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# THE VEGETATION OF DARTMOOR

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The combined procedures of ground examination of the vegetation, using association-analysis, and the examination of air photographic prints are used to produce a vegetation map of Dartmoor. An attempt is made to trace the development of the vegetation types described by comparing the present vegetation with descriptions made at the end of the eighteenth and at the beginning of the nineteenth century. The processes of change which can be observed on Dartmoor are elucidated by comparing them with those of other hill areas where they have been studied in greater detail and documented more fully.

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## INTRODUCTION

*Background and objectives*

Dartmoor has been the subject of considerable discussion in recent years because of the management of the moor for grazing livestock and the effects upon the vegetation of grazing and burning. Against this background a research programme was devised to consider the effects of grazing pressure against the background of the vegetation of Dartmoor. A substantial part of that programme was concerned with the study of vegetation which is the subject of this paper. In particular the programme aimed to produce a vegetation map of the moor and simultaneously to comment on the principal features of the vegetation types. This provides a simple comprehensive account of the vegetation suitable as a basis for more detailed ecological studies.

The study area comprises the unenclosed common lands of Dartmoor. Much of it consists of an upland plateau 480 km.$^2$ (185 sq. miles) commencing at 300 m. and just attaining an altitude of 600 m. in the north around High Willhays. Dartmoor is a southern outlier of the western oceanic uplands of Britain, and the contrast between this unenclosed upland area lying amidst the intensive agricultural lowlands of Devon is very marked. Marshall (1796) described Dartmoor thus: "The surface, of Dartmore proper, is truly mountainous. The composition is grand, the lines in general lengthened, and the features large . . . the summits of several of the higher swells of Dartmore are truly savage, and rendered finely picturesque, by reason of immense piles of stones . . ."

*A brief review of past work on the vegetation of Dartmoor*

No previous comprehensive account of the vegetation of Dartmoor has been produced. An early description of the vegetation of the moor is given by Vancouver (1808) who recognized the elevated deep peat areas, which he likened to a "red Irish bog", and the outer depasturable parts of the moor. Worth (1933) produced a general account of the habitat preferences of some of the common plant species occurring on the moor. A comparison of its vegetation with that of the Pennines has been made by Harris (1938).

A fuller account is provided by Harvey and St. Leger Gordon (1953). They divide the vegetation of the area into wet and dry moors. The wet moors constitute "two great patches of blanket bog in the heart of the region". That in the northern part of the moor is considered to be one of the most important natural features not only of Dartmoor, but of the whole county of Devon. The dry regions are sub-divided into grass moors, heather moors and bilberry moors, whilst dwarf-furze (*Ulex gallii*) and bracken (*Pteridium aquilinum*) are locally important. Valley bogs and seepage areas occur which tend to be floristically richer than the blanket bog.

Johns (1957) produced a vegetation map for part of north-east Dartmoor. Simmons (1962) briefly discusses the present vegetation, but his study is essentially concerned with pollen analysis. The vegetation of the blanket bog has been discussed by Simmons (1963) in more detail, and describes a range between very wet areas where peat may still be accumulating and areas of deeply eroded peat. Two recent brief descriptive accounts have been produced, by Proctor (1969) and by Brunsden and Gerrard (1970). As in earlier descriptions a distinction is made between the blanket bog and the drier peripheral vegetation of grassy moorland and heath. Proctor compares the eroded condition of the blanket bog today with an area at Tor Royal

which may resemble its original condition. Brunsden and Gerrard list some of the species to be found in the various habitats of the moor including those of the tors and marginal woodlands.

## SECTION I

The derivation of vegetation categories for mapping purposes and their interpretation on the aerial photographs.

### Methods

The study area covers approximately 480 km.$^2$ (185 square miles) and is divided by the main roads traversing the moor into three sections (Fig. 1). The area north of the A384 and B3212 connecting Tavistock and Moretonhampstead forms the North Moor; south of the A384 connecting Tavistock and Ashburton comprises the South Moor; lying between the B3212 and A384 within a triangle formed by Two Bridges, Moretonhampstead and Ashburton is an eastern section fragmented by areas of enclosed land and a network of unclassified roads.

Thirty-four transects traversing the main areas of the moor were drawn, on the one-inch Ordnance Survey map, from one point of access to another. These were followed on the ground using compass bearings, and the vegetation was sampled at approximately every kilometre interval. The length of the interval was measured by a set number of paces which were calculated according to the length of the transect to be traversed. Samples were thus objectively placed at pre-determined intervals and the process approximated to a systematic random sample.

The size of a sample was 2 m. $\times$ 2 m. Descriptive notes were made on the vegetation. A list was made of the vascular plants present within the sample and the representation of each species was recorded on the Domin Scale (see Appendix). Species not present in the sample, but in its immediate vicinity were also recorded. Notes were made on bryophytes and lichens, and on a number of factors relevant to the condition of vegetation in each sample. These included a record of the land form, soils, and the effects of burning, grazing and drainage.

Species-lists of the vascular plants were collected for 162 samples and the data used for an association-analysis (Williams and Lambert, 1959, 1960). For each of the possible pairs of species represented in the lists an association-index, $\sqrt{\frac{\chi^2}{N}}$, was calculated between all pairs of species but only those were summed which individually had a positive or negative significance equal to or greater than an $\chi^2$ of 6·64 (equivalent to 1 per cent probability level).

| | X present | X absent | |
|---|---|---|---|
| Y present | a | b | (a+b) |
| Y absent | c | d | (c+d) |
| | (a+c) | (b+d) | (a+b+c+d) = N |

In the table "a" is the number of samples in which both X and Y are present, and

"d" the number in which neither is present, while "c" and "d" are numbers in which either one or the other, but not both, is present.

$\chi^2$ is defined as

$$\frac{(ad-bc)^2 .N}{(a+b)(c+d)(a+c)(b+d)}$$

$$\text{so that } \sqrt{\frac{\chi^2}{N}} = \sqrt{\frac{(ad-bc)^2 .N}{(a+b)(c+d)(a+c)(b+d)}}$$

In one set of observations where X was *Calluna vulgaris* and Y *Erica tetralix* the figures for a, b, c and d were 10, 67, 14 and 71 respectively, and $\sqrt{\frac{\chi^2}{N}}$ was 0·62.

The whole set of association-indices having been calculated, the first classification of the samples is into two groups of samples, containing or not containing that species giving the highest total of the association-index. These two primary groups are then divided again by a repetition of the same procedure, and the process of subdivision is brought to an end when no single $\chi^2$ (with Yates' correction) exceeds the 1 per cent probability level or alternatively when there are less than 11 individuals left in the group under examination.

If the main cause of floristic differences between samples is that sites vary greatly in wetness, then the first division will be likely to be into a set from wet and a set from dry sites. The process being repeated a number of times the samples in any of the final sets will be more or less similar in their vegetation. The samples from the end-groups must then be examined in detail to derive criteria for their recognition on the ground and from aerial photographs.

To enable the vegetation of the whole area of unenclosed common land to be examined, colour aerial photography of the whole moor was obtained on 29th June 1969 at a scale of 1:10,000 by Fairey Surveys Ltd. Previous work by Mott (1966) and others indicates that reversal colour film developed to the negative stage only offers a number of advantages, including wider latitude in the exposure of the film and greater ease and flexibility in the reproduction of either colour or black and white prints and transparencies. Kodak Ektachrome Type 8442 was used for the photography and colour negatives produced. The actual interpretation was made on colour prints produced from the negatives by Fairey Surveys Ltd. The vegetation of the moor was related to the vegetation mapping units derived using association-analysis by comparing the appearance of a vegetation type in the field and the simultaneous examination of its appearance on the aerial photographic prints. By this process characteristic features by which vegetation types could be demarcated on the prints were noted. Once such features had been listed for all the vegetation types their interpretation was extrapolated to other prints where such simultaneous examination had not been carried out. Hence the actual interpretation of the prints, encompassing the identification of the vegetation types and the delineation of boundaries, is inevitably subjective. The use of association-analysis to provide vegetation mapping units is an essential step in the simplification of vegetation interpretation over such a large area.

The vegetation types derived by association-analysis of the 162 samples provided a simple and comprehensive assessment of the main vegetation types. The vegetation of much of the moor is relatively uniform over large areas and hence this approach

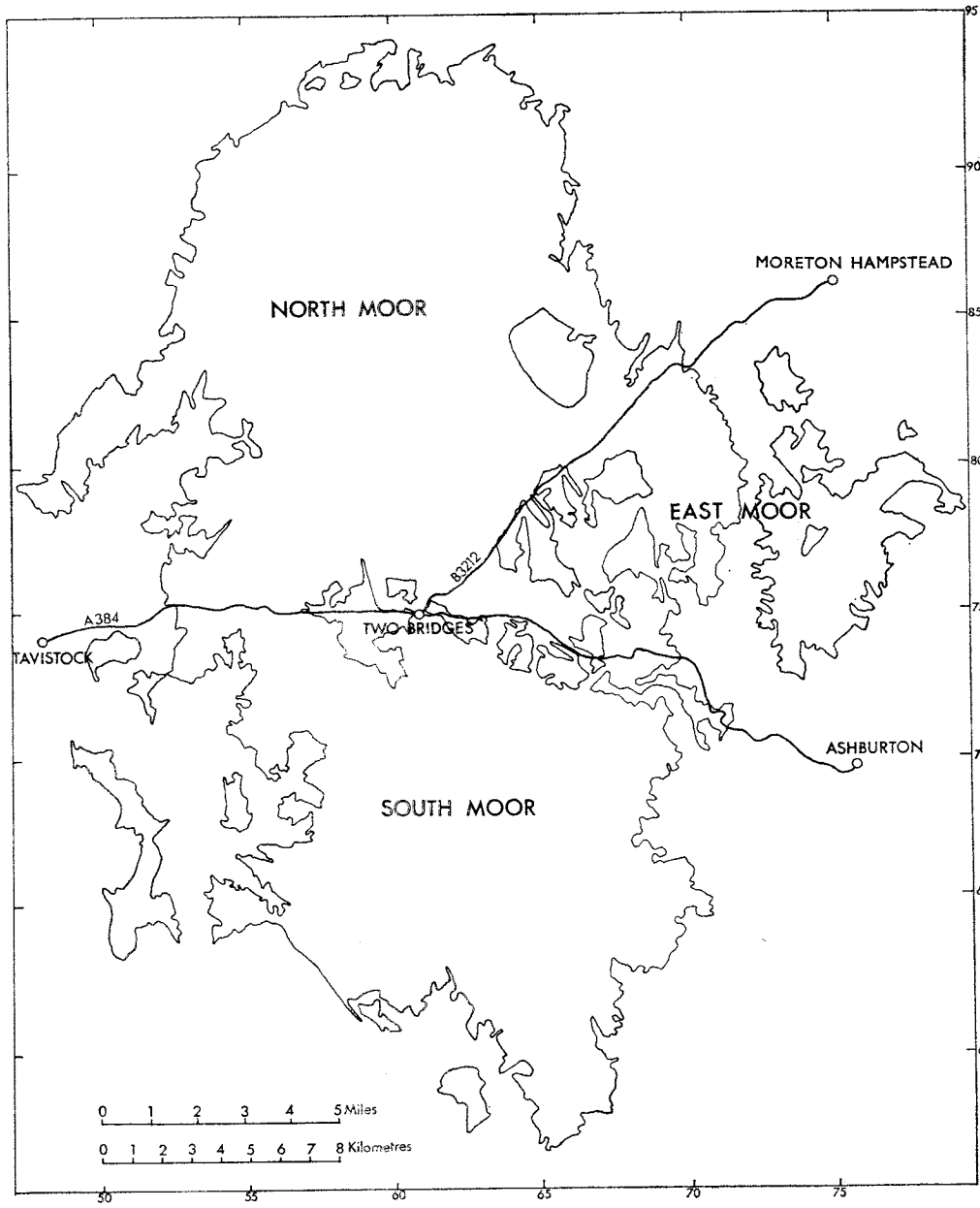


FIG. 1.
The study area.

