THE NATURE CONSERVANCY COUNCIL

MOOR HOUSE

1984

25th ANNUAL PROGRESS REPORT

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CONTENTS

I. GENERAL

a) Introduction
(I R Bonner)

This 25th Report covers the period from 1 October 1983 to 30 September 1984.

The User Group met for the second time in March at Blackwell, in June we were pleased to congratulate Judith on her marriage to Geoffrey Robinson and in October we bade farewell to Norman English retiring after 20 years as Chief Warden, welcoming in his stead Robbie Bridson who joined us from Argyllshire where he was Warden of the group of NCC reserves centred on Taynish. The pattern of work and other arrangements were much as in the previous year, hopefully setting a pattern of some stability for the future.

However it is highly likely that there will be further changes early in 1985 and the latest situation will be described in my covering letter to User Group Members.

b) Warden's Report, 1984
(P Burnham)

As this will be the last annual report I will write as warden of Moor House I would like to reflect on the changes to the warden's post and duties which have occurred over the past few years.

When I took up the post in 1977 I was based and lived at Moor House. Most of my duties were confined to the eastern side of the Reserve and a full-time estate worker was also employed to help. The Field Station was in use daily by NCC staff and the laboratory was regularly used by students during the summer.

I knew I would be cut off by snow drifts most winters but in 1979 during the bad winter, my wife and I were cut off for 4 months and when the last drift was dug out in April it was still over 7 feet deep on the track.

My transfer to the west side of the Reserve in 1980 therefore, was greeted mostly with relief but also with thoughts that perhaps we would be the last people to live at Moor House. Having the opportunity to live in such an isolated position in this crowded country was an experience we both appreciated and will never forget.

The warden's role during the past 4 years has been completely changed. With added commitments to other reserves, inevitably less time has been spent on Moor House. However, with the closure of the Field Station and the less intensive use of the area by researchers and the recent replacement of enclosure fencelines, a warden's commitment to the Reserve has been much reduced.

I have lived on both sides of the Reserve and I think it important to record the need for a man on the ground with whom the local community can relate. Relationships within the farming community, in particular with the Commoners whose sheep graze the area, also other users of the Reserve, is good. I think this will only be maintained by a local contact who can be aware of what is happening locally and generally in the northern Pennine area.

Access to the Reserve

Public pressure does not seem to have increased over the Reserve despite the superb summer weather experienced, with the high fells free from cloud and sunny and warm for long periods. Numbers supplied by Dufton Youth Hostel of Pennine Way walkers indicate a slight increase with people able to complete longer sections due to the dry conditions underfoot. Approximately 1,000-1,300 crossed the summit of the Reserve this year.

Skiing started in January when strong winds and heavy snow falls produced good areas for skiing but the fell road was blocked by drifts up to 3.7 m (12 ft) deep in places until 4 February and skiers used the lower slopes on private ground. The out-door activity and educational centres regularly used the Reserve when the road was open again, until the Easter weekend when skiing was ended for the season. Few individual down-hill skiers use the Reserve now but there has been an increase in the number of cross-country skiers who generally follow the public footpaths. No problems from skiers were experienced, the majority being well-behaved. The track from Garrigill to Moor House was also blocked on 24 January and remained so until well into April.

During the summer an orienteering event was held at Dufton by the Pendle Forest Orienteers and part of the Reserve was included in the course. I liaised closely with the organisers, planning the route to avoid sensitive areas, and re-routing the main course in places to avoid disturbance to birds etc. I think it is worth recording that the organisers were considerate and conscientious and by allowing restricted access to the Reserve, I was able to influence the entire route in the Appleby Fells area.

Research workers continued to use the Reserve, albeit in reduced numbers and a summary of their activities occurs within this Report.

Geologists continue to visit the Reserve, the majority working on the exposures in Swindale Beck and Knock Ore Gill, thereby concentrating pressure on these 2 sites. Five colleges and universities brought students to the Reserve under permit but parties and individuals are still visiting without permission. Some permit holders are known to ignore the 'no hammers' rule as the evidence left behind shows, but due to time available and the remoteness of the sites it is almost impossible to catch offenders.

Silverband Mine has been sold and is now owned by 2 local men. Regular checks were made on the workings and during the heavy rain of October and November a number of overflow incidents occurred and working operations were voluntarily suspended. A number of improvements have since been carried out to the lagoons and dams and there is a genuine attempt to clean up the area. They do intend, however, to pursue the barytes vein higher up the fell in future.

Permission has been granted to CAA to build a radar dome on Great Dun Fell after a public enquiry was held. The existing aerials will be taken down and housed within the radar dome, which is to be built on the same site. We are liaising closely with CAA over the planned work of construction to minimise the disturbance and effect on the Reserve.

Field Station and Buildings

Sadly, the interior of the Field Station continues to deteriorate. Work has been completed on the Moor House Annex as a shelter base for research workers and a former kennel has now been converted to house toilet facilities. The workshops and stores were broken into a number of times and some small tools stolen. The cost of repairs after the break-in far exceeded the cost of the replacement of tools stolen. An emergency telephone was installed in the house yard for the use of the general public and research workers.

Management and Estate Work

A part-time estate worker was employed for 6 weeks to assist in the general estate duties during the summer months. This allowed many tasks to be carried out that would otherwise have been impossible or too time consuming for one person.

General maintenance was carried out on enclosure fencelines before the return of the sheep in spring. Due to the heavy snow falls during the winter, repairs were needed to most of the enclosures. Over 1.8 m (6 ft) of snow was removed from the Rough Syke fenceline in late April and part of the fence, crushed by the weight of snow, had to be replaced. It was also necessary to dig snow from the Green Hole fenceline to prevent sheep gaining access by walking over the top. A new fenceline was erected around the house complex and the wall around the meadow and tree nursery was repaired to prevent sheep access. A number of enclosures no longer in use with poor fencelines were dismantled and removed. The old hut on the east side of Great Dun Fell had become an eyesore in recent years and this too was removed.

A survey was carried out to locate dangerous mine shafts and work started on covering over the most dangerous, ie closest to public footpaths. This work is to continue in 1985. Materials were transported to the shafts using an Argocat, which proved an extremely efficient vehicle over the terrain on the Reserve. Looking back, one can only wonder at the time and effort that could have been saved with the use of such a vehicle in erecting and maintaining the enclosures.

Cattle again grazed the meadow, with 6 cows being turned in on 1 August until 4 September. It was not necessary to strip graze the area this summer as a sweeter sward had been left after last year's intensive grazing. The adjoining pasture area was grazed as an experiment to remove rank grass which has accumulated over the past few years.

Survey

I continued with an Upland Bird Survey started in 1983, to compare the east side with the western escarpment's species and habitat. Mapping and monitoring of rare plant species was also continued.

Natural History

As previously mentioned, my presence on the Reserve was less than in previous years and therefore these notes are far from complete and only give a rough sketchline of events through the year.

January to March was a fairly harsh quarter with frequent snow falls and complete snow cover occurring on the tops and down to approximately 457 m (1500 ft) on the east fellside, after blizzards on 24 January. During this period the grouse were absent from the Reserve and large flocks (400+) were reported from lower altitudes in Teesdale. Large areas of the eastern fellside remained covered during the last days of the quarter as fresh falls occurred and grouse numbers observed at this time were low. Of note during this time was a flock of up to 45 snow buntings regularly seen on the tops in February, but numbers dwindled to 3 on 19 March. A dipper was seen feeding in Knock Ore Gill during blizzard conditions in the narrow channel of the stream left unfrozen (9 January). Three grey partridges feeding near the fell gate, also on 9 January, were a new species for the Reserve. Peregrines were recorded hunting over the Reserve on 3 occasions and the first signs of breeding birds attempting to return to these high tops, were observed when 4 golden plover were flushed from the western escarpment on 19 March and 2 lapwings were displaying near the fell gate on 28 March.

One of the best spring periods followed when the cold, frosty, sunny days of early April suddenly turned hot and sunny and continued so throughout most of the summer. Golden plover were establishing their breeding territories in early April and 2 pairs were recorded on Hard Hill on 3 April, whilst other breeding birds including redshank, snipe, teal, mallard and common sandpiper, had also returned to the Tees river valley. Some migrants, however, were late arriving when compared with previous years; the first ring ouzels seen on 22 April (recorded 1 April 1982) and several wheatears (usually seen the last week of March). A trip of 5 dotterel passed over the Reserve on 26 April and a new bird for the Reserve, a male black redstart, was seen feeding on the block scree on Little Dun Fell on the same date. A golden plover nest with a complete clutch was found towards the end of April and another, containing 2 eggs, on 1 May. The fine, warm, sunny days encouraged buzzards to soar regularly over the western escarpment, but none bred on the Reserve. Good numbers of butterflies, in particular green-veined whites and small tortoiseshells, were seen and several common lizards were recorded during the last days of April. A pair of grey wagtails, a rare species on the Reserve, were recorded in Crowdundale Beck and a pair of short-eared owls were seen displaying near Force Burn in May. The 2 main badger setts were in use throughout the spring and early summer period and a third outlying sett was found at the foot of Crumpley Hill.

Grouse were much in evidence in the spring with the males displaying during the good weather. A good breeding season followed on the Reserve and from reports locally, on most adjoining moors too. Numbers must now be approaching their peak again after the 1979 crash.

Of note bird-wise in the late summer time were the large flocks of mainly juvenile starlings feeding on the high fells, with flocks of 1000+ birds in the area of Moor House and Tees Head in July.

Peregrines were again seen hunting the Reserve on 3 occasions, with 2 birds hunting together on 8 August and 1 September. Two attempts to kill pigeons were seen, but both eluded capture, one by taking refuge in the Moor House trees, the other by crashing into tall heather and hiding. Other raptors seen were 2 juvenile merlin, buzzard and several kestrels. A single whimbrel, a rare autumn migrant, was recorded over the reserve on 21 August. The first signs of the main migration occurred on 26 September when wheatears and meadow pipits were seen along the track and ring ouzel, chaffinches and 8 redwings were recorded feeding in the pasture trees.

Large numbers of small tortoiseshells were seen throughout the summer, in particular in July, when they were commonly found around the many small limestone outcrops on the east side of the Reserve. Several peacocks, and a single red admiral, were seen at Moor House, and what was thought to be a green fritillary in the Moor House meadow on 21 August but not confirmed.

Two large red damsel flies, Pyrrhusona nymphala, were recorded over a peaty pool on Hard Hill on 3 July and 2 common Aeshnas, Aeshna juncea, were seen near Moor House.

October to December was a quiet period for wildlife on the high fells, with parties of mixed thrushes moving over the Reserve on migration. A few meadow pipits were seen on the tops on 4 October and a flock of 30+ fieldfares, with a few redwings, were seen passing over. Fieldfares and redwings continued to pass over during November with occasional parties of blackbirds mixed in with them. Of note was a late record for the Reserve of a ring ouzel in Crowdundale Beck on 13 November. Two buzzards were also seen on 13 November circling near Middle Tongue Beck. A few snow buntings were heard calling in the mist above Silverband Mine on 20 November and single woodcock and snipe were recorded along Troutbeck on 30 November.

The badger setts above Crowdundale Beck and Knock Ore Gill were found to still be in use during November.

II. SCIENTIFIC

a) Tree Survey, 1984
(M Rawes)

The main purpose of the original tree plantings at Moor House was largely exploratory; to test a few species, mainly native, under a limited range of conditions and managements. Unfortunately, apart from a nutritional trial with lodgepole pine on peat, little work followed the initial planting in the 1950s and early 1960s. It is these trees that have been surveyed this year.

