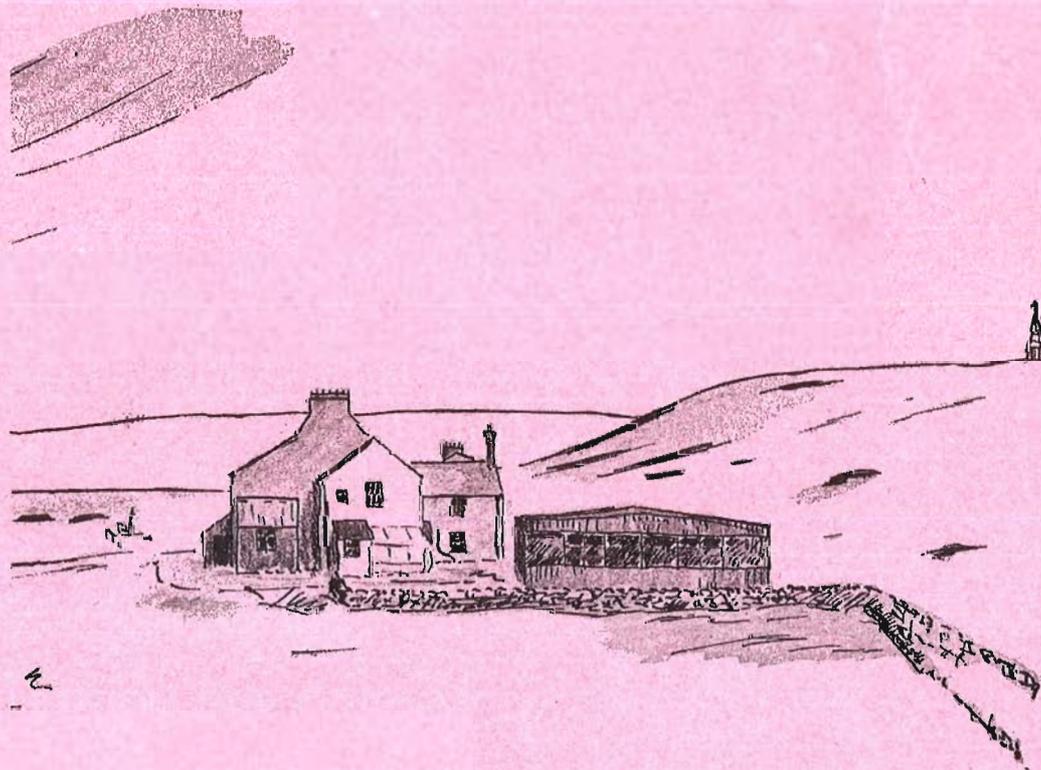


Aspects of the Ecology of The Northern Pennines

Occasional Papers

No. 8



MOOR HOUSE

"Aspects of the Ecology of the northern Pennines" is a series of informal review and discussion papers for the reader with a general interest in the subject. They are not official publications of the Nature Conservancy Council and do not necessarily reflect the Council's official views.

I regret there has been a delay in producing the vegetation map (Fig 1).
When available a map will be sent to accompany your copy.

Aspects of the Ecology of the northern Pennines

8. The botany of Moor House

by

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Introduction

Since 1954, the Reserve has received a wide range of botanical attention. The knowledge gained is being applied to aspects of moorland management. The vegetation of the whole Reserve has been mapped (Fig 1) and described, species lists have been published, and a herbarium containing most of the flowering plants, mosses, liverworts and lichens has been built up.

Regular recording of the botanical composition of a dozen sites, which cover seven different vegetation types, with treatments of burning, draining and grazing, as well as grazing removal, is one of the main features of the Field Station's programme of work. There are therefore a number of botanical descriptions in publications which are concerned primarily with sheep grazing and productivity. Between 1960 and 1970 research emphasis was focussed on production ecology. After 1966, this effort was increased under the auspices of the International Biological Programme, within which Moor House was the main United Kingdom moorland site for the measurement of terrestrial production. It is not intended to detail the productivity results, although some will be mentioned, as there are a number of publications available on the subject.

The Reserve is commonly divided for description into three areas, based on elevation and topography, the 671 m (2200 ft.) contour being the divisor. The western area includes the steep scarp slope of the Pennines with a wide range of habitats, but primarily poor grassland, with much Juncus squarrosus (moor rush) and Nardus stricta (white bent). The central area, consists of the highest ground, the summits and ridges that form the watershed of the River Eden on the west and the River Tees on the east. Sub-alpine grasslands, dominated by Festuca ovina (sheep's fescue) are common, but there is also much blanket bog. The eastern plateau is the upper catchment of the River Tees, to which the ground gently slopes. It is almost completely vegetated by Calluna vulgaris (heather), Eriophorum vaginatum (cotton grass) and Sphagnum moss, but is widely dissected by streams and erosion channels.

This account deals first briefly with the vegetational history of the area, then the main vegetation types are described and some of the physiological, ecological and productivity studies that have been made are mentioned.

