transferred to a chamber with warm, long days (16 hour photoperiod; 20°C day/15°C night; 1500 foot candles illuminance) for 21 days to allow fixing of any vernalisation which had occurred, before transference to a heated glasshouse to await the development of inflorescences.

Results:

The only plant to flower as a result of this series of treatments was a tussock of the Moor House clone, one of three replicates which had received the maximum of 35 days of both pre- and post-treatment; the inflorescence was a depauperate panicle which never emerged from the tussock and comprised only 4 spikelets. It appeared exactly three months after the termination of post-treatment.

Experiment 2

Procedure:

A single treatment of cold short days (8 hour photoperiod; 5°C day and night; 1200 foot candles illuminance) was employed for plants of the Moor House clone and a diploid (2n = 26) clone from the Chiltern Hills. Three plants of each clone were removed from the treatment after 15, 26, 37, 45, 54, 61, 68, 75, 81, 87, 101, 108 and 115 days; all remaining plants were removed after 175 days. On removal they were placed in the warm long day regime, as in the previous experiment, for 7 days before being placed in the heated greenhouse.

Results:

No inflorescences were produced by the diploid clone. A plant of the Moor House clone which had undergone 81 days' treatment produced a panicle of one spikelet on a 130 mm culm. All ramets of the Moor House clone which had received more than 81 and less than 175 days' treatment produced inflorescences at about the same time, the height of the culms and the number of spikelets in the panicles increasing with the length of treatment. After 175 days' treatment inflorescences were comparable in size and structure with those seen in the field; one of these plants subsequently became proliferous, as the original tussock of the clone had been. Again no fertile seed was produced by any of the flowering plants.

Discussion

Perhaps the most striking aspect of these results is the difference in behaviour between the diploid and tetraploid clones. After flowering in the field, the lowland, diploid plant normally produces considerable quantities of seed which germinates readily. The propensity of the Moor House plant for spikelet proliferation might be regarded as an adaption to sterility which is itself probably connected with the increased chromosome number. No evidence is yet available concerning chromosome behaviour at meiosis in this clone. However, these results do represent clear evidence for ecotypic differentiation with respect to floral induction in this species.

Obviously, more work is required to define the combinations of environmental conditions which are conducive to flowering in various genotypes. Although all plants which flowered had received both cold and short day treatments, the evidence for both of these being necessary rather than merely one or the other rests on a single plant from the first experiment; the possibility of synergism between the two factors remains unexplored, as does the possibility of discovery of a critical day-length. In particular, the failure of the diploid clone to respond to almost six months simulated winter requires further investigation, and this and other aspects of the work are still in progress.

We would like to thank Mr. R. Scott for chromosome counts of 2 clones. One of us (A.J.D.) gratefully acknowledges financial support from the N.E.R.C. during this work.

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c) Knock Ore Gill & Swindale Beck Fish Surveys - Preliminary Report (D.T. Crisp)

Introduction

The survey was made on 22nd and 23rd August, 1973. The primary aim was to investigate the distribution of fish in those parts of Knock Ore Gill, Swindale Beck and Sink Beck which are within the boundaries of the Moor House National Nature Reserve. In addition, it was possible to obtain an approximate estimate of the total number of fish in each stream, some details of the length-frequency distribution of the populations and estimates of population density and biomass.

Methods

A series of stations spaced along the length of each stream was electrofished once. The dimensions of each station were carefully measured. At one station in each stream, a double fishing was performed and the results from this were used to obtain an estimate of the efficiency of capture from single fishings at the remaining stations. The data were processed in the manner described by Crisp, Mann and McCormack (in preparation).

All fish captured were measured to the nearest mm, scales were taken from all fish other than fry and the fish were then replaced in the stream.

Sampling station and fish distribution

Details of the station are given in Table 1.

Table 1 Details of the positions and dimensions of the sampling stations. Stations where no fish were found are marked *

Stream	Station No.	Nat. Grid Ref.	Length (cm)	Width (cm)	Area (m^2)	Stream area represented by each station (m^2)
Knock Ore Gill	1	NY/697301	26.2	3.75	98.25	1433.6
	2	NY/700301	28.0	2.59	72.52	521.1
	3	NY/701301	21.3	2.35	50.06	567.5
	4	NY/704303	21.3	2.07	44.09	1208.3
	5	NY/708305	14.0	2.07	28.98	770.7
	6	NY/712306	17.7	1.83	32.39	736.6
	6a*	NY/715307	c 18	c1.2	c 22	
	7*	NY/716308	21.9	1.86 c1.5	40.73	1199.5
	8*	NY/717312	21.9	1.40	30.66	
Swindale Beck	1	NY/703286	25.0	2.01	50.25	849.6
	2	NY/706287	15.5	2.32	35.96	1447.4
	3	NY/712292	c 18	c1.5	c 27	2143.3
Sink Beck	1*	NY/702293	c 24	c0.9	c 22	1449.0
	2*	NY/707295	c 21	c0.5	c10.5	