In 1974 measurements were taken of a sample batch of 50 Scots pines in Green Hole, Force Burn and Pasture enclosures and of 50 lodgepole pines in Force Burn, Nether Hearth and Pasture. These measurements of top height, girth at 135 cm above ground level and annual shoot increment were retaken in 1979 and again in 1984. However, in 1984 all remaining Scots pine in Green Hole were measured. In the other enclosures mountain pine had been planted, and survives well, but because of the numerous stems it produces from the base and the closeness of planting, it is now impossible to distinguish individuals. Other species were counted and measured where possible. The survey was confined almost entirely to these early plantings. Notes were made of storm, pest and other damage.

Green Hole is the earliest of the enclosures and here planting was confined to native species apart from 3 lodgepoles which were planted in error. It was soon clear after heavy losses in the first few years that success was likely to be small, and this has been borne out in the surveys of 1979 and this year. Scots pines have deteriorated to such an extent that only 3.5% of those planted (2444) remain alive, and only 3 of the 50 sample trees. However, there have been few, if any, losses of birch, bird cherry, ash and willow over the past 5 years. Mortality in these species was very high before then (see 20th Annual Report). But since 1979, 43 rowans have been lost, mainly destroyed by herbivores. Yet rowan is one of the more promising species and when protected from grazing (61 out of 141 have been so severely grazed they were less than 50 cm high) can form reasonable trees. The mean height of 80 rowans, which were above 50 cm, was 3.4 m and of these 20 were over 4.0 m and 4 more than 7.0 m high. Of the larger trees 20 recorded girths more than 30 cm, the largest being 52 cm. Thirty-three rowans bore fruit, but only 5 seedlings (22 in 1979) were found. Of the Scots pines, 53 of the 85 found alive were measured, but their average height was only 1.9 m and girth 16 cm. The marked sample trees recorded no increase in height but slightly larger girths. Only 10 of the 31 surviving birches were big enough to measure and they were, with few exceptions, grazed and growing close to the ground in a multi-stem form. Their average height was 1.5 m. Once established bird cherry and willow have been equally successful and clumps of them cover the ground by 4 to 18 m^2. In both cases they have grown to 4.0 m high and appear to withstand a considerable amount of grazing. If grazing continues at anything approaching the present level I would expect the remaining Scots pine and most of the smaller hardwoods to die within the next 5 years. Barking of rowan and birch has been excessive in the past year, especially with sheep wintering in the enclosure, and, there now being for the first time a resident rabbit population. Heavy grazing of the ground flora has arrested and destroyed the development of vegetational patterns described in Rawes (J Ecol 69) and the future of the enclosure is precarious.

In Force Burn planting was almost entirely confined to Scots, lodgepole and mountain pines. Examination of the 50 sample trees showed that half the Scots and 6 of the lodgepole were dead by 1984, but 8 of the latter were also untraced, their number tags having either been lost or buried beneath fallen trees. Whereas most of the mortality in Scots occurred in the upright trees, in the lodgepole it was those that had been prostrated by storm, either from heavy snow fall, ice burden or wind, or a combination of factors. In 1984 only a few Scots looked sufficiently healthy to survive another 5 years. A count of all the trees in the enclosures showed that death was increasing with age, the more so with Scots. Thus 67% of the Scots and 34% of the lodgepole alive in 1979 had died by 1984.

Nether Hearth, like Force Burn, has mainly pines, and losses have been heavy. Only 7 of the original Scots pine remained alive in 1984, but many had been planted on unvegetated mine waste, a physically and nutritionally difficult medium on which to grow trees. Lodgepole has suffered storm damage in the past 5 years and there have been more losses in this period than in the previous 20 years. Whilst there are some sizeable trees - 10 have girths greater than 50 cm and others are over 9.0 m high - 30% are small or storm damaged to such an extent as to certainly die within the next 5 years. Thirty-seven of the sample trees remained alive. Their average height had increased by nearly 1.0 m since 1979 and girth by 5 cm. Sitka spruce and larch have generally grown well, but Swedish whitebeam has lost half its number mainly due to rabbit and sheep grazing.

The Pasture tree enclosure is one of many disasters. Tree counts have been made on 7 occasions since planting in 1961. Although 13 species were used only 6 have survived, and they with varying success. Snow damage is most severe in this enclosure and when combined with year-round grazing the hardwoods have little chance. Swedish whitebeam and rowan, both of which can to a marked degree compete with the soil and weather conditions, have been coppiced continuously by herbivores; even so nearly half the whitebeam and 30% of the rowan were alive. But since 1979 the remaining 42 Scots pine have died and there has been an increase in the rate of mortality among lodgepole, which were reduced by 50%. After heavy losses in the early years, larch and Sitka spruce were maintaining their numbers in 1984 and have generally grown well. The larches averaged 3.6 m in height and 23 cm in girth, while Sitka were 2.4 m high. Thirty-seven of the 50 sample lodgepoles were found alive, but they were mainly small and almost all were storm damaged. The sample average height of 2.3 m showed an increase of only 50 cm in the 5 years. This average arose from there being some sample trees that actually measured less due to main stem breakage. Girth increment, however, at 15 cm was 40% better than in 1979.

In conclusion, despite some disastrous results, the trials, which were very limited in their choice of species, provenances and especially management (or lack of it), have shown that some species can grow at Moor House.

Acknowledgement

I thank NCC (NW Region) for financial support to undertake this survey.

Reference

Rawes M 1981. Further results of excluding sheep from high-level grasslands in the north Pennines. Journal of Ecology, 69, 651669.

Note

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b) Moorland Management - Bog recovery after heavy sheep grazing (House Hill heavily grazed plot).
(M Rawes and Judith Robinson)

Since this trial started in 1968 the botany of the plot has been recorded by point quadrat on 11 yearly occasions. The frequency of recording was annual at the start when sheep were introduced, reduced after 6 years of this heavy grazing regime, and increased again as the rate of recovery improved when grazing ceased in 1975.

Cover of Calluna, which had been entirely eliminated, has doubled in the past 4 years, but it is still low and in 1984 was, despite being present in 80% of 30 1 m^2 quadrats, only 15% of that in the Control plot. Calluna has regenerated from seed only. Eriophorum vaginatum, the Assocations's co-dominant species (with Calluna), still retained a greater cover value than the Control, but despite fluctuations in recent years, there are indications of it stabilising to the more usual 60-70% cover. Eriophorum angustifolium, like Empetrum nigrum and Rubus chamaemorus, is a constant species of the Association; it increased dramatically in 1983, but not this year, when cover actually dropped to 1982 levels. Thus the need for continuity in recording over a long period of time so that seasonal differences, which are usually attributable to climate, can be ironed out. Rubus is even more sensitive to recording difficulties as its relatively large deciduous leaves have high cover value. Nevertheless records of presence, rather than cover, of live buds and leaves in 30 1 m^2 quadrats remain consistently high throughout 16 years. The recovery of Empetrum, which was almost entirely erased from the plot, is very slow, and the first "hit" since 1974 was recorded this year.

According to Eddy, Welch and Rawes (1969) the most important bryophytes in the Association are Sphagnum rubellum, Hypnum cupressiforme, Pleurozium schreberi, Calypogeia trichomanes, Lepidozia setacea and Mylia taylori. Probably of greatest significance in accessing bog recovery is the status of Sphagnum, and point quadrat records show that its cover has been least (1%) in 1974, since when it has only increased threefold. Sphagnum cover in the Control was 15%. Pleurozium is scarce on the House Hill site and has not been recorded in the plot since 1970. The cover of Calypogeia has decreased (halved) since the peak in 1980, but is now similar to the Control. The scatter of recordings for both Lepidozia and Mylia remained predictably inconsistent, but like most small leafy liverworts the trend is for a return from the high cover values in the 1970s to those at the start of the trial. The extent of bare peat and its algal colonisation has responded likewise. In 1968 bare ground cover was < 1% of the plot, in 1975 it was 23% and in 1984 it had fallen to 4%; over the same period the algae cover was < 1%, 28% and 2% respectively. However, one group of plants, the lichens, is, without exception, being very slow to recolonise. Cladonia impexa - the most common lichen of the Association - was for example, only recorded once in 1984 (nil in 1980) compared with on 78 occasions in 1968.

Thus the complete recovery of the bog to a pre-1968 state is slower than often stated. For instance Eddy, Welch and Rawes (1969) state that "complete recovery (after burning) takes about 20 years when regeneration of Calluna is good". It would seem that in this trial Calluna may recover in a further 10 years, but Empetrum will take longer, whilst the progress of Sphagnum is uncertain and it could be another 50 years before the lichen flora is re-established. This emphasises how drastic intensive sheep grazing can be, especially as this plot is surrounded by vegetation that is little grazed and thus there is a readily available seed and spore source close by.

Acknowledgements

Mr Rawes thanks NCC (NW Region) for supporting this work with funds and making Judith Robinson available for field assistance.

Reference

Eddy A, Welch D & Rawes M. 1969. The vegetation of the Moor House National Nature Reserve in the northern Pennines, England. Vegetatio 16, 239-284.

Note

Please do not use the data contained in this report without written permission from NCC.

c) Monitoring Vegetation Change at Moor House NNR

(*R H Marrs and +Judith S Robinson)

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\+ Nature Conservancy Council, Blackwell, Cumbria.

During 1984, 2 studies were done in the field.

1. Monitoring vegetation change in J1.

The vegetation both inside and outside the J1 exclosure was monitored using the stratified point quadrat system developed by M Rawes. In addition 10 sub-quadrats (30 x 30 cm) were positioned at random in each area. The vegetation was clipped, and a soil sample was taken. Nutrient analysis of both plants and soils will be done in 1985.

2. Studies on the Hard Hill burning experiment (D35-38).

Unfortunately it was not possible to burn the short rotation plots in 1984 due to inclement weather. It is hoped to burn these plots in 1985. During 1984 vegetation and soil samples were taken for nutrient analysis in each of the 28 treatments.

In addition to this field programme all of the accumulated data for 10 of the long term experiments has now been transferred to the computer at Monks Wood. It is hoped during the next year to document each experiment and start numerical analysis and modelling.

Acknowledgement

NCC kindly provided funds to help with the transfer of data to the computer.

d) Report on the weather, October 1983 - September 1984
(Judith S Robinson)

Heavy snow falls and drifting during January and to a lesser extent during February and March, meant that snow lay around on the fell tops for much of the winter, some deep snow in gullies and hollows staying well into spring. The coldest air minimum temperature recorded over the winter months at Moor House was -17.9°C and days of snow-lie (when the ground was completely or more than half covered) amounted to 79 days (31 year average - 68 days).

A warm, dry spring followed with a total rainfall of 85.6 mm over the months of April and May, compared with the average for the 2 months of 236 mm. The highest maximum temperature recorded during April was 18.9°C, this was also the highest maximum ever recorded for that month at Moor House. Summer too was warm and exceedingly dry over much of the country, the highest maximum temperature at Moor House reaching 23.5°C, although this was lower than the highest maximum recorded for the summer months of 1983 (26.7°C). Rainfall for the months of June, July and August totalled 250.5 mm, being well below the average for the 3 months of 389 mm.

III. RESEARCH BY THE INSTITUTE OF TERRESTRIAL ECOLOGY

a) Studies on methods of measuring available nitrogen in soils
(Dr A Harrison, Merlewood Research Station).