The description of vegetation types and plant associations follows the arrangement of plant communities in the phytosociological description of the Reserve by Eddy, Welch & Rawes (1969). This method is comparable to the system used by McVean and Ratcliffe (1962) in the Scottish Highlands. Table 1 gives details, and the extent to which the types are present on the Reserve, whilst Fig. 1 is a simplified version of the vegetation map of the Reserve.

Vegetational history

The valley glaciation of the Pennines during late glacial times left evidence of erosive activity in the morainic drift deposits at several places on the Reserve. This glacial period was followed by a long interval during which solifluction was very active, and unconsolidated glacial deposits were much eroded. Little evidence of the presence of plants in Upper Teesdale at this time has been found, but little peat in which they might have been preserved was formed then. Samples from the early post-glacial period around 8000 B.C., showed pollen of Betula nana (dwarf birch), Juniperus (juniper) and Salix (willow) species with some 30 herbaceous plants.

Between 6800 - 6000 B.C. alder was common lower down the Tees valley (pollen is recorded from Valley Bog for this time), whilst pine was well established in parts of the region and hazel was common on limestone. Oak and elm pollen has been recorded from Valley Bog, but whether these trees were growing locally is not clear; wood remains have not been found. Around 3000 B.C. the tree cover was probably at its maximum. Oak and alder started to replace pine when peat formed again, hazel and birch were common, but the woodland was open with small lakes in the hollows and bogs forming in wet depressions. Fen peat grew in such places in the late Boreal period (5000 B.C.) and Phragmites (Reed), the remains of which have been found up to 686 m O.D. was abundant over a large part of Hard Rigg. Phragmites-Menyanthes (bog bean)-Betula (birch) remains have been recorded on Shaft Hill, and small lakes, such as Valley Bog, were filled with aquatic reedswamp and fen vegetation. In Valley Bog, the fen became acid during the warm and wet Atlantic (c.4000 B.C.), Sphagnum subsecundum being displaced by S. acutifolium, but Carex curta (white sedge) and Paludella squarrosa were found in the Sub-Boreal (1000 B.C.) indicating a temporary return to more flushed conditions in this warm and dry period; a following cold and wet climate resulted in the Carex spp. being superseded by Sphagnum, Calluna and Eriophorum. At higher altitudes the vegetation was always more open and sedges, grasses, Empetrum nigrum (crowberry), Filicales and Selaginella (clubmosses) were common.

With increasing wetness the spread and depth of blanket peat increased to cover most of the area. Calluna, Eriophorum and Sphagnum became the dominants and trees died in the waterlogged conditions. Since then bog growth has stopped from time to time. In some places this is shown by the occurrence of thick layers of the moss Rhacomitrium lanuginosum in the peat stratigraphy. Otherwise an examination of the peat indicates that there has been little change in the plant composition over the past 2000 years. On the better drained limestone soils where the remaining trees were eventually destroyed by deer and sheep grazing, and by man, grassland developed and the landscape of the whole took on the form we see today.

Present day vegetation

1. Blanket bog:

a) Description

Ombrogenous peat, that is peat that does not receive nutrients from the bedrock but is entirely dependent on rainwater, covers 50% of the Reserve in a blanket of peat one to four metres in depth. Erosion, which probably started 2000 years ago, has removed much peat and this continues to the present day. Different types of erosion can be identified and

Table 1 The extent of the map units in hectares on three parts of the Moor House National Nature Reserve. These are the western escarpment below 671 m (W), the central ridge above 671 m (C), and the eastern plateau below 671 m (E). (From Eddy, Welch & Rawes, 1969).

Map Unit	W	C	E	Total
<u>Calluneto-Eriophoretum</u>	0	63	1106	1169
Burnt areas	0	0	31	31
<u>Trichophoro-Eriophoretum</u>	0	0	15	15
<u>Eriophoretum</u>	72	218	129	419
Eroding bog	2	104	217	323
Recolonised peat-complexes and peat-edge vegetation	8	46	196	250
TOTAL for blanket bog	<u>82</u>	<u>431</u>	<u>1694</u>	<u>2207</u>
<u>Sphagneto-Juncetum effusi</u>	15	10	47	72
<u>Carex rostrata facies</u>	0	0	3	3
<u>Sphagneto-Caricetum alpinum</u>	1	30	2	33
Calcareous springs and flushes	2	9	3	14
TOTAL for poor fens & flushes	<u>18</u>	<u>49</u>	<u>55</u>	<u>122</u>
<u>Species poor Juncetum squarrosi sub-alpinum</u>	121	239	17	377
<u>Species-poor Nardetum sub-alpinum</u>	191	154	71	416
mixed with <u>Juncetum squarrosi</u>	44	48	12	104
mixed with <u>Festucetum</u>	5	0	11	16
mixed with both above	15	64	0	79
<u>Festucetum</u>	35	144	1	180
mixed with <u>Juncetum squarrosi</u>	0	3	0	3
<u>Agrost-Festucetum</u> a) alluvial	3	0	22	25
b) limestone	82	28	15	125
Sandstone scree	79	8	0	87
Shingle	0	0	2	2
Made ground	6	19	10	35
<u>Pteridietum</u>	34	0	0	34
Flushed gleys	15	6	9	30
TOTAL for grassland and dry-ground vegetation	<u>630</u>	<u>713</u>	<u>170</u>	<u>1513</u>
TOTAL AREA OF THE PARTS AND THE WHOLE OF THE RESERVE	<u>730</u>	<u>1193</u>	<u>1919</u>	<u>3842</u>