worked well. Sampling of the vegetation continued after initial guidance had been given to the aerial photographic interpreters based on the 162 samples, until data were available for 216 samples.* Association-analysis of this set revealed the same vegetation types as at the 162 sample level, with no increase in the level of complexity

* A copy of the data set consisting of 216 samples has been lodged with the Flora of Devon Secretariat, Hatherly Biological Laboratories, University of Exeter.

which could be interpreted. This suggested that the former level provided a satisfactory summary of the vegetation types found on the moor.

An interesting applied aspect of this work was the speed with which it was achieved. The use of association-analysis provided an objective method by which the main vegetation types were described. Sampling of the vegetation commenced in mid-May 1969 and was completed during July. The aerial photographs of the moor were taken on 29th June, and the first prints were available for interpretation on 14th July. The complete vegetation map was produced by February 1970.

## RESULTS

The results of the association-analysis are shown in Fig. 2. The initial division is on *Trichophorum caespitosum** into wet or damp vegetation where it is present, and dry categories in which it is absent. Within the group which contains *Trichophorum*, division is on *Sphagnum* spp., dividing wet from damp vegetation. In the group lacking *Trichophorum* division is on *Luzula campestris* broadly separating grassland and moorland.

There are 13 final association-analysis groups. Each group has been closely scrutinized in terms of:

(i) the physiognomy of the constituent stands;
(ii) the constancy of each species within the group; and
(iii) the average cover of constant species.

The aim was to try and deduce features likely to be of use in the aerial photographic interpretation and these criteria require a word of further explanation. Physiognomy means the appearance of vegetation as determined by the life-form of the dominant plants, e.g. heather moorland, bracken, short-cropped grassland. Constant species are those occurring in 81–100 per cent of the stands of an end group. It is these species which are likely to prove important in recognizing the vegetation category from the air. Finally, it is important to know the average cover for constant species, thus *Calluna vulgaris* could be constant but with an average cover of 1 per cent, in which case it would not be an important species in the structure of the vegetation. Alternatively it might have an average cover of 90 per cent and be an important component.

As a result of the scrutiny of the 13 end groups, some were recombined, and seven vegetation groups A–G remained, which could be distinguished with certainty in the field, and which might therefore be recognizable from the air. These seven covered all the vegetation types which had been observed on Dartmoor, with the exception of one distinct physiognomic type, i.e. short-cropped sward with gorse bushes (*Ulex spp*). This was denoted type H.

### A. Blanket bog

This contains 41 stands and comprises association-analysis groups 1, 2 and 3. The constant species† in this category are *Calluna vulgaris* (heather), *Erica tetralix* (cross-leaved heath), *Eriophorum angustifolium* (common cotton-grass), *Molinia caerulea* (purple moor-grass), *Trichophorum caespitosum* (deer-grass) and *Sphagnum spp.* (bog moss).

* Nomenclature of vascular plants follows Clapham, Tutin and Warburg (1962), of mosses Warburg (1963), and of lichens James (1965).

† Constant species are those present in 81-100% of the samples; common species range from 21-80% constancy.

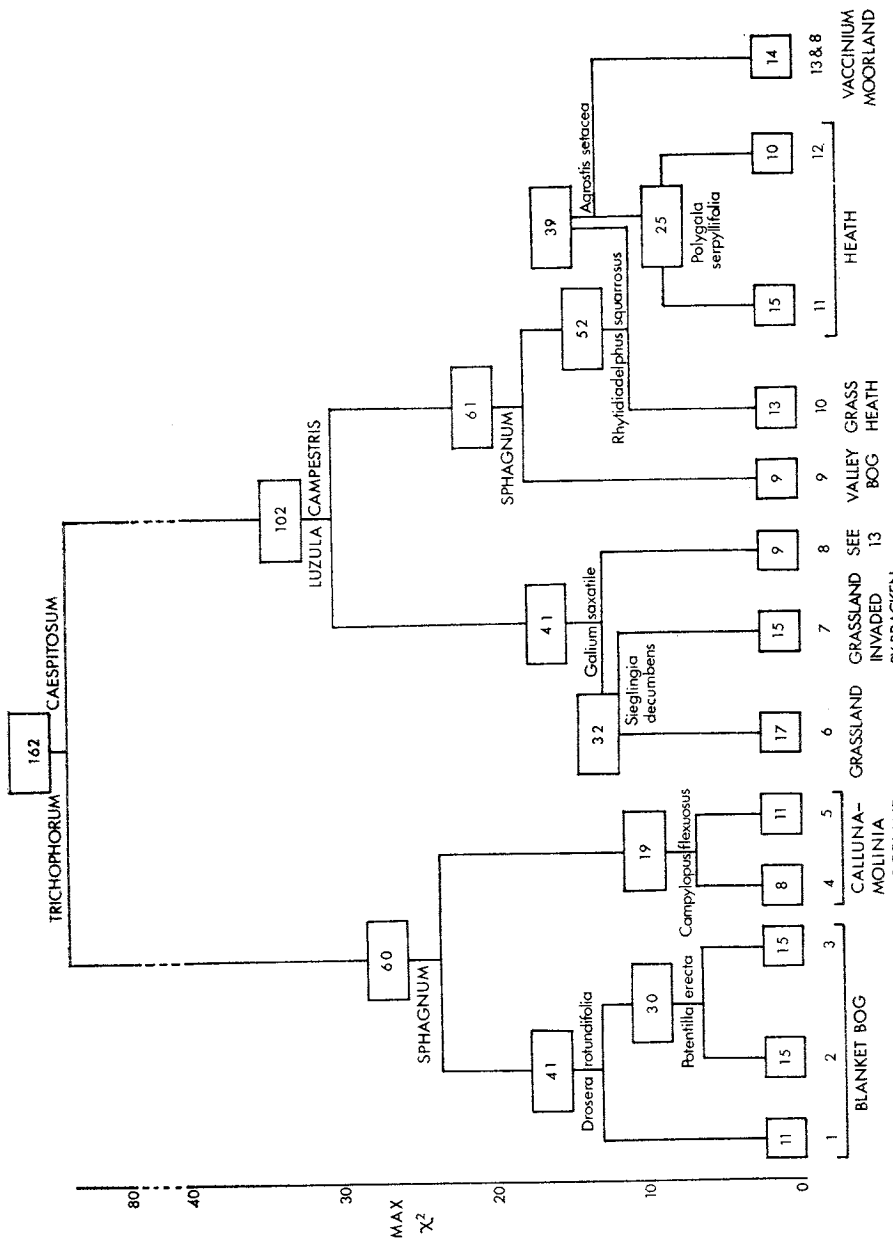


FIG. 2.
Association-analysis hierarchy of 162 vegetation samples on Dartmoor.

Several other species are common, although not constant. These include *Eriophorum vaginatum* (cotton-grass or hare's tail), *Juncus squarrosus* (heath rush) and *Vaccinium myrtillus* (whortle-berry). The herbs *Potentilla erecta* (tormentil) and *Polygala serpyllifolia* (milkwort) are often present. In the wetter areas *Narthecium ossifragum* (bog asphodel) and *Drosera rotundifolia* (sundew) are common.

The lichen *Cladonia impexa* is a feature of the older undisturbed vegetation.

*Sphagnum* predominates in the wetter areas, but where it is slightly drier *Hypnum cupressiforme* becomes widespread.

This vegetation type occupies the deep peat areas which blanket the gently rolling hills of the interior of the North and South Moors. It occurs in round or oval shapes which coalesce at the edges or, at the periphery of the main upland masses, intergrades with drier vegetation types. These round or oval areas have a characteristic radiating drainage pattern, except on one or two areas such as Red Lake Mire (SX 645675) where the topography is level and the characteristic drainage pattern is lacking. The drainage pattern and topography proved to be the main features of identification.

Blanket bog is subjected to swaling (the local term for heather burning), but this does not impair interpretation of the vegetation type, although locally it does result in sharp boundaries, because of the underlying drainage pattern.

B. *Calluna-Molinia* Moorland

This contains 19 stands and comprises association-analysis groups 4 and 5. Only three species are constant in this category: *Calluna vulgaris*, *Molinia caerulea*, and *Trichophorum caespitosum*.

Other common species are *Agrostis setacea* (fine bent), the sedge *Carex panicea*, *Erica tetralix*, *Juncus squarrosus*, *Potentilla erecta* and *Vaccinium myrtillus*. *Hypnum cupressiforme* is the commonest moss.

This type could be distinguished from blanket bog with ease in the field by the absence of *Eriophorum* spp. and *Sphagnum*. It proved impossible, however, within the short term of the present study, to interpret this type from the air. The reason for this difficulty was due to swaling. In the mature form the *Calluna* is dark in appearance and the *Molinia* has a dense white litter. However, during swaling both these distinctive features of the vegetation are destroyed. The vegetation then undergoes a recovery cycle in which the *Calluna* slowly re-establishes itself; the new growth of *Molinia* is bright green. It appears to take several seasons for the dense accumulation of *Molinia* litter to build up again.

The probable distribution of this vegetation type is peripheral to areas of blanket bog, or even intermingled with it in local areas of better drainage. During interpretation the mature form of this vegetation type has been classed with blanket bog, the regenerating form with grassland (category C) or heath (category G), see Table 5.