Humified peat from Moor House, is one of a number of soils which are being used to develop methods of measuring available nitrogen in soils. It is hoped to provide more details of the work in next year's annual report.

IV. RESEARCH BY THE FRESHWATER BIOLOGICAL ASSOCIATION

a) Fish populations
(D T Crisp).

Examination and tagging of brown trout from Cow Green reservoir, whilst spawning in streams within the Moor House National Nature Reserve, was continued during the autumn of 1984.

Studies on fish populations in streams afferent to Cow Green reservoir have now been published. The data on fish in the reservoir is being processed.

V. RESEARCH BY UNIVERSITIES

a) The use of climatic records in an analysis of the altitudinal range of selected components of the vegetation in the northern Pennines
(J D Graves and K Taylor, Department of Botany and Microbiology, University College London).

Climatic data

Epsylon automatic weather stations were installed in Helbeck Wood, Brough, Cumbria, at 275 m (900 ft), in April 1974 and adjacent to Moor House, Cumbria at 549 m (1800 ft) in June 1974, on loan from the Natural Environment Research Council and maintained by the Institute of Hydrology, Wallingford. At each station 6 measurements were recorded on magnetic tape at 5 minute intervals; namely solar radiation, ambient air temperature, temperature depression, wind speed, wind direction and rainfall. Approximately every 6 weeks, the tapes were changed and processed. The initial processing was completed by the Institute of Hydrology at Wallingford where the data was translated into hourly and daily means and made available as printed paper output. This data for the period 1974 - 1979 was also made available on magnetic tape which could be loaded onto the UCL computing system. A computer program was written to permit a more detailed analysis of the data to be made.

Additional climatic records were obtained from Great Dun Fell radio station, Cumbria, at 847 m (2800 ft). Integrated hourly readings of solar radiation were recorded using a Kipp-Zonen solarimeter and a Lintronic Agromet data acquisition system from 1977 to 1983. Details of air temperatures were also available from the station records in the form of instantaneous temperature recorded daily every 3 hours between 09.00 and 15.00 hours on each working day. To build up a more detailed picture of the temperature environment at this site a linear regression was calculated between a large sample of the 3 hourly temperature data and corresponding hourly mean temperatures recorded at Moor House automatic weather staion. An excellent straight line relationship was found between temperatures at the two sites (Fig. 1).

The data accumulated at these sites provides a detailed, valuable, continuous record of climatic conditions in the northern Pennines for a 10-year period, which can be compared with the records for 1953-1982 available for the Moor House standard climatological station. Similar observations were made at Great Dun Fell between 1963 and 1972 and since then only on each working day.

The first temperature recordings made at Moor House and Great Dun Fell were by Manley between 1933 and 1946. These results and the standard climatological records for Moor House up to 1972 have been incorporated into an analysis of the Moor House environment for the IBP tundra biome project by Rosalind Smith (Moor House Occasional Papers No. 4, 1972). She observed that the climate can generally be regarded as severe and sub-arctic in affinity at the altitude of Moor House, being characterised by cool wet and windy conditions with a short growing season (mean monthly temperatures > 5.6°C) of about 6 months from May to October. However, winter temperatures were significantly higher than those found at the other sites in the IBP tundra biome.

The climatic data for the period 1974-83 has been analysed in order to investigate the changes which occur with altitude and to determine how these changes are related to cyclic variations in the environment. Emphasis was placed on changes that might be of importance in plant growth and development. Cyclic climatic changes were identified as occurring over 3 time scales: annual, cyclonic and daily. The nature of the annual and daily cycles show a rigid periodicity related to the earth's movement relative to the sun. Cyclonic patterns, however, are caused by the passage of successive weather systems across the country and so have no fixed periodicity.

The annual cycle of monthly mean temperature over a period of 8 years is shown in Fig. 2. The amplitude of the annual temperature cycle remains the same as altitude increases, an average of 13.2 for Moor House and 12.8 for Helbeck Wood, but the curves are displaced towards lower temperatures. A tundra climate has traditionally been considered to be one where the warmest month averages less than 10°C. On this basis only the Dun Fell site may be considered to have a tundra climate. At Helbeck Wood and Moor House the level of solar radiation is similar (Fig. 3), however, in 3 particular years the level at Moor House during the summer was considerably higher. At Dun Fell the level of solar radiation is consistently lower than at the other 2 sites. Wind speed shows a much more erratic distribution through the year (Fig. 4). There is a winter maximum in most years, which is especially noticeable at the Moor House station. Wind speeds are consistently higher at Moor house. Rainfall shows no discernable annual pattern. What is clearly noticeable however is the considerably higher rainfall at Moor House (Fig. 5).

An example of the variation in temperature found within a year is shown in Fig. 6. Clearly there is considerable variation in temperature from day to day. The daily fluctuations in temperature may be smoothed out by calculating a 6 day moving average, the results of which are shown in Fig. 7. Examination of these figures reveals a cyclic change in temperature over a time scale that varies between approximately one and 3 weeks. Variations in temperature on these time scales may be termed cyclonic since they are related to the movement of weather systems across the British Isles.

These variations undoubtedly have a considerable effect on plant function. Environmental instability may directly inhibit physiological processes. Temperature variations over this sort of time scale are of particular importance at the beginning and end of the season. In very cool climates they may be of importance throughout the year; when the average temperature is close to that required to inhibit some plant process, cyclonic variations will constantly move the temperature above and below this critical level. Consequently plants able to exploit short periods of favourable temperatures will be at an advantage during these periods of the year.

To provide an average expression of this cyclonic variation, the 5 differences in temperature between a day and the period of days from 5 to 10 days in the future were found and the mean of these calculated. This was done for all the days over a 5 year period at 2 altitudes and the results were then grouped by month. Cyclonic variation was found to be about the same throughout the year and at each altitude. These values were then superimposed on the annual temperature cycle for each site (Fig. 8). These graphs represent a clear view of the average variation found within the annual cycle.

The amplitude of the daily temperature cycle was found to be related to the mean temperature for that day (Fig. 9). As temperature increases, a plant must therefore cope with a more varied temperature environment.

Average figures for temperature, solar radiation, wind run and rainfall over a period of 4 years (1974 - 1978) are shown in Table 1. The difference in average temperature between the 2 weather stations is equivalent to a lapse rate of 5.28°C per KM. The lapse rate between Moor House and Great Dun Fell was found to be considerably greater at 7.54°C per KM and solar radiation was very similar at the 2 weather stations. The slightly higher figure for Moor House is probably due to the increased summer values noted earlier. There is a considerably greater wind speed at the higher site, which is likely to have a considerable effect on plant form and growth. The rainfall found at the higher site is nearly twice that at the lower and the probability of water stress is consequently greatly reduced.

Another aspect of the fall in temperature with increasing altitude is that plants are exposed to increased low temperature stress. Fig. 10 shows the number of hours where the temperature was below 0°C in each month of the year at 3 altitudes. Apart from the clear increase in the degree of low temperature stress with increasing altitude, there is also an increase in the number of months when frost occurs.

The altitudinal range used in this study has been shown to display a wide range of climatic conditions within a very restricted geographical area. Conditions range from a fairly mild temperate climate at the lowest altitude, through a sub-arctic type climate at the height of Moor House, to true arctic temperature conditions at Great Dun Fell. The alpine tundra zone is usually defined as those areas above the treeline. It is difficult to determine where the true treeline is in this heavily managed area, but various estimates put it between 458 m (1500 ft) and 610 m (2000 ft). Therefore, this altitudinal range also covers the transition from subalpine to alpine tundra conditions.

A comparison of the performance of Geum rivale and Geum urbanum over the altitudinal gradient.

In order to investigate the potential importance of the different factors that influence the altitudinal distribution of plant species in the vegetation, a pair of species was studies - Geum urbanum and Geum rivale, which are interfertile and commonly produce hybrids where they come into contact with each other. They differ strikingly both in their altitudinal and latitudinal distribution. In the northern Pennines Geum rivale occurs in natural populations up to an altitude of about 793 m (2600 ft) whereas Geum urbanum is not found above 381 m (1250 ft). Thus it would seem that on distributional grounds Geum rivale is better able to tolerate the stresses placed on a plant in the upland environment.

To investigate the relationship between altitude and the distribution pattern of the Geum spp, sets of potted plants were placed within fenced sites at Helbeck Wood, Moor House and Knock Fell. Replicate samples were harvested at intervals and subjected to growth analysis. The Relative Growth Rate (RGR), Unit Leaf Rate (ULR) and Leaf Area Ratio (LAR) of plants was assessed during periods in the summer, autumn and winter. The mean temperature was calculated over the period of each experiment using the hourly weather data from the automatic weather stations. The RGR is clearly temperature-dependent over the temperature range found in the field (Fig. 11).

The graph may be divided into 3 zones, a low temperature range where there is only a slight increase in growth rate with temperature, a central zone where it increases rapidly with temperature and a high temperature range where again it is relatively insensitive to any further temperature increase. The response of the 2 plant sizes is largely similar, although rates are slightly depressed in the larger plants. The 2 species are almost the same in their responses, although smaller plants of Geum urbanum do slightly better at lower temperatures.

The ULR also shows a relationship with temperature, but the form of this is quite different from that found for the RGR (Fig. 12). The ULR peaks at a temperature between 7°C and 9°C and on either side of this falls off sharply. The responses of the different sizes and species are similar although again the smaller Geum urbanum plants do better at lower temperatures.

The LAR shows no trend with temperature. It does, however, display a clear relationship with total plant weight indicating that its magnitude is related more to the stage of plant development than to any environmental effect.

The relationship between growth and average daily temperature may be used to investigate the way in which the length and form of the growing season vary with altitude. The division of the response of the RGR into 3 temperature zones provides a basis for dividing up the year into 3 corresponding periods. One period is where the temperature is above 7°C and growth is uninhibited by temperature. A period of temperature-dependent growth may be identified when the temperature is between 2°C and 7°C, and a period of minimal growth when the temperature is below 2°C.

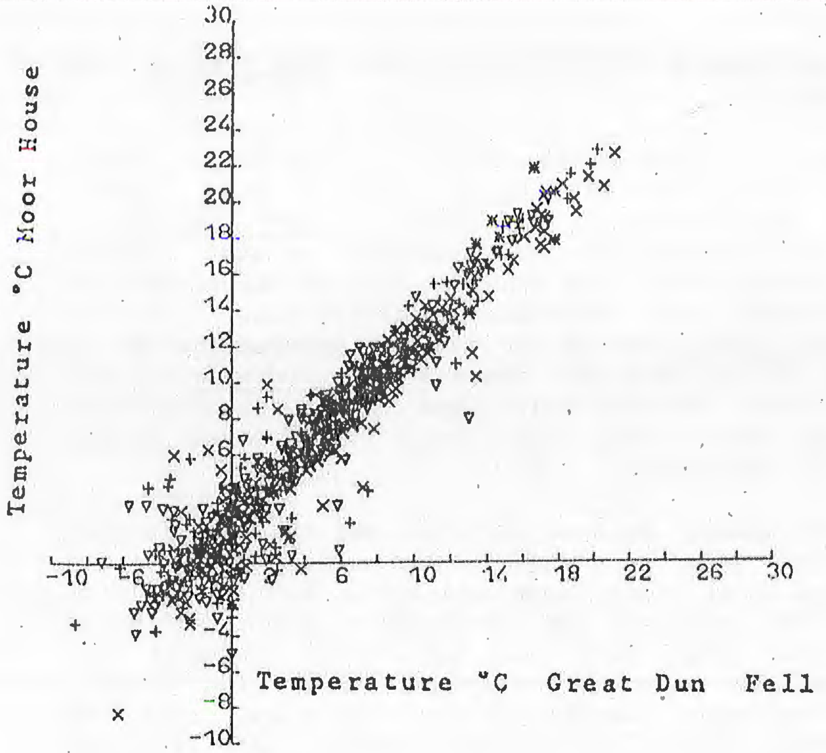


Fig. 1 The relationship between mean hourly temperatures at the Moor House weather station and instantaneous temperature recorded daily every three hours between 09.00 and 15.00 during each working weekat the summit of Great Dun Fell.