different stages in the diverse processes of recolonisation can be observed. Eddy et al recognised (Table 1) a number of vegetations, or mapping units, and associated human influences with the more recent development of the present associations and their facies. A facies is defined as vegetation in which there is a clear discontinuity in the botanical variation within a unit; it may be where a change in dominance is recognised, as when Eriophorum vaginatum becomes the sole dominant after burning blanket bog.

The most extensive association of the blanket bog is Calluneto-Eriophoretum in which Calluna vulgaris and Eriophorum are co-dominant, E. angustifolium (cotton grass), Empetrum nigrum and Rubus chamaemorus (cloudberry) frequent, and Sphagna, usually S. rubellum, and other bryophytes such as Aulacomnium palustre and Pleurozium schreberi are always present. Besides the typical vegetation there are burnt facies and Sphagnum recurvum facies. The successional stages that follow burning are constant in one factor, the dominance of Eriophorum vaginatum, and this continues for at least the first eight years. There are few rarities in either the typicum or the facies.

Trichophoro-Eriophoretum occurs on wetter and deeper peat than Calluneto-Eriophoretum, and is typically found as a hummock-hollow community. It is not extensive on the Reserve and is confined to the flatter and lower (below 600 m) ground. Sphagnum subsecundum ssp. auriculatum, S. cuspidatum and S. palliosum are predominant and Erica tetralix (cross-leaved heath), Narthecium ossifragum (bog asphodel) and Drosera rotundifolia (sundew) are characteristic species. Among the rarer species found are Carex paupercula, Sphagnum imbricatum and S. fuscum. Where this vegetation occurs in Scotland Myrica gale (bog myrtle) and Molinia caerulea (purple moor grass) are always found, but although the latter has been found to grow experimentally, neither species occur naturally on the Reserve with the exception of a few plants of Molinia.

The Eriophoretum is divided into high-level, Juncus squarrosus and grazed facies, but in all cases it is generally poor in species and presents a habitat of degraded appearance, often with little Sphagnum cover and much bare peat.

It is extensive on the western escarpment and summit areas. Although considered to be derived from Calluneto-Eriophoretum, Calluna is usually absent, or has only little cover, as in the Juncus squarrosus facies. Empetrum is frequent, especially on some of the higher ground, and takes the place of Calluna which is less able to withstand late frosts. Vaccinium myrtillus (bilberry) and Sphagnum capillaceum are common in the drier vegetation. The grazed facies contain Deschampsia flexuosa (wavy-hair grass), Festuca ovina and Juncus squarrosus, and the possibility is that where grazing pressure is maintained at present rates, the latter plant will eventually become dominant.

Peat remains have been examined at a number of sites and the pollen deposits analysed. In general, a basal forest layer, composed almost entirely of easily recognisable birch remains, is found, lying either immediately above the mineral substrate, normally glacial drift, or within 10 cms of it. The wood layer itself varies in thickness, but is commonly 20 cm deep with individual tree stems 5 - 12 cms thick. This forest stratum is followed by a layer, also of variable depth, composed mainly of the remains of Eriophorum spp., Carex spp., Calluna

and Sphagna spp. The Sphagna may or may not be conspicuously present but Eriophorum vaginatum is always apparent, the bases of the shoots being preserved as recognisable fibrous clumps. Calluna may occur scattered throughout the whole layer, which is compact, well humified and sticky. Often this is immediately overlain by the present day vegetation, but on occasion there is a rich Sphagnum peat, usually little humified and characteristically reddish-yellow. Other distinct layers can be found, eg. Polytrichum commune, up to 10 cm in thickness, may occur between the forest layers and sometimes towards the top of the profile.

About 10% of the blanket peat is eroded, usually into gulleys, but on occasion, areas extending to 100 and more square metres are completely denuded of vegetation. Blanket bog erosion is brought about by water and by mass movement. A recent case of mass movement, when about 835 tons (dry weight) of peat slid down Meldon Hill, occurred in 1963. But the most important erosion is dissection due to water movement. Climate is thought to be the prime causative factor in initiating erosion, and physical attributes, such as slope, are considered more important than biotic activities such as sheep grazing.