C. Grassland

This contains 17 stands and comprises association-analysis group 6. These stands are typically close-cropped hill grassland but some coarser areas of grass are included, and occasionally grass swards which have replaced heath following burning. The constant species are *Agrostis tenuis* (common bent-grass), *Festuca ovina* (sheep's fescue), *Galium saxatile* (heath bedstraw), *Luzula campestris* (field woodrush), *Potentilla erecta* (tormentil), *Sieglingia decumbens* (heath grass), and the moss *Rhytidiadelphus squarrosus*.

Other common species are *Agrostis setacea*, *Anthoxanthum odoratum* (sweet vernal grass), *Calluna vulgaris*, *Carex binervis* (ribbed sedge), *Carex pilulifera* (pill-headed sedge), *Festuca rubra* (red fescue), *Nardus stricta* (mat-grass), and *Vaccinium myrtillus*. The following mosses are also fairly common: *Dicranum scoparium*, *Hylocomium splendens*, *Hypnum cupressiforme* and *Pleurozium schreberi*. *Polygala serpyllifolia* and *Ulex gallii* (dwarf furze) are occasionally present.

In the interpretation of this category the smooth texture of the grasses intermingled in the sward was a good guide, but the colour was variable both within and between prints. This was partially due to the problems of controlling the colour balance between photographs. This difficulty is always present with colour photography and is heightened between photographs in adjacent strips, especially when another roll of film is involved. In addition, the greater sensitivity of the colour film will enhance differences in the nature of the sward itself as well as the well-known differences due to aspect and sun angle. It is possible that panchromatic film would not have been so variable as it is less sensitive to green light. The colour on the prints ranged from a light green to a straw colour. The latter can be attributed to the extremely close grazed nature of these swards. The aerial view in fact reveals the dead litter and soil visible through the sward. *Calluna*, although a common constituent of the swards, does not affect the interpretation, as it is only present in very small amounts.

D. Grassland invaded by bracken (*Pteridium aquilinum*)

This contains 15 stands and comprises association-analysis group 7. Constant species are *Agrostis tenuis*, *Galium saxatile*, *Luzula campestris*, *Potentilla erecta*, *Vaccinium myrtillus*, and *Rhytidiadelphus squarrosus*. In addition *Anthoxanthum odoratum* was common. This is a very similar list of constant species to those described for the grassland category "C". Although *Pteridium* was only 66 per cent constant in the category as defined by association-analysis, in practice all dense bracken areas were included here for the purposes of interpretation for the map. The bracken is easily distinguished from the air by its texture and deep green colour. Some areas of bracken may, however, be incompletely depicted because although the aerial photographs were taken in late June not all the fronds had emerged.

E. *Vaccinium* (whortleberry) moorland

This contains 22 stands and comprises association-analysis groups 8 and 13. Constant species are *Calluna vulgaris*, *Potentilla erecta* and *Vaccinium myrtillus*. A large number of other species may be found, including *Agrostis canina* (brown bent-grass), *A. tenuis*, *Carex binervis*, *Carex panicea* (carnation grass), *Carex pilulifera*, *Deschampsia flexuosa* (wavy-hair grass), *Festuca ovina*, *F. rubra*, *Juncus squarrosus*, *Luzula campestris*, *Molinia caerulea*, *Nardus stricta*, *Polygala serpyllifolia* and *Sieglingia decumbens*.

*Vaccinium* is common over the whole moor. The stands grouped together here contain variable amounts of *Vaccinium* and intergrade with the heath vegetation (category G). For interpretation purposes, however, it was necessary to adopt criteria whereby moorland in which *Vaccinium* is predominant can be distinguished from moorland with a significant amount of *Calluna*. The areas mapped under this category are those in which *Vaccinium* forms a virtually continuous carpet. Such areas are very localized and occur principally on south-facing slopes in the southern moor. They are so few in number that it seems worth naming them, together with a spot reference: North Hessary Tor (SX575738), Penn Beacon (SX600630), the flanks of Hilson's House (SX635616), parts of Ugborough and Harford Moors (SX650625), Hickley Plain (SX670620), parts of Brent Moor (SX670640), parts of Smallbrook Plains (SX685655), Buckfastleigh Moor (SX675678) and Huntingdon Warren (SX665665).

The *Vaccinium* canopy is an easily interpreted category. It is dark green in colour and has a reticulate pattern of sheep tracks within it.

F. Valley bog

This contains 9 stands and comprises association-analysis group 9. This category has been separated from blanket bog by the association-analysis due to the absence of *Trichophorum caespitosum*. Valley bog occurs in narrow linear zones, and it is immediately apparent from the vegetation map that its distribution reflects the drainage system. Occasionally the narrow upper reaches open out into quite large hollows in which the drainage system expands to form locally extensive valley bogs. Fox Tor Mires (SX615707) is an example of legendary fame and several other examples occur, particularly in the north-east of the moor, such as Taw Marsh (SX620910), Raybarrow Pool (SX640900), Ruelake Pit (SX640885) and Gallaven Mire (SX633885). Also included here are the seepage areas where streams arise, e.g. west of Hangershell Rock (SX655595).

There was only a slight chance that a vegetation sample would fall within this linear system, and it would be inappropriate, on the basis of only nine samples, to make any general statements about a vegetation category which is very variable and potentially floristically rich.

Several of the species encountered on the open moor can occur here including the ericaceous shrubs *Calluna vulgaris* and *Erica tetralix*, a variety of sedges (e.g. *Carex panicea*), and large conspicuous species of rush such as *Juncus effusus*, whilst *Juncus squarrosus*, *Molinia caerulea* and *Sphagnum* are abundant.

The interpretation of this category on the aerial photographs is essentially topographical. It flanks the streamsides, and is often differentiated from the surrounding vegetation by colour and texture. Dense *Sphagnum* often gives a green colour, and plants such as *Juncus effusus* give rise to a varied texture. Seepage areas are distinguished by the water trickling over the surface contrasting black against the green flushed vegetation.

G. Heath

This contains 26 stands and comprises association-analysis groups 11 and 12. The only constant species in this category are *Agrostis setacea* and *Calluna vulgaris*. Other frequent dwarf-shrubs are *Erica cinerea* (bell heather), *Erica tetralix*, *Ulex gallii* and *Vaccinium myrtillus*. Several other species are commonly present: *Carex panicea*, *C. pilulifera*, *Molinia caerulea*, *Nardus stricta*, *Polygala serpyllifolia*, *Potentilla erecta* and *Sieglingia decumbens*. *Hypnum cupressiforme* is often present beneath the *Calluna* canopy and the lichens *Cladonia impexa* and *C. squamosa* are encountered fairly frequently.

A well-developed *Calluna* canopy is conspicuous on the aerial photographs, being dark brown. The heath areas are regularly swaled and the pattern of this is conspicuous from the air. It is the drier heath vegetation which is classified here. *Calluna* is a constant in the blanket bog vegetation, but the two categories are easily distinguished by the radiating drainage pattern of the latter. Dry heath has a smoother texture often irregularly interspersed with protruding rocks. Such heaths occur around the periphery of the moor.

H. Grassland with Gorse

Both *Ulex gallii* (dwarf furze) and *Ulex europaeus* (gorse) occur, but the former is commoner. Only small areas of this vegetation category occur distributed around the periphery of the moor. One of the largest areas is at Roborough Down (SX515670).

The interpretation criterion used was based on observing the *Ulex* bushes in the sward. Their position was often emphasized by the shadows cast by the bushes.

I. Grass-heath

A ninth vegetation category has subsequently been described, termed grass-heath.

In the course of the association-analysis a group of stands was produced, the ecological significance of which was not immediately apparent. This was group 10 (13 stands). When the subsequent analysis of the larger data set of 216 samples was examined, however, it was found that a similar group was produced by that analysis. The stands appeared to be a fairly heterogeneous collection in terms of their physiognomy, but they did have in common the fact that they were all transitional between heath and grassland. Some were basically swards, originally derived from heath, in which isolated bushes of *C. vulgaris*, *U. gallii* or *V. myrtillus* still persisted. Others contained sward with a fine intermixture of these dwarf-shrubs, but with a very low percentage cover of them.

Constant species are *Calluna vulgaris*, *Potentilla erecta* and the mosses *Hypnum cupressiforme* and *Rhytidiadelphus squarrosus*. Other common species are *A. tenuis*, *Carex panicea*, *C. pilulifera*, *Festuca rubra*, *Galium saxatile*, *Sieglingia decumbens* and the moss *Pleurozium schreberi*, whilst the following species occur in slightly less than half the samples: *Agrostis setacea*, *Carex binervis*, *Festuca ovina*, *Molinia caerulea*, *Nardus stricta*, *Ulex gallii* and *Dicranum scoparium*. When this assemblage of species is viewed against the background of each of the categories described above it is evident that species typical of the heath are present such as *Calluna* and *Ulex* and a whole range of the species commonly encountered in the Dartmoor grasslands.

This group was not recognized at the time that the mapping categories were described, but due to the extremely variable appearance of the vegetation, it would not have been possible to define suitable criteria on which to recognize it. In practice, such stands have been classed either as grassland, heath or grassland with *Ulex* spp.

A vegetation map of Dartmoor based on the seven mapping categories finally adopted is presented in Fig. 3 (see back cover).

## SECTION II
## The use of aerial photographs to study the pattern and extent of swaling

### Methods

"Swaling" is the local term for the burning of vegetation (principally *Calluna*, but also some *Ulex* and *Molinia*) in order to create a flush of new growth for grazing livestock. As a management process it causes profound changes in the appearance of the vegetation. Following burning the vegetation may gradually revert to its former state, or, under the influence of grazing, it may be prevented from returning to this condition. Hence under the combined effects of burning and grazing, the vegetation affected assumes a whole range of different facets. The availability of a complete set of aerial photographs for Dartmoor provided an opportunity for a comprehensive survey of the extent of swaling. The knowledge of the actual year in which an area was burnt helps those carrying out further studies to interpret the changes which have occurred.

Two of the vegetation categories mapped, namely the blanket bog and the heath, are regularly subjected to burning. The area of these two extensive types, as measured by planimeter on the one-inch map, is 13,630 ha. (33,680 acres) and 10,554 ha. (26,080 acres) respectively, making a combined total of 24,184 ha. (59,760 acres).

Initially the complete set of photographs was examined and all clearly demarcated burns were marked, and the spot map-reference recorded. There were one hundred and seven areas which had been affected by fires. Thirty-six of these were visited and samples of *Calluna* stems collected. By an examination of the dead charred stems it was possible to estimate the age of the canopy at the time of the fire. The year in which the fire had occurred could be determined from the age of the regenerating *Calluna* stems. Using the appearance of the fires of known age as a guide, the ages of the other fires were estimated from the air photographs.

