THE NATURE CONSERVANCY

A REPORT OF SCIENTIFIC WORK AT THE MOOR HOUSE NATIONAL NATURE RESERVE, WESTMORLAND.

JANUARY, 1958.

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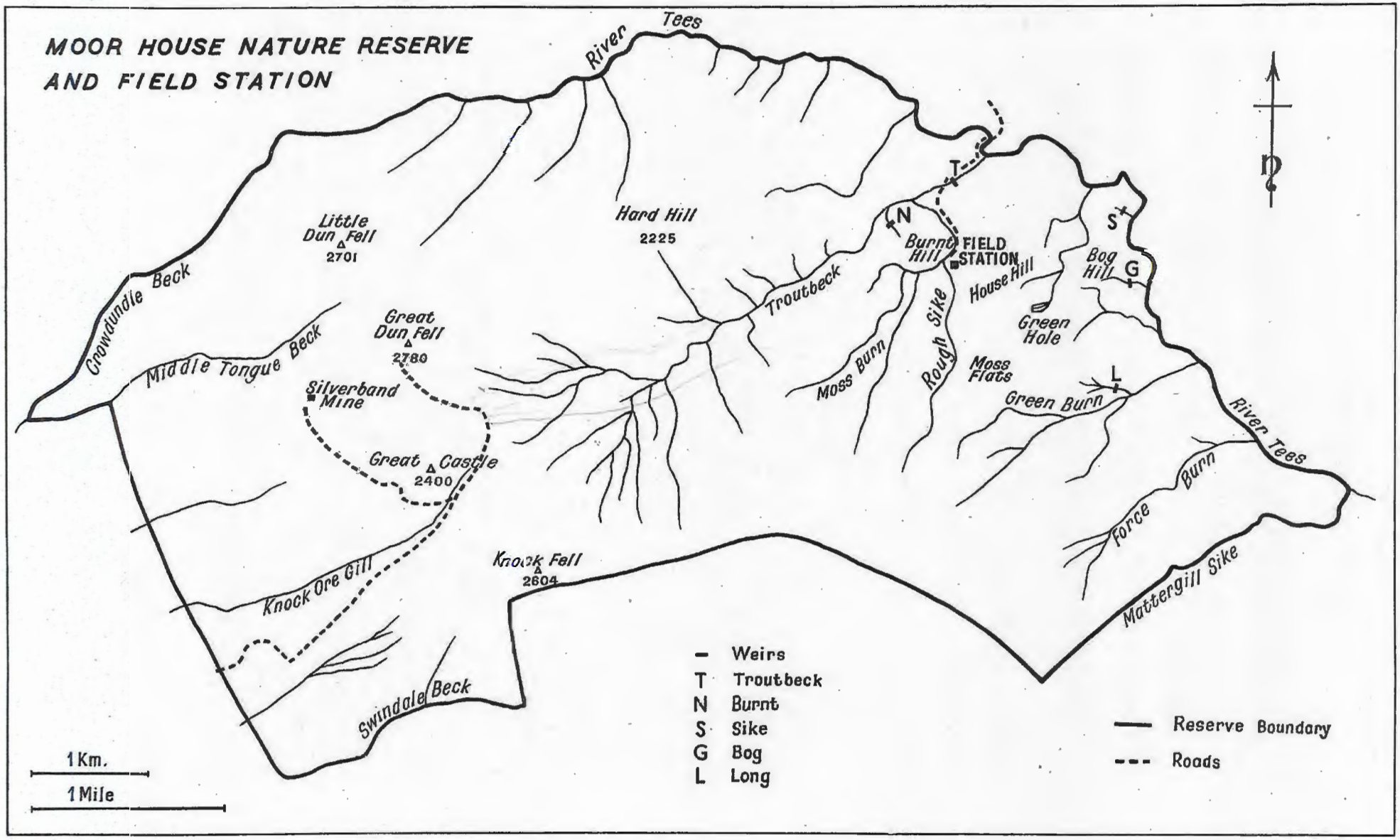
CONTENTS (cont'd.)

FOREWORD

Now that the Moor House Field Station has been a centre of work for six years, quite a number of people up and down the country have heard of it and have become interested in the research going on there. In consequence, there are quite frequent requests for information, and there is also a need for something on paper to help us maintain liaisons already established. The Annual Report of the Nature Conservancy contains of course some references each year to some of the work in progress, but it is naturally impossible in such a report to give accounts full enough to be informative to scientists working on related topics, but in other organisations. It therefore seemed useful to ask everyone now engaged on any full-time or long-term research on the Reserve, to contribute an account outlining the results so far obtained and the aims of current experiments. These accounts have been put together into the pages which follow, without any editing except for quite trivial matters of format, punctuation, and so on.

When the Moor House area came into the market in 1951, the Nature Conservancy were seeking some place where they could carry out intensive investigations, both observational and experimental, of upland peat bogs. For this the Moor House area offered ample scope; but it had other features also which made it seem valuable as a nature reserve. It is extensive enough to include a fair variety of upland soil and vegetation. It crosses the main ridge of the North Pennines, including both scarp and dip slopes and thus forms a representative example of the considerable tracts of land in northern England which lie above 1,600 ft. The field station itself is at 1,800 ft. and must be the highest centre for scientific research in the British Isles. Thus although many of the research projects are of types familiar elsewhere, the programme as a whole has novelty, and is likely to give valuable results, because it is focussed on a type of land which has never before received intensive study of wide scope.