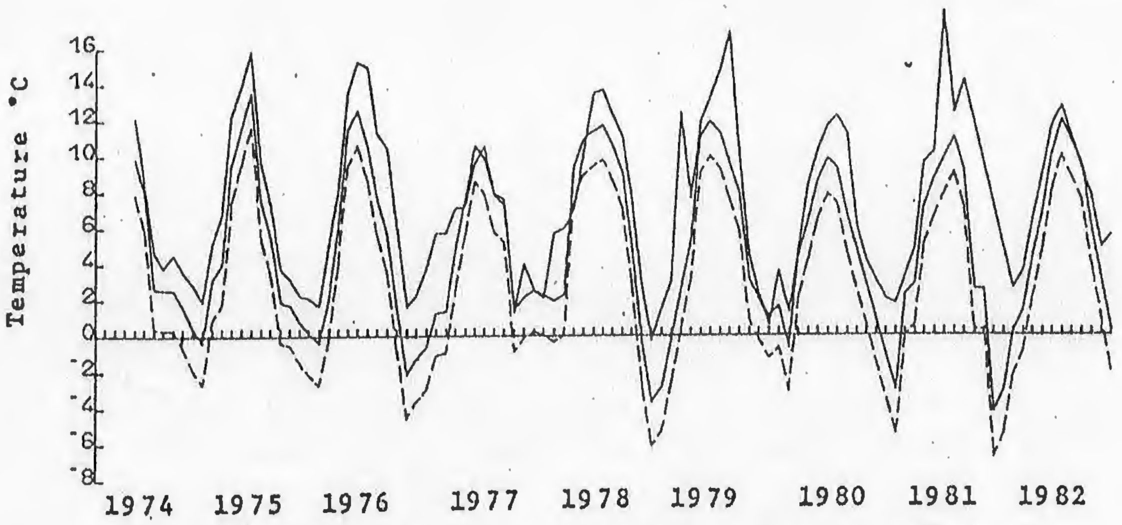


Fig. 2 , Mean monthly temperature over a period of eight years at three altitudes; Helbeck Wood 275 M Moor House 549 M and Great Dun Fell 847 M (------predicted temperatures)

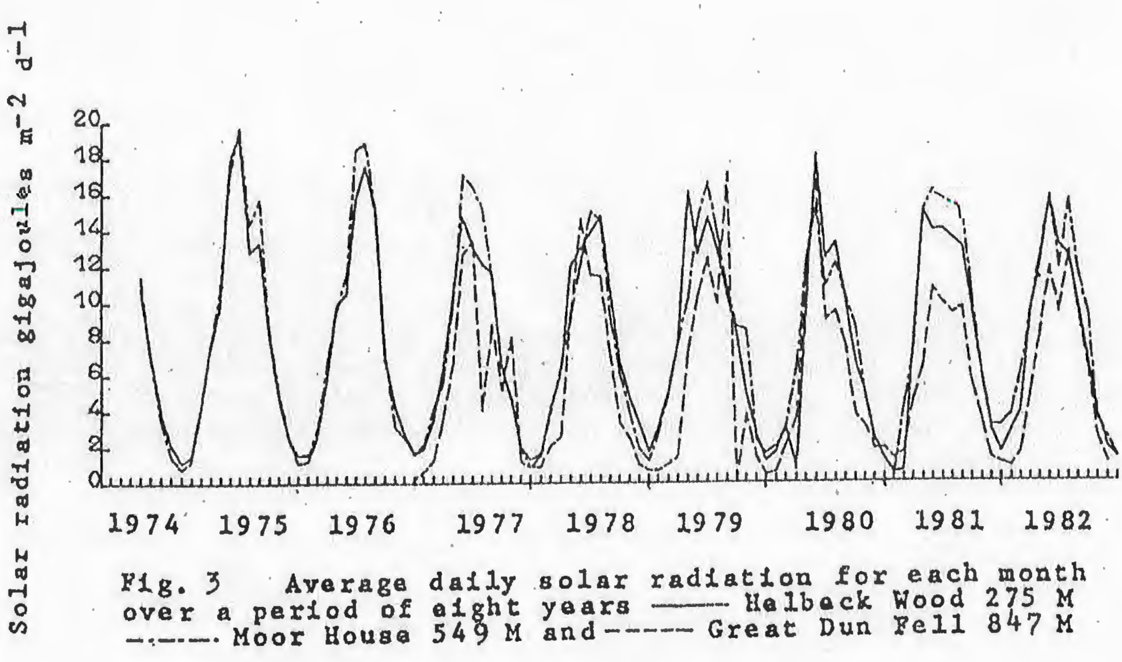


Fig. 3 Average daily solar radiation for each month over a period of eight years ——— Halbeck Wood 275 M —·—·— Moor House 549 M and ----- Great Dun Fell 847 M

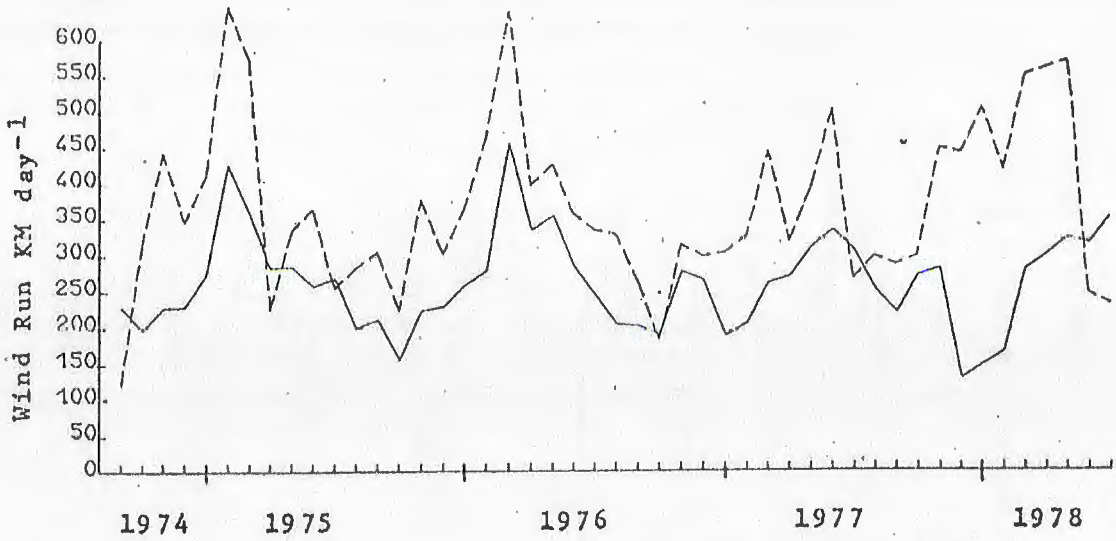


Fig. 4 Wind runs at ——— Helbeck Wood 275 M and - - - - Moor House 549 M over a four year period.

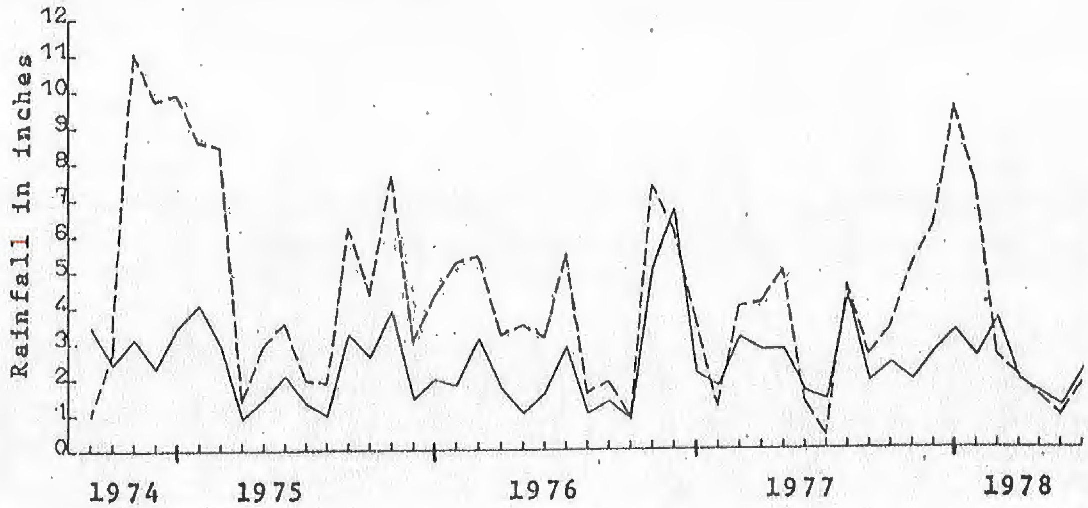


Fig. 5 Rainfall at ——— Helbeck Wood and ---- Moor House over a four year period.

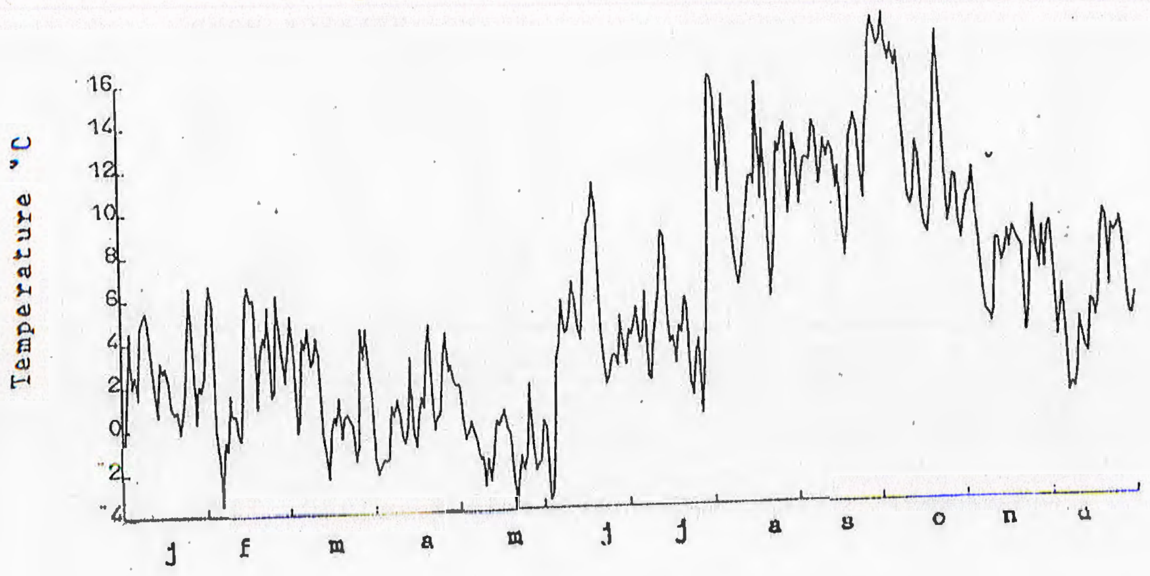


Fig. 6 Daily mean temperature at Moor House during 1975.