Recolonisation of eroded areas is variable, depending largely on the degree of wetness. Bog species colonise the wetter habitats, whilst grassland with Festuca ovina, Deschampsia flexuosa, Nardus stricta and Juncus squarrosus may develop in the drier situations.

b) Ecological studies

Analyses have shown that the blanket bog is very deficient in plant nutrients and that the rain input is an important source of nutrients. Nutritional factors may be the cause of the marked restriction in species number on the bog, but hydrological and climatic factors are also important. The role of these factors in limiting diversity and plant growth is being investigated.

Comparisons in the growth of Eriophorum vaginatum and Molinia caerulea have been made. Under waterlogging the yield and root penetration of Eriophorum was greater than that of Molinia. The addition of nutrients increased the yield of both species. However, neither phosphate nor calcium carbonate have been found to be important in limiting growth of these two species on blanket peat.

In transplant experiments, at Moor House and sea level, growth of a common stock of Molinia was compared. Under these different climatic conditions the initial relative growth rates were found, under varying nutrient treatments, to be similar. However, later in the season a sharp fall occurred, but at Moor House only. Production was greater at sea level where flowering occurred about five weeks earlier. Under similar treatments with nitrogen and phosphate, the dry weight of basal stems and roots at sea level was about 100g/m² more at each of the seven harvests taken in the year.

In order to study blanket bog and especially the reaction of Calluna at higher altitudes, two exclosures have been erected at 700 m O.D. One is on the west scarp and the other at the head of Trout Beck. In both cases the present ericaceous cover is mainly composed of Empetrum nigrum, but changes in composition are slowly occurring after 8 years. At a lower altitude an experiment to show the effects of different burning regimes began in 1954. The short rotation plots were reburnt in 1965 and again with the long term plots in 1975. Botanical analyses are made both in this

experiment and where burning has been done elsewhere on the Reserve, but the results, which are related to grazing by grouse and sheep, need to be collected over a long period to be meaningful.

The effect of the present day sheep grazing regime on Calluneto-Eriophoretum is seen to be small, but the habitat is fragile and susceptible to minimal interference. However, the greater part of the fell dominated by this vegetation gives an appearance of stability and more closely approximates to a climax than much of the other vegetation. This has been shown by the small effect which preventing sheep grazing for 20 years has had on botanical composition.

Rubus chamaemorus, a characteristic but now less common species of Pennine blanket bog, has been the subject of an ecological study. Flowering, fruiting, germination and the distribution of this dioecious plant have been investigated in the absence of grazing and after burning, as well as under grazing. Factors influencing growth and the mineral nutrient content of the plant were measured to determine the effect of sheep grazing and rotational burning. Where grazing was prevented, and in the absence of recent burning, the above ground standing crop (yield) was five times greater than the equivalent grazed treatment. Where the vegetation was burnt in the traditional manner, but without sheep grazing yield was ten times greater than in the unburnt and grazed treatments. Fruits were produced on plants in the fenced area but not in the grazed plots.

Trials to encourage bog growth on eroded areas by retarding run-off with low dams and by transplanting Eriophorum vaginatum have been made with some success, but the extent to which this can be carried out is small. More promising has been the seeding of bare peat with Deschampsia flexuosa and a minimum of fertiliser. Nitrogen is an essential requirement whilst fencing to exclude sheep at least initially. The main difficulty however, is an adequate seed source of Deschampsia flexuosa.

Physiological studies of Calluna have included measurements of photosynthesis and the way in which photosynthate is distributed in the plant. In June the emphasis is on shoot production, in July - August this slows down and most of the wood increment is formed, whilst in September a second flush of shoot growth occurs. The poorly developed root system of Calluna in the bog situation is probably responsible for stomatal closure at mid-day, the supply of water being insufficient to compensate for moisture loss in transpiration. This must affect productivity.

c) Studies on productivity

Attempts have been made to quantify energy cycling in Calluneto-Eriophoretum applying energy contents to biomass and using data on production, standing crop and decomposition from a variety of sources.

A range of production values are given in published papers and the Reserve Record for different sites as well as after burning, grazing and draining. An average community production has been quoted at 635 g/m²/year from a summer biomass (yield) of 2450 g/m². Both production and yield are considerably higher than for most types of moorland vegetation.

Some workers consider blanket bog to be in a steady state, the mortality rate of both mature Calluna plants and Eriophorum tussocks being constant with time. Two major factors are responsible for maintaining a steady state in Calluna, losses by desiccation under certain winter weather conditions and blockage of older stems by heartwood. Total annual input to Calluna of 351 g/m^2 was balanced by an output of 108 g/m^2 to litter, 60 g/m^2 to standing dead and 183 g/m^2 to below-ground dead. The most productive part of the Calluna population, which had a mean age of 11.5 years, was found to be in the age range 12-20 years. Of the total Eriophorum production of $22 \text{ g/m}^2/\text{year}$, 53% went to leaf material in shoot base layer and only 26% was retained above ground. Eriophorum had the highest turnover rate.