MOOR HOUSE NATURE RESERVE
AND FIELD STATION
River Tees
Little Dun Fell
2701
Hard Hill
2225
Crowdundle Beck
Middle Tongue Beck
Great Dun Fell
2780
Silverband Mine
Great Castle
2400
Knock Ore Gill
Knock Fell
2604
Swindale Beck
Troutbeck
Burnt Hill
FIELD STATION
House Hill
Bog Hill
Green Hole
Moss Burn
Rough Sike
Moss Flats
Green Burn
Force Burn
Mattergill Sike
T
N
S
G
L
1 Km.
1 Mile
Weirs
Troutbeck
Burnt
Sike
Bog
Long
Reserve Boundary
Roads

I. GEOLOGY AND CLIMATOLOGY

1. Geology. G. A. L. Johnson.

The geological survey of the Moor House area was started early in July 1954 by G. A. L. Johnson in conjunction with Professor K. C. Dunham, F.R.S., and based on the University Geology Department, Durham. Little detailed research has previously been carried out in this area though research on the Carboniferous sequence goes back to 1809 when Westgarth Forster examined and published the section in Crowdundle Beck. The area was geologically surveyed by the primary surveyors of the Geological Survey in the latter part of the 19th century but no description of the region was published. The present survey comprises the detailed mapping of solid deposits, drift and soils on the reserve, together with laboratory studies on the Carboniferous palaeontology and clay mineralogy. For the determination of clays apparatus for differential thermal analysis has been installed in Durham. The study of peat deposits has lately been added to widen the scope of the survey; examination of blanket and basin peat stratigraphy and determination of the exact horizons of interstratified stone implements and remains of Bos is planned for the near future.

Mapping. The survey of solid deposits on the Reserve was completed early in the summer of 1956 and clean copies of the seven six-inch quarter sheets (old county series), which cover the area, have been prepared. So far only the Dun Fell Sheet (Westmorland V. N.E.) has been printed and a hand coloured manuscript copy of this sheet is available. The drift survey was completed in 1957 and clean copies of the drift maps are being prepared; the drift edition of the Dun Fell sheet (Westmorland V. N.E.) will soon be ready for printing. Soil mapping on the reserve is now in progress and will be completed during the 1958 field season.

Geological sequence. The geological formations on the Moor House Nature Reserve are summarized in the following table:-

SUPERFICIAL FORMATIONS

Recent and Post-Glacial:-
- Blanket peat.
- Basin peat.
- Alluvium.
- Alluvial fans.

Glacial and Periglacial:-
- Solifluxion deposits: sandy and stony clays.
- Boulder clay.

SOLID FORMATIONS

Carboniferous.
- Carboniferous Limestone Series:-
  - Upper Limestone Group: sandstones, grits and shales with coals and limestone bands.
  - Middle Limestone Group: rhythmic sequence of sandstones, shales, limestones and coal seams.
  - Lower Limestone Group: massive limestone overlain by thin limestones, shales and sandstones.
- Basement Series:-
  - Upper division: sandstones and shales with thin limestones.
  - Lower division: massive conglomerates with interbedded sandstones.

GREAT UNCONFORMITY

Ordovician:
- Skiddaw Slate Series

Solid geology

Lower Palaeozoic: The eastern margin of the Cross Fell inlier of Lower Palaeozoic rocks lies just inside the Reserve along the foot of the Pennine escarpment. The beds are composed of dark slates and tuffs of Ordovician age which are exposed in the westward flowing streams off the escarpment, particularly well in Swindale Beck, Sink Beck and Knock Ore Gill. The slates and tuffs in general form low rounded hills but the more craggy Burney Hill, above Knock Ore Gill, is an exception.

Carboniferous Limestone Series: There is a great unconformity between the Lower Palaeozoic beds and the overlying Lower Carboniferous Basement Series. On the west of the Pennine escarpment the junction is complicated by the Inner Pennine Fault which frequently drops the Basement against Lower Palaeozoic Strata.

The Basement Series is only exposed at the foot of the Pennine escarpment where it is composed of two divisions - a lower series of conglomerates, grits and sandstones, and an upper series of sandstones and shales with limestones; only the upper division is fossiliferous. The coarse lower division is of variable thickness, due to variations in the plane of unconformity, and is well exposed in several of the stream sections at the foot of the escarpment - particularly Sink Beck. The upper fine grained series is poorly exposed but is visible in Swindale Beck and Knock Ore Gill.

The Lower Limestone Group overlies the Basement Series and is exposed along the Pennine escarpment and also in the Tees Valley at the extreme east of the Reserve. The Group consists of the Melmerby Scar Limestone (130 feet thick) at the base, overlain by a series of thin limestones separated by shales and sandstones. The top of the Group is taken at the Smiddy Limestone. The overlying Middle Limestone Group consists of a rhythmic alternation of limestones, shales, sandstones and coal seams. It crops out on the western side of the Pennine escarpment and on the eastern side it forms the country rock for the whole Reserve except for the eastern extremity. The top of the Group is taken at the Great Limestone. Above this, and including the Great Limestone (60 feet thick) we have the Upper Limestone Group - a series of sandstones and grits and shales with few thin coal seams and limestones; the Great Limestone at the base of the Group is exceptionly thick; the other limestones are all of the order of a few feet thick. The Upper Limestone Group sequence is restricted to the summit ridge of the escarpment and other high ground; the peaks of Cross Fell, Little Dun Fell and Great Dun Fell are formed of these strata as are the tops of Knock Fell, Knock Ridge and Meldon Hill. Little was known of the details of this succession before the present survey during which the sequence was worked out in detail.

Palaeontology - Certain bands in the Carboniferous succession of the Nature Reserve are richly fossiliferous and detailed collecting here has proved rewarding. Fossil lists for the various bands are being compiled. Several important zonal fossils including Orionastraea, Tylonautilus, Posidonia and goniatites have been found on the Reserve during this work and the exact zonal position of the sequence is being elucidated.

Drift Deposits

For the purpose of this survey the term drift is restricted to deposits of glacial and periglacial origin - i.e. the boulder clay, solifluxion deposits and alluvium. The Geological Survey (Gt. Britain) frequently map blanket peat as drift but this deposit is here regarded as a deep organic soil and will be shown on the soil maps of the Reserve.