In estimating the area of stream represented by each station, it is necessary to make a decision as to the point at which each stream is no longer inhabited by fish. The only fish found during the survey were brown trout (Salmo trutta L.). No fish were found in Sink Beck. In Swindale Beck trout were found up to Station 2, but none were found at Station 3. It has been assumed that the upper limit of trout in the latter stream was the almost vertical waterfall some 4 m high at NY/709289. In Knock Ore Gill trout occurred at Station 6, but none were found at Station 6a (immediately downstream of the point where the stream crosses the road), nor in any of the stations upstream of this. The point midway between Station 6 and 6a has, therefore, been taken as the upstream limit of trout distribution in Knock Ore Gill.

Details of the estimated area of each stream and of the estimated area containing trout are given in Table 2.

Efficiency of Electro-fishing

Double fishings were performed in Knock Ore Gill at Station 2 and in Swindale Beck at Station 2. Details of the results are given in Table 3. It is clear for both stations that there was little difference between the efficiency of capture of fry and older fish, and the total catches of fish of all ages have therefore been taken as the best estimate of efficiency of capture. For Knock Ore Gill it has, henceforth, been assumed that a single fishing will caputure 60% of the trout in any given reach. The corresponding value for Swindale Beck is 95%. The difference in efficiency between the two streams probably reflects the more irregular nature of the substratum in Knock Ore Gill which increased the probability of some trout escaping capture.

Table 2 Estimated area of each stream within the Moor House National Nature Reserve, area of each stream containing fish and percentage of total stream area containing fish.

Stream	Total area within the N.N.R. (m^2)	Area with fish (m^2)	Area with fish, as a percentage total area
Knock Ore Gill	6437	5238	81
Swindale Beck	4440	2297	52
Sink Beck	1014	0	0

Table 3 Details of the results of double fishings at two stations.

Knock Ore Gill (Station 2)	Fry	Older Fish	Total
First fishing	15	9	24
Second fishing	5	5	10
Total catch	20	14	34
Estimated population	23	20	41
% of estimated population taken in first fishing	61	45	58
Swindale Beck (Station 2)			
First fishing	5	10	15
Second fishing	0	1	1
Total catch	5	11	16
Estimated population	5	11	16
% of estimated population taken in first fishing	100	91	94

Estimates of population density and total stream populations

Table 4 shows estimates of the population density of fry and older trout in each sampling station. Note that two values are given for each station. The first is an absolute minimum value and is based on the number of fish actually caught during a single fishing of each station. The second estimate assumed that fishing efficiency was as outlined in the previous section of this report.

Table 4 Estimated population density of fry and older trout in each station.

Stream	Station No.	Minimum population density based on batch, from a single fishing (No/m^2)			Population density assuming that a single fishing captured 60% of the fish in Knock Ore Gill & 95% in Swindale Beck (No/m^2)		
		Fry	Older Fish	Total	Fry	Older Fish	Total
Knock Ore Gill	1	0.071	0.244	0.316	0.130	0.447	0.578
	2	0.207	0.124	0.331	0.379	0.227	0.606
	3	0.040	0.040	0.080	0.073	0.073	0.146
	4	0.136	0.408	0.544	0.249	0.747	0.996
	5	0.035	0.242	0.276	0.664	0.443	0.505
	6	0.093	0.463	0.556	0.170	0.847	1.017
	6a	0	0	0	0	0	0
	7	0	0	0	0	0	0
	8	0	0	0	0	0	0
Swindale Beck	1	0.080	0.159	0.239	0.084	0.167	0.251
	2	0.139	0.278	0.417	0.146	0.292	0.438
	3	0	0	0	0	0	0
Sink Beck	1	0	0	0	0	0	0
	2	0	0	0	0	0	0

Table 5 Estimated number of trout in each stream, within the boundaries of the Moor House National Nature Reserve.

	Fry	Older Trout	Total
Knock Ore Gill	901	2668	3569
Swindale Beck	283	564	847

The second set of estimates of population density have been used, in conjunction with data in Table 1, to calculate the total trout population of each stream. The results are shown in Table 5.