Other work has shown Calluna growth to be related to age, wetness and altitude of habitat. Taking Calluna over the whole Reserve, age was found to range from 1-40 years, but the majority of plants were 15-20 years old. Reproduction is almost entirely vegetative. The production of Sphagna can be very high and has been found to range from $180-790 \text{ g/m}^2$. Trials to assess the rate of decomposition of Calluna, Eriophorum, Sphagnum and other bog plants show it to be very slow in all cases. Detailed information on blanket bog production and rates of turnover will be found in a book (1975) synthesising the Moor House International Biological Programme project. The book is published by Springer-Verlag.

2. Studies on poor fens and flushes.

a) Description

The associations in this group are small in area but they contribute many species to the Reserve list. Sphagneto-Juncetum effusi and Sphagneto-Caricetum alpinum occur in oligotrophic conditions, and there are several vegetation units, too small to be shown on a vegetation map of the Reserve, in the calcareous springs and flushes.

Sphagneto-Juncetum effusi

The association occurs on flat wet ground, by water courses, on soils of a peaty silt. This typicum is remarkably constant in its composition, Agrostis canina (brown bent grass), Festuca ovina, Juncus effusus (soft rush); Polytrichum commune and Sphagnum recurvum invariably being present. The Carex rostrata (bottle sedge) facies, which may contain the rare Carex limosa (mud sedge) and C. paupercula, is found in conjunction with standing water. Nine species of Sphagna are found in the association, S. fimbriatum, S. girgensohnii and S. robustum being occasional species. S. fimbriatum is more commonly found in lowland bogs whilst S. girgensohnii is a montane species.

Sphagneto-Caricetum alpinum

This association occurs mainly on the higher slopes of the Dun Fells, where it may grade into adjacent calcareous flushes, the whole forming a vegetation mosaic of high botanical interest. Eriophorum angustifolium and Carex nigra (common sedge) are the most constant angiosperms, whilst there is usually a continuous carpet of Sphagna, with S. subsecundum var. auriculatum and frequently S. cuspidatum, S. recurvum and S. squarrosum. Polytrichum commune is nearly always present. It is unlikely that the presence of Carex curta (white sedge), C. bigelowii (stiff sedge),

Nardus stricta and Saxifraga stellaris (starry saxifrage) is a result of prolonged snow-lie, but this may be the case. Flushes are dynamic communities under constant change in boundary and composition, often erupting and eroding due to water movement, frost and trampling by sheep. One flush site has been mapped in detail to monitor such changes.

It has been suggested that the vegetation of these two associations is close to a climax, but more recent observation indicates that, in the case of Sphagneto-Caricetum are least, sheep grazing has considerable influence and goes a long way to maintaining interest.

3. Calcareous springs and flushes

a) Description

Five vegetation units are described, the three most common being Philonoto-Saxifragetum stellaris, Poa annua-Montia fontana and Cratoneuron-Carex. The flushes are often close, one below the other down a slope, with marked zonation of species richness and locally rare species occurring in all.

Philonoto-Saxifragetum stellaris is predominantly a mossy flush with Philonotis fontana forming even lawns of pale green and always constant, while Dicranella palustris is nearly so. Carex nigra, Poa subcaerulea (spreading meadow grass), Cardamine pratensis (cuckoo flower) and Saxifraga stellaris are frequent.

The Poa annua-Montia fontana nodum occurs where springs emerge, often immediately above Philonoto-Saxifragetum. It is comparatively species-poor, but further down the slope the species-rich Cratoneuron-Carex nodum may occur and here there are a number of exceptional plants including Alopecurus alpinus (alpine foxtail), Juncus triglumis (three flowered rush), Epilobium alsinifolium (chickweed willow-herb), Polygonum viviparum and Saxifraga hirculus (yellow marsh saxifrage), Cinclidium stygium, Meesia uliginosa and Oncophorus virens.

There is another interesting calcareous flush found on the Reserve, belonging to the Carex rostrata-Sphagnum warnstorffianum nodum. The flush has two bryophytes, Camptothecium nitens and Mnium pseudopunctatum of note, the first, the attractive and rare Camptothecium, is not found in similar, but very local, flushes in Scotland, whilst the Mnium is found in quantity in both situations.

b) Ecological studies

The pH, conductivity, Ca and Fe content of several flushes, including Cratoneuron-Carex has been examined. Base status, and associated with this, the depth of the water table and flow rate, is clearly all important in determining the distribution of the vegetation. Cratoneuron commutatum agg has been tested as an indicator of the amount and kind of minerals utilizable for growth. The species generally indicates base-rich conditions.

In the course of biosystematic studies with Alopecurus alpinus these flushes have been described and cytological and breeding investigations undertaken. The importance of Nature Reserves as reservoirs of genetic material for study and subsequent plant breeding is particularly relevant in the examination of grasses.

The vegetation of these calcareous flushes is heavily grazed by sheep. An enclosure erected to protect Saxifraga hirculus from grazing resulted in considerable growth by Carices, and other more aggressive species, resulting in the eventual extinction of the saxifrage. Further trials are being undertaken to find out the reaction of species to the changes circumstances of sheep removal.