Boulder clay is widespread up to a height of slightly above 2000 ft. O.D. on the eastern side of the summit ridge. The presence of usually abundant striated limestone boulders serves to distinguish it from the solifluxion deposits. On the western side of the ridge boulder clay is mainly restricted to the base of the escarpment though isolated patches do occur in some of the higher valleys. One such pocket occurs in Knock Ore Gill below Green Castle at 2,200 feet O.D. and was probably formed by the last corrie-glaciation of the Pennines.

Early post-glacial solifluxion deposits are widespread throughout the Reserve. The deposits are composed of grey clay with varying amounts of sand, pebbles and sandstone boulders; limestone boulders are rare in the solifluxion deposits.

Stream alluvium occurs in small terraces along the River Tees and the major streams. Alluvial fans and boulder fans are present in some places.

Soils.

Except for the small area at the western margin of the Reserve where the Lower Palaeozoic rocks outcrop, the mineral soils of the Moor House area are derived from the underlying Carboniferous formations or from the drift deposits. The drift deposits themselves are also wholly derived from Carboniferous sediments as there is no foreign glacial material over almost all the Reserve. Illite is the dominant clay mineral in the Carboniferous sediments and forms the clay mineral fraction of the local soils. The mineral has a low exchange capacity and does not form soils of high fertility. In general the drainage of the area is poor as the stiff clay drifts are impervious; thus ill-drained gley soils are widespread throughout the region. On the gley soils thick blanket peat deposits have formed. On better drained slopes on the summit ridge and western escarpment soils of the peaty podsol group are present, and where Yoredale limestones are exposed at the surface, skeletal or thin clay loams of the brown earth soil group are developed.

The dominant soils of the region are peats (organic soils). Blanket peat covers all the ground to the east of the summit ridge up to about 2,300 feet O.D. and isolated patches of blanket peat occur up to 2,850 feet O.D.; the thickness of the deposits varies up to a maximum of 14 feet on the flat. There is much evidence in the region which indicates that peat cover once extended over the whole of the area. Several small peat filled basins are present on the Reserve.

Pre-history of the Reserve.

During the survey of the Reserve horn-sheaths of ancient cattle and Mesolithic stone implements have been found in the blanket peat deposits; these discoveries are new as nothing of this type has previously been recorded in this area. The horn-sheaths have been submitted to experts for examination but due to lack of comparable material no definite determination has yet been possible - they are tentatively referred to Bos longifrons, however.

The stone implements found on the Reserve are of two types - flint blades and chert blades. The flint blades are of Mesolithic, late Tardenoisian, type and have been found twice in association with the remains of Bos. The chert blades, which have been found at one locality only, are of poor workmanship but represent a Mesolithic type of culture. Research into the pre-historic activity on the Reserve is continuing and expert opinion is being obtained on the material found.

2. Climatological Work. F. H. W. Green.

Standard Climatological Observations.

1. At Moor House was established in 1952 an Auxiliary Climatological Station under the Meteorological Office scheme of "voluntary" observations. The station is, at 1830 feet, the highest in Britain making standard observations daily. (The term "auxiliary" is used for stations which observe only once daily.)

2. In 1955 a pressure-tube anemograph and 50' tower was provided by the Meteorological Office and erected by the Conservancy's staff. This instrument (the top of the tower is 1,950 feet above sea level) is well over twice as high as the second highest anemograph in Britain. Summaries of the records, as for the Climatological station, are published in the Monthly Weather Report. (For an earlier year, "run of wind" observations were also made with a wind counter provided by the Electrical Research Association.)

3. Observations of potential evaporation (or "evapo-transpiration") began in 1956. These are made from an apparatus installed in the paddock in front of the house, a site which is not ideal, but was the only one accessible to the house with a sufficient depth of soil.

4. Certain daily weather observations are made by the mechanics at the Radar Station on Great Dun Fell, and the Conservancy have also made some rainfall and earth temperature measurements, during summer months, at nearby sites.

5. Additional Raingauges are kept at the sites of Dr. Conway's peat catchment area experiments.

Studies

Studies have been made, or are being made, of:-

1. The general climate of the Reserve, chiefly by comparison of the observations now being kept within it and those kept in neighbouring areas.

2. Potential evaporation in relation to rainfall and run-off.

3. Earth temperature in relation to air temperatures.

Available accounts of observations and studies.

1. Standard climatological, and anemograph, records are published by the Meteorological Office in the Monthly Weather Report. The Conservancy have also duplicated Annual Summaries.

2. There exists a first draft of a general account of the climate of Moor House based on the observations to the end of 1956 (in the case of earth temperatures to mid - 1957).

3. Considerable reference is made to the Moor House climate in W. E. Richardson's Leeds University M.Sc. Thesis, "The Climate of Alston Moor", completed in 1957.

4. "Basic Research on Mountain Climates in Gfeat Britain and their relation to Ecology and Land Use" - a paper by F. H. W. Green in "Proceedings and Papers of the 6th Technical Meeting of the International Union for Conservation of Nature and Natural Resources, Edinburgh, 1956".

5. There are duplicated accounts of various aspects of the evaporation observations at various sites, which make reference to those being made at Moor House.

II. VEGETATION AND LAND-USE

3. Experiments on grassland in relation to grazing. K.J.F.Park.

a) Measurement of changes in vegetation and soil following the removal of the grazing factor.

In this series of experiments the work consists essentially of enclosing sample areas of the main grassland types and analysing the soil and vegetation at the time of enclosure and at intervals afterwards.

Sheep exclosures, each 34 x 34 metres, were erected in 1955 on the higher parts of the Reserve on Knock Fell (limestone), Little Dun Fell (sandstone) and Hard Hill (acid solifluxion clay).

In each case the vegetation at the time of enclosure was mapped on a large scale and photographed. Additionally 1,000 point quadrats were recorded from each site and representative samples of the main communities were chosen for Braun-Blanquet analyses and the preparation of permanent chart quadrats.