Trout Biomass

No fish were weighed during the survey. However, details of the length-weight relationship for trout in Trout Beck are given by Crisp et al (in preparation) and have been used to attribute weights to the Knock Ore Gill and Swindale Beck trout. This procedure will probably tend to give a slight underestimate of biomass, since a subjective impression was obtained that the "condition" of the trout in the streams on the western side of the National Nature Reserve was better than that of the Trout Beck trout. It was assumed that $w = 0.006\ l^{3.5}$ for trout fry and $w = 0.015\ l^{2.9}$ for older trout, where w = weight in g and length in cm. From these equations the recorded lengths of the trout examined, and the higher estimates of population density in Table 4 it was possible to derive biomass estimates given in Table 6.

Table 6 Population density and biomass of trout in the two streams

Stream	Station No.	Population density (No/m^2)	Biomass (g/m^2)
Knock Ore Gill	1	0.578	13.86
	2	0.606	13.41
	3	0.146	2.58
	4	0.996	23.47
	5	0.505	11.96
	6	1.017	25.14
	Mean	0.641	15.15
Swindale Beck	1	0.251	6.13
	2	0.438	10.54
	Mean	0.345	8.34

Length frequency distribution

The length frequency distribution of the catch from each stream is shown in Figure 1. In both streams, the fry can be clearly separated from the older trout and in the Swindale Beck sample, it is possible to make a tentative separation of the I and II age-group fish, though this distinction may be more apparent than real and could simply reflect rather small sample size. The histograms suggest that growth may be rather better in Swindale Beck than in Knock Ore Gill, but a more definite statement on this subject must await the reading of the scales.

Age determination and growth

A total of 79 sets of scales from Knock Ore Gill and 18 sets from Swindale Beck were taken from trout of age I or more. The cleaning and reading of these scales may be delayed, possibly for a year or two. When this is done it will be possible to examine the age structure of the population and the growth of the fish. It might also be possible to make very approximate estimates of trout production.

Future developments

During the survey of August 1973 it was possible to collect a comparatively large quantity of data and material in a short time and without killing any fish. These are, however, three points which could profitably be examined in more detail, they are:

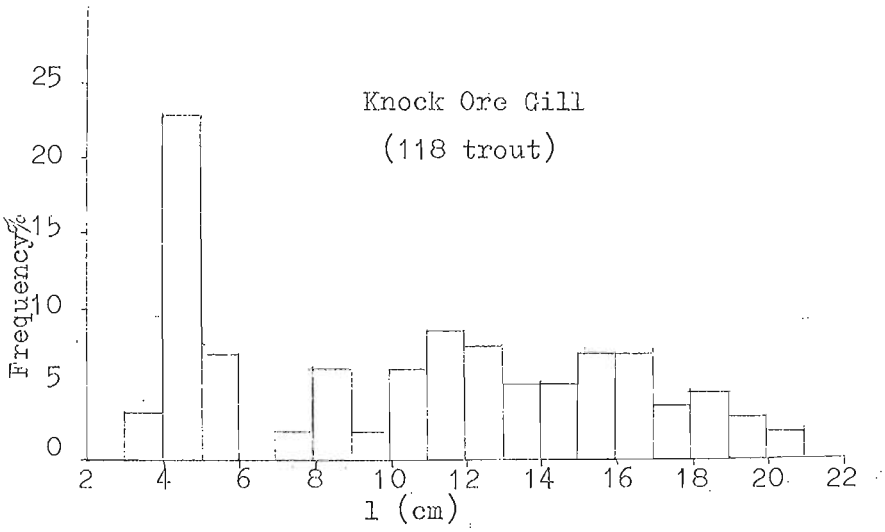
(i) Changes in population density, age composition and length = weight relationship at intervals through a season.