4. Species-poor Juncetum squarrosi sub alpinum

a) Description

Juncetum squarrosi is widespread throughout the Reserve especially in the central and western areas. In between the tussocks of the dominant, grasses, chiefly Festuca ovina and Deschampsia flexuosa, often grow to a height of 15 cm. Flowering plants are few; but Galium saxatile (heath bedstraw) is constant. Three noda have been recognised within this species-poor association. In the most frequent, on peaty gleys, Polytrichum commune has much cover and Sphagnum spp. are present. The other noda over drier and gleyed mineral soils and podsols respectively have more Agrostis tenuis and Nardus stricta, and more Vaccinium myrtillus and Pleurozium schreberi. Rhytidiadelphus squarrosus is constant in both. Much intermingling is found between the Juncetum squarrosi and the Nardus and Festuca grasslands. This has caused a number of difficulties with mapping.

b) Ecological studies

The autecology of the dominant Juncus squarrosus has been investigated and much attention has been paid by zoologists to the moth, Coleophora alticollella, whose larvae live in the rush capsules and sometimes cause a sharp decrease in seed production. It has been confirmed that both larval incidence and plant performance, ie. length of flower stalk, number of florets, and number of capsules that mature, become less with increasing altitude.

The seral status of Juncetum squarrosi is being examined by a long-term study of its botanical composition under both known grazing pressures and in the absence of grazing. Removal of grazing has been quickly followed by the disappearance of Juncus squarrosus and a spread of Deschampsia flexuosa, but so far the inevitable change to an ericaceous sward has been slow.

c) Studies on productivity

This association was found, somewhat surprisingly, to be the most productive on the Reserve under the prevailing grazing regime. At an altitude of 550 m Juncus squarrosus itself contributes only 18% of the total above-ground production of 340 g/m² but the associated grasses produce 160 g/m². The actual growth rates are comparatively low, and it is thought that the large production arises because the standing crop itself is large. Root yield is even greater, weighing more than eight times the above ground crop. Sheep removed 130 g/m², largely grass, during the seven month grazing season, despite only moderate grazing pressures that average 1.1 sheep/ha. The rate of intake is high due to the ready availability of the grass to the grazing animal.

Decomposition studies in this vegetation have been carried out. A loss of only 20% in dry weight of Juncus squarrosus leaves was found during the first year of decay. This indicates that even relatively productive swards have a low rate of turn-over and a continuing accumulation of organic matter.

4. Species-poor Nardetum sub-alpinum

a) Description

Nardetum covers large areas both on the Reserve and throughout upland Britain. The vegetation varies from swards with an almost complete cover of the dominant to those in which dominance is shared with grasses and Juncus squarrosus. The typical facies of the association contains large tussocks of Nardus in which the living parts are surrounded by slowly decaying leaves. Agrostis canina, A. tenuis, Anthoxanthum odoratum (sweet vernal grass), Festuca ovina, Luzula multiflora (many-headed woodrush), Galium saxatile and Rhynchospora squarrosus are the most important of the subsidiary species. Under wetter conditions Carex nigra, Plagiobothrys undulatum and Polytrichum commune have more cover. The soils are typically gleyed and poor in nutrients, but do not have a thick H horizon. The association occurs on alluvial terraces and ill-drained drift-covered slopes.

b) Ecological studies

Long-term effects of grazing and enclosure are being measured by methods similar to those used for Juncetum squarrosi. Some areas under grazing have been mapped and charted and others analysed botanically by point quadrats. Enclosures have been erected to follow changes, using 1,000 point quadrats at permanent positions. Seven years after fencing has seen little change in sward composition.

c) Studies on productivity

Above ground production of 190 g/m² has been recorded at 550 m under sheep grazing. 55% of this total was Nardus. The standing crop of a Nardetum changes little as the season progresses, although the respective weights of the different plant components, such as the amount of dead material, differs widely. Nardeta support moderate numbers of sheep, and in this environment are a useful adjunct to the range of sward diversity. The effect of moderate dressings of N, P, K and Ca fertiliser is to increase growth, but without further treatment there is a reversion to the previous state within a few years.

5. Festucetum

a) Description

The highest ground, the summits of Great Dun Fell, Little Dun Fell and part of Hard Hill, is vegetated by a Festuca ovina sward, described as Festucetum. These sheep derived grasslands have soils that are podsolised to varying extents with surface boulders frequently to be found.

The number of angiosperms in the sward may be restricted, in which case, cover is largely provided by bryophytes, mainly Dicranum fuscescens, Polytrichum alpestre and P. alpinum. The typicum however, includes Agrostis canina and A. tenuis and abundant Deschampsia flexuosa. The Festuca species is frequently vivipara. A Carex bigelowii facies is recognised, it lacks broad-leaved grasses, but Vaccinium myrtillus, Barbilophozia floerkii, Cladonia arbuscula and Cornicularia aculeata are additional constant species.