Soil samples collected from the upper horizons of typical profiles have been analysed for water content, ash, N, organic matter, pH, total cation exchange capacity, total exchangeable metals, total Fe and P and total and exchangeable Ca, Mg, Na and K.

Changes in the vegetation cover are expected to be comparatively slow. While a few new species may be expected to appear, and a few of the original species disappear, it is thought that the main change, for the first 10 years at least, is likely to be in the relative proportions of species present.

b) The re-establishment of natural grassland communities.

The nature of the "original" vegetation on the various types of grassland is a matter for conjecture but it is apparent that many of the present communities represent degraded types resulting from long continued exploitation including heavy sheep grazing.

In the case of limestone outcrops, their history is uncertain, but it seems likely that at least some of them may once have supported scrub with Juniperus and dwarf forms of Betula and Sorbus aucuparia. At higher altitudes trees may have been absent but certain montane and Arctic-Alpine species may have been more frequent than at present. There is evidence that any trees which may have been present on outcrops at low altitudes would be lost at an early stage of post-Roman history owing to the use of wood for lead smelting and the early introduction of sheep and cattle. Further, it seems likely that many of the Arctic-Alpines would be unable to survive heavy grazing.

In the cases of grassland areas developed on sandstone and on acid solifluxion clay the history is even more obscure: trees may have been present on some of the drift areas but it is unlikely that the climate will ever have been favourable enough to support tree growth on the sandstones which are exposed well only on the summits of the peaks.

It will be quite impossible to re-create exactly the types of communities which may have existed formerly, but it is thought that by the erection of sheep exclosures and the introduction of various species it will be possible to produce communities closely resembling natural communities.

Small exclosures have been erected on the higher parts of the Reserve on Knock Fell (limestone), Little Dun Fell (sandstone) and Hard Hill (solifluxion clay). In addition a larger exclosure has been erected on an area of limestone at 1,850 feet above sea level; this includes part of the gorge of Rough Sike.

A number of montane and Arctic-Alpine species have been introduced from Perthshire and the Lake District. The bulk of these transplants comprise species which are present in other parts of the Pennines and/or the Lake District. At the same time, a very small number of species of much greater rarity have been introduced so that their performance can be observed. In the case of Rough Sike exclosure a number of trees have been planted including alder (Alnus glutinosa), common ash (Fraxinus excelsior), birch (Betula spp.) and rowan (Sorbus aucuparia).

Samples so far obtained have been analysed and the concentrations of the different mineral nutrients determined. (By correlating these values with the run-off volumes for the catchment and the mean rainfall figures an estimate of the nett mineral loss on burning should be obtained.)

A small number of soil and crop samples have been taken from the catchment and their mineral content determined. Soil samples will be analysed after the catchment is burned. The difference in mineral potential thus estimated should tie up with the "mineral loss" appearing in the run-off after burning.

III. FAUNAL STUDIES.

9. Observations on spiders. J. M. Cherrett.

a) A preliminary investigation into the spider fauna of the reserve.

A species list for the area is in preparation, material being collected by direct searching, and incidentally, as the result of other experimental work. So far, about seventeen species have been recorded, and attempts are being made to relate these to the vegetational communities in which they occur. In future, it is hoped that this work will be greatly extended by the use of extraction apparatus, which is being designed at the moment.

b) The spinning activities of moorland spiders under natural conditions.

Three colonies of the orb-web spinning spider Meta merianae (Scopoli), have been kept under close observation since September 1957. As this species appears to be largely restricted to eroding peat edges, it has been possible to mark individual animals and webs, together with their positions. This is yielding quantitative data on these spider populations, their movements, and spinning activities, and attempts are being made to correlate the latter with climatological data obtained from the station. As yet, there is insufficient data for reaching any definite conclusions, but it is hoped that the work will be continued and extended.

c) The feeding habits of moorland spiders.

Work has just started on these investigations, and their object is to try and assess the type and amount of prey caught by certain orb and hammock-type webs during the various seasons of the year, and so give some indication of the ecological position of spiders in moorland food systems. It is planned to use web inspection, control webs, and sticky surfaces in this project, together with laboratory feeding experiments, if the problem of suitable culture methods can be solved.

10. Observations on crane-flies. J.C.Coulson.

a) A study of the species, numbers, distribution and ecology of crane-flies (Diptera; Tipulidae) was begun in 1953 and is still in progress.

b) A study of the Meadow Pipit (Anthus pratensis) with particular reference to its food and its predation on crane-flies was begun in 1953 and concluded in 1956.

7. Hydrological experiments and observations. V. M. Conway.

a) Measurement of flow-rates from catchments with different types of cover.

The main object of the work is to find out whether and in what way the run-off characteristics of a bog-covered area are altered by artificially draining the surface (by standard moor-gripping methods) or by burning the bog surface at regular intervals.

The preliminary indications are that both burning and draining have the effect of giving an earlier and a larger peak-flow after heavy rainfall as compared with the untreated bog surface. Observations over at least another year are, however, needed before this conclusion can be relied upon, even for the Moor House area. After that time it should be increasingly possible to assess the relative importance of the two factors of draining and burning in producing the observed effects on run-off.

Observations are planned for the coming year on the effects of draining or burning on the texture of peat and its permeability to water movement through it. These small-scale results should tie up with deductions made from the gross measurements of run-off. Small wells with floats have just been installed on each of the catchments and will be read weekly. This should give us a rough picture of the range of fluctuation of water-table level in the peat and hence some notion of the water-storage capacity of the peat blanket as a whole under different moisture conditions.

The data so far collected can also be used to examine the annual water-budget for the individual catchments, but at present no valid conclusions can be drawn because of the uncertainties concerning possible leakage from the catchment surface into the underlying rock, and possible errors in measuring precipitation and run-off in periods of heavy snow and frost, especially in the more distant and inaccessible catchments.

b) Flow-measurements on the Troutbeck catchment.