The stems of regenerating *Calluna* were collected during April 1970. At this time no growth would have occurred during 1970; thus a regenerating canopy one year old indicated that the fire had taken place between the autumn of 1968 and the spring of 1969, and the fire was recorded as a 1969 fire.

Fires which had occurred in 1969 and 1968 could be interpreted with ease on the photography. New fire areas on the heath vegetation are typically a deep pink in colour. This is due to the dead *Calluna* leaf-litter which remains unburnt. After one year the area of the fire appears darker and is mottled by regenerating vegetation. New fire areas on the blanket bog are initially pink also, but this rapidly fades in the succeeding two or three years and tones in with the general appearance of the mature vegetation type. Fires which occurred on both vegetation types in 1967 and 1966 were more difficult to interpret and it was not possible to differentiate fires of the two years consistently. The fires for these two years have therefore been grouped together. Only one fire was discovered which was estimated to have occurred in 1965. Thus fires prior to 1966, i.e. which had occurred more than four years previously, are no longer identifiable on the photography. The boundaries become blurred by well-established regenerating vegetation. New fires partially invade the regenerating canopy and the pattern becomes too complex to interpret. Occasionally instances were encountered where the fires of different years abutted along common boundaries creating complex burns which were difficult to interpret.

The burnt areas have been transferred from the prints to six-inch Ordnance Survey maps, and the area measured on the map using a planimeter.

## RESULTS

The results are presented in map and table form as follows:

1969 fires, see Fig. 4 and Table 1
1968 fires, see Fig. 5 and Table 2
1966/1967 fires, see Fig. 6 and Table 3

The age of the *Calluna* canopy at the time of burning, for each of the thirty-six fires visited on the ground, is presented in Table 4. This information is not available for those fires whose year of burning was estimated from the aerial photographs.

## DISCUSSION

### *The Vegetation map*

A map of the vegetation of Dartmoor has been produced. The term vegetation category or type has been used advisedly to distinguish the units from plant com-

munities (see Ward *et al.*, 1971). These units consist of broad categories encompassing one or several plant communities and further detailed analysis is required before any attempt is made to distinguish communities. The map could be described as illustrating vegetation potential, in that, on the whole, the differences caused by burning are not reflected, i.e. vegetation which is redeveloping following burning comes under the same vegetation category as the mature vegetation type. Thus the map should not become rapidly out-dated with renewed burning. It forms a suitable backcloth on which to base more detailed vegetation studies.

Since the interpretation of the association-analysis categories on the aerial photographs is inevitably subjective, the interpreter has to be permitted an element of freedom in deciding to which category an area should be allocated and at what point a boundary should be drawn between two categories. It is not feasible to carry out a detailed ground check on interpretation over such a large area. An appraisal of the vegetation map (Fig. 3) does, however, confirm one's general impressions of the distribution pattern of the principal vegetation types. The map reflects the topography of Dartmoor. The blanket bog areas of the North and South Moors are immediately apparent and cover the greater part of the upland plateau. Dissecting these areas is the pattern of valley bogs following the drainage system. Surrounding the areas of blanket bog are the peripheral zones containing a mixture of drier heaths; grasslands, dominated in places by bracken; and areas of grassland with gorse. This is in accord with the verbal description given by Harvey and St. Leger-Gordon (1953).

A simple spot check on the accuracy of interpretation in detail was available by comparing the aerial photographic interpretation of each of the stands with that obtained by ground examination. In practise six of the stands were omitted and a study was made of the remaining 210 stands. Due to the difference in scale at which the two surveys were made stands determined as belonging to a given category on the ground might only cover a restricted geographical area and would not appear on the vegetation map. For instance, small areas of grassland, category C, in the middle of a large bracken infested area would appear on the vegetation map as category D. Interpretations similar to this are considered acceptable and in Table 5 these, and the correct interpretations, are in heavy italics. Out of a total of 210 stands 186 are considered to have been correctly or acceptably interpreted. This gives an accuracy of 88·5 per cent.

The blanket bog areas and *Calluna-Molinia* moorlands

One of the striking features of much of the Dartmoor blanket bog is the prevalence of *Molinia*. Indeed, in some areas it forms almost pure stands, e.g. near Fox Tor (SX625698), Tavy Head (SX592818) and on the open moor west of Fernworthy Forest (SX643827). Simmons (1963) describes a similar area at East Dart Head (SX610855). McVean and Ratcliffe (1962) quote examples of blanket bog communities in Scotland (the Trichophoreto-Callunetum and the Molinieto-Callunetum) in which *Calluna* is sparse or absent over extensive areas dominated by *Trichophorum* or *Molinia* and describe these as fire-climaxes from which the heather has been eliminated by repeated burning. The mechanism by which this comes about has been described for *Molinia* by Grant, Hunter and Cross (1963); the tiller buds are situated deep within the basal leaf sheaths of the tussock and are unaffected by the fire. Such

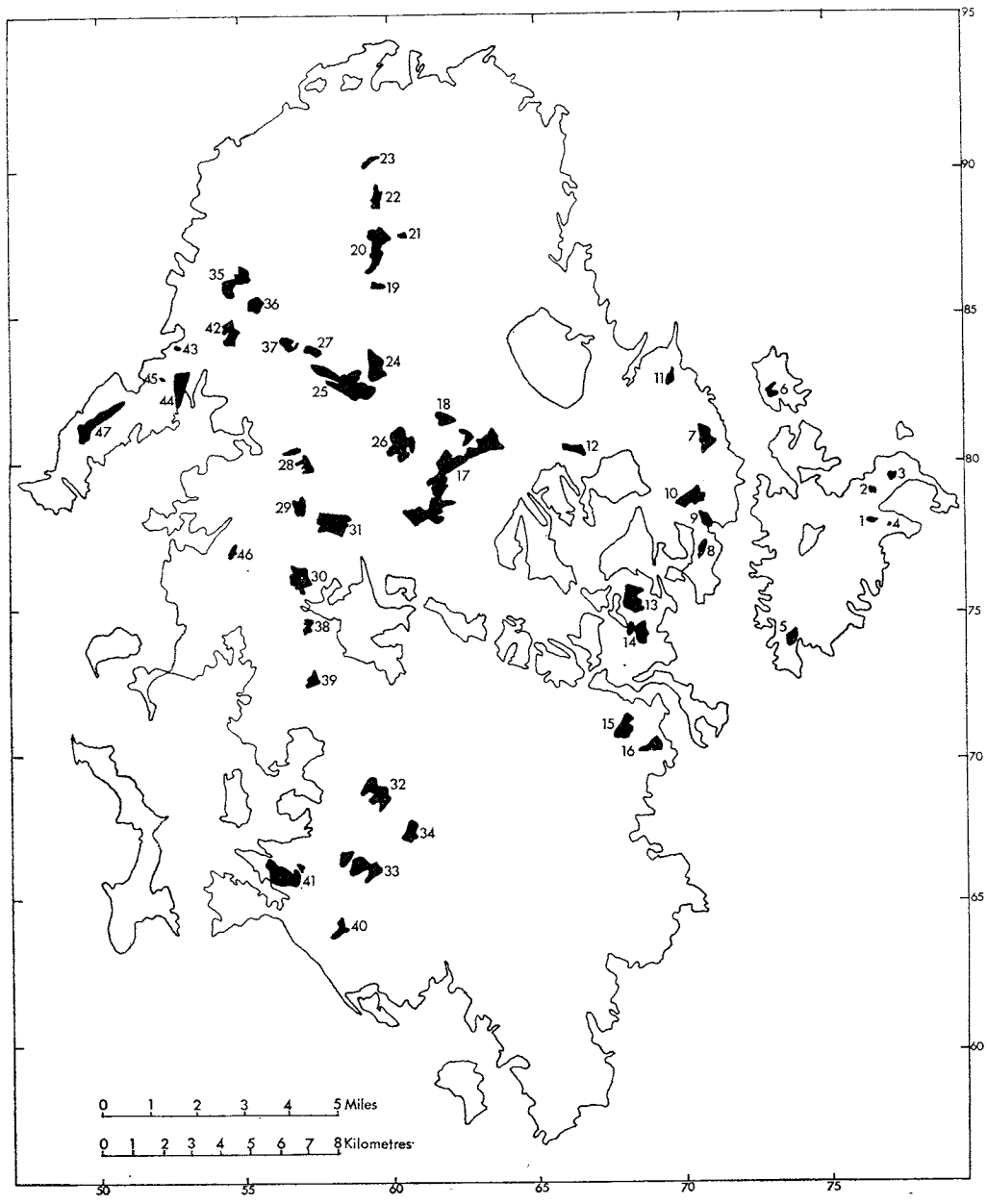


FIG. 4.
The extent of fires on Dartmoor in 1969.

Table 1. *Details of fires occurring on Dartmoor in 1969*

1 hectare = 2·471 acres

*FIRES 1969*

Total area burnt = 3,369·0 acres (this includes fire No. 6 which is a 1967/1969 complex) = 1,363·4 ha.