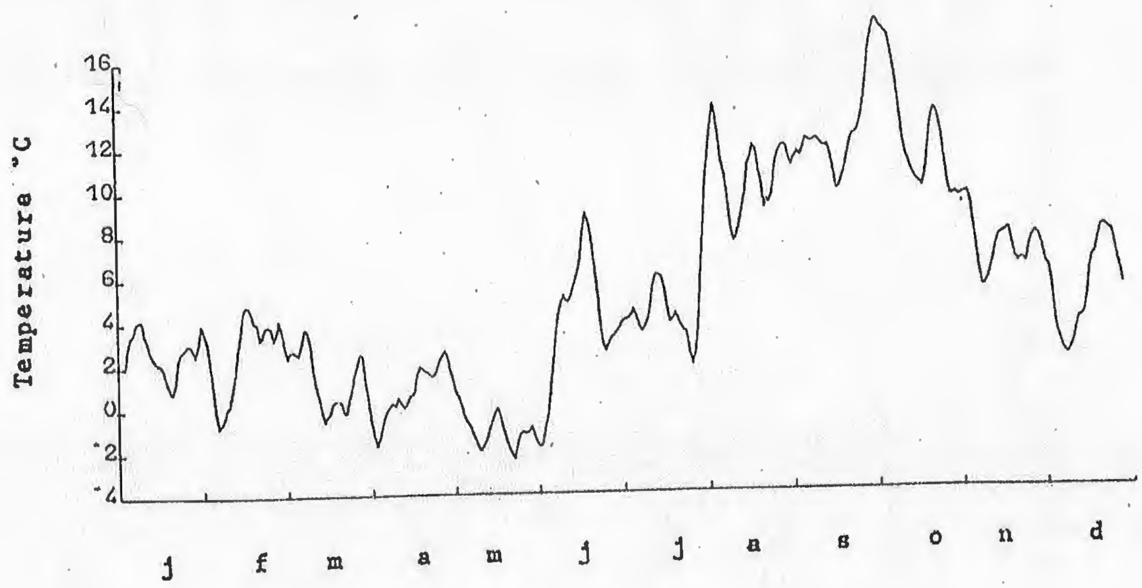


Fig. 7 Six day moving average of daily mean temperature at Moor House during 1975.

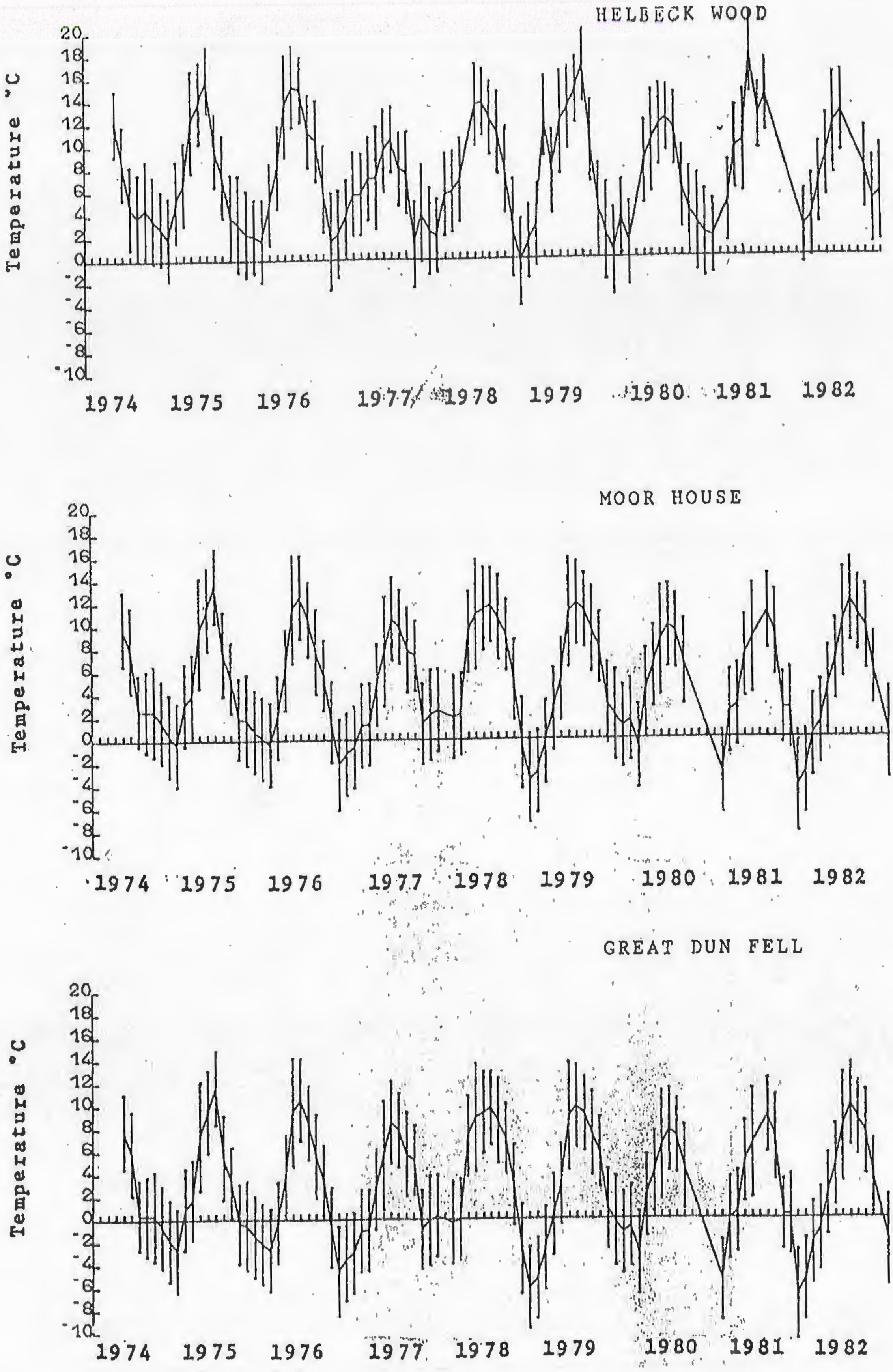
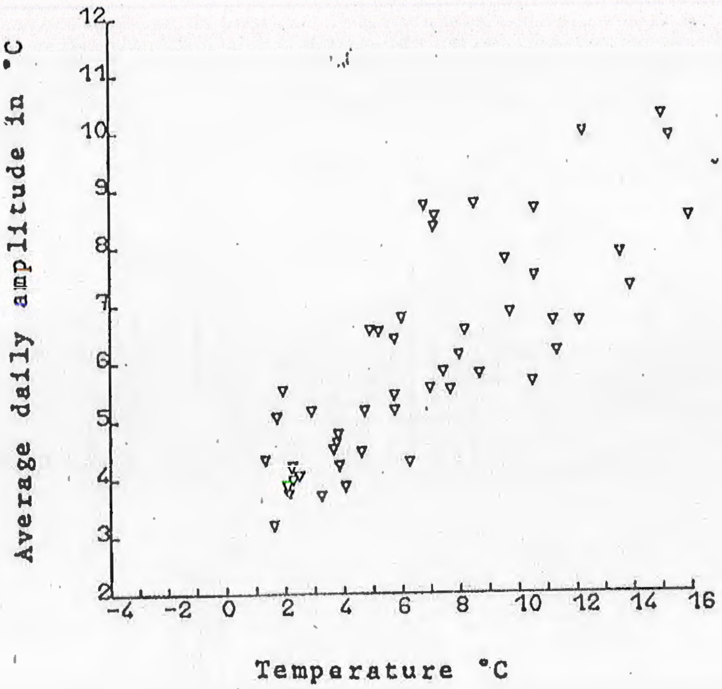
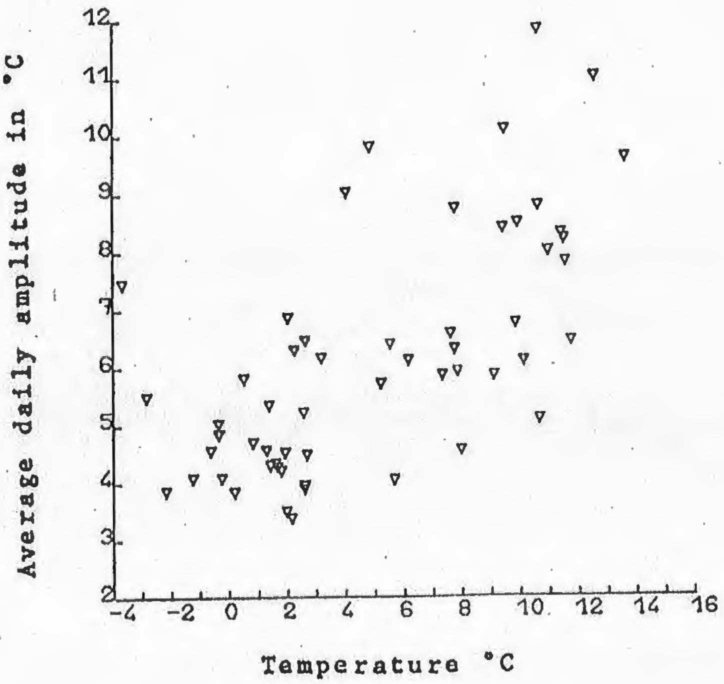


Fig. 8 Monthly mean temperatures over a period of eight years at Helbeck Wood 275 M, Moor House 549 M and Great Dun Fell 847 M with the average temperature variation found over periods of 5-10 days shown as bars.



Helbeck Wood 275 M



Moor House 549 M

Fig. 9 The relationship between mean daily temperature and the daily temperature amplitude at Helbeck Wood and Moor House weather stations.