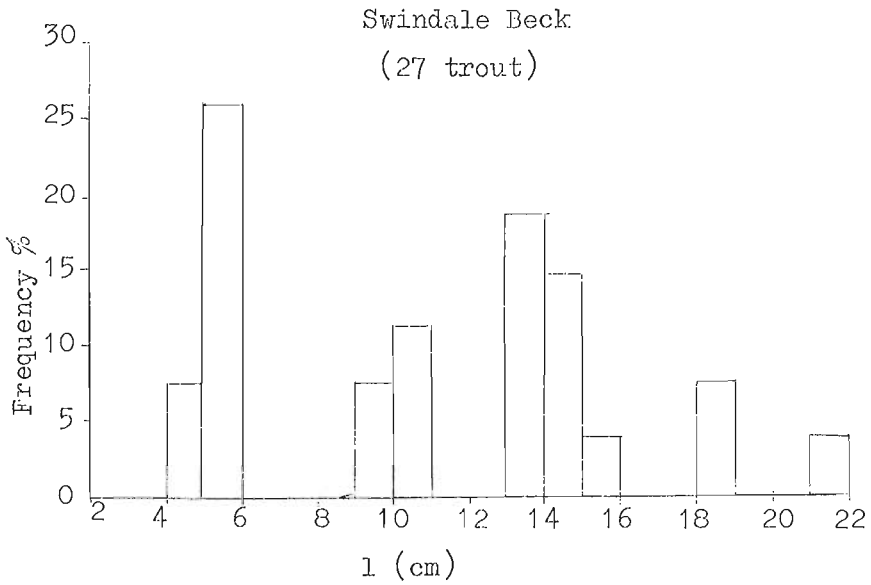
(ii) An examination of the length : weight relationship at a single time of year, for comparison with data from Trout Beck.

(iii) An examination of the relationships between fish length (or age) and sexual maturity and between fish length (or age) and fecundity.

Item (i) would require a fairly large-scale research commitment and is not feasible under present conditions. Items (ii) and (iii) would be of great value for comparison with comparable data from Trout Beck and also in making approximate estimates of trout production in Knock Ore Gill

Figure 1 Length-frequency distributions of trout in Knock Ore Gill and Swindale Beck





and possibly Swindale Beck. The essential requirement is a collection of about 50 trout of age I and over, killed for detailed examination shortly before spawning commences. Our ability to collect these fish may be limited by commitments at Cow Green during the crucial period of time. However, subject to Nature Conservancy Council approval, every effort will be made to achieve this goal.

Discussion

Detailed discussion of the results will be more appropriate when the scales have been read and a more detailed analysis of the data has been made. It will then be possible to make a useful comparison between the fish populations of Trout Beck (Crisp et. al., in preparation) and Knock Ore Gill and Swindale Beck.

Meantime, it should be noted that the population densities and biomass recorded in Knock Ore Gill and Swindale Becks (0.146 to 1.017 fish/m^2 and 2.6 to 25.1 g/m^2) are appreciably greater than corresponding values for the Trout Beck system (0.04 to 0.25 fish/m^2 and 1.4 to 6.2 g/m^2).

Acknowledgements

The author is grateful to the Nature Conservancy and the Cumbrian River Authority for permission to conduct the survey, Mr. M. Rawes for advice and help, and Mr. P. Cubby who played a major part in the field survey (a far from easy task in the type of terrain encountered!)

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Staff List

Officer-in-Charge	M. Rawes
Scientific Staff	R. Williams
	R.B. Marsh
	Miss L.M. Teasdale
Warden	J.P. Houlton
Estate Worker	P.J. Holms
Housekeeper	Mrs G.G. Dunn (April - October)
Part-time Warden	J. Rose (December - March)
Honorary Wardens	B.J. McArthur
	J. Hollington
	O.W. Harrison
F.B.A. Staff	Dr. D.T. Crisp
	Dr. P. Armitage
	P. Cubby