The large weir, designed and built on the Troutbeck by Mr. Clay for the Wear and Tees River Board, is giving data that should be related in an interesting way to those from our own small catchments. This has only been in operation since May 1957, so that we are only just starting work on such comparisons.

8. Experiments on burning. R. J. Elliott.

a) Long-term investigations on the effects of burning.

The object of this experiment is to follow the vegetational and soil fertility changes associated with different treatments.

Four blocks of heather-dominated vegetation on the southern slope of Hard Hill were burned in Spring 1954. Six plots of 30 x 30 yds. have been set up on each of the burned blocks giving a total of 24 plots. Half of the plots are fenced. 8 of the plots will be burned on a short rotation, 8 on a long rotation and the remaining 8 will not be burned at all. The plots are randomly distributed to fulfil statistical requirements.

No analyses of vegetational cover are available but this will be rectified in 1958.

b) Short-term investigations on the effects of burning on the Long Weir catchment.

The aim of this investigation is to obtain a measure of the mineral losses under field conditions when a catchment of known area is burned.

Samples of run-off water have been collected since January 1957. A parallel series of rainwater samples has been obtained. Sampling will be continued until after the catchment is burned.

The second experiment laid down so far takes the form of three pilot plots, each approximately 100' x 100', on peat 2-3' in depth at Force Burn in the east of the reserve, lying on an east-facing slope rising from 1700' to 1800'. Drains were ploughed at spacings varying from 5' to 20' apart, and fencing of the plots was completed in December 1957. Depending on the resultant growth of the trees, these plots will be extended to cover an area of up to 20 acres, mainly peat-covered, and thus provide the first introduced woodland of any extent on the reserve. Ultimately, a stand of Scots Pine is desired on the peat, but it is proposed to include a few groups of lodgepole pine (Pinus contorta), a native of Pacific Northwest America, in the scheme of planting. Under natural conditions, young trees would benefit from the shelter of the mature trees from which they originated, and, in the climate of these altitudes, it is essential that this shelter be replaced as far as is possible to ensure the best development of the young trees. Lodgepole pine has proved to be faster-growing than Scots pine on similar exposed peat areas elsewhere in Britain, and therefore will be used at Force Burn to provide shelter for the young Scots pine, being gradually removed after the Scots pine has become properly established.

Woodland can be expected to attain its highest altitude in the valleys, where maximum shelter from the wind is obtained, and, in order to form an estimate of this altitude, it is proposed to establish a series of small plots ascending one of the valleys to the summit ridge. Each plot will contain a group of at least 25 trees of birch (Betula pubescens), the species commonly found at the higher altitudes in Britain. In order to facilitate comparison of tree growth at the different levels, the sites for the plots will be selected so as to be as similar as possible with regard to soil, aspect and exposure relative to the surrounding topography.

During the short period in which trees have been growing at Green Hole, the greatest damage has been caused by animals. Shortly after the fence was completed, a sheep and then a rabbit entered the enclosure and caused extensive damage among the few trees which had been planted. This was remedied by improving the fence. Field voles (Microtus agrestis) damage trees every year by gnawing the bark near the base of the stem, but never to such an extent as to cause the death of a tree, and there are only rare instances where the vigour of the damaged tree has apparently been impaired to any appreciable extent. Although no outbreaks of serious damage have occurred, attempts have been made to keep the vole population down to a non-injurious level by intensive trapping and spraying the vegetation with toxaphene emulsion. Water voles (Arvicola amphibius) causeddamage in late summer 1957 by completely biting off stems near the ground. Intensive trapping was carried out and no further damage occurred. It is of interest to note that all these animals attacked rowan almost to the complete exclusion of the other species planted.

The commonest type of climatic damage has been caused by low temperatures, particularly obvious in the case of rowan, and is characterised by the current year's shoot being killed partly or wholly back during the first winter after planting, but rarely in the second winter. Damage by snow occurred during the winter of 1954-5 but only to a small number of trees which had been buried in snowdrifts, and the trees were more commonly bent than broken.

The number of deaths caused by these animal and climatic agents has been negligible, and damaged trees have shown good powers of recovery on the whole.

It will be many years before any definite conclusions can be drawn from the experiments. If the trees manage to grow into close canopy, some of the objects of the experiments will have been achieved and the others will be within realisation, for it is then that the trees will be exerting their greatest influence on the soil and vegetation, and providing the maximum mutual shelter from the climate. The results obtained so far from the first trial plot at Green Hole are encouraging. Actual deaths have been few and those trees which have been damaged have recovered to a greater or lesser extent. In general, it can be said that the experiment is successful in so far as the trees are growing and with a vigour which appears to increase every year.

6. Experiments on the establishment of high altitude woodland

A. Millar.

The reserve is typical of upland Britain generally in that, except for a few scattered trees of rowan (Sorbus aucuparia), juniper (Juniperus communis), and hazel (Corylus avellana) growing in the lower parts of the main stream valleys in the west of the reserve, trees are absent. Tree remains in the peat, which covers much of the area of the reserve, indicate that post-glacial woodland, composed mainly of birch (Betula sp.), grew to at least 2,400 ft. on the eastern side of the summit ridge in the west of the reserve. There are several probable factors which contributed to the disappearance of this woodland. First, some 8,000 years ago, climatic change caused blanket bog to develop over much of the earlier woodland. Later there arose the demand for fuel for mining operations which have been carried out since post-Roman times at least, and in the most recent centuries there has been heavy grazing, especially by sheep.

The primary objects of these experiments are to determine if, in fact, tree cover can be re-established on the better-drained slopes of the reserve, and to determine the altitudinal tree limit as set by the climate. In addition, by systematically following the development of the trees and woodland and the changes in soil and vegetation, it will be possible to determine the effect of climate and the various habitats on the trees, the effect of the trees on soil and vegetation, and the productivity of woodland on the area.