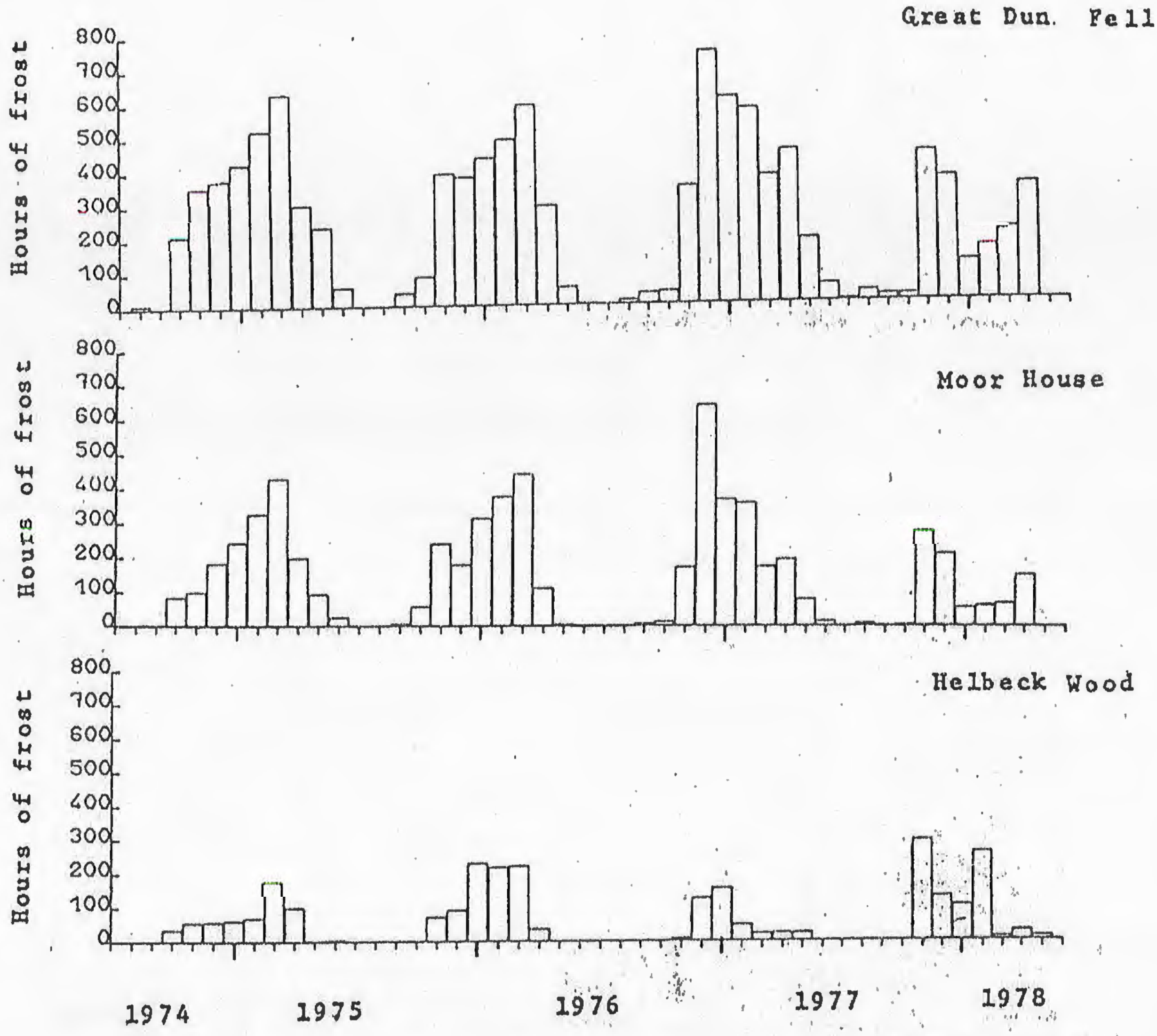
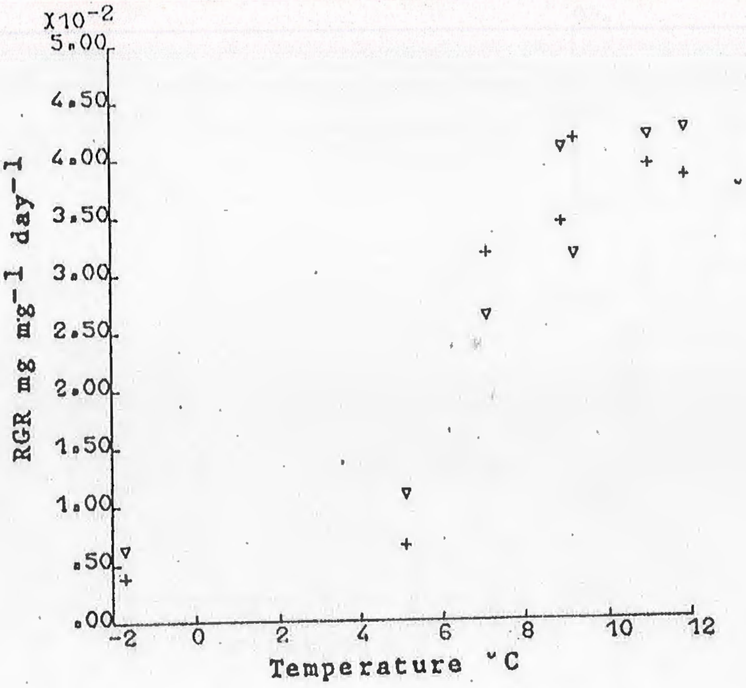
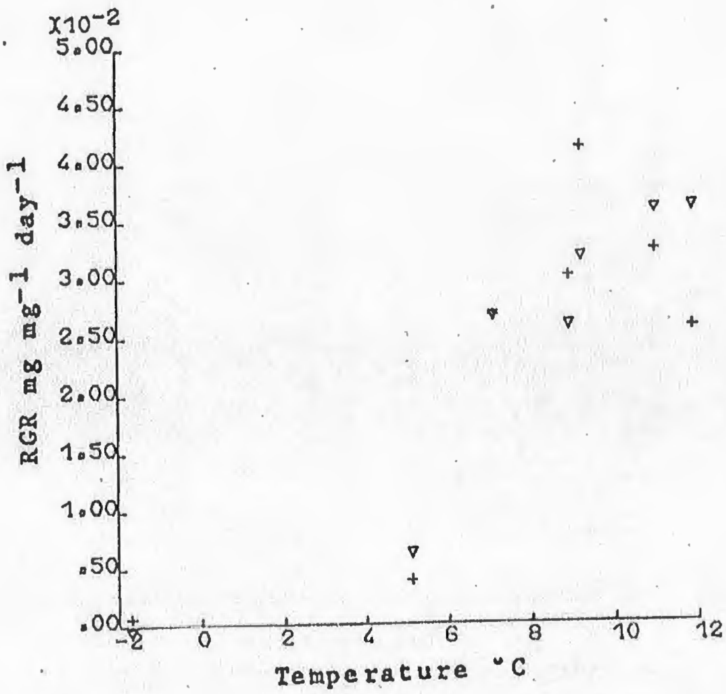


Fig. 10 Hours of frost in each month over a four year period at Great Dun Fell 847 M, Moor House 549 M and Helbeck Wood 275 M

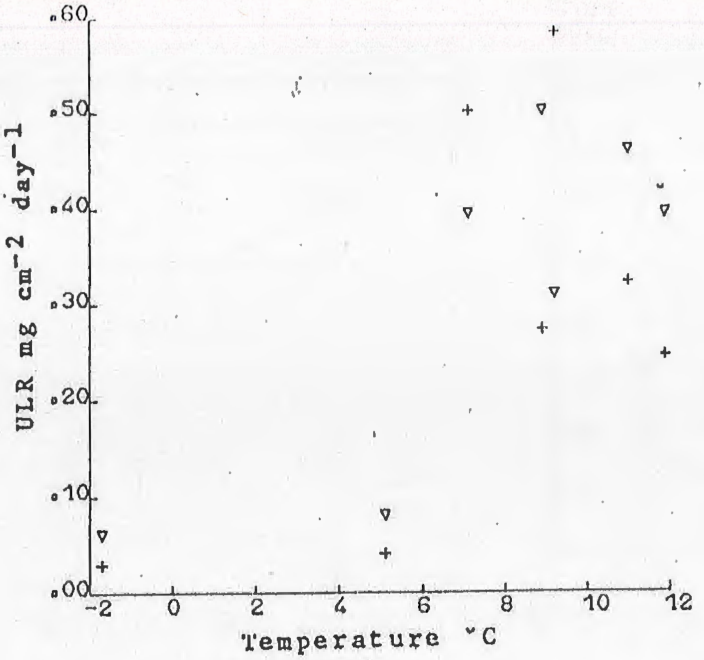


a) Small plants

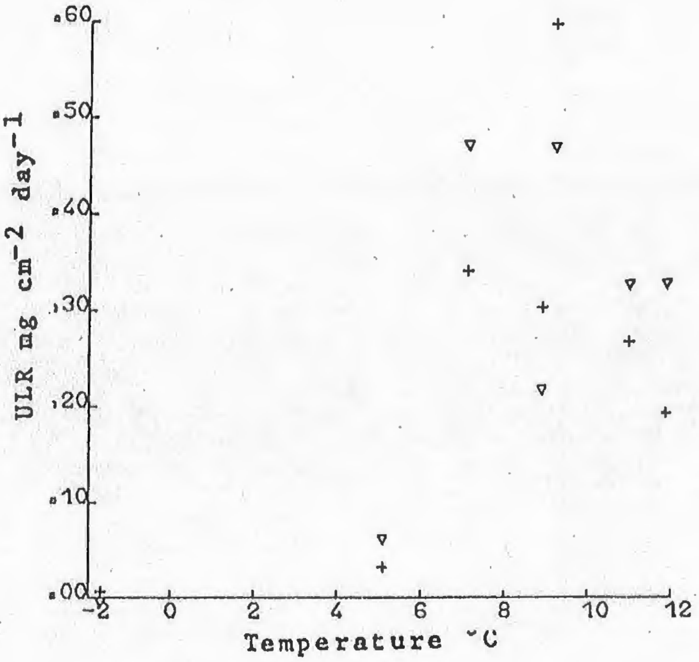


b) Large plants

Fig. 11 Relationship between temperature and Relative Growth Rate for all altitudes and seasons.
▽ <u>Geum urbanum</u> + <u>Geum rivale</u>



a) Small plants



b) Large plants

Fig. 12 Relationship between temperature and Unit Leaf Rate for all altitudes and seasons.
▽ <u>Geum urbanum</u> + <u>Geum rivale</u>

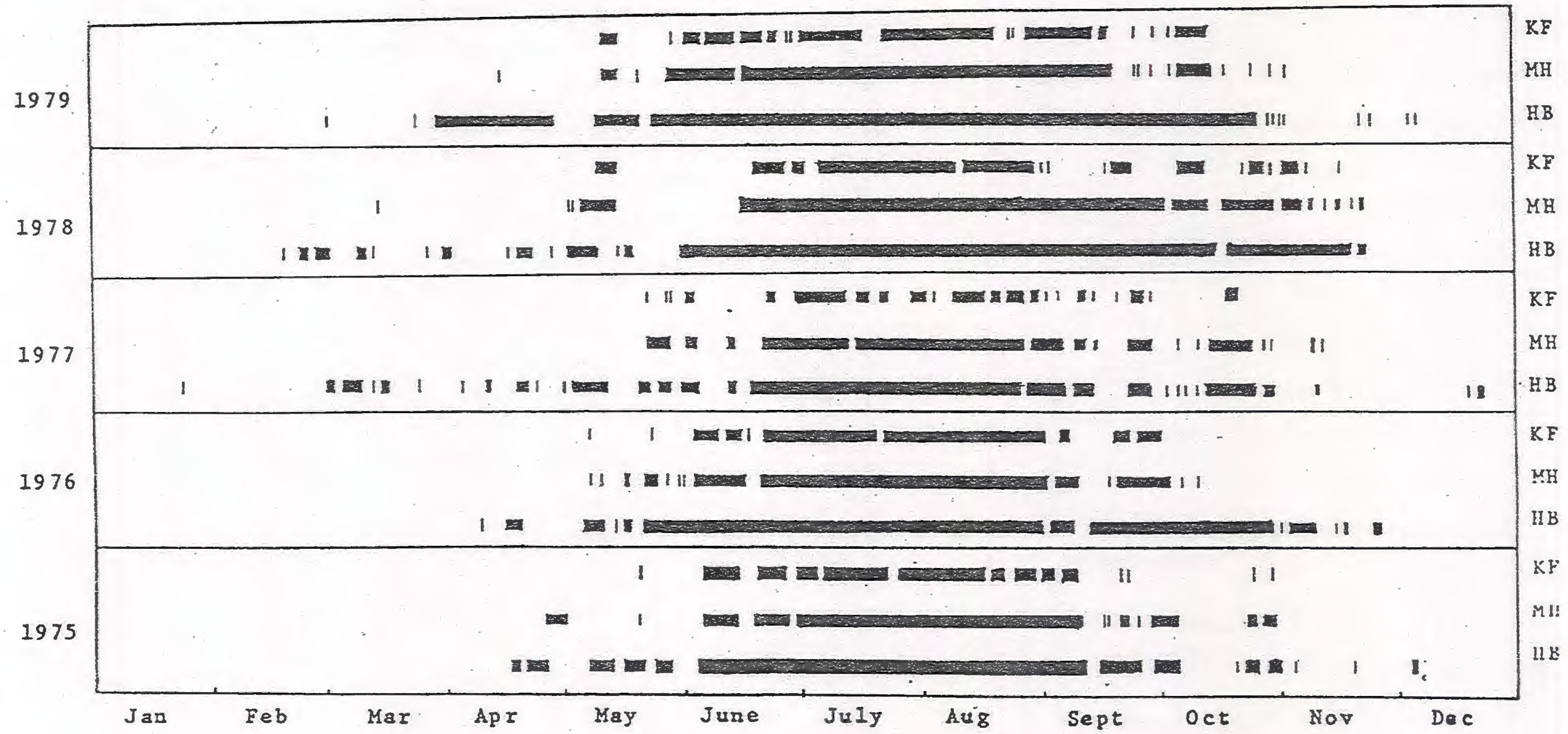


Fig. 13 Days where temperature was not limiting growth at three altitudes and over four seasons. HB = Helbeck Wood 275 M MH = Moor House 549 M KF = Knock Fell 762M