| Fire reference number | Locality | Map reference of fire (All SX) | Method of dating C = *Calluna* stem count. E = estimated from photography | Area in acres | Areas in hectares |
|---|---|---|---|---|---|
| 1 | Haytor Down | 765780 | C | 14·4 | 5·8 |
| 2 | Black Hill | 765790 | C | 8·7 | 3·5 |
| 3 | Trendlebere Down | 772795 | C | 12·0 | 4·9 |
| 4 | Haytor Down | 771777 | E | 1·7 | 0·7 |
| 5 | Buckland Common | 737740 | C | 23·2 | 9·4 |
| 6 | Easdon Tor | 732825 | E | 30·9 | 12·5 |
| 7 | Hameldown Tor | 707807 | C | 86·3 | 34·9 |
| 8 | W of Widecombe | 705770 | E | 18·8 | 7·6 |
| 9 | W of Widecombe | 708780 | E | 28·8 | 11·6 |
| 10 | Blackaton Down | 703788 | E | 89·6 | 36·3 |
| 11 | Shapley Common | 696828 | C | 15·1 | 6·1 |
| 12 | Merripit Hill | 665805 | C | 48·6 | 19·7 |
| 13 | N of Corndon Tor | 683752 | C | 126·0 | 51·0 |
| 14 | Corndon Tor | 685740 | C | 60·1 | 24·3 |
| 15 | Ventford Reservoir | 680710 | E | 45·0 | 18·2 |
| 16 | Holne Moor | 687702 | E | 39·4 | 15·9 |
| 17 | Broad Down to Longford Tor | 635807 to 610782 | E | 421·4 | 170·5 |
| 18 | Sandy Hole Pass | 618815 | E | 63·5 | 25·7 |
| 19 | Great Kneeset | 595860 | C | 27·1 | 11·0 |
| 20 | Okement Hill | 592866 to 598880 | C | 111·2 | 45·0 |
| 21 | Okement Hill | 603879 | C | 5·0 | 2·0 |
| 22 | Black-a-ven Brook | 596890 | C | 37·9 | 16·3 |
| 23 | New Bridge | 593903 | C | 13·0 | 5·3 |
| 24 | Cut Combe Water | 595835 | E | 120·2 | 48·6 |
| 25 | Fur Tor | 573832 to 595825 | E | 313·6 | 126·9 |
| 26 | Cowsic Head | 603805 | E | 146·2 | 59·2 |
| 27 | Amicombe Brook | 573838 | E | 31·1 | 12·6 |
| 28 | Lynch Tor | 570800 | E | 31·3 | 12·7 |
| 29 | Cocks Hill | 570785 | E | 78·2 | 31·6 |
| 30 | Little Mis Tor | 570760 | E | 89·5 | 36·2 |
| 31 | Blackbrook Head | 580780 | E | 183·7 | 74·3 |
| 32 | Eylesbarrow | 595685 | E | 140·4 | 56·8 |
| 33 | Ditsworthy Warren to Shavercombe Tor | 585665 to 595658 | E | 124·0 | 50·2 |
| 34 | Calveslake Tor | 605675 | E | 60·3 | 24·4 |
| 35 | Arms Tor | 545860 | E | 77·2 | 31·2 |
| 36 | Rattlebrook Hill | 555855 | E | 48·9 | 19·8 |
| 37 | Rattle Brook | 565840 | E | 30·2 | 12·2 |
| 38 | Hollow Tor | 571745 | E | 20·4 | 8·2 |
| 39 | Walkhampton Common | 573726 | E | 33·3 | 13·5 |
| 40 | Trowlesworthy Tors | 580640 | E | 22·3 | 9·0 |
| 41 | Ringmoor Down | 560660 | E | 159·2 | 64·4 |
| 42 | Doe Tor | 545845 | E | 105·3 | 42·6 |
| 43 | Willsworthy | 525840 | E | 5·2 | 2·1 |
| 44 | Willsworthy | 530825 | E | 58·7 | 23·7 |
| 45 | Willsworthy | 522830 | E | 1·0 | 0·4 |
| 46 | Roos Tor | 545770 | E | 22·1 | 8·9 |
| 47 | Gibbet Hill | 493813 to 506821 | E | 139·5 | 56·4 |

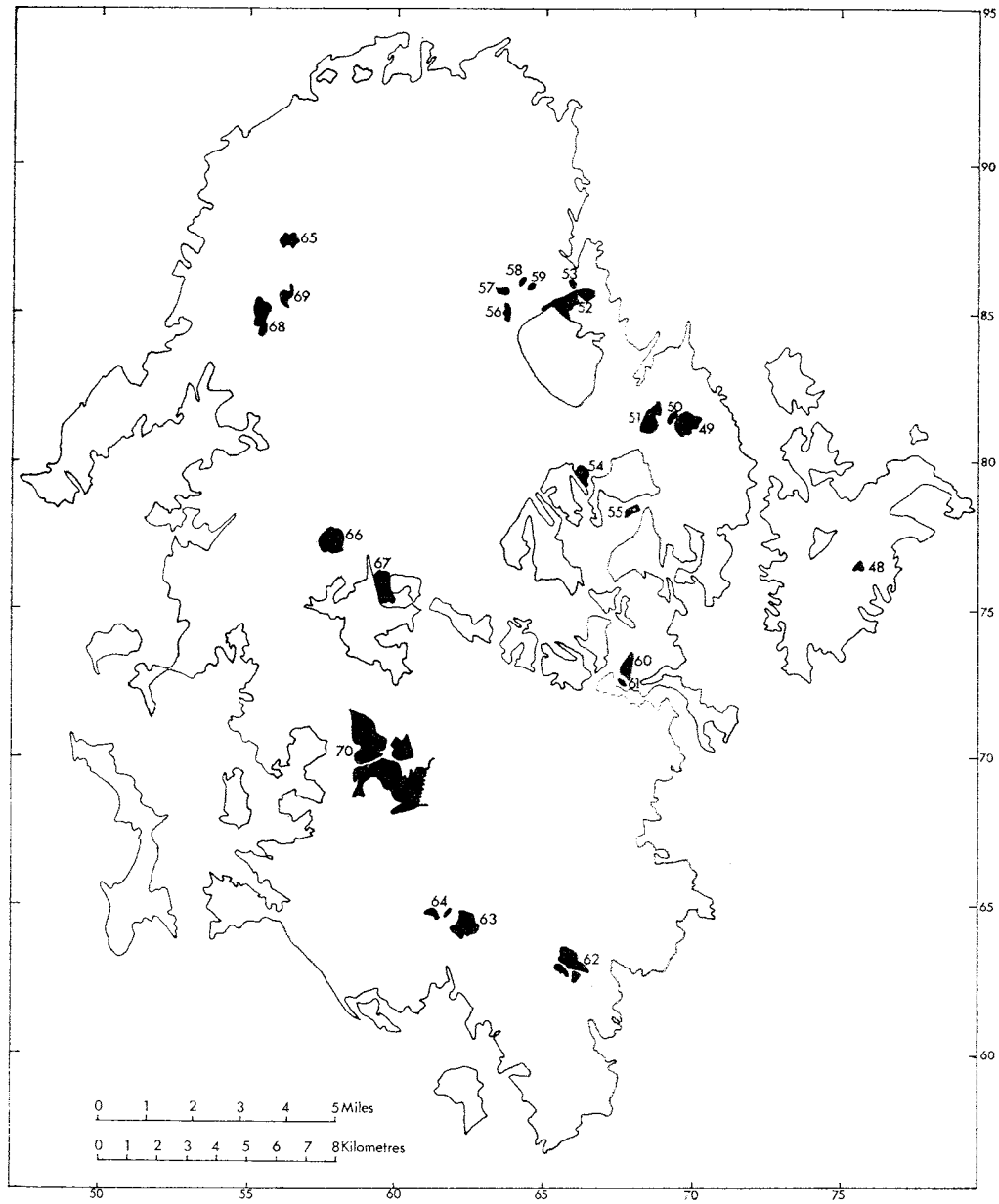


FIG. 5.
The extent of fires on Dartmoor in 1968.

vegetation is managed by swaling on Dartmoor and it appears that fire-climaxes are becoming evident.

The vegetation may have been evolving towards this condition for a long time. Vancouver (1808) described the elevated parts of northern Dartmoor thus (modern names in brackets): "This annually teems with a luxuriant growth of purple melic grass (*Molinia caerulea*), rush cotton grass (*Eriophorum vaginatum*) flags (*Iris*

Table 2. *Details of fires occurring on Dartmoor in 1968*

*FIRES 1968*
Total area burnt = 2,119·0 acres
= 857·5 ha.

| Fire reference number | Locality | Map reference of fire (All SX) | Method of dating C = *Calluna* stem count. E = estimated from photography | Area in acres | Area in hectares |
|---|---|---|---|---|---|
| 48 | Saddle Tor | 756766 | C | 5·6 | 2·3 |
| 49 | Hookney Tor | 700813 | C | 69·4 | 28·1 |
| 50 | Hookney Tor | 694813 | C | 8·2 | 3·3 |
| 51 | Birch Tor | 690817 | C | 84·6 | 34·2 |
| 52 | Shovel Down | 655855 | E | 144·8 | 58·6 |
| 53 | Shovel Down | 659860 | E | 2·2 | 0·9 |
| 54 | Postbridge | 662795 | C | 44·9 | 18·2 |
| 55 | Soussons Down | 680787 | C | 8·0 | 3·2 |
| 56 | Manga Hill | 637850 | E | 19·2 | 7·8 |
| 57 | Manga Hill | 635857 | E | 19·0 | 7·7 |
| 58 | North Teign River | 643860 | E | 9·0 | 3·6 |
| 59 | North Teign River | 647860 | E | 10·7 | 4·3 |
| 60 | Sharp Tor | 679730 | E | 19·5 | 7·9 |
| 61 | Sharp Tor | 676725 | E | 8·2 | 3·3 |
| 62 | Red Brook | 660630 | C | 174·8 | 70·7 |
| 63 | Stall Moor | 625645 | E | 128·9 | 52·2 |
| 64 | Yealm Head | 615648 | E | 25·6 | 10·4 |
| 65 | Kitty Tor | 565874 | C | 45·7 | 18·5 |
| 66 | Black Dunghill | 580775 | E | 99·2 | 40·1 |
| 67 | Holming Beam | 595755 | E | 91·8 | 37·1 |
| 68 | Sharp Tor | 555850 | E | 124·1 | 50·2 |
| 69 | Rattle Brook | 561856 | E | 29·6 | 12·0 |
| 70 | Cramber Tor | 590710 | C | 946·0+ | 382·8+ |
| | Nun's Cross, Combshead Tor (Eastern boundary not discernible) — A complex burn | 602702<br>595695 | | | |

*pseudacorus*), rushes (*Juncus* spp.) and a variety of other aquatic plants." The inclusion of flags and rushes suggests that his description embraces the valley bogs also. Vancouver did not attempt to give an exhaustive species list of the plants of the blanket bog. He presumably named those species which were most conspicuous and thus it is of interest that *Molinia caerulea* and *Eriophorum vaginatum* should be mentioned and not any of the ericaceous species such as *Calluna* and *Erica tetralix*.