The general principle in all the experiments is to plant those species which are most capable of withstanding the severe climatic conditions of the area, which compare closely with those at sea level in Southern Iceland, and when these have grown sufficiently to provide the necessary shelter, groups of less hardy species will be introduced into gaps cut in the shelterwood. The trees are planted on a group system, each group consisting of 25 trees planted approximately 2 ft. apart and the centres of the groups being approximately 20 feet apart. One particularly relevant advantage of such a planting pattern is that it produces a very windfirm stand. The methods of planting vary according to the nature of the soil, planting in pits being employed wherever there is mineral soil of sufficient depth and notch-planting where it is too shallow, whilst turf-planting combined with phosphatic fertiliser is employed on the deeper peats in accordance with modern forestry practice. Draining is carried out where required.

Green Hole, the site selected for the first trial plot, lies at an elevation of c. 1,900 feet and is a small narrow valley, running NW-SE, surrounded by blanket peat. The area enclosed, 1.6 acres, includes some of this peat which forms an upper rim round the valley, falling away to redistributed peat dominated by Juncus squarrosus and Deschampsia flexuosa, and limestone grassland in the centre where the underlying limestone has been exposed. In the south-east extremity of the enclosure there is a bluff of shaly clay, bare for the most part but with Calluna in patches. A stream, Dodgen Pot, finds its outlet here after running underground for the greater part of its length down Green Hole. The principal aspect is easterly, but all aspects are provided by the topography of the site, which is relatively well sheltered and is, in fact, a pronounced frost hollow. This site is almost ideal for a first trial plot in that a variety of habitats are present, from very fertile modified drift over limestone to deep peat of low fertility, in combination with a relatively high degree of shelter from the prevailing high westerly winds, which are almost certainly the main factor determining the altitudinal tree limit. If trees cannot grow successfully under the most advantageous conditions possible at Green Hole, then it is extremely unlikely that they will be capable of growing successfully anywhere on the higher ground of the reserve.

Work was begun in September 1953 with the erection of a fence to exclude grazing, and planting was completed in April 1957, by which time a total of over 5,000 trees had been introduced. In accordance with the general principles and methods outlined above, a mixture of rowan (Sorbus aucuparia), birch (Betula alba), and Scots pine (Pinus sylvestris) was planted, and, in addition, a small number of the less hardy species, ash (Fraxinus excelsior), alder (Alnus glutinosa), and cherry (Prunus padus), was introduced into small areas which appeared to be particularly favourable. Soil analyses and vegetation records have been made.

5. Experiments on peat productivity and nutrient levels.

A. J. P. Gore.

a) A comparison of the response of two moorland plant species, Molinia caerulea and Eriophorum vaginatum to added calcium and phosphate.

It is desired to further the understanding of blanket peat fertility (or infertility), to define more precisely what the term fertility in this context means, and what are the limits to growth in existing species and in introduced species. The initial hypothesis was that in peat the prime nutritional limits to plant growth were low pH and low phosphate; these were suggested by other work on this subject. Increased pH could have multiple effects, the most important of which is that of making plant nutrients more easily available. Increased phosphate could also have multiple effects but mainly one in its own right as a plant nutrient.

Eriophorum vaginatum was selected as a local species. Molinia caerulea was selected as an introduced species. They were laid out in plots to receive combinations of "no treatment", calcium as $CaCO_3$, phosphate, at two levels as $NaH_2PO_4.2H_2O$. The whole experiment was replicated three times within a sheep-proof enclosure on deep peat.

The data being collected include dry weight production per annum, total nitrogen, total phosphate, total potassium and total ash of annual growth. Three separate harvests are being made in any one year to help to eliminate differences in developmental cycles of the species. At this early stage we need to know the best criteria for optimal growth since this is vital to the assessment of a specific reaction by a certain plant species to existing or experimentally changed nutrient conditions.

b) Reclamation of heavily eroded peat on Moss Flats.

There is much eroded peat in the high Pennines and many acres of such land on the Moor House Reserve. In 1957 a preliminary attempt to reclaim, that is, to recolonize with vegetation, was made on a small area at Moss Flats. The peat was roughly levelled, temporarily enclosed against sheep using light but effective fencing, treated with lime and basic slag at (i) low level, (ii) high level, and (iii) no treatment, and then sown to a mixture of grasses and clover.

There has been an excellent take of Dactylis glomerata at both levels of fertilizer treatment. No germination occurred in the absence of raised pH. The effect of the winter frosts on the new plants will be watched with interest since the prime object of the experiment is to stabilize the surface and to extend vegetational cover. Further lines of work will include measuring the minimum requirements of levelling and fertilizing necessary to obtain a pioneer vegetational cover.

c) House Hill trials of grass species and clover trials on (i) drift denuded of peat and (ii) similar drift material mechanically mixed with the lower 2" - 3" of peat.

If the peat were removed from large areas now so covered how could the underlying material be improved and raised to a grassland status rather than deteriorating to secondary peat development?

Two plots were laid out in 1957. One had a sandstone drift surface fully exposed without peat and the other had some 2" or 3" of original peat mixed into the drift material to form a "soil". Six species, Agrostis tenuis, Anthoxanthum odoratum, Deschampsia flexuosa, Festuca rubra, Poa pratensis, and Trifolium repens, each in 1 sq. metre plots, were treated in blocks containing all six, with calcium, phosphate, calcium plus phosphate and no treatment (Calcium as $CaCO_3$ at 250 gms. per sq. metre; phosphate as $Ca(H_2PO_4)_2.2H_2O$ at 40 gms. per sq. metre).

Photographic records only are being collected. One photograph is taken per year per plot irrespective of the result. So far it is clear that germination and establishment depend in all cases, with the possible exception of D. flexuosa, on lime application and presumably therefore on raised pH.

II. VEGETATION AND LAND-USE

3. Experiments on grassland in relation to grazing. K.J.F.Park.

a) Measurement of changes in vegetation and soil following the removal of the grazing factor.