Meteorological Summary for Moor House 1972 (Met. Office Station No. 7188)
c. 558 m O.D. (Main 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 maximum temperature °C	1.7	1.6	4.9	7.2	9.7	10.7	15.2	14.1	11.1	9.9	4.2	4.6	7.9
Mean minimum temperature °C	-1.9	-1.9	-0.7	0.4	2.8	4.0	5.7	6.6	3.3	2.7	-0.6	-1.0	1.6
½ (max. + min.) temperature °C	-0.1	-0.1	2.1	3.8	6.3	7.3	10.5	10.3	7.2	6.3	1.8	1.8	4.8
Highest maximum temperature °C	7.3	4.7	14.0	10.6	13.7	14.6	23.9	17.5	18.9	16.8	11.7	9.6	23.9
Lowest minimum temperature °C	-18.5	-16.0	-4.3	-5.0	-3.8	0.3	-0.7	1.4	-2.1	-3.6	-10.7	-8.0	-18.5
Lowest maximum temperature °C	-5.4	-1.7	-0.5	4.1	6.5	7.0	10.0	10.3	7.1	3.9	-1.9	0.0	-5.4
Highest minimum temperature °C	2.9	0.9	3.5	5.0	6.8	9.0	10.6	10.5	8.4	10.5	8.0	3.6	10.6
Lowest grass min. temp. °C	-9.5	-17.0	-7.5	-10.5	-8.8	-5.2	-4.5	-2.9	-7.4	-9.1	-15.8	-11.2	-17.0
Average earth temperature at 30 cm - 0900 GMT - °C	2.5	1.5	2.7	4.7	6.4	8.3	11.2	11.7	9.7	7.6	4.8	2.9	6.2
Rainfall (mm)	198.6	91.8	150.3	157.9	222.9	159.0	103.6	97.3	30.4	41.8	328.2	206.3	1788.1
Greatest daily rainfall(mm)	21.2	17.4	31.0	28.7	34.6	32.9	34.7	22.3	9.6	12.2	53.4	44.7	53.4
No of rain days	28	22	18	22	23	27	12	11	9	13	25	20	230
No of wet days	26	17	15	17	21	21	10	9	6	8	22	14	186
Days with snow or sleet falling	17	11	7	6	1	0	0	0	2	0	10	9	63
Days with snow lying 0900 GMT	17	23	8	2	0	0	0	0	0	0	14	7	71
Days with hail	1	0	2	5	4	0	0	0	0	0	3	1	16
Days with snow or ice pellets	4	4	6	0	0	0	0	0	1	0	1	0	16
Days when thunder heard	0	0	2	0	0	2	2	1	0	0	0	0	7
Days with fog at 0900 GMT	12	8	6	2	3	2	1	1	0	6	7	5	53
Days with air frost	21	24	18	11	2	0	1	0	6	7	17	17	124
Days with ground frost	27	27	27	18	9	11	9	8	12	15	23	29	215
Total sunshine hours	15.3	31.4	99.7	92.4	104.9	142.6	163.9	161.7	116.1	96.0	28.1	36.0	1088.1
Av. daily bright sunshine hours	0.49	1.08	3.22	3.08	3.38	4.75	5.29	5.22	3.87	3.10	0.94	1.16	2.97
Total snow fallen, cm	85	62	50	5	0	0	0	0	0	0	147	20	369
Greatest depth snow lying, cm	22	18	20	2	0	0	0	0	0	0	46	11	46
Days with gale (anemograph record)	10	0	2	2	1	1	0	1	0	3	4	9	33
Potential evaporation mm	-	-	(20)	41	51	66	67	60	31	21	(11)	(11)	316(Apr -Sep)
Potential water deficit mm	-	-	3	10	0	0	28	31	20	11	0	2	89 "
Potential water surplus mm	-	-	133	127	172	93	65	68	19	32	317	197	544 "

Meteorological Summary for Great Dun Fell 1972
c. 655 m O.D. Lat 54° 35' N. Long 02° 28' W. National Grid Ref: No. NY/710322