There are approximately 13,760 hectares (34,000 acres) of *Molinia* communities on Dartmoor. Grant *et al.* state that, "If large areas of *Molinia* are burnt . . . the *Molinia* will overgrow the less fire-resistant species and the grazing available from these areas in winter will be reduced". In view of this observation, the wisdom of continuing to manage these communities by swaling must be carefully questioned. Havinden and Wilkinson (1970) state that *Molinia* is relished by stock on Dartmoor during the early summer, but regard it as worthless after it has flowered. C. R. Tubbs (personal communication) considers, however, that in the New Forest *Molinia* constitutes important fodder for cattle and ponies throughout the year. Miles (1971), working on red deer range in the Isle of Rhum, has found that burning *Molinia*

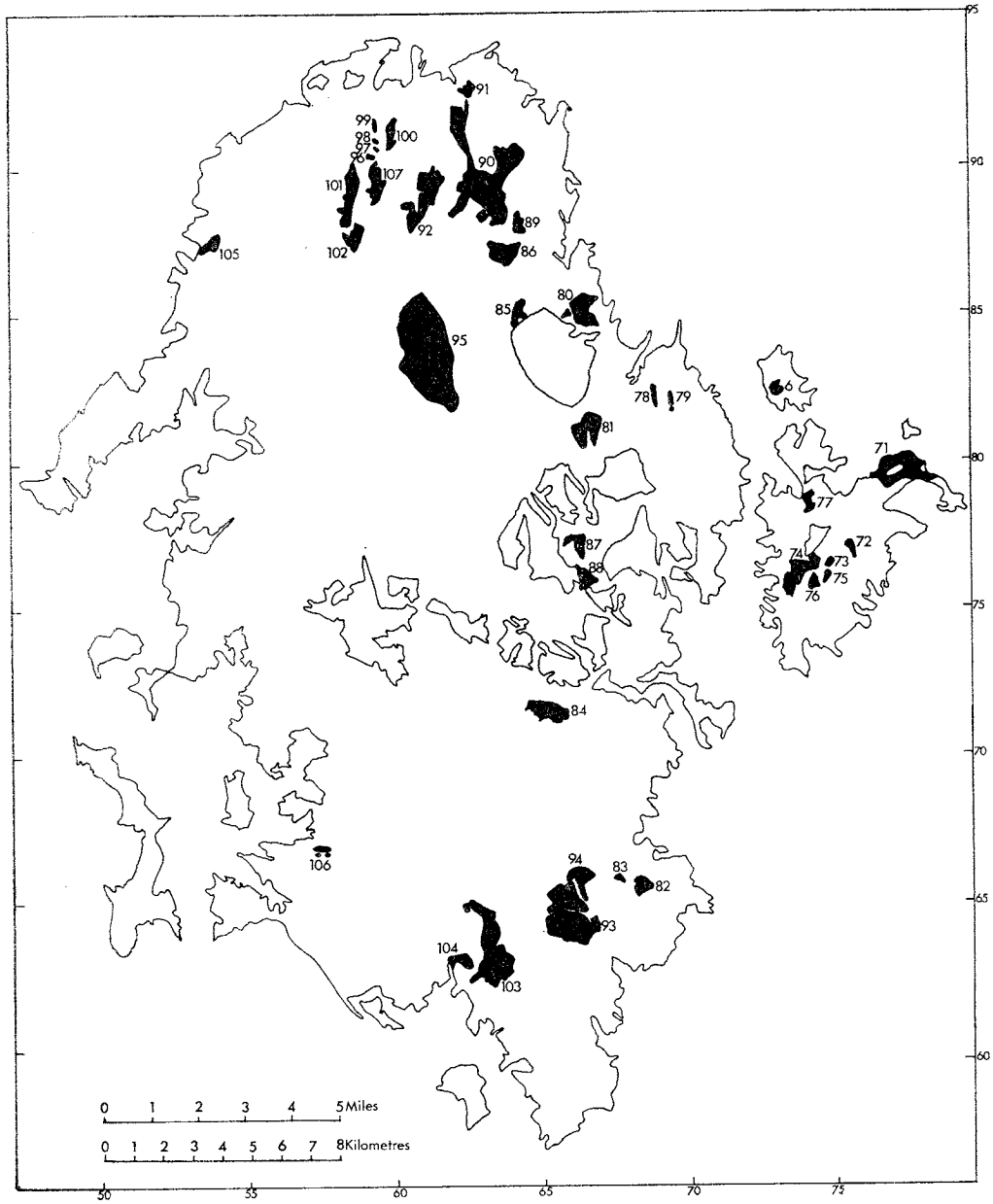


FIG. 6.
The extent of fires on Dartmoor in 1966/1967.

Copies of figures 4, 5 and 6, on a scale of one inch to one mile have been deposited at Slapton Ley Field Centre and The Nature Conservancy's offices at Taunton and Bangor.

dominant vegetation does result in a temporary improvement in range value, even though the overall effect is a gradual down grading of the grazing value of the vegetation. The problem can thus be seen to be complex. Measures should be taken to discourage the formation of pure *Molinia* areas by conserving areas where *Calluna*

Table 3. *Details of fires occurring on Dartmoor in 1966/67*

*FIRES 1966/1967* (including one 1965)
Total area burnt in 1966/1967 5,292·7 acres (excluding fire No. 6, a 1967/1969 complex) = 2,141·9 ha.

| Fire reference number | Locality | Map reference of fire (All SX) | Method of dating C = *Calluna* stem count. E = estimated from photography | Area in acres | Area in hectares |
|---|---|---|---|---|---|
| 71 | Trendlebere Down | 775795 | C | 275·1 | 111·3 |
| 72 | Haytor Rocks | 755770 | C | 16·2 | 6·5 |
| 73 | Saddle Tor | 748764 | C | 17·6 | 7·1 |
| 74 | Seven Lords Land–Blackslade Down | 745760 | E | 128·4 | 52·0 |
| 75 | Hemsworthy Gate | 747760 | E | 8·0 | 3·2 |
| 76 | Hemsworthy Gate | 744758 | E | 23·1 | 9·3 |
| 77 | Hound Tor | 741785 | E | 22·1 | 8·9 |
| 78 | East Bovey Head | 689825 | C | 13·6 | 5·5 |
| 79 | Shapley Common | 695820 | E | 15·2 | 6·1 |
| 80 | Thornworthy Tor | 665850 | E | 153·3 | 62·0 |
| 81 | Water Hill | 665812 | C | 168·4 | 68·1 |
| 82 | Smallbrook Plains | 685655 | E | 56·4 | 22·8 |
| 83 | Dean Moor | 676660 | E | 9·1 | 3·7 |
| 84 | Down Ridge (Western boundary not discernible) | 650715 | E | 205·8+ | 83·3+ |
| 85 | N. Teign River/ Fernworthy | 642850 | E | 38·1 | 15·4 |
| 86 | Thirlstone | 638870 | E | 122·0 | 49·4 |
| 87 | Riddon Ridge | 663772 | E | 52·3 | 21·2 |
| 88 | Riddon Ridge | 665760 | E | 67·2 | 27·2 |
| 89 | Gidleigh Common | 642880 | E | 37·5 | 15·2 |
| 90 | Hound Tor | 637881 to 625919 | E | 857·4 | 347·0 |
| 91 | Belstone | 628928 | E | 26·0 | 10·5 |
| 92 | Oke Tor | 613895 | C | 217·0 | 87·8 |
| 92a | Okement Hill | 608884 | C | 69·0 | 27·9 |
| 93 | Brent Moor | 665635 to 655655 | C | 626·4 | 253·5 |
| 94 | Bishop's Meads | 665658 | E | 86·7 | 35·1 |
| 95 | W of Quintin's Man | 620820 to 610856 | E | 1,216·9 | 492·5 |
| 96 | E of West Mill Tor | 595905 | C | 3·0 | 1·2 |
| 97 | E of West Mill Tor | 594907 | E | 1·0 | 0·4 |
| 98 | E of West Mill Tor | 595909 | E | 0·9 | 0·4 |
| 99 | E of West Mill Tor | 595913 | E | 10·0 | 4·0 |
| 100 | Black-a-ven Brook | 600910 | E | 46·5 | 18·8 |
| 101 | High Willhays | 585881 to 587900 | C | 97·3 | 39·4 |
| 102 | Dinger Tor | 587875 | C | 71·0 | 28·7 |
| 103 | Stall Moor | 635623 to 628650 | C | 474·9 | 192·2 |
| 104 | Stall Moor | 623632 | E | 40·2 | 16·3 |
| 105 | Great Nodden | 540876 | E | 15·7 | 6·3 |
| 106 | Gutter Tor | 575669 | E | 3·5 | 1·4 |
| 107 | Curtery Clitters | 594895 | E | 126·5 | 51·2 |

is still prominent. Robinson (1953) notes that where cattle have been substituted instead of burning, in Scotland, this is often followed by an incipient growth of young heather. As Dartmoor is subjected to mixed grazing by cattle and ponies in addition to sheep, the continued burning of blanket bog may be unnecessary.

In addition to degrading the value of the herbage, swaling causes peat and soil

erosion, Imeson (1971). There are impressive areas of peat-bogs in northern Dartmoor. The reasons for the onset of widespread erosion in blanket bog have been variously attributed to natural erosion processes, change in climate, or an inevitable

Table 4. *Age of* Calluna *canopy at time of burning*

| Fire reference number | Age of canopy at time of fire |
|---|---|
| 1 | 9 |
| 2 | 9 |
| 3 | 12 |
| 5 | 12 |
| 7 | 7 (isolated clumps up to 15) |
| 11 | 11 |
| 12 | 8 |
| 13 | 7 |
| 14 | 11 |
| 19 | 14 |
| 20 | 9 (isolated clumps up to 19) |
| 21 | 9 |
| 23 | 13 |
| 35 | 12 |
| 36 | 8 |
| 48 | 10 |
| 49 | 10 |
| 50 | 9 |
| 51 | 5 |
| 54 | 7 |
| 55 | 14 |
| 62 | 7 |
| 65 | 13 |
| 70 | 7 (isolated clumps up to 14) |
| 71 | 7 |
| 72 | 9 |
| 73 | 12 |
| 78 | 5 |
| 81 | 15 |
| 92 | 11 |
| 92a | 11 |
| 93 | 10 |
| 96 | 11 |
| 101 | 11 |
| 102 | 11 |
| 103 | 12 |

Table 5. *A comparison of the ground interpretation and aerial photographic interpretation of the vegetation samples*

(Note—Category B was not constant in its appearance and could not be interpreted. Those classed with A or G are considered acceptable.)

| Ground description | Aerial photographic interpretation | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | A | C | D | E | F | G | H | |
| A. Blanket Bog | ***45*** | — | — | — | — | 2 | — | 47 } 76 |
| B. *Calluna-Molinia* moorland | ***18*** | 4 | — | — | — | *7* | — | 29 } |
| C. Grassland | 2 | *7* | ***1*** | — | — | 2 | ***2*** | 14 |
| D. Grassland + *Pteridium* | — | ***1*** | ***14*** | — | — | 1 | ***1*** | 17 |
| E. *Vaccinium* moor | 4 | ***2*** | — | ***9*** | 1 | 3 | — | 19 |
| F. Valley Bog | ***1*** | — | — | — | ***8*** | — | — | 9 |
| G. Heath | 3 | 4 | — | ***1*** | — | ***56*** | — | 64 |
| H. Grassland + *Ulex* | — | ***2*** | ***1*** | — | — | — | ***8*** | 11 |
| Total | 73 | 20 | 16 | 10 | 9 | 71 | 11 | 210 |

feature in a cycle of peat accumulation and subsequent erosion, Conway (1954), Bower (1962), whilst other workers consider biotic interference in the form of burning, drainage and grazing to be responsible, Pearsall (1950, p. 155), Radley (1962). Tallis (1964a, b, 1965) working in the Pennines, considered that the basic erosion pattern may have been established prior to human settlement, but that human influence has greatly aggravated it since the Middle Ages. Since Dartmoor has a long history of human settlement a similar sequence is not unlikely. Tallis (1964a), McVean and Ratcliffe (1962) and McVean and Lockie (1969) all record examples, some of them spectacular, of erosion of peat or mineral soil attributable to burning.