In this series of experiments the work consists essentially of enclosing sample areas of the main grassland types and analysing the soil and vegetation at the time of enclosure and at intervals afterwards.

Sheep exclosures, each 34 x 34 metres, were erected in 1955 on the higher parts of the Reserve on Knock Fell (limestone), Little Dun Fell (sandstone) and Hard Hill (acid solifluxion clay).

In each case the vegetation at the time of enclosure was mapped on a large scale and photographed. Additionally 1,000 point quadrats were recorded from each site and representative samples of the main communities were chosen for Braun-Blanquet analyses and the preparation of permanent chart quadrats.

Soil samples collected from the upper horizons of typical profiles have been analysed for water content, ash, N, organic matter, pH, total cation exchange capacity, total exchangeable metals, total Fe and P and total and exchangeable Ca, Mg, Na and K.

Changes in the vegetation cover are expected to be comparatively slow. While a few new species may be expected to appear, and a few of the original species disappear, it is thought that the main change, for the first 10 years at least, is likely to be in the relative proportions of species present.

b) The re-establishment of natural grassland communities.

The nature of the "original" vegetation on the various types of grassland is a matter for conjecture but it is apparent that many of the present communities represent degraded types resulting from long continued exploitation including heavy sheep grazing.

In the case of limestone outcrops, their history is uncertain, but it seems likely that at least some of them may once have supported scrub with Juniperus and dwarf forms of Betula and Sorbus aucuparia. At higher altitudes trees may have been absent but certain montane and Arctic-Alpine species may have been more frequent than at present. There is evidence that any trees which may have been present on outcrops at low altitudes would be lost at an early stage of post-Roman history owing to the use of wood for lead smelting and the early introduction of sheep and cattle. Further, it seems likely that many of the Arctic-Alpines would be unable to survive heavy grazing.

In the cases of grassland areas developed on sandstone and on acid solifluxion clay the history is even more obscure: trees may have been present on some of the drift areas but it is unlikely that the climate will ever have been favourable enough to support tree growth on the sandstones which are exposed well only on the summits of the peaks.

It will be quite impossible to re-create exactly the types of communities which may have existed formerly, but it is thought that by the erection of sheep exclosures and the introduction of various species it will be possible to produce communities closely resembling natural communities.

Small exclosures have been erected on the higher parts of the Reserve on Knock Fell (limestone), Little Dun Fell (sandstone) and Hard Hill (solifluxion clay). In addition a larger exclosure has been erected on an area of limestone at 1,850 feet above sea level; this includes part of the gorge of Rough Sike.

A number of montane and Arctic-Alpine species have been introduced from Perthshire and the Lake District. The bulk of these transplants comprise species which are present in other parts of the Pennines and/or the Lake District. At the same time, a very small number of species of much greater rarity have been introduced so that their performance can be observed. In the case of Rough Sike exclosure a number of trees have been planted including alder (Alnus glutinosa), common ash (Fraxinus excelsior), birch (Betula spp.) and rowan (Sorbus aucuparia).

11. Investigations of the Biology of Protozoa. O. W. Heal.

The work which has so far been carried out has been on the distribution of Testacea (Thecamoebae) in the Sphagnum of Valley Bog, Moor House, with the aim of learning something of factors which affect their distribution. This work can be divided into two parts.

(a) A comparison of the testate fauna of the stages in the "regeneration complex" of the actively growing bog, simply by noting the species present and their relative abundance in squeezings from the Sphagnum.

(b) A detailed study of the vertical distribution of Testacea in Sphagnum recurvum. The testates were extracted by washing and centrifuging and then counted in a cell of known volume.

The results of the first section of the work show that the stages in the regeneration succession have distinct testate faunas. In this, the Genus Difflugia, represented by 6 (possibly 7) species, is confined almost completely to the pools and this is true also of the largest species of Nebella present - N. carinata. Other species, e.g. N. militraris and Acsulina muscorum show affinities to the drier parts of the succession. The pools on the bog are dominated by S. cuspidatum or S. subsecundum and, in certain features, the testate faunas of the two types of pool are very different.

Another feature of the succession is the dominance of the large species in the wet areas, while in the drier areas, small species are dominant.

In the second part of the investigation, it is indicated that some species of Testacea are strongly associated with a given region of the Sphagnum plant, e.g. Amphitrema flavum and Hyalospheria papilio are found mainly in the 'heads' of the plant of S. recurvum.

It is hoped that further work will indicate some of the factors which affect the general and vertical distributions of Testacea and also improve our knowledge of the feeding habits of these animals.

12. Studies of moorland Enchytraeidae (with particular reference to population density, biomass and spatial distribution).

J. E. Peachey.

The Enchytraeidae, a family of small Oligochaete worms, are particularly common in organic soils. The work initially involved the comparison of soil extraction methods throughout the year 1956-7 and population surveys on selected sites. Special micro-distribution maps were constructed to give information on spatial distribution.

Representative peak populations and biomass figures:

Sample Site	Population/m^2	Live wt.gms/m^2
Juncus squarrosus dominant (1956, 1957)	250,000-300,000	50
Nardus grassland (1956)	100,000	20
Alluvial grassland (1956)	30,000	16
Bare peat (Moss Flats) (1956)	50,000	10

The worms were generally distributed in the top 2-3 cm. of the soil profile, although they moved deeper in very dry or cold conditions, and mortality occurred at these times. Peak densities were recorded in late summer and autumn. The animals were highly aggregated in all sites. Attention is drawn to the ecological importance of Enchytraeids.

13. The effect of current speed on the distribution of the larvae of the blackflies, Similium variegatum, Mg., and Simulium monticola, Friederichs. (Diptera). J. Phillipson.

Material for laboratory experiments in 1955 and 1956 was obtained from Cross Gill, a tributary of the South Tyne, near Alston, Cumberland. In 1955 laboratory experiments were carried out at the Moor House Field Station and in 1956 at the Science Laboratories, Durham.