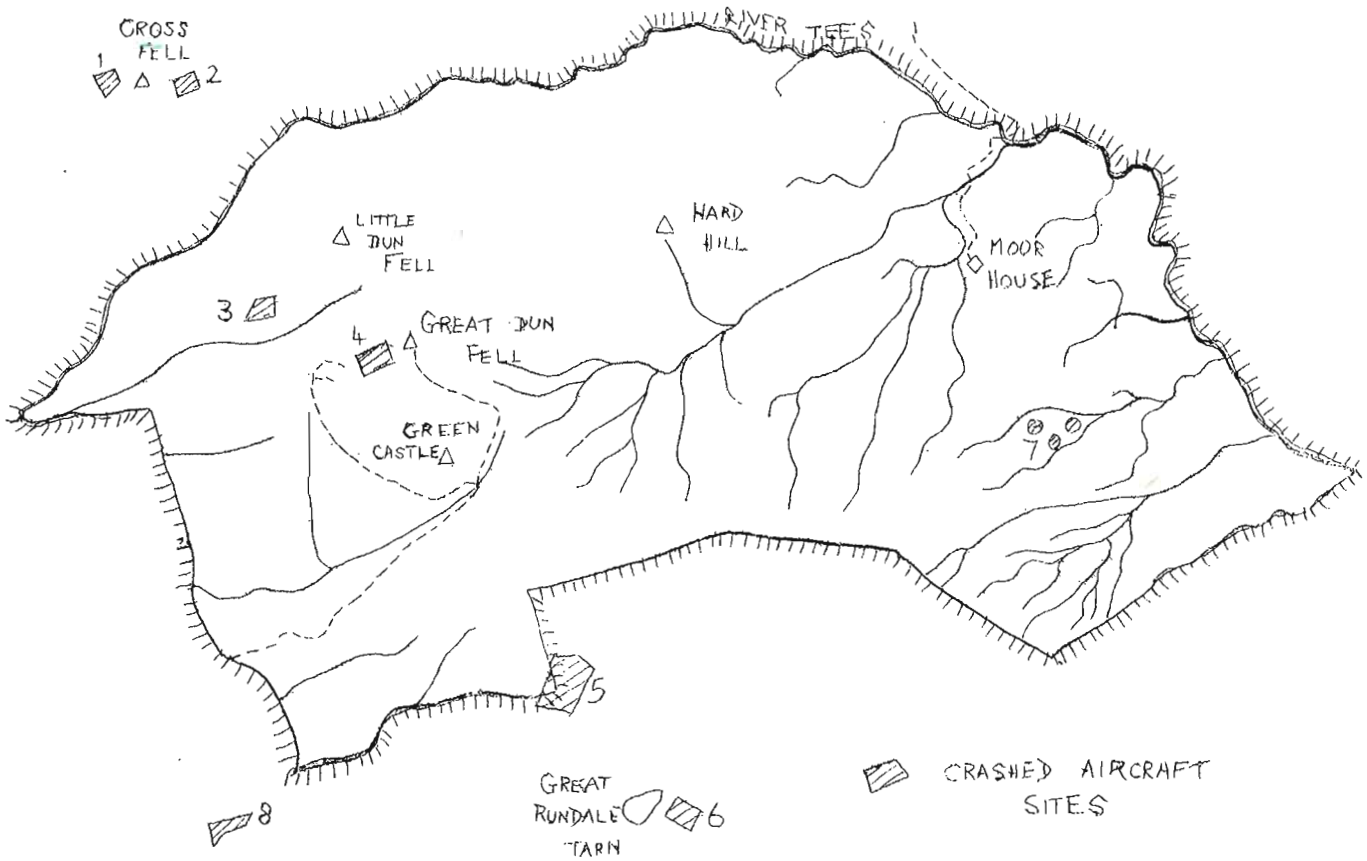
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Mean maximum temperature °C	-0.5	(-0.5)	-	4.3	6.8	8.1	12.8	-	-	-	-	-	-
Mean minimum temperature °C	-2.5	(-2.4)	-1.4	-0.8	1.5	3.0	6.8	-	-	-	-	-	-
½(max + min) temperature °C	-1.5	(-1.5)	-	1.7	4.1	5.5	9.8	-	-	-	-	-	-
Highest maximum temperature °C	5.2	1.7	-	8.7	11.9	12.4	22.4	-	-	-	-	-	-
Lowest minimum temperature °C	-11.7	-11.6	-5.3	-4.1	-1.7	-0.4	2.5	-	-	-	-	-	-
Days with snow lying	23	29	19	5	1	0	0	-	-	-	18	7	102
Fog at 0900 GMT	27	27	25	21	17	19	14	-	-	-	21	19	-
Days with air frost	28	29	23	24	8	1	0	-	-	-	-	-	-
Wind speed, knots	23.7	21.1	21.2	22.7	22.9	21.1	13.8	17.3	15.7	22.2	26.3	24.8	21.1
Sunshine hours (daily mean)	0.29	0.19	2.02	2.09	2.51	2.48	4.43	3.54	3.23	2.98	0.39	1.16	2.11

- No records available (Monthly Weather Report)

Solar radiation measurements from Moor House Meteorological Station

gm cals/cm^2/month	1117	2503	6685	8269	9676	11762	12718	11136	7445	4457	1849	1194

Sites of Aircraft crashed on and close to the Moor House Reserve



The following is a list of sites located by the No. 1264 (Windermere) Squadron A.T.C., who in the past few years have been searching the Lake District and north Pennines.

1.	D.H. Moth	Crashed 24.4.36	Few remains and engine
2.	A. Anson	Crashed 18.2.43	No remains
3.	H.P. Halifax	Crashed 12.4.44	Many small remains and ammunition
4.	D.H. Spitfire	Crashed 19.7.39	Few fragments
5.	D.H. Meteor	Crashed 24.3.54	Large remains
6.	H. Hurricane	Crashed 18.7.41	Very few fragments
7.	V. Wellington	Crashed 20.8.42	Few remains found to date
8.	H. Hurricane	Landed 9.1.42	No remains