Simmons (1963) studied the distribution of the Dartmoor blanket bog in detail. He considers that in very wet areas (Taw Head SX609868; Cater's Beam SX625690) peat may still be accumulating and describes a vegetation of *Molinia*, *Eriophorum* spp. and *Sphagnum*. *Sphagnum papillosum* acts as the main hummock builder and *S. cuspidatum* is prominent in the intervening pools. At Tor Royal bog, Proctor (1969) describes *S. papillosum* as carpeting the surface, whilst amongst those forming hummocks is *S. imbricatum*—formerly an important peat former, but now very rare. Pearsall (1956) comments that absence of *S. imbricatum* from most British bog systems currently is due to draining and burning.

Both Worth (1933) and Harris (1938) were of the opinion that the chief peat former of the blanket bog areas is *Eriophorum vaginatum*, which is commonly found in association with *Molinia*. This is another species which becomes prevalent following disturbance of *Calluna* based vegetation by burning and grazing, Pearsall (1941), Ratcliffe (1959), Tallis (1964a, b, 1969). A further plant indicative of the disturbance of the bog surface by grazing and drying out processes is *Juncus squarrosus*, Welch (1966), Welch and Rawes (1964, 1966), Ratcliffe (1959).

Thus the prevalence within the blanket bog system of *Molinia caerulea*, *Trichophorum caespitosum*, *Eriophorum vaginatum* and *Juncus squarrosus* is indicative of the disturbance caused by management by swaling for use as an upland grazing system.

Grasslands

The grasslands peripheral to the upland bog areas have long been important as a source of grazing. Marshall (1796) said, "The present production of Dartmore and its uncultivated environs may with some little licence be said to be herbage!—'green-sward!' . . . frequently intermixed, however, with heath." What the extent of the grasslands was at that time is a matter of conjecture. Evidence from the short-cropped swards in the present study suggests that the grasslands are now more extensive than formerly. *Calluna* is commonly present. The plants comprise part of the sward and are sparsely distributed. The presence of *Calluna* in this diminutive form suggests that the vegetation has changed due to grazing pressure in recent years, as *Calluna* normally plays a fairly prominent role in the structure of the vegetation. Its presence suggests that these swards may be derived from *Calluna* communities. This could be due to either an increase in grazing pressure or to the establishment of a sward following burning. Fenton (1935) has observed a similar process in the derivation of grassland from moorland in Scotland.

An intermediate stage in this process can be seen in the form of short-cropped swards with isolated bushes of *Calluna*—the "grass-heath" category produced by the association-analysis (Fig. 2). The group is intermediate between the grassland and the heath. The only positive criterion by which the group is defined by the analysis is

the presence of *Rhytidiadelphus squarrosus*. This moss can occur in both heath or grassland, but on Dartmoor it is characteristic of the latter and may indicate the occurrence of former heathlands, which are being converted by progressive burning and grazing to grasslands. A similar process is described by Ratcliffe (1959) on the Carneddau, North Wales.

Despite the derivation of grassland from heath, which can be observed currently, it is evident from a plant list given by Vancouver (1808) that grasslands with a species-content not dissimilar to those of today were a natural feature of Dartmoor 150 years ago. Under his description of the depasturable parts of the forest he says (modern names in brackets): "The spontaneous vegetation of this part of the forest, among many other herbs and grasses, consisted of the purple melic grass (*Molinia caerulea*), mat-grass (*Nardus stricta*), downy oat grass (I think this may refer to *Sieglingia decumbens* rather than *Helictotrichon*, which does not occur on Dartmoor), bristled-leaved bent (*Agrostis setacea*), eye-bright (*Euphrasia* spp.), bulbous rooted rush (*Juncus squarrosus*), common termental (*Potentilla erecta*), smooth heath-bed straw (*Galium saxatile*), common bone-binder (*Narthecium ossifragum*), cross-leaved heath (*Erica tetralix*), common heath or ling (dwarf) (*Calluna vulgaris*), milk-wort (*Polygala serpyllifolia*), dwarf dock (*Rumex acetosella*), and Agrostis vulgaris (*Agrostis tenuis*) in very large quantities."

The biology of *Nardus stricta* on Dartmoor is unusual. It is not as abundant as on other upland sheep areas. It occurs sparsely in the acid grasslands but appears to be kept in check by the diversity of grazing stock, i.e. cattle and ponies in addition to sheep. Havinden and Wilkinson (1970) state that cattle and sheep avoid it, but that the ponies nip out the green centres of the tufts and discard the tough leaf bases, thus helping to keep it in check. Fenton (1936, 1937) and Wilson (1936) record that in grasslands infested by *Nardus* in Scotland, the *Nardus* became replaced by better grasses under the grazing influence of Galloway cattle. The presence of cattle and ponies on the Dartmoor pastures helps to maintain better pastures than would be possible under sheep alone. However, the appearance of the unenclosed short-cropped pastures on Dartmoor, on the aerial photographs and by ground examination, leaves no doubt that maximum use is being made of them by grazing stock. In contrast with enclosed pastures which appear to be a deep green on the aerial photographs, they are often straw-coloured due to the low standing crop.

Grasslands invaded by Bracken

None of the early writers mention bracken, perhaps because it was not as extensive formerly as today. One possible reason for its increase, mentioned by the Dartmoor Commoners' Association (1956) is that it is no longer cut by the Commoners as winter bedding for stock. The areas which have been invaded by bracken include formerly cultivated ground, and the areas of grassland and heath on the deeper, better soils. The bracken litter appears to break down quite quickly during the winter, and the swards it occupied during the summer become available again for grazing. This may be due to its short stature (3 feet) on the exposed moorland slopes, commented on by Worth (1933).

Burning vegetation containing bracken certainly favours it in the ensuing competition between the regenerating components. Swaling may thus account for the invasion of heath areas by bracken, but not of grasslands as these are not subjected to burning. Most swaling occurs in March when the bracken is only present as

rhizomes beneath the surface. Whereas *Calluna* takes some years to regenerate effectively after a fire, the bracken fronds emerge unaffected in the summer and flourish in the absence of competition from the heather. This is very evident on parts of Trendlebere Down (SX775795). Ratcliffe (1959) states that *Pteridium* readily invades newly burnt ground, but cannot compete with vigorously growing *Calluna*. Harvey and St. Leger-Gordon (1953) attributed the spread of bracken over large areas of formerly good heather to this process.

The invasion of short-cropped grasslands by bracken results from intensive grazing by sheep. Sayer (1969) looked at the grazing pressure in an area containing grassland and sparse bracken (70 per cent cover or less) in Southern Dartmoor and found that it was so heavily grazed by sheep that cattle did not use the area. Consequently the bracken is not trampled and eventually it completely colonizes the ground, excluding even the sheep. Ritchie (1909) describes a striking example of bracken invading a Scottish pasture after the removal of cattle and their replacement by sheep.

*Vaccinium* moorland

The localized *Vaccinium myrtillus* moors have probably been derived from *Calluna* heath following burning, but Worth (1933) and Harvey and St. Leger-Gordon (1953) comment that it flourishes in boulder-strewn areas, the rhizomes presumably being able to colonize the interstices. It is a common plant over the whole moor. After a fire the underground rhizomes are able to establish a canopy more rapidly than the *Calluna*, and it becomes dominant for a transitory period until the *Calluna* has fully regenerated. Fenton (1935, 1937), and Gimingham (1964) have described this in Scotland. Ratcliffe (1959) noted that *Vaccinium* is less heavily grazed than *Calluna* and where the two occur together in a regenerating canopy this may place the *Vaccinium* at a competitive advantage. Dense *Vaccinium* canopies can be very stable. Those on Dartmoor appear so, but they are probably susceptible to treading and have a pattern of sheep tracks through them.

Valley bog

The floristic diversity of most of the vegetation types of Dartmoor is very limited, but a variety of delightful flowering herbs may be encountered in the valley bogs or seepage areas. This type of area is termed "mire" by McVean and Ratcliffe (1962) and they comment that the soil factors affecting mires are more complex and variable than those determining the vegetation of blanket bog. There is lateral movement of water in the substrate and washed-in mineral matter is incorporated within the peat. This accounts for the greater variety of vegetation in the valley bogs. These areas have been insufficiently sampled in the present survey to advance the knowledge of their ecology, but amongst the herbs noted are *Hypericum elodes* (marsh St. John's wort), *Dactylorchis fuchsii* (common spotted orchid), *Drosera rotundifolia* (sundew), *Menyathes trifoliata* (bog bean), *Narthecium ossifragum* (bog asphodel), *Ranunculus omiophyllus*, (a water crowfoot), *Succisa pratensis* (devil's-bit scabious), and *Viola palustris* (marsh violet). Harvey and St. Leger-Gordon (1953) name several others which may be found in such situations including *Anagallis tenella* (bog pimpernel), *Drosera intermedia* (long-leaved sundew), *Hydrocotyle vulgaris* (marsh pennywort), *Lychnis flos-cuuli* (ragged robin), *Pedicularis palustris* (red rattle), *Pinguicula lusitanica* (pale butterwort), *Potamogeton* spp. (pondweed), *Ranunculus*

*flammula* (lesser spearwort), *Scutellaria minor* (lesser skull cap), and *Wahlenbergia hederacea* (ivy campanula).