Field experiments were conducted in Cross Gill and in Troutbeck, a tributary of the Tees on the reserve.

The studies show that both Simulium variegatum and S. monticola occur in velocities of 0.5 - 2.5 m./sec. but aggregate in the velocity range 1.0 - 2.0 m./sec.

The velocity range that different Simulium species can withstand indicates that current speed plays an important part in governing the distribution of blackfly larvae, and perhaps isolating different species along water courses.

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14. A population study on Coleophora alticolella (Zell). Lepid.
R. C. Reay.

C. alticolella is the rush moth and on the study area (parts of the reserve and the neighb uring moorland) feeds almost exclusively on the ripening seeds of the rush Juncus squarrosus.

The work has thus involved making the following groups of observations:

a) On Coleophora.

(i) Number of adults per unit area emerging in the spring. A measure of over-wintering mortality can be obtained by combining the estimate of the spring population with the estimate of larval numbers made by my predecessor, A. M. Jordan. This involves the use of emergence traps and the figures obtained are not very satisfactory.

(ii) Number of eggs per stem of J. squarrosus. This gives an estimate of fecundity. Egg biomass has also been measured.

(iii) Number of larvae per stem. By subtracting maximum larva numbers from maximum egg numbers a further estimate of mortality can be obtained.

b) On Juncus.

(i) Number of flowering or fruiting stems per unit area; this is found by using a quadrat frame of known area. This datum is the starting point for calculating all other units per unit area, an essential in a population study.

(ii) Number of developing florets per stem, taken early in the season; this is an estimate of the potential number of seed capsules.

(iii) Number of ripe seed capsules gives the actual measure of food production and is tied up with weighings of the amount of seeds produced by these capsules.

(iv) Number of damaged capsules per stem: this is a direct measure of Coleophora activity and can be correlated with the above and with larval weighings to give an estimate of the productivity of the seeds.

c) On Parasites.

(i) Number of parasites per stem - this is a direct measure of a specific mortality cause.

(ii) Species involved - only hymenopterous parasites have been recorded and of these, 4 species were found by A. M. Jordan, and 2 further ones by myself. All are new to Coleophora alticolella.

These data have been collected since 1955, enabling a year-to-year comparison to be made. As well as this estimate, figures have been collected from various altitudes within Coleophora's range, from both the East and West-facing pennine slopes.

15. Ecological investigations of the beetles of the genus Aphodius.
E. White.

The work was carried out between 1954 and 1956. The biology of several species of Aphodius was studied in some detail, which enabled the author to discover some of the factors which separated ecologically these closely related species.

Attempts were made to assess the place of Aphodius beetles in the utilisation of sheep dung. With this end in view observations were also made on dung-inhabiting dipterous flies and lumbricid worms.

Sixteen species of Aphodius were found at Moor House. Egg-laying behaviour, larval feeding habits, and the site of pupation were described for several species, and information was given for the length of some of the immature stages. There was one generation per year in all species, with the possible exception of A. tenellus. Most of the species overwintered in the adult stage, but A. rufipes spent this time as a prepupa, and A. fimetarius and A. contaminatus overwinter partially as eggs.

Although these closely related species of Aphodius were living in a similar habitat, namely dung, many differences were found in their biology which separated them ecologically. The seasonal succession in the adult stage was particularly effective in this respect, never more than four species being common at the same time.

Adult beetles were more common in dung during the first half of the summer. A study of the relative abundance of species at Moor House showed that A. lapponum comprised 50% of the animals taken. A. ater comprised 25% of the adults caught.

Sheep dung as a habitat for Aphodius beetles was studied in some detail. The form and condition was observed throughout 1956, and the effect of age, size, type, and density, was examined in relation to the beetles. Adult beetles began to leave sheep dung after several days, so that dung 'more than one week old' contained fewer beetles than that which was 'less than one week old'. On average larger droppings contained more beetles, and 'compact' droppings were more suitable for beetles than 'pellet-form' droppings. At the beginning of the season more beetles per dropping were found where dung density was low.

The removal of sheep dung by physical and biotic agents was examined on three vegetational types, grassland, Juncus squarrosus and Calluna-Eriophoretum. Dung remained recognisable longest on Calluna and Eriophorum, and disappeared most rapidly on the grassland. Weathering by the physical elements was more intensive on grassland than on the other areas which had taller vegetation. Biotic agents in the form of lumbricid worms were most active on grassland. Worms were also found more often on J. squarrosus areas than on Calluna and Eriophorum where they were uncommon. Dipterous fly larvae and Aphodius were the other major dung removers. These two groups of animals were not restricted in their activities by the soil type as were the worms. Infestation of dung was similar on all three vegetational types when Aphodius was considered; on average 18% of all droppings were attacked by beetles. Infestation by diptera was more intensive than this. It was concluded that lumbricid worms were the most important organisms removing dung, dipterous larvae came next, and beetles third.

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NOTE: The work carried out by the staff and research students of the Department of Zoology, Durham Colleges, University of Durham, has been carried out in consultation with, or under the direction of, Professor J. B. Cragg, head of the Department.

OTHER WORK NOT DESCRIBED IN THE REPORT

The fore-going account has dealt only with full-time or long-term researches at present in progress or recently completed. Four other research projects were carried out in the first years of the field station by research students or research assistants from the Department of Zoology, Durham Colleges. These were concerned with:-

Plecoptera: V. M. Brown.
Earthworms: J. A. Svendsen.
Coleophora casspititiella: A. M. Jordan.
Collembola and associated microfauna: D. H. Murphy.

Many small experiments, short investigations, descriptions of vegetation, surveys of animal groups and so on, are recorded in the Reserve Record book, copies of which are kept at the field station, at Merlewood, and at the Conservancy's London Headquarters. It has not been considered worth while to deal in this report with such items which, though they are greatly valued, are impossible to summarise because they are so many and so diverse.