The boulders on Little Dun Fell provide suitable habitats for rare cryptograms, such as Grimmia doniana, G. incurva and Hypogymnia alpicola, an arctic-alpine lichen new to England.

b) Ecological studies

Long-term changes in sward composition have been followed since 1955 in grazed and ungrazed swards at Little Dun Fell and Hard Hill. The botanical composition and sward standing crop after 7 years changed so that fewer bryophytes, lichens and flowering plants were present in the ungrazed enclosure, but the cover of Deschampsia flexuosa had increased. This trend has continued since, although at a less rapid rate. Crop yields on Little Dun Fell and Hard Hill were found to be little more than after one year, but the former, the highest site, had the largest increase in litter, presumably because of slower decomposition.

The enclosures should provide further evidence not only of the effects of the long-existing sheep grazing regime, but also of the relationship between the present swards and the Cladineto-Vaccinetum and Festuceto-Vaccinetum associations of McVean and Ratcliffe (1962) in the Highlands where the grazing has been of more recent date and very much less intensive.

c) Studies on productivity

The herbage production of Festucetum on Little Dun Fell and Hard Hill has been measured under grazing and in its absence. The smallest annual production, 42 g/m², for any sward examined on the Reserve was obtained from Little Dun Fell. Further evidence of the drop in production with increasing altitude was given by studies of Carex bigelowii, which had an estimated growth of 127 g/m² at 678 m (Hard Hill) compared with 31 g/m² at 830 m (Little Dun Fell).

6. Agrostu-Festucetum

a) Description

These grasslands occur on the better soils, and are invariably heavily grazed. It has been estimated that nearly half the herbage produced is eaten by sheep. Grazing pressure averages between 3 and 13 sheep/ha, but the vegetation map shows how small many of these swards are and that they occur mainly on the western escarpment. The grasslands on Knock Fell and on the screes and slopes of Green Castle are among the highest (c.750 m) of their kind in England. Small areas also occur by streams and sink holes as oases of lushness amidst the predominant blanket bog of the eastern area.

An extensive species list occurs for this association, featuring over 100 of the 270 flowering plants found on the Reserve, whilst bryophytes with a number of rarities, are abundant (65 moss species and 22 liverworts occurred in 31 0.5 m² quadrats). In the typicum the constant species are Agrostis tenuis, Anthoxanthum odoratum, Festuca ovina, F. rubra (red fescue), Achillea millefolium (yarrow), Cerastium holosteoides (chickweed), Euphrasia confusa (eyebright), Prunella vulgaris (self-heal), Thymus drucei (thyme) and Trifolium repens (white clover). The Sesleria facies includes Linum catharticum (cathartic flax) and Sesleria caerulea (blue sesleria), but only Festuca ovina of the grasses of the typicum, and fewer of the flowering plant constants.

b) Ecological studies

Species occurring in the association and collected from the Reserve have been used by a number of research workers. The distribution and status of the Alchemilla vulgaris L. (lady's mantle) aggregate has been looked at, including the morphology and cytology of A. filicaulis and A. minima. In a study of the biology of Poa subcaerulea the species was found to be generally variable in chromosome number, and both transplants and seedlings from Knock Fell were shown to be smaller than from other sites in Britain. Autecological studies on Gentiana verna (spring gentian) and Myosotis alpestris (alpine forget-me-not) have shown that both species are adapted now to grazing; a dwarf ecotype of Myosotis having developed under the biotic pressure on the Pennines. Differentiation within Deschampsia cespitosa (tufted hair grass) has shown that the Moor House plants, with increased chromosome number (tetraploid instead of the more usual diploid) will flower under a variety of environmental conditions, whereas the lowland plants are more demanding. The chromosome numbers and pollen assemblages of Viola spp. (violets) and Circaea alpina (alpine enchanter's nightshade), which occurs rarely on Knock Fell, have been investigated, and a number of other species have been used for research as yet unpublished.

The limestone ledges are particularly good for Hieracia (hawkweeds) species of which there are a number of interest. But for sheep grazing many Agrost-Festuceta swards would be replaced by scrub woodland, ferns, or tall-herb vegetation, so cliffs and ledges are particularly important indicator habitats. Here species such as Sedum rosea, (rose-root), Geranium sylvaticum (wood cranesbill), Anthriscus sylvestris (cow parsley), Pimpinella saxifraga (burnet saxifrage), Galium boreale (northern bedstraw), Draba incana (hoary whitlow grass) and Solidago virgaurea (golden-rod) occur, and this shows how different the vegetation might be but for grazing. Speculation as to the climax vegetation, in particular on the limestone areas, but also on the Festucetum led to trials in which a number of montane and arctic-alpine species not occurring on the Reserve were introduced. A paper describing these trials has been published. The species were planted in the period 1955-1957. Enclosures were erected and plant performance recorded annually. In general, establishment has been poor and many micro-habitats, especially on sandstone, have proved unsuitable for survival. On limestone dwarf willows have grown well, especially Salix arbuscula, S. phylicifolia (tea leaved willow) and S. reticulata (reticulate willow) but few other species have retained their early population. Of the 59 plants of Alchemilla alpina (alpine lady's mantle) only 29 were still alive after 15 years, but 23 seedlings had established and performance, as measured by leaf size and flower number of the original plants, was best on the limestone habitats. The most successful species have been Thalictrum alpinum (alpine meadow rue), Saxifraga aizoides (yellow mountain saxifrage), Saussurea alpina (alpine saussurea) and Potentilla crantzii (alpine cinquefoil). Thalictrum already occurs rarely on the Reserve and a few plants of Potentilla are nearby.