Heath

The peripheral dry heaths are subjected to swaling. The principal species at the two extreme stages of the burning cycle are, in the mature state, *Calluna vulgaris* which is variously intermixed with other dwarf-shrubs and, in the regenerating state, *Agrostis setacea* which is variously intermixed with other grasses and herbs. *Agrostis setacea* is characteristically present even in the mature canopy, but its percentage cover is negligible. The tough fibrous bases appear to be fire resistant, and following a fire it flourishes and may for a time form a virtually continuous sward. In the absence of fire it is merely a constituent of the acidic grasslands and heaths. Ivimey-Cook (1959) noted that it may form pure stands on recently burnt heaths, but that grazing stock tend to avoid it. Tubbs (1968) describes a similar phase following heath burning in the New Forest in which *Agrostis setacea* and *Molinia caerulea* form a sward until the *Calluna* canopy re-establishes. *Agrostis setacea* is extremely fine-leaved and does not appear to be palatable to grazing stock on Dartmoor; where it occurs intermixed with other grasses in a sward it is avoided and the tufts protrude in a manner reminiscent of *Nardus* on hill pastures elsewhere.

Swaling on Dartmoor is the subject of much controversy. Its history as a regular management procedure on Dartmoor is unknown. Marshall (1796) advocates the burning of heath with subsequent grazing to encourage a sward, but does not indicate whether such a practice was observed at that time. McVean and Lockie (1969) discussing the history of regular burning in Scotland comment that the practice is only about two centuries old and arose from a haphazard process of forest and scrub burning. Within this period, however, the practice has become "so deeply ingrained as to be almost an article of faith". Harvey and St. Leger-Gordon (1953) indicate a similar attitude to moor-burning on Dartmoor on the part of some members of the general public who consider they have the right to set fire to vegetation. The Commoners themselves appear to be aware of the need for much stricter control.

The purpose of swaling is to encourage the growth of young heather and gorse, by burning the *mature* canopies of each. The regenerating growth provides nutritious grazing and is especially valuable to stock wintered on the moor, notably in times of snow when the protruding growth-form is far more accessible than grass. McVean and Lockie (1969) comment that the average burn is a distinctly hit or miss affair, which probably does a great deal of harm, and that there is rarely the manpower available to supervise moor fires properly. Worth (1933) considered that swaling was carried out to excess. From his description he clearly indicates that back-burning against the wind was practised at that time. This results in an efficient burn in which the old wood is destroyed, although Worth comments that the effect, especially on moist ground, is often to create a waste of burnt twigs. Harvey and St. Leger-Gordon (1953, p. 70) consider that swaling is haphazard and that as a result the area of heather is being reduced. They mention (1953, p. 170) the tendency to set fire to "a piece that will run", indicating that there has been a change in firing practice. This would result in fires covering far larger acreages, and would account for the size of many of those listed in Tables 1, 2, and 3. Such fires tend to be superficial and hardly touch the sparse cover of grasses. On the better soils and under grazing pressure a good sward of *Agrostis tenuis* and *Festuca* spp. may eventually be

established, and this has been discussed above; but on the poorer soils the resulting sward of *Agrostis setacea* and *Molinia caerulea* which replaces the *Calluna* forms poor grazing.

The Commoners, under the auspices of the Dartmoor Commoners' Association, are fully aware of the need to control swaling. In their memorandum of evidence to the Royal Commission on the law relating to Common Land (1956), the Commoners favour the setting up of a Council which would have the power to make regulations to control, among other activities, swaling. A voluntary system of co-operation is suggested whereby each parish or manor Commoners' Association notifies the local police of the area they intend to burn, with a view to rapidly identifying unauthorized fires.

Tubbs (1968) discusses the control of burning in the New Forest, an area of common land, which prior to the New Forest Act 1949, had problems of burning control not dissimilar to those of Dartmoor. In the 1949 Act, the Forestry Commission was assigned the responsibility of maintaining the grazings and keeping them clear of herbage, scrub and self-sown trees. The result has been a control system in which 600–1,200 ha. (1,500–3,000 acres) are burnt annually. Tubbs writes (p. 188), "The heaths are burnt . . . on a rotation, which may vary from six to twelve years from site to site, depending on the varying needs of reducing the hazard to extensive accidental fires by breaking up large tracts of old, fire-prone heather; of providing young growth for stock; and of fulfilling the statutory duty of the Commission to keep the grazings clear of scrub." In a well-managed burning programme on Dartmoor, the first two considerations would be particularly relevant. "The burning is planned on a fragmentary basis, on lines not dissimilar to those adopted on a grouse moor, in order to achieve the maximum variation in age classes of the vegetation which in turn facilitates fire control" . . . This is particularly relevant to Dartmoor. Most of the fires cover too great an acreage, and tend to obliterate whole canopies of heather rather than fragmenting them and retaining a variable age structure.

McVean and Lockie (1969, p. 81) discuss the statistics of some fire acreages in Scotland. These range from an ideal of 0·4 ha. (one acre) for a closely managed grouse moor to fires of 12–16 ha. (30 to 40 acres) on the more remote parts of the moor. Tubbs (personal communication) would ideally favour a fire size of 0·4 ha. (one acre) in the New Forest, but considers that the largest acceptable fire would be about 24 ha. (60 acres). It is probable that fires of the 16–24 ha. (40 to 60 acres) range would also constitute the largest acceptable size on Dartmoor, in order to fragment large canopies of *Calluna*. Of the fires listed in Tables 1, 2 and 3 approximately one-third cover a substantially greater area than 24 ha. (60 acres).

Heath burning is confined by the Heather and Grass Burning (England and Wales) Regulations (Statutory Instrument 386, 1949) to the period between 1 November and 31 March. In practice most burning takes place in hill areas during February or March, the only time during the permitted period when the vegetation is dry enough to burn effectively. Swaling is carried out by the Dartmoor Commoners within this period, but accidental fires may occur at any time. Thompson (1971) records the incidence of fires caused by lightning in Galloway.

In the study of swaling on Dartmoor in the present survey, one hundred and seven fire-areas were discovered. These comprised one dated in 1965, thirty-six 1966–67, twenty-three in 1968, and forty-seven in 1969. The total area of the one hundred and seven fires occurring between 1965 and 1969 is 4,414 ha. (10,907 acres). The average

area burnt annually over the four-year period 1966–1969 is 1,104 ha. (2,727 acres). This is a conservative estimate as it is probable that some 1966 fires may not have been included because regenerating vegetation makes them no longer easily discernible, especially in the blanket bog areas.

Gimingham (1970), considering the concentration of major nutrients in the young heather plant and the accumulation of biomass, concludes that up until the age of approximately 10 years it increases or maintains its value as a source of grazing. Thereafter, with clipping or intensive grazing productivity can be maintained. However, sheep are unable to graze it with sufficient intensity, hence a 10-year burning cycle. Miller and Miles (1970) found that regeneration is most satisfactory from heather 6–10 years old. However, repeated burning of a heather area when the canopy is less than 10 years old is liable to reduce the dominance of *Calluna* in the long term, because the canopy does not attain its maximum cover until about that age. Miller and Miles therefore advocate burning on an 11–15-year cycle where the long-term maintenance of *Calluna* is desired. A study of the age of the heather canopies of the 36 fires visited on the ground shows that in 16 cases the canopy was less than 10 years old, Table 4. The combined acreage of blanket bog and heath, the two vegetation types subjected to burning, is approx. 24,184 ha. (59,760 acres). This allows for 2,200–1,600 ha. (5,433–3,984 acres) to be burnt annually on an 11–15-year burning cycle, although the long-term disadvantages of burning the blanket peat (approx. 13,760 ha. (34,000 acres)) have already been alluded to. Assuming an optimum fire size of 24 ha. (60 acres), this would allow for between 90 and 66 fires annually. Within the period under review this acreage or number was not exceeded, but it is probable that larger areas have been burnt previous to this period. Ground examination of the vegetation in the North and South Moors reveals the influence of fire in all but extremely wet areas, and old stands of *Calluna* are very rare and usually very small.

This suggests that considerably larger areas have been burnt in the past. McVean and Lockie (*loc. cit.*) discussing moor burning in western Scotland for sheep and deer grazing, record that the fires are uncontrolled and cover many hundreds of acres at one time. From the size of some of the fires recorded in Tables 1, 2 and 3 it is clear that similar fires occur on Dartmoor. The importance of a swaling programme which creates a mosaic of heather canopies of mixed ages cannot be over-stressed.

Grasslands with gorse

The grassland category containing *Ulex gallii* is of limited distribution around the periphery of the moor. Formerly it would have been more extensive. Marshall (1796) commented that "furze, particularly the trailing sort" was prevalent on the lower ground. *Ulex gallii* typically grows as low rounded bushes, but is occasionally present in short-cropped sward as very diminutive plants. On such sites it has been reduced to this state by burning and grazing. It also often forms a constituent of heath. Worth (1933) comments that furze is important fodder for the ponies, especially in times of snow. He notes that they not only browse the young growth, but can be observed to crush the older growth with their hooves prior to browsing it. Havinden and Wilkinson (1970) also refer to the valuable fodder provided by furze.

## Conclusion

The present discussion has aimed to elucidate the ecology of vegetation types on Dartmoor by reference to the picture which emerges from historical articles and by comparing the vegetation of other hill areas in England, Wales and Scotland with those of Dartmoor.

Nine broad vegetation types have been described, based on an association-analysis, which are distinguishable on the ground. Seven of these proved interpretable on the aerial photographs for purposes of vegetation mapping.

Of these, two broad groups are subjected to management by burning. These are the wet or damp areas of blanket bog and *Calluna-Molinia* moorland and the dry areas of heath. The effect of fire on the former group is detrimental and is resulting in a progressive change towards fire-climaxes of *Molinia*, *Trichophorum* and *Eriophorum vaginatum* at the expense of heather. On the dry heaths fire can be used as a management tool to maintain the heath provided it is based on a disciplined burning programme. Over frequent burning is resulting in the gradual invasion of heaths by bracken; and the progressive replacement of heather by a poor quality sward. Areas of *Vaccinium* may represent stable seral stages in the recovery of heath from burning. There is also a reduction in gorse, which, together with heather probably constitutes valuable winter forage. The grasslands are intensively utilized and are subjected to invasion by bracken. *Agrostis tenuis-Festuca ovina* swards have replaced heath on the better soils, but on poorer soils the resulting sward is of *Agrostis setacea* and *Molinia caerulea* and does not appear to give good grazing.

No new information has been contributed on the Dartmoor woodlands, and little has been said on the bryophytes and lichens. Recent references giving leads to the literature on these respective topics are Simmons (1965), Proctor (1964) and Yarranton (1967).

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## APPENDIX

Domin scale of cover-abundance estimates for species present in a vegetation sample.

1. One or two individuals
2. Sparsely distributed
3. Frequent, but low cover (5 per cent)
4. Cover 5–20 per cent
5. Cover 20–25 per cent
6. Cover 25–33 per cent
7. Cover 33–50 per cent
8. Cover 50–75 per cent
9. Cover 75–90 per cent
10. Cover complete or almost so

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