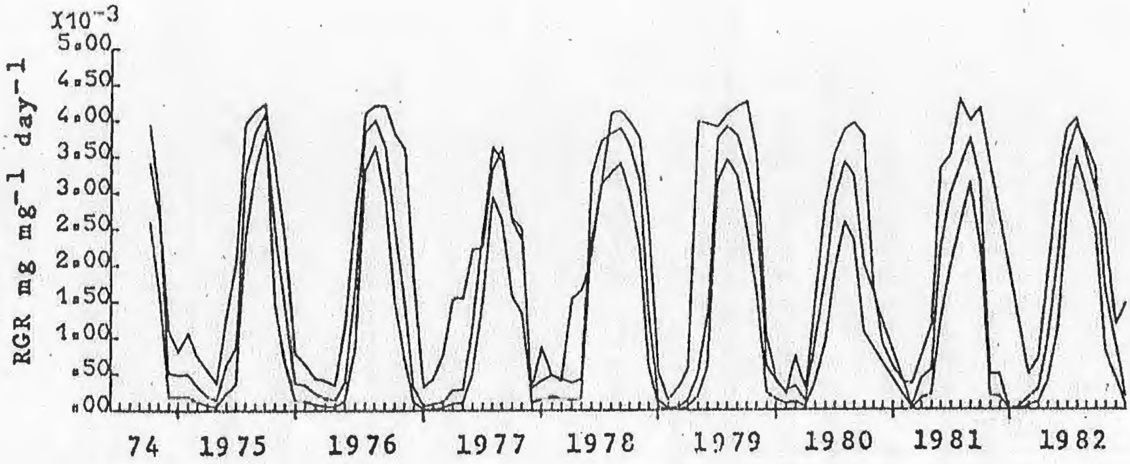


Fig. 14 Predicted seasonal pattern of Relative Growth Rate at three altitudes of 275 M, 549 M and 847 M over a period of eight years.

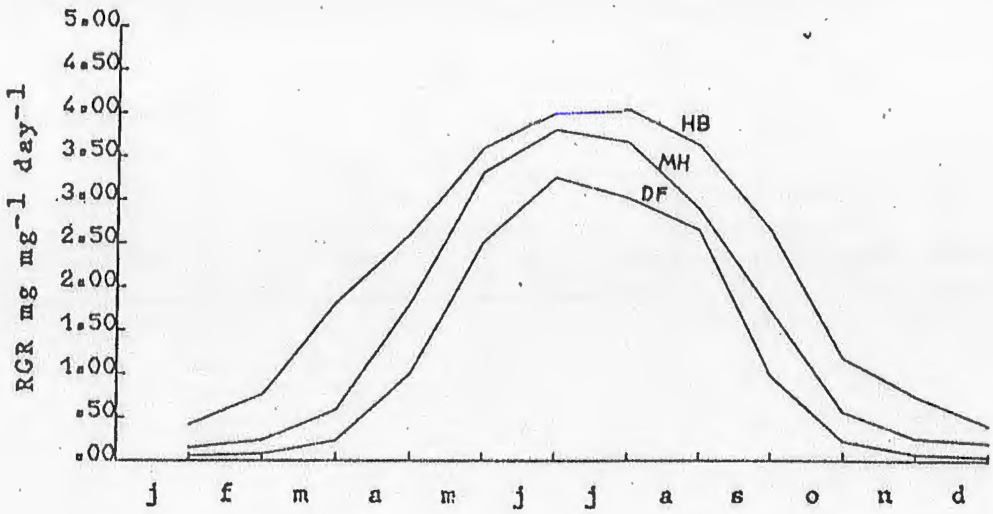


Fig. 15 Average annual cycle for Relative Growth Rate. HB = Helbeck Wood 275 M MH = Moor House 549 M DF = Dun Fell 847M

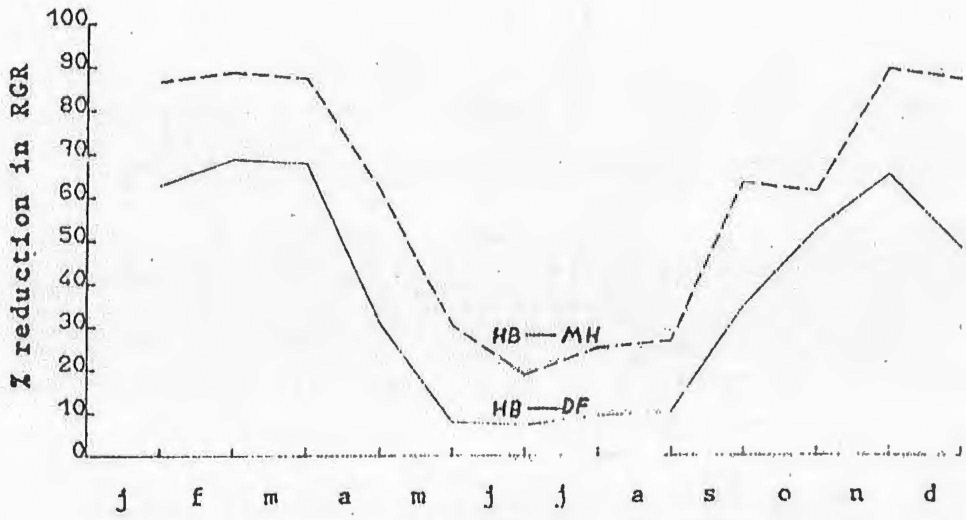


Fig. 16 Percentage reduction in Relative Growth Rate between --- Helbeck Wood and Moor House, —— between Helbeck Wood and Dun Fell.

Table 1 Average climatic conditions over a four year period 1974-1978 at the Helbeck Wood and Moor House automatic weather stations.

	Temperature °C	Solar Radiation gigajoules $m^{-2}d^{-1}$	Wind Run Km d^{-1}	Rainfall mm d^{-1}
Helbeck Wood	7.00	7.56	257.7	2.43
Moor House	4.81	7.99	364.7	4.75

Table 2 The distribution of the growing season at three altitudes over a period of eight years.

	Helbeck Wood			Moor House			Knock Fell		
Year	Ind.	Dep.	Zero	Ind.	Dep.	Zero	Ind.	Dep.	Zero
1975	147	158	60	122	121	122	87	106	172
1976	190	160	66	124	130	112	102	108	156
1977	172	147	46	122	123	120	76	122	167
1978	179	134	52	160	116	89	105	153	107
1979	209	89	67	139	97	129	113	79	173
1980	165	135	66	106	162	96	44	194	127
1981				131	100	134	79	111	175
1982	182	128	55	141	126	98	90	142	133
X	178	136	59	131	122	113	87	127	151
%O/X	10.9	17.7	13.8	12.4	16.5	14.7	24.8	27.9	17.0

Key
Ind. = No. of days of temperature independant growth
Dep. = No. of days of temperature dependant growth
Zero = No. of days of zero growth
X = Mean
%O/X = % Coefficient of variation

Using this relationship the length of the growing season in each period was assessed from the weather data available for 3 different altitudinal sites (Table 2 and Fig. 13). These results show that there was a considerable reduction in the length of the uninhibited season over the altitudinal range being investigated. Its length at the Knock Fell site is less than half that found at Helbeck Wood and it decreases by about 16.5 days for every 100 m. As the altitude increases the number of days where growth is not possible rises sharply and the relative importance of growth in the temperature-dependent zone increases.

The distribution of the uninhibited growing season over the year is shown in Fig. 13 and examination of this shows that the year may be divided up into 4 sections roughly corresponding to the seasons; there is a winter period with just the odd day rising above 7°C, 2 transitional periods, spring and autumn, where the temperature oscillates above and below this level, and a summer period where temperature is optimal for most of the time. As the altitude rises the length of the summer period decreases and the transitional periods come closer together. At the highest altitude, in some years there is in fact no distinguishable summer. The absence of sufficiently long periods of uninterrupted optimal temperatures may be of considerable importance in limiting yearly production at high altitudes.

The coefficient of variation shown in Table 2 is a measure of the variability of the data relative to its mean size. In these circumstances it may be considered as an expression of the stability of the growing season from year to year. There is a clear decrease in stability as the altitude gets higher.

The relative growth rate results were used in conjunction with the weather data available over an 8 year period to produce a prediction of RGR in each month over this period. The effect of temperature on RGR (Fig. 11) approximates to a logistic curve of the form

$$RGR - \frac{Rmax}{(1 + be^{-ct})}$$

Where Rmax = The maximum relative growth rate
t = Temperature
b, c = Constants

this may be linearised to

$$Loge\ ((Rmax/RGR) - 1) = Loge\ b\ -ct$$

The data for small plants of both Geum urbanum and Geum rivale was used throughout. Rmax was estimated visually from the graphs of RGR against temperature. The constants, b and c, were found by plotting the data in the linearised form and fitting a straight line by eye. Equation 1 was then used to make the predictions of RGR.

The seasonal pattern of RGR for an 8 year period is shown in Fig. 14. As altitude increases so the seasonal curves for RGR both decrease in amplitude and become narrower. The average annual RGR curves for this period (Fig. 15) show this effect most clearly. The effect of altitude on RGR shows a seasonal trend itself. The percentage reductions in RGR between the altitudinal stations (Fig. 16) indicate that the effect of altitude increases as the severity of the seasonal climate increases. Therefore, the altitudinal effect is least in the summer months and greatest in the winter.

b) Population dynamics of heather psyllid
(J B Whittaker, Department of Biological Sciences, University of Lancaster).

This study is now complete and has been accepted for publication in Journal of Animal Ecology 1985.

The summary of that paper is as follows:

(1) A psyllid, Strophingia ericae feeding on phloem sap of Calluna vulgaris has a 2-year life cycle in which the cohorts overlap at high altitudes. The dynamics of this species have been studied for 16 years on the Moor House National Nature Reserve.