Measurement of long-term changes in composition and production under exclosure and in the presence of sheep grazing is taking place on Knock Fell. Results after seven years showed there were fewer species of flowering plant and decreases in the abundance of several bryophytes. Since then botanical composition has continued to change in the same manner, but more slowly, and the major difference is in the morphology of the plants.

c) Studies on productivity

Much of the work on sward productivity has centred on these grasslands because of their importance as sheep grazing areas and their considerable influence on the moorland ecosystem as a whole. Annual production under grazing varies from 200 g/m² at 510 m O.D. to 80 g at 747 m O.D. and the percentages utilised at high. As a result standing crops are always low, ranging from 35-100 g/m² at a number of sites in April and August, but root yield is high, over 9 times the above ground figure.

7. Other vegetation types

These include sandstone scree, made ground (mines and tracks), Pteridietum, flushed gleys, shingle and the Moor House meadow. These units have little extent and few studies have taken place specifically on them.

The sandstone screes are considered as block scree, block field and whin sill block scree. Flowering plants are few but Rhacomitrium lanuginosum, Barbilophozia floerkii, Cladonia pyxidata, C. squamosa, Cornicularia aculeata and several crustaceous lichens are constant. The total number of lichens is considerable.

Made ground entails a variety of soils and rock habitats some of which are polluted by lead or zinc. The degree of colonisation and dryness of the habitat is variable, some ground alongside spoil heaps being under water. The species list is long. Cochlearia officinalis (scurvy grass), Minuartia verna (vernal sandwort), and Thlaspi alpestre (alpine pennycress) are characteristic of polluted soils. Tolerance to lead poisoning in Festuca and Agrostis spp. has been examined. The number and diversity of lichens in these habitats is particularly noteworthy, especially the crustaceous species.

Pteridietum on the Reserve is confined to soils with sufficient depth and dryness below 475 m. The typicum has a grassy field layer with abundant Festuca ovina and Agrostis tenuis. There is also a rocky facies, with less Agrostis tenuis and a distinctive bryophyte and lichen flora.

The flushed gleys, comprising a number of vegetation types, occur mostly at the lower altitudes, but there are some around 700 m. The Carex panicea (carnation grass)-Ctenidium molluscum nodum is species-rich and includes a large number of flowering plants. Crepis paludosa (marsh hawkbeard), Ophioglossum vulgatum (adder's tongue) and Sedum villosum (hairy stonecrop) are noteworthy. The species-rich Nardeto-Juncetum squarrosi sub-alpinum has fewer species and is dominated by grasses. Species-rich Juncetum effusi occurs below limestone and contains a large number of species including Epilobium alsinifolium,

E. anagallidifolium (alpine willow-herb), Dactylorhiza maculata ssp. ericetorum (moorland spotted orchid), Parnassia palustris (grass of parnassus) and Saxifraga hirculus. The Juncus acutiflorus (sharp-flowered rush)-Acrocladium cuspidatum nodum is confined to the lower parts of the western escarpment and is very small in extent.

Related to the Agrost-Festucetum is the vegetation of riverside shingle and the Moor House meadow. The shingle vegetation varies according to the stage of colonisation. Agrostis stolonifera (fiorin), Epilobium nerterioides, Tussilago farfara (coltsfoot) and Polytrichum urnigerum occur, more abundantly than in Agrost-Festucetum. Different yet again is the Moor House meadow, which has received manure from animals fed on hay brought in from lower lying holdings. Thus it includes such species as Alopecurus pratense (meadow foxtail), Helictotrichon pubescens (hairy oat grass) and Rhinanthus minor (yellow rattle), typical of local upland farms, but rarely or never, found in the grassland of the Reserve.

Conclusions

Man by his activities in mining, farming and sport has had much influence on the way in which the vegetation of the Reserve developed. Grazing has affected all vegetation types to a greater or lesser extent, and, over the past hundred years the increase in sheep number has made this probably the most important single factor in determining botanical composition on the drier soils. Hence, much of the emphasis in botanical research has been directed to the relationship between grazing and vegetation, and to following composition and productivity changes.

An important finding has been that under grazing, production totals are not directly related to the utilisation by sheep of the sward. Indeed the grasslands thought most valuable produce less herbage than many of the other vegetation types.

The autecological and specialised botanical studies undertaken help to give a better understanding of the biological processes involved, and together with the studies now being pursued provide a sound basis for management experiments.

Additional reading

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