(2) Overlapping cohorts which appear to constitute separate gene pools coexist on the same Calluna shoots. Small individuals of each new cohort are likely to be exploiting the same resource as large individuals of the previous cohort.

(3) Each cohort set (odd or even years) showed 3 regularly spaced peaks of abundance during the 16 years.

(4) When recruitment to a new cohort ended mortality became density independent up to the onset of winter. Mortality was very low during winter and there was little change in age structure from November to March. Mortality from the first spring to the second winter was density dependent. Again during the second winter there was little mortality or change in age structure. Mortality from the second spring to the end of the life cycle was density dependent.

(5) Log increase in biomass of a new cohort during its first full year was negatively correlated with the log total biomass of psyllids in both cohorts, but not significantly correlated with the log biomass of the new cohort. This interaction appeared to be the cause of oscillation in biomass from one year to the next.

(6) The density of psyllids on a 100 m^2 area of blanket bog was halved in 1978 by a single application of Malathion. Subsequent recovery of the population was compared with a nearby control area. Although experimental and control populations converged in density after one year, it took 2-3 generations before densities and age structure converged.

(7) It is concluded that S. ericae at Moor House shows population regulation which is largely due to interactions within and between cohorts and that these appear to have a cyclical effect on population density.

c) <u>Gas production during peat formation</u>
(Jane Claricoates, Department of Botany, Westfield College, London).

Analysis of the data is continuing and it is hoped to be able to give a summary of the results in next year's annual report.

d) <u>Species diversity on mineral soil "islands"</u>
(Lucy J Lloyd, Department of Zoology, Durham University)

During the first field season of this 3-year research programme, investigations were carried out to determine the nature of the Carabid and Staphylinid (Coleoptera) communities present on the mineral soil areas scattered throughout the Reserve.

Ten <u>Agrosto-Festucetum</u> limestone sites were chosen initially, varying in their respective sizes, altitude and degree of isolation. At each site sampling was effected by a series of pitfall traps and windowtraps - the latter designed to give information on the aerial moving component of the fauna. Similar trapping procedures were employed on the intervening moorland between sites to investigate the extent of the effective isolation of these grasslands for the different taxa. The data obtained are currently being analysed for information on the diversity and species composition of each site, and how any similarities or differences in these qualities may reflect differences in the nature of the sites concerned.

Totals of 31 Carabid species and 130 Staphylinid species have been found on the Reserve. Multivariate Data Analysis has revealed the close similarity in overall species diversity amongst the limestone sites: average values of 9.2 ± 2.2 Carabid species and 36.5 ± 1.5 Staphylinid species per site have been obtained. The species compositions peculiar to each site are now being studied. Special interest is being given to the results from the windowtraps (last year's warm dry weather proved providential for such a study) which reveal that only one (5%) of the commoner Moor House Carabid species was caught on the wing, whereas 23 (50%) of the commoner Staphylinid species were present in both pitfall and windowtraps, and 62% of all Staphylinid species sampled at Moor House were capable of flight.

The relationship between aerial mobility and the pattern of distribution and abundance of species is presently being investigated, and future research will concentrate on elucidating this aspect of the system, as well as studying in greater detail the effectiveness of the surrounding vegetation in restricting the limestone fauna to its habitat.

e) <u>Atmospheric Physics Research at Great Dun Fell (a brief summary)</u>
(Dr M J Gay, Physics Dept, UMIST, Manchester).

1984 saw the completion of the second year of a 3 year programme of research funded by the Natural Environment Research Council to investigate 3 separate but intimately linked facets of the interaction between boundary layer dynamics and cloud microphysics. Cloud evolution between the Silverband Mine, using our mobile laboratory housed in a Mercedes-Benz 409, and the summit, has been analysed within the framework of an extended model of the airflow over Great

Dun Fell (Choularton et al 1985). Further validation and improvements to the airflow model resulted from a series of measurements made using an instrumented glider, launched from a field at Newbiggin and which was able to make both vertical and horizontal traverses of the flow field upwind of the fell. Further studies of the orographic enhancement of rainfall using the novel raindrop disdrometers developed at UMIST to operate in the usually windy conditions prevailing at Great Dun Fell (Illingworth & Stevens, 1985) have been aided by the development of digital techniques of recording and displaying information from a small radar operated in RHI mode.

Concurrent with these studies have been detailed measurements of the nature of the cloud base region, using high speed (40 Hz) measurements of the drop size distribution together with electro-magnetic transmission at several wavelengths using a modified Barnes transmissometer. A separate pilot study investigated the feasibility of effecting some measure of fog dispersal by the introduction into the cloud of highly charged drops whose greatly enhanced collection efficiency might be expected to dramatically reduce the cloud droplet concentration (see, for instance, Smith, 1976).

For some time the Institute of Terrestrial Ecology, Penicuik, has been utilising Great Dun Fell and Wharleycroft (the UMIST valley station near Dufton) as part of a network of sites in northern Britain to investigate variations in rain water chemistry (Cape et al, 1984). A recent grant from the Department of the Environment in response to a collaborative proposal by ITE, AERE (Harwell) and UMIST will significantly broaden the scope of these studies to investigate several aspects of the evolution of acidic precipitation, including the study of the oxidation of sulphur dioxide in cloud drops. Preliminary measurements of the concentrations of sulphur dioxide, ozone and oxides of nitrogen (carried out in conjunction with the Central Electricity Research Laboratories) have shown the occurrence of significant departures from a general low level background. Instruments are currently under construction to collect cloud water samples for analysis by ion chromatography or to determine the concentration of hydrogen peroxide, thought to play an important role in the oxidation of sulphur dioxide.

Other visitors to Great Dun Fell to carry out short investigations in collaboration with us included CERL (studying the dispersion of tracer gas released from the Eden valley and monitored at the summit - see report on page 19), British Telecom (studying the effects of riming on antennae radomes) and Thorn-EMI.

<u>References</u>

Chourlaton, T W et al. 1985. Submitted to Quart J R Met Soc.

Illingworth, A J & Stevens, C J. 1985. In preparation.

Smith, M H. 1976. J App Met, <u>15</u>, 275-281.

Cape, J N et al. 1984. Atmos Env, <u>18</u>, 1921-1932.

VI. RESEARCH BY THE CENTRAL ELECTRICITY RESEARCH LABORATORIES

a) Cloud Chemistry
(P A Clark, G P Gervat and A R W Marsh).

The Central Electricity Generating Board is currently investigating the way air pollutants are transported and transformed. As part of this study, chemical processes within cloud drops are being examined. Great Dun Fell, with over 200 days of cloud at ground level, provides an ideal site for field experiments.

In October 1984, initial dispersion experiments were carried out. For each experiment, inert gas was released for about an hour from sites at Blencarn and Knock. The gas was released at only a few litres per minute. The objectives were to examine the air flows round the south-west slopes of Great Dun Fell and see whether it was possible to detect the gas at, and near, the summit. This was successfully achieved using a very sensitive detector developed at CERL. This instrument can measure natural background concentrations less than one part in a million millions.

Preparations are underway for further experiments that will incorporate the low clouds on Great Dun Fell.

b) Ambient Monitoring
(G P Gervat, CERL, and M J Gay, UMIST)

To investigate ambient levels of pollutant gases at the summit of Great Dun Fell, several gas analysers were installed and run, in and near the UMIST Cloud Physics building, during November and December 1984. The results are yet to be fully processed but it provisionally appears that there can be wide variations in pollutant levels with different wind directions. For SO_2 concentrations for example, a few parts per billion may be present when the wind reaches the summit from the south-west but peaks of 40 parts per billion may occur with south-easterly winds.

Appendix 1

Publication List

CRISP, D T, MANN, R H K & CUBBY, P R. 1984. Effects of impoundment upon fish populations in afferent streams at Cow Green Reservoir. Journal of Applied Ecology 21, 739-756.

GRAVES, J D. 1984. Factors determining the upper altitudinal limits of the genus Geum in the nothern Pennines. PhD Thesis, London University.

POTTS, G R, TAPPER, S C & HUDSON, P J. 1984. Population fluctuations in red grouse: analysis of bag records and a simulation model. Journal of Animal Ecology 53, 21-36.

ROBERSTON, K P & WOOLHOUSE, H W. 1984. Studies of the seasonal course of Carbon uptake of Eriophorum vaginatum in a moorland habitat. 1. Leaf production and senescence. Journal of Ecology 72, 423-435.

ROBERTSON, K P & WOOLHOUSE, H W. 1984. Studies of the seasonal course of Carbon uptake of Eriophorum vaginatum in a moorland habitat. II. The seasonal course of photosynthesis. Journal of Ecology 72, 685-700.

WHITTAKER, J B. 1985. Population cycles over a 16-year period in an upland race of Strophingia ericae (Homoptera: Psylloidea) on Calluna vulgaris. Journal of Animal Ecology 54, 311-323.

Appendix 2

METEOROLOGICAL SUMMARY FOR MOOR HOUSE 1983

c. 558 m OD (Instrument Site) Lat 54° 41'N Long 2° 23'W Nat Grid Ref NY 758328

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Mean max temp °C (See * below)	4.4	-0.3	4.4	5.4	8.9	13.1	19.3	17.3	11.7	8.8	6.3	4.5	8.7
Mean min temp °C (See * below)	-0.5	-5.1	-0.2	-0.9	2.2	5.9	10.0	8.1	6.2	3.1	1.3	-0.4	2.5
½ (max + min) °C (See * below)	2.0	-2.7	2.1	2.3	5.6	9.5	14.7	12.7	9.0	6.0	3.8	2.1	5.6
Highest max temp °C	8.5	3.8	8.5	10.5	14.8**	21.1	26.7	22.0	17.6	14.5	13.1	10.3	26.7
Lowest min temp °C	-6.5	-14.9	-6.0**	-6.2	-2.1	0.6	3.1	-4.9	-1.4	-9.5	-9.9	-11.6	-14.9
Lowest grass min temp °C	-8.0	-11.5+	-9.0 -> -14.0**	-9.4	-6.0	-2.0	-0.6	-7.8	-3.4	-10.0	-12.0	-11.5+	-
Days snow lying (See * below)	10	28	13	8	0	0	0	0	0	0	0	5	64
Air frost (days) (See * below)	19	27	18	20	2	0	0	1	2	7	11	16	123
Ground frost (days) (See * below)	26	28	23	25	13	4	4	6	7	12	13	23	184

* Estimates reached by comparing Moor House and Widdybank data (Widdybank Met Station, Teesdale, County Durham)

\+ *Snow covered.*

** Temperatures not recorded therefore estimated figures given.

See separate table (Page 22) for rainfall.

Appendix 3

Monthly Rainfall Totals for Moor House 1983

Raingauge Site c. 558 m OD
Nat Grid Ref NY 758328

Month	Total mm
January 3-28 January inclusive	277.4
February 29 January - 28 February inclusive	118.2
March 1 March - 9 April inclusive	245.9
April 10-30 April inclusive	140.2
May 1-26 May inclusive	137.2
June 27 May - 30 June inclusive	99.1
July 1-23 July inclusive	64.9
August 24 July - 23 August inclusive	27.4*
September 24 August - 30 September inclusive	181.4
October 1-31 October inclusive	278.0
November 1 November - 3 December	82.5
December 4 December - 1 January 1984	180.6

* This total may have been marginally more - raingauge pulled out by vandals therefore a small amount of rainfall may have